A WATER RESOURCES AND SANITATION SYSTEMS SOURCE BOOK WITH SPECIAL REFERENCE TO KWAZULU-NATAL:

PART 5

by

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Part 5 contains the following:

Chapter 16: Health aspects of water and sanitation **HEALTH**

Chapter 17: *Solid waste management in South Africa* **SOLID WASTE**

Each chapter has its own contents page/s. The pagination in **Part 5** is consecutive. A comprehensive set of contents pages for the entire thesis can be found in Part 1.

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- Part 1. Chapters 1 - 5
- Part 2. Chapters 6 - 9
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- Part 4. Chapters 13 - 15
- **Part 5. Chapters 16 - 17**
- Part 6. Chapters 18 - 20

CHAPTER 16: HEALTH ASPECTS OF WATER AND SANITATION

The tragic consequences of infant mortality...

Burial
Among the Manyika, a dead infant is buried
by its mother without a ceremony

Under the scrub and the weeds I bury you,
Here in the clay where the bracken grows.

Here on the hill the wind blows cold,
And the creepers are wet with the driving mist...

* * *

Alas! I am old, and you are the last -
Mwanango, the last of me, here on the hillside.

* * *

The hoe that I use to fashion your dwelling
Is caked with the earth that is taking you from me.

* * *

Alas! Alas! My little child!
I bury you here by the edge of the lands.

K. Fairbridge, quoted in Chapman, M. (ed), 1982. A Century of South African Poetry. AD. Donker, Johannesburg, 397 p.

CHAPTER 16: HEALTH ASPECTS OF WATER AND SANITATION

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16.1 Diseases related to water and soil

16.1.1 Human bacteriological and viral diseases

The major theme of the present chapter concerns bacteriological and viral diseases - mainly in view of their implications for the health of the black population of South Africa. Sources of medical data for epidemiological studies accordingly, form an integral part of the discussion. Malaria and schistosomiasis (bilharziasis) as specific and important diseases in this country are examined in some detail, while the role of wetlands in disease transmission is briefly outlined. The blackfly plague in the northern and eastern Cape (as a result of river disturbance) is also discussed. A detailed analysis of chemical water quality and health is beyond the scope of the source book, although a few aspects such as nitrate and fluoride levels in natural waters as well as cardiovascular disease are considered in more detail. One of the greatest threats to health in rural and peri-urban South Africa involves human infectious disease patterns, rather than comparatively isolated (although significant) instances of chemically-induced pathology*. Emphasis is therefore placed on the former. The chapter on health provides relevant information for water quality, solid waste management and sanitation (see the respective chapters, elsewhere in this publication).

Water and soil-related diseases are numerous and may vary from region to region and from country to country. In the tropical and sub-tropical areas of the world these diseases are responsible for a great deal of human misery and death, especially in the least developed and developing countries. Some of the more important diseases (with particular reference to South Africa), are listed in Table P1. Diseases linked to water can be divided into four groups, although categorization is sometimes problematic and depends inter alia on the extent of transmission involving water (or the lack thereof). The respective groups are: waterborne diseases; water-washed diseases; water-based diseases and diseases with water-related insect vectors. Soil-based diseases involve excreted organisms which are spread through the soil.

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* The health implications of organic compounds are not discussed to any extent in this publication (with the partial exception of agrichemicals - see the chapter on solid waste management).

Table P1: Some water-related and soil-based diseases in man.

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
(i) Waterborne diseases (ingestion of organism/s from drinking water) **General control measures: adequate sanitation, personal hygiene and improved water quality**			
Amoebiasis (Amoebic dysentery)	Entamoeba histolytica (protozoan)	Dysentery/fever/abdominal pain	Faecal/oral
Campylobacter enteritis	Campylobacter jejuni (spiral and curved bacteria)	Fever/dysentery/abdominal pain	Faecal/oral
Cholera*	Vibrio cholerae (Gram-negative bacteria)	Severe diarrhoea ("watery")/vomiting/possible fatal dehydration	Faecal/oral
Cryptosporidiosis	Cryptosporidium parvum (protozoan)	Diarrhoea/vomiting/anorexia	Faecal/oral
E. coli enteritis	Escherichia coli (Gram-negative bacteria)	*Diarrhoea ("travellers")/vomiting/dehydration*	*Faecal/oral*
Giardiasis	Giardia lamblia (protozoan)	Diarrhoea/vomiting/anorexia	Faecal/oral
Viral (infectious) type A hepatitis*	Hepatitis-A virus (Picornaviridae) (enterovirus, now hepatovirus)	Fever/fatigue/jaundice	Faecal and urine/oral
Non-A/non-B hepatitis* • Type C (negligible possibility of waterborne transmission)	Hepatitis-C virus (Flaviviridae) (hepatitis C-like virus)	Fever/jaundice/cirrhosis of the liver/ hepatocellular (liver) cancer	Blood into water/ percutaneous
• Type E (waterborne)	Hepatitis-E virus (Caliciviridae) (?)	Abdominal pain/vomiting/diarrhoea/jaundice	Faecal/oral

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
Serum hepatitis* (negligible possibility of waterborne transmission)	Hepatitis-B virus (Hepadnaviridae) (hepadnavirus)	Fever/jaundice/cirrhosis of the liver/ hepatocellular (liver) cancer	Blood into water/ percutaneous (poor socio-economic conditions)
Paratyphoid fever*	Salmonella paratyphi (Gram-negative bacteria)	Enteric fever/myalgia	Faecal and urine/oral
Poliomyelitis*	Picornaviridae (poliovirus - a type of enterovirus)	Paralysis of the limbs	Faecal/oral
Rotaviral enteritis	Reoviridae (rotavirus)	Diarrhoea	Faecal/oral
Shigellosis (Bacillary dysentery)	Shigella dysenteriae (Gram-negative bacteria)	Diarrhoea/dysentery/fever/abdominal pain	Faecal/oral
Typhoid fever*	Salmonella typhi (Gram-negative bacteria)	Fever/dysentery/peritonitis	Faecal and urine/oral
Yersiniosis (Yersinia enteritis)	Yersinia enterocolitica (Gram-negative bacteria)	Fever/diarrhoea/abdominal pain	Faecal and urine/oral
(ii) Water-washed diseases (infections which can be reduced by improved hygiene and hence by increasing the quantity of water available) General control measures: provision of water, personal hygiene education and improved housing (less overcrowding)			
Candidiasis	Candida albicans (fungus)	Thrush	Cutaneous/cutaneous
Conjunctivitis (Acute bacterial conjunctivitis)	Streptococcus or Staphylococcus spp. (Gram-positive bacteria)	Infection of the eye with discharge	Cutaneous/cutaneous

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
Enterobiasis (Pinworm/threadworm infection)	Enterobius vermicularis (nematode)	Asymptomatic/pruritis ani	Faecal/oral
Epidemic (louse-borne) typhus fever*	Rickettsia prowazekii (rickettsia)	Fever/myalgia/headaches/rash	Bite/bite
Impetigo	Streptococcus (Group-A) or Staphylococcus aureus (Gram-positive bacteria)	Skin pustules/glomerulonephritis	Cutaneous/cutaneous
Lice	Pediculus humanus capitis Pediculus humanus humanus Phthirus pubis (arthropod)	Head lice Body lice Pubic lice ("crabs")	Bite/bite
Louse-borne relapsing fever (Epidemic relapsing fever)*	Borrelia recurrentis (spirochaete bacteria)	Fever/flu-like illness/collapse	Bite/bite
Ringworm	Epidermophyton; Microsporum and Trichophyton spp. (fungi)	Athlete's foot (tinea pedis)	Cutaneous/cutaneous
Scabies (Acariasis)	Sarcoptes scabiei humanus (arthropod)	Itchy skin lesions	Cutaneous/cutaneous
Trachoma*	Chlamydia trachomatis (rickettsia)	Conjunctivitis/corneal scars/blindness	Cutaneous/cutaneous
Trench (louse-borne) fever (Five-day fever)	Rochalimaea quintana (rickettsia)	Fever/malaise/myalgia	Bite/bite
Yaws	Treponema pertenue (spirochaete bacteria)	Lesions/ulcers	Cutaneous/cutaneous

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
(iii) Water-based diseases (the pathogen spends part of its life in an intermediate or aquatic host) **General control measures: improved potable water quality and reduced access to source/s of infection**			
Clonorchiasis (Chinese or oriental liver fluke)	Clonorchis sinensis (trematode)	Fever/diarrhoea/mild jaundice	Faecal/ingestion of raw or insufficiently cooked freshwater fish or crayfish
Diphyllobothriasis (Broad or fish tapeworm infection)	Diphyllobothrium latum (cestode)	Anaemia/diarrhoea/obstruction of the bile duct or intestine	Faecal/ingestion of raw or insufficiently cooked fish
Dracontiasis (Guinea worm infection)	Dracunculus medinensis (nematode)	Painful blisters/abscesses/diarrhoea	Cutaneous/oral
Fascioliasis (Sheep liver fluke) - also found in cattle and goats and sometimes in horses and pigs	Fasciola hepatica (trematode)	Intermittent fever/vomiting/diarrhoea/mild jaundice	Faecal/ingestion of (uncooked) edible water plants or (uncooked) flood-irrigated vegetables
Leptospirosis (Weil's disease)	Leptospira interrogans (spirochaete bacteria)	Nephritis/liver disease/jaundice	Cutaneous and urine/ cutaneous and oral
Paragonimiasis (Lung fluke)	Paragonimus africanus and P. uterobilateralis (trematode)	Coughing/chest pain/haemoptysis	Faecal/ingestion of raw or insufficiently cooked freshwater crabs and crayfish

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
Schistosomiasis (Bilharziasis)	Schistosoma haematobium (urinary) S. mansoni (rectal/urinary) and S. mattheei (rectal/urinary) (trematode)	Katayama fever/asymptomatic/lassitude Asymptomatic/abdominal cramps/malaise (haematuria is a classic symptom of urinary schistosomiasis)	Urine/cutaneous Faecal/cutaneous
(iv) Diseases with water-related insect vectors (infections transmitted by insects which breed in or bite near water) General control measures: surplus water drainage and management, together with the use of appropriate insecticides			
Chikungunya fever	Togaviridae (alphavirus)	Joint pains/fever/rash/haemorrhagic fever	Mosquito bite/ Mosquito bite
Dengue fever*	Togaviridae (flavivirus)	Fever/eye pain/severe myalgia/cramps/ haemorrhagic fever	Mosquito bite/ Mosquito bite
Filariasis (Elephantiasis)	Wuchereria bancrofti (nematode)	Inflammation and blocking of lymph vessels resulting in gross enlargement of the skin and underlying connective tissues	Mosquito bite/ Mosquito bite
Malaria*	Plasmodium spp. (protozoan)	Fever/anaemia/hot and cold shivers/fatigue	Mosquito bite/ Mosquito bite
Onchocerciasis (River blindness)	Onchocerca volvulus (nematode)	Blindness/skin lesions	Simulium fly bite/ Simulium fly bite
Rift Valley fever*	Bunyaviridae (bunyavirus)	Fever/myalgia/haemorrhagic fever/jaundice	Mosquito bite/ Mosquito bite
Trypanosomiasis (Sleeping sickness)	Trypanosoma brucei gambiense and Trypanosoma brucei rhodesiense (protozoan)	Fever/anaemia/lethargy/CNS involvement	Tsetse fly bite/ Tsetse fly bite

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
Wesselsbron disease	Wesselsbron virus (arbovirus)	Fever/myalgia/headaches/mild skin rash	Possibly by mosquito bite
West Nile fever	West Nile virus (arbovirus)	Fever/myalgia/joint pain/asymptomatic	Mosquito bite (rare)/ Mosquito bite
Yellow fever*	Togaviridae (flavivirus)	Fever/haemorrhagic fever/jaundice	Mosquito bite/ Mosquito bite
(v) Soil-based diseases (excreted organisms spread through the soil) General control measures: improved excreta disposal (latrines)			
Ancylostomiasis, Uncinariasis and Necatoriasis (Hookworm infection)	Ancylostoma duodenale; A. ceylonicum; Necator americanus and Ternidens deminutus (false hookworm - a parasite of African monkeys, also found in man) (nematode)	Weight loss/anaemia/coughing/tracheitis	Faecal/cutaneous and oral
Ascariasis (Large roundworm infection)	Ascaris lumbricoides (nematode)	Abdominal pain/loss of appetite/diarrhoea/ asymptomatic	Faecal/oral
Hydatidosis *(Dog tapeworm)*	Echinococcus granulosus (cestode)	Growth of cysts in the liver, lungs, brain, kidneys and abdomen resulting in damage to surrounding tissue	Oral entry, no spread from one human to another
Hymenolepiasis (Dwarf tapeworm infection)	Hymenolepis nana (cestode)	Asymptomatic/diarrhoea/vomiting/nervous distress	Faecal/oral

Table P1: Some water-related and soil-based diseases in man (continued).

Name of disease	Most important causative organism/s	Some (main) clinical features	Route leaving/route entering man
Strongyloidiasis (Threadworm infection)	Strongyloides stercoralis (nematode)	Abdominal pain/nausea/weight loss	Faecal/cutaneous or faecal/oral
Taeniasis (Tapeworm infection in the human intestine)	Taenia saginata (beef tapeworm) and T. solium (pork tapeworm) (cestode)	Weight loss/abdominal pain/digestive disturbances. The presence of T. solium larvae in body tissues can result in a serious disease known as cysticercosis, characterized by weakness and considerable pain where larvae are found in muscle tissue. Larvae in the brain may cause paralysis, epileptic attacks and death	Faecal/ingestion of raw or insufficiently cooked beef or pork
Toxocariasis (Dog/cat roundworm)	Toxocara canis and T. cati (nematode)	Fever/blindness/hepatomegaly	Faecal/oral
Toxoplasmosis	Toxoplasma gondii (protozoan)	Asymptomatic/severe infection of lymph nodes in serious cases	Faecal/ingestion of insufficiently cooked meat, also cutaneous
Trichuriasis (Whipworm infection)	Trichuris trichiura (nematode)	Anorexia/abdominal discomfort	Faecal/oral

Source: (i) After Arbuckle, A., 1990. Unpublished data, Faculty of Medicine, University of Natal, Durban.

(ii) After Walters, I., 1994. Personal communication, City Health Department, Pietermaritzburg Corporation, Pietermaritzburg.

(iii) Fieldwork.

See also: (i) Anonymous, 1993. South African water quality guidelines, VOL 1, Domestic use, Department of Water Affairs and Forestry, Pretoria, 216 p. (The publication provides useful water quality guidelines data on algae, faecal coliforms, coliphages, enteric viruses and protozoan parasites - such as Giardia lamblia, in terms of health implications).

(ii) Coovadia, H.M. and Loening, W.E.K. (eds), 1992. Paediatrics and Child Health: a Handbook for Health Professionals in the Third World, Oxford University Press, Cape Town, 630 p.

(iii) Fripp, P.J., 1983. An Introduction to Human Parasitology With Reference to Southern Africa, second edition, Macmillan South Africa (Publishers), Johannesburg, 168 p. (The book is concise and is highly recommended).

(iv) Grabow, W.O.K., 1992. *Navorsing oor menslike virusse in water*, WRC Report No. 265/1/92, Water Research Commission, Pretoria, 43 p. + app.

(v) Grabow, W.O.K., 1996. Waterborne diseases: update on water quality assessment and control, Water SA, VOL 22(2), p. 193 - 202.

(vi) Grabow, W.O.K. and Nupen, E.M., 1968. The role of water in the transmission of pathogenic microorganisms from animals to man and man to animals - a review, File No. W 6/206/3, Code No. 6201/6206, National Institute for Water Research, CSIR, Pretoria, 62 p.

(vii) Vivier, F.S., 1983. Some diseases in southern Africa related to inadequate water supply and sanitation, Seminar on Appropriate Technology Transfer in Water Supply and Sanitation, International Water Supply Association (IWSA), the Division of Water Technology of the CSIR and the Venda Government, 28 - 30 September 1983, Thohoyandou, 12 p.

(viii) Vlok, M.E., 1986. Manual of Community Nursing and Psychiatry: a Textbook for South African Student Nurses, Juta, Cape Town, 816 p.

(ix) Von Schirnding, Y., Yach, D. and Mathee, A., 1993. Health aspects of sanitation, with special reference to South Africa, CHASA Journal of Comprehensive Health, VOL 4(3/4), p. 73 - 79.

Note: (i) The asterisk indicates a notifiable disease. Twenty-eight groups of diseases are notifiable in South Africa (with regard to Government Regulation Notice GN R328/91 issued in terms of Section 45 of the Health Act No. 63 of 1977). Such diseases (including any deaths) must be reported by the local authority or the district surgeon (in rural areas), to the regional office of the Department of National Health and Population Development. The Department maintains a database on notifiable diseases (including a Geographic Information System).

(ii) The following brief definitions are relevant to the above table:

Asymptomatic	Without symptoms
Cutaneous	Direct contact with the skin
CNS involvement	Disturbance of the Central Nervous System - in extreme cases - severe mental confusion or a coma
Conjunctivitis	Inflammation of the conjunctiva of the front of the eye
Glomerulonephritis	Inflammation of part of the kidney
Haematuria	Blood in the urine
Haemoptysis	Coughing up of blood or blood stained sputum
Hepatomegaly	Enlarged liver
Katayama fever	General fever
Lassitude	Fatigue
Malaise	A sense of discomfort and uneasiness
Myalgia	Muscle pain
Nephritis	Inflammation of the kidney
Percutaneous	Absorbed through the skin
Peritonitis	Inflammation of the abdominal cavity (peritoneum)
Pruritis ani	Itchy anus
Skin pustules	*Infected lumps on the skin*
Tracheitis	Inflammation of the trachea

(iii) Although waterborne infections are transmitted through water, many such infections are spread by other routes (hands, clothes and food, plus eating and drinking utensils). Pathogens from faeces which reach the mouth by one of these routes are termed faecal/oral transmission diseases. Most waterborne diseases can also be regarded as water-washed diseases. It is again stressed that the classification of diseases in terms of the five categories is difficult. Considerable disagreement is evident in the literature. No (overall) definitive literature source was found on water/soil based diseases and causative organisms specific to South Africa. Detailed research is therefore required, which should include a locational analysis.

(iv) Sanitation is defined as the careful disposal of human urine and faeces in some form of acceptable latrine; as well as the proper disposal of redundant containers which store water (and which would otherwise provide ideal breeding conditions for mosquitoes). Sanitation in addition, involves the drainage of small open pools of freshwater which are also mosquito breeding sites. Sanitation therefore encompasses the proper disposal of waste in general.

Upgraded drinking water supplies improve human health by eliminating a route through which pathogens are ingested. Personal hygiene refers to water used for cleaning the body (namely, bathing and the washing of eyes, face and hands). Domestic hygiene concerns the use of water to keep the home clean, as well as the cleaning of food, clothing and towels, plus utensils and the kitchen area - which are all related to pathogen transmission. Improving hygiene often involves increasing the quantity of water available (as noted above), but can also include the provision of soap, and the avoidance or reduction of direct contact with pathogen-laden waters as well as faeces. Frequent washing of the body and household items is important.

(v) According to Potgieter (1992, quoted in Grabow, 1992) more than 120 different viruses are excreted in human faeces, which can then *become pollutants of water. The viruses are mainly those* transmitted by the faecal/oral (waterborne) route. The viruses are derived from the gastrointestinal tract of infected individuals and are accordingly termed enteric viruses. All the enteric viruses are potentially pathogenic and may result in a wide range of diseases including meningitis, paralysis, gastroenteritis, conjunctivitis and hepatitis. The human enteric viruses are cause for concern in terms of waterborne diseases, since the viruses can survive conventional water treatment and may be present in both surface and groundwaters from which drinking water is obtained. Some of the viruses - usually the enteroviruses - often cause asymptomatic infections, especially in children. Fortunately, the number of human enteric viruses found in water is usually very limited, although the minimum human infective dose of certain enteric viruses may be as low as 1 - 10 cell culture infective doses (number of viral organisms). A low minimum infective dose is also evident for most protozoan parasites. By contrast, a generally high infective dose of 10 - 1 000 (or more) pathogenic bacteriological organisms is required to cause disease. As pathogenic counts increase, so smaller volumes of ingested water will result in illness (Anonymous, 1993).

(vi) It should be noted that the most modern classification for hepatitis (with regard to the discussion) is: hepatitis A, hepatitis B, hepatitis C and hepatitis E. The terms "infectious hepatitis"; "non-A/non-B hepatitis", and "serum hepatitis" are used in older texts. A useful description of the various types of hepatitis (including hepatitis D, F and G)*, can be found in the South African Medical Journal, 1994, VOL 84(8), Part 2, p. 523 - 583. The whole issue comprising several papers, is devoted to hepatitis. See also Viral Hepatitis: Diagnosis and Management, Supplement to South Africa's Continuing Medical Education Monthly, 1994, VOL 12(6), 16 p. Examine in addition: Grabow, W.O.K., Taylor, M.B. and Webber, L.M., 1996. Hepatitis E virus in South Africa, South African Journal

* Hepatitis F - only discovered fairly recently - is regarded as a waterborne disease. The nomenclature of the viruses (A to G) is abbreviated as HAV; HBV; HCV; HDV; HEV; HFV, and HGV.

of Science, VOL 92(4), p. 178 - 180. Considerable research work is still required, in order to fully understand many aspects of hepatitis.

(vii) The following diseases are not found in South Africa (excluding the arrival of already infected people): clonorchiasis; Dengue fever; *diphyllobothriasis; dracontiasis; filariasis; louse-borne relapsing fever;* onchocerciasis; paragonimiasis; trench fever; trypanosomiasis; yaws, and yellow fever. Infrequent epidemics of Chikungunya fever occur in South Africa (confined to the Transvaal Lowveld)*, although the disease may also be present in Maputaland on rare occasions.

16.1.2 Animal diseases

Several water and soil-related diseases are common to both man and animals. These diseases (with varying degrees of impact on different species of animals) include the following: enteritis, leptospirosis, paratyphoid fever, Rift Valley fever and trypanosomiasis**; as well as fascioliasis, schistosomiasis and various round and tapeworm infestations (Table P1). Lice and mites similarly, afflict several species of animals (Mönnig and Veldman, 1989)***. Animals, like man, are also susceptible to poisoning through naturally occurring substances or contaminants in water, for instance, high *nitrate and fluoride concentrations. As a general rule - although not without* exception - livestock are able to tolerate higher concentrations of chemicals in water than man****.

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* See McIntosh, B.M., Jupp, P.G. and Dos Santos, I., 1977. Rural epidemic of Chikungunya in South Africa with involvement of Aedes (Diceromyia) furcifer (Edwards) and baboons, South African Journal of Science, VOL 73(9), p. 267 - 269. For a discussion of West Nile fever see McIntosh, B.M., Jupp, P.G., Dos Santos, I. and Meenehan, G.M., 1976. Epidemics of West Nile and Sindbis viruses in South Africa with Culex (Culex) univittatus Theobald as vector, South African Journal of Science, VOL 72(10), p. 295 - 300.

** Limited outbreaks have recently occurred amongst cattle in Natal/KwaZulu, in isolated areas between the Mfolozi River and the Mozambique border. The outbreaks first apparent in 1990 are confined to *animals, particularly cattle (The Director, 1995. Personal communication, Allerton Regional* Veterinary Laboratory, Department of Agriculture, Pietermaritzburg).

*** See Mönnig, H.O. and Veldman, F.J., 1989. Handbook on Stock Diseases, Tafelberg, Cape Town, 408 p. (A *more formal and up-to-date reference is: Coetzer, J.A.W., Thomson, G.R. and Tustin, R.C.* (eds), 1994. Infectious Diseases of Livestock With Special Reference to Southern Africa, VOL 1, 729 p. + app., and VOL 2, p. 733 - 1605 + app., Oxford University Press, Cape Town).

**** *Some health implications of several determinands (with respect to livestock) are outlined in* Anonymous, 1993. South African water quality guidelines, VOL 4, Agricultural use, Department of Water Affairs and Forestry, Pretoria, 286 p. (Further useful references are listed in Section 15.16.1 in the chapter on water quality).

A number of plant species are highly toxic to both small and large livestock. Probably the most important water-related poisonous plants are the blue-green algae (see the bibliographic database)*. Certain types of plants in conjunction with highly mineralized waters may also be the cause of stock losses. For example, urinary calculi (bladder stones) *can occur in all livestock and are responsible for severe losses, particularly in* sheep. The condition appears to be more common in areas where hard, alkaline (brack) water with a high total dissolved salts (solids) content is found, and where plants accordingly contain more mineral salts than elsewhere (Mönnig and Veldman, 1989). In such areas during winter, the scarce surface water sources have a higher concentration of salts due to a reduced dilution factor. Grazing is limited and is of poor quality. The plant moisture content is low. Livestock therefore increase their direct water consumption (including groundwater), thereby ingesting a higher concentration of salts. The excess salts are excreted by the kidneys which results in an unusually high salt content in the urine. Urinary calculi can then form, prompted by various other causes such as inflammation of the bladder. Vitamin A and phosphate deficiencies in winter or during droughts also play a role, while certain plants such as the diamond fig, sorrel and beet *promote the formation of bladder stones. (The oxalic acid in these plants combined with* the lime in the water results in the precipitation of insoluble oxalates in the bladder. This process is especially prevalent in sheep). Bladder stones in livestock vary from the size of a pea to a tennis ball or even larger. Difficulty or an inability to urinate usually accompanied by infection occurs in male animals. In severe cases, the bladder bursts and the abdomen becomes extended, resulting in death.

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* See Amann, M.J. and Eloff, J.N., 1980. Preliminary study of the toxins of different Microcystis strains, South African Journal of Science, VOL 76(9), p. 419 - 420., as well as Meyer, C.M., 1987. Contamination of water by the toxic blue-green alga Microcystis aeruginosa, South African Journal of Science, VOL 83(9), p. 517 - 518. (Both the Institute for Water Quality Studies, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001; and the Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort, 0110, are involved in research on the toxicity and control of algal blooms in water bodies).

in morbidity was suggested for ascariasis (four better studies) (range 15 - 83%); while a 77% median reduction in morbidity for schistosomiasis (three better studies) was established within the range 59 - 87%. With regard to the latter two diseases, the available evidence implied that a reduction in disease severity was also likely. All studies of hookworm were flawed with one exception, although a very slight reduction in incidence was reported for the study in question. A 27% median reduction in morbidity within the range 0 - 79% (seven better studies) was apparent for trachoma. Guinea worm is not found in South Africa, and has almost been eradicated where endemic in Africa.

In terms of overall child mortality, evidence based on six better studies suggested a median reduction in deaths of 55% within the range 20 - 82%, as a result of better services. The quoted studies however, did not specifically examine mortality reduction with regard to diarrhoeal diseases. It is difficult to precisely define the extent of health improvements following from upgraded water supplies and sanitation practices per se - given inter alia other factors prevailing in the home - although a clear decline in morbidity and mortality (where relevant), was apparent in the studies cited (Esrey et al). Some debate surrounds epidemiological studies and it appears that not all interventions may necessarily result in health improvements (or those at any rate, which can be properly measured).

It is important to bear in mind that improvements in water systems may result in water of a better (usually microbiological) quality and/or an increased supply of water per se which is available at a site closer to the household. The latter can be of considerable significance primarily in terms of general domestic and personal hygiene. Esrey et al observed that a higher household or per capita consumption of water could have a more significant impact on diarrhoea and ascariasis, than a better quality of drinking water alone. Friedman (1985)* working in the Valley Trust area of KwaZulu, found that a daily (household) per capita consumption of less than 10 ℓ appeared to be associated with a higher incidence of infantile diarrhoea. A similar linkage between consumption levels and morbidity was suggested in Lesotho (Feachem, Burns, Cairncross, Cronin, Cross, Curtis, Khalid Khan, Lamb and Southall, 1978)**. It is probable that a decrease in morbidity due to

* See Friedman, I., 1985. A multiple intervention point strategy in PHC, In: The Valley Trust Annual Report 1984, Valley Trust, Botha's Hill, p. 36 - 43.

** See Feachem, R., Burns, E., Cairncross, S., Cronin, A., Cross, P., Curtis, D., Khalid Khan, M., Lamb, D. and Southall, H., 1978. Water Health and Development: an Interdisciplinary Evaluation, Tri-Med Books, London, 267 p.

improved hygiene (reflecting a higher water consumption), is most apparent at subsistence consumption levels. Diarrhoea however, is multifactorial in origin with drinking water constituting only one of several routes of infection.

Water and sanitation in less developed countries received considerable attention during the 1980s, following the United Nations inspired declaration of the International Drinking Water Supply and Sanitation Decade. In a mid-point progress analysis by the World Health Organization in 1985, it was found that the greatest achievement had been in terms of rural water supplies, although much less success was evident for urban areas. Conversely, while urban sanitation services had shown some improvement, very little progress was visible in the rural areas. On an overall basis, gains were noted in terms of absolute numbers and in terms of the proportion of the rural population covered, although the percentage of people with improved services remained low due to population increases (Esrey et al). A similar pattern (with some regional variations) was evident in South Africa, although recent progress (especially for water supplies) has been rather more impressive.

Estimates of the number of people in South Africa "who lack access to a safe water supply" (itself a problematic concept), are very difficult to determine. Pearson (1991) as well as Palmer and Eberhard (undated, both quoted in Palmer and Eberhard, 1994)* suggested that some 10 - 11 million people (approximately 6,1 million rural and 4,7 million urban) could be so described. A further estimate of 19 million people (11,1 million rural and 7,67 million urban) has been put forward in terms of the population lacking adequate sanitation (Pearson, 1991; Palmer Development Group and the University of Cape Town, 1992, both quoted in Palmer and Eberhard, 1994). With regard to the overall urban population of Natal/KwaZulu and northern Transkei (proclaimed urban areas and "dense" settlements in peri-urban and rural areas), a "guesstimate" of 18,6% (22,7% for the Durban/Pietermaritzburg Metropolitan region) has been suggested as an indication of the

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* See Palmer, I. and Eberhard, R., 1994. Evaluation of water supply to developing urban communities in South Africa, Phase 1 - overview, WRC Report No. KV 49/94, Water Research Commission, Pretoria, various pages. (The data quoted refer to 1990, and include the homelands and the national states).

urbanized population with an inadequate water supply (Palmer and Eberhard, 1994)*. In rural areas of KwaZulu, some 75% of the population lacks access to "improved water supplies" (Water and Sanitation 2000 Work Group, 1991, quoted in Emmett and Rakgoadi, 1993)**. With reference to sanitation in urban areas and dense settlements in Natal/KwaZulu, an estimated 36% of the urbanized population do not have adequate sanitation (Palmer Development Group, 1992, quoted in Emmett and Rakgoadi, 1993). Only 10% of the rural population in KwaZulu has adequate sanitation (Water and Sanitation 2000 Work Group, 1991, quoted in Emmett and Rakgoadi, 1993). Obvious definitional and locational problems are inherent in these estimates. The data however, provide an indication of the magnitude of the problems to be addressed. Further estimates on water and sanitation services can be found in Emmett and Rakgoadi (1993). Other estimates at a more localized level are available in consulting engineering and planning agency reports (see for example, Smith, 1993)***.

One method of attempting to obtain an overall assessment of the adequacy of water and sanitation services (in terms of possible health implications), is to examine the types of systems in use. Data are seldom available on a specific geographic basis however, and wide variations are apparent with rural areas lacking most services. The Central Statistical Service in an analysis of socio-economic survey information including access to services (Table P2), found for example that only 18,7% of black households in Natal/KwaZulu had at least one tap within the dwelling; while 54,7% of households used a pit latrine (type unspecified). Only 24,3% of black householders - those in more formal housing in certain

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* Palmer and Eberhard (1994) defined an adequate water supply in a (proclaimed) urban area as constituting at least one standpipe per 25 households or within 50 m of each household, where at least 30 ℓ capita^{-1} is available on a daily basis. Adequate supplies in dense settlements were defined as a water point within 250 m or possibly 500 m of each household, where at least 15 ℓ capita^{-1} is available on a daily basis. The latter definition applies in the interim and the service level could more properly be described as rudimentary, pending upgrading to (proclaimed) urban standards. Adequate sanitation may be defined as one facility per household, and which is functional, acceptable to residents, contributes to health in the broadest sense, and can be managed by householders and the local authority. The minimum acceptable system is a Ventilated Improved Pit (VIP) toilet (site conditions permitting). The sanitation definition refers more to urban areas.

** See Emmett, T. and Rakgoadi, S., 1993. Water supply and sanitation services in South Africa, Project for Statistics on Living Standards and Development, Southern Africa Labour and Development Research Unit, University of Cape Town, Rondebosch, 218 p. + app.

*** See Smith, G., 1993. Economic development strategies for Region E, Phase 1: socio economic analysis and assessment, Working document for input into synthesis report - infrastructure, services and utilities, Regional Development Advisory Committee - Region E, Pietermaritzburg, 50 p. + app.

Table P2: Access to water, sanitation and waste disposal services with regard to dwelling type for the black population in Natal/KwaZulu, 1993.

Service	*Total dwellings*	*House*	*Flat*	*Townhouse/ cluster house*	*Traditional dwelling (hut)*	*Shack*	*Hostel*	*Other*
Water (main supply)								
Household tap/s	18,7	40,5	11,0	23,0	0,7	5,2	-	2,4
Yard standpipe	8,4	13,1	8,4	28,8	1,9	8,6	-	13,9
Communal standpipe	15,4	11,5	1,9	4,0	9,2	54,3	28,5	34,1
Borehole/well	16,1	10,5	8,7	24,2	26,4	3,3	-	17,4
River/dam/spring	39,5	23,4	65,7	18,6	61,8	23,0	5,9	32,2
Other source	1,8	1,1	4,4	1,3	-	5,5	65,6	-
Sanitation								
Flush/chemical toilet in dwelling	17,0	38,3	9,2	22,4	0,1	0,8	-	-
Flush/chemical toilet in yard	10,8	14,6	8,5	48,6	2,9	10,3	65,6	21,0
Latrine with bucket system	2,1	2,8	-	0,7	2,0	-	21,7	-
Pit latrine	54,7	37,5	79,6	28,3	67,7	75,4	12,7	38,0
No facility	15,5	6,8	2,7	-	27,3	13,6	-	40,9

Table P2: ***Access to water, sanitation and waste disposal services with regard to dwelling type for the black population in Natal/KwaZulu, 1993 (continued).***

Service	*Total dwellings*	*House*	*Flat*	*Townhouse/ cluster house*	*Traditional dwelling (hut)*	*Shack*	*Hostel*	*Other*
Waste disposal								
Removed by local authority	24,3	50,2	17,3	43,3	1,7	6,8	-	21,0
Communal refuse dump	9,3	6,7	12,6	4,2	3,4	37,1	21,7	19,0
Own refuse dump	46,3	34,5	12,7	39,3	65,2	40,0	5,9	45,7
None	20,1	8,7	57,3	13,3	29,7	16,1	72,4	14,3

Source: After Anonymous, 1994. Provincial statistics 1994, Part 5: KwaZulu/Natal, CSS Report No. 00-90-05 (1994), Central Statistical Service, Pretoria, 99 p. (Reports for the other new provinces as well as for South Africa as a whole have also been published).

Note:

(i) The above data were abstracted from a new series of surveys recently initiated by the Central Statistical Service (the October Household Survey). The first such survey was undertaken in 1993. Some later survey information is also available. Survey data are derived in October (hence the name). The survey (not to be confused with a census) has a development orientation with particular reference to the Reconstruction and Development Programme (RDP), and the socio-economic condition of South Africa. The data are available in the form of statistical (news) releases.

(ii) The data in the table do not directly distinguish between rural and urban areas.

(iii) Certain definitional problems are evident. For example, no distinction is made between types of springs (unprotected or protected); the types of pit latrines ("original" or improved in some form), and types of boreholes/wells (powered by engine, windmill, hand pump or drawn by hand in the case of wells). It is also not clear how far communal standpipes are from households - although this type of detail is difficult to obtain in broad surveys.

(iv) A brief overview of water supplies in informal settlements in Natal/KwaZulu, excluding the metropolitan areas, can be found in Hindson, D. and McCarthy, J., 1994. Chapter 1. Defining and gauging the problem, In: Hindson, D. and McCarthy, J. (eds), Here to Stay: Informal Settlements in KwaZulu-Natal, Indicator Press, Durban, p. 1 - 28. (See also Chapter 10. Settlement types and reconstruction, p. 123 - 132., as well as Chapter 11. Electricity and water provision, p. 133 - 142).

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urban areas - had a waste disposal service operated by the local authority. Further data on sanitation services are provided in the chapter on sanitation.

Considerable emphasis has been placed on improving water and sanitation services in South Africa as a primary objective of the Reconstruction and Development Programme (RDP)*. In order to help achieve this aim a new chief directorate, namely, the Chief Directorate: Community Water Supply and Sanitation, has been established in the Department of Water Affairs and Forestry**. An interim objective of the RDP is to provide all households with a potable supply of 20 - 30 ℓ capita^{-1} day^{-1} within 200 m of the household; as well as an adequate on site sanitation facility. The provision of a solid waste removal service for all urban households is also envisaged. (See the chapter on water supply planning, elsewhere in this publication). A medium term procedure is to provide an on site water supply of 50 - 60 ℓ capita^{-1} day^{-1} and an improved on site sanitation system. An adequate supply of water to nearly 100% of rural households as well as adequate sanitation facilities at 75% of rural households forms part of the medium term aims. The long term goal is to provide every household with an accessible water and

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* See African National Congress, 1994. The Reconstruction and Development Programme: a Policy Framework, Umanyano Publications, Johannesburg, 147 p. See also, Anonymous, 1994. White Paper on Water Supply and Sanitation Policy, Report No. WP-I, Department of Water Affairs and Forestry, Cape Town, 38 p. Note that a draft White Paper on sanitation policy per se will be released in the near future.

** For an overall discussion see Anonymous, 1994. The role of the Department of Water Affairs and Forestry in the National Reconstruction and Development Programme, Water Sewage and Effluent, VOL 14(3), p. 15 - 19.

sanitation service. It has been recommended that a (minimum) life-line or social tariff should be applied for on site metered connections in urban areas (Palmer Development Group, 1994)*. Such a tariff would be based on a consumption of 20 - 30 ℓ capita^{-1} day^{-1}, which would ensure sufficient water to meet health and basic needs requirements. *Consumption in excess of this figure would attract a higher unit (block rising rate) tariff.*

16.3 <u>Some sources of medical data for human epidemiological studies</u>**

The availability of various sources of medical data in South Africa, with particular reference to epidemiological studies, was discussed by Bourne, Sayed and Klopper (1990). Relevant health data are of two main types, namely, the incidence and prevalence of selected diseases, and death statistics. It is a legal requirement in South Africa that all deaths must be reported to the Department of Home Affairs (via the magistrate's court in smaller centres). The most accessible source of overall mortality data is the Central Statistical Service, Private Bag X44, Pretoria, 0001. Numerous reports are issued by the Service***. The information provided, excludes the national states from the date of *independence. Mortality statistics for the black population generally, are not complete* (especially for rural areas), while the quality of reporting may vary. It has been suggested that up to 80% of deaths amongst the black population are not officially recorded, where death statistics refer to registered deaths only. In any event, mortality data for the black

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* See Palmer Development Group, 1994. Water and sanitation in urban areas: financial and institutional review, Report 3. Meeting the demand for water and sanitation services: getting it right in the transition, WRC Report No. 571/3/94, Water Research Commission, Pretoria, 101 p. + app.

** Discussion based on Bourne, D.E., Sayed, A.R. and Klopper, J.M.L., 1990. A data base for use in the epidemiological surveillance of potential changes in drinking water quality in South Africa, WRC Report No. 186/1/90, Water Research Commission, Pretoria, 81 p. A useful text on epidemiological research procedures is the following: Katzenellenbogen, J., Joubert, G. and Yach, D., 1991. Introductory manual for epidemiology in southern Africa, Medical Research Council, [Tygerberg], 166 p. + app.

*** See for example, Anonymous, 1992. Deaths: whites, Coloureds and Asians, 1990, Report No. 03-09-01 (1990), Central Statistical Service, Pretoria, 559 p., as well as Anonymous, 1992. Deaths of blacks: 1990, Report No. 03-10-01 (1990), Central Statistical Service, Pretoria, 255 p. (Readers *requiring specific data are advised to study these reports <u>very carefully</u>. Data are presented for 1990* only. The procedure for obtaining earlier (and later) reports is described at the end of the chapter. Reports on deaths, published from 1993 onwards, do not distinguish between the various population groups. Only one report per year accordingly, is issued).

population are only available from 1978 onwards for the whole country (Anonymous, 1994)*.

The Central Statistical Service report for the black population for 1990 lists the number of deaths in the various magisterial districts (including homeland magisterial districts), although the cause of death is not specified per district, nor are any death rates provided for the given areas. The necessary information can however, be derived from abstracts of death certificate data which are available on computer tapes from the Central Statistical Service (Bourne et al, 1990). The published data for 1990 have been divided into urban and non-urban areas for each district, with age at death information also available for selected statistical regions and homelands. Data in addition, are provided on the overall number of deaths per age group, and per disease category for certain age intervals. Month of death statistics are likewise available per disease category. A further breakdown of the data refers to infant deaths. A standard classification and coding system for the causes of death (based on the International Statistical Classification of Diseases, Injuries and Causes of Deaths (ICD), 1975, ninth revision - as compiled by the World Health Organization), can be found in the reports. The classification system has been adapted for South African conditions. A separate publication describing the classification system is available from the Central Statistical Service**.

Another source of mortality data are the South African life tables which are also compiled by the Central Statistical Service***. Such data are not available for the black

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* See Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p.

** An earlier version of the publication is as follows: Anonymous, 1971. Statistical classification of diseases, injuries and causes of death (based on the International Classification of Diseases, I.C.D., eighth revision, 1965): for the use and guidance of the medical profession in South Africa, Report No. 07-03-00, Department of Statistics, Pretoria, 38 p.

*** See for example, Anonymous, 1985. South African life tables 1979 - 81, Report No. 02-06-03, Central Statistical Service, Pretoria, 28 p. (Useful statistics reflecting the probability of death and the expectation of life at intervals of five years of age, are provided in the report for the core periods 1925 - 1927; 1935 - 1937; 1945 - 1947; 1950 - 1952; 1959 - 1961; 1969 - 1971 and 1979 - 1981 for whites; 1935 - 1937 onwards for Coloureds, and 1945 - 1947 onwards for Asians. The greater life expectancy and a reduction in the probability of dying, evident for the period of record, reflect overall improvements in standards of living and socio-economic circumstances amongst the three population groups). Projected life table data for the black population can be found in the following: Sadie, J.L., [1976]. *Projections of the South African population 1970 - 2020*, Industrial Development Corporation of South Africa Ltd, Johannesburg, 66 p. See also: Dorrington, R.E., 1987. African mortality rates - an initial estimate, Transactions of the Actuarial Society of South Africa, VOL 7(1), p. 169 - 202.

population. Life tables are an artificially constructed tool and provide a method for combining the mortality rates of a population at different ages, into a single statistical model. Life tables are based on the concept of a hypothetical population of 100 000 people of a specified sex and population group, who are regarded as having been born at the same time. The initial cohort is then tracked through successive ages (year by year) with the mortality of the survivors at each age, being in accordance with the mortality rates prevailing for a particular period. Accordingly, survival is assessed in terms of given mortality conditions (for example, those conditions existing in the period 1979 - 1981, which are assumed to apply for a lifetime). The specific life tables quoted, were based on the 1980 population census, plus birth and death statistics for the period 1979 - 1981, centred on the census year. Separate life tables are calculated for males and females (reflecting different mortality rates), with respect to whites, Coloureds and Asians.

Bourne, Sayed and Klopper (1990) used Central Statistical Service data (including census information), for a detailed spatial analysis of death rates and for the compilation of a mortality atlas, in terms of 263 magisterial districts. The mapping of mortality statistics formed part of a larger survey aimed at building up a database for use in epidemiological studies with regard to potable water. All homelands and national states plus certain magisterial districts where boundaries had been altered for the survey period were excluded from the spatial analysis. Also excluded were data for the black population. The data-set for whites, Coloureds and Asians covered the period 1978 - 1982. Results of two special regional surveys (undertaken earlier) were incorporated in the overall study, namely, data for Windhoek and Cape Town (both with regard to the possible health implications of recycled sewage water)*. A further public health measure of mortality - the potential years of life lost with reference to an age of 65 years - was calculated on a spatial basis for <u>all</u> population groups; as were life tables for whites, Coloureds and Asians. The mortality atlas is available on computer tape from the authors at the Department of Community Health, Medical School, University of Cape Town, Observatory, 7925. Maps showing the distribution of life expectancy in terms of statistical region, sex and three

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* See Isaäcson, M., Sayed, A.R. and Hattingh, W.H.J., 1987. Studies on health aspects of water reclamation during 1974 to 1983 in Windhoek, South West Africa/Namibia, WRC Report No. 38/1/87, Water Research Commission, Pretoria, 77 p. See also, Bourne, D.E., Sayed, A.R., Watermeyer, G.S. and Klopper, J.M.L., 1987. Epidemiological studies pertaining to the possible reclamation and reuse of purified sewage effluent in the Cape Peninsula, WRC Report No. 74/1/87, Water Research Commission, Pretoria, 155 p. and map. (Guidelines drawn up by the Department of National Health and Population Development for the domestic reuse of wastewater are contained in the latter report, and also in Anonymous, 1986. <u>Management of the Water Resources of the Republic of South Africa</u>, Department of Water Affairs, Pretoria, various pages).

population groups can likewise be obtained from the authors. The Central Statistical Service computer tapes used in the study are stored at the Medical School as well as at the head office of the Medical Research Council, P O Box 19070, Tygerberg, 7505.

Besides mortality statistics, other health indicators are required for epidemiological studies. Accordingly, sources of routinely available morbidity information were investigated by Bourne et al. Important sources include hospital and other medical facility data*; notifiable diseases (discussed elsewhere in this chapter), and the National Cancer Registry (NCR). The NCR is maintained by the South African Institute for Medical Research, P O Box 1038, Johannesburg, 2000. A further source of morbidity data (appropriate for surveillance purposes), namely, the National Disease and Therapeutic Index - South Africa, was identified by Bourne et al. The latter data are compiled by a private company (mainly for the pharmaceutical industry), and are derived from a rotating panel of general practitioners and specialists in private practice.

Part of the overall research programme undertaken by Bourne et al involved the establishment (in conjunction with the Department of National Health and Population Development), of a national birth defects surveillance system - initially centred on Cape Town. The project determines the incidence of clinically observable birth defects for the first week of life. Birth defects are rapidly apparent and provide one indication of environmental damage to the foetus (caused by exposure to toxic chemicals inter alia in the water supply). (There are of course, various natural causes of birth defects as well). A copy of the health database compiled by Bourne et al has been placed on computer tape and is available at the Computing Centre for Water Research, University of Natal, Private Bag X01, Scottsville, 3209. The database has already been used for an investigation into hard water and cardiovascular disease mortality (see Section 16.12.3).

* The Central Statistical Service publishes a series of reports based on hospital and other medical facility statistics. Only limited data are available on morbidity, in terms of population group and province/homeland. No detailed analysis is provided of the causes of morbidity by age or sex. See for example, Anonymous, 1993. Census of hospitals, community health care centres and other health service establishments, 1990, CSS Report No. 93-01-01 (1990), Central Statistical Service, Pretoria, 176 p. (The morbidity data in the report refer only to May and June 1990. The procedure for obtaining earlier (and later) reports is described at the end of the chapter. Those requiring local health statistics should contact the medical officer of health of the relevant local authority, the regional office of the Department of National Health and Population Development, or the KwaZulu Department of Health in Ulundi).

16.4 Interpretation of medical statistics

The problems described by Bourne, Sayed and Klopper (1990 - above) with reference to available mortality and morbidity statistics especially for the black population - together with evidence from elsewhere - suggests that health data should be interpreted with caution. Considerable difficulties are evident particularly in the rural areas where deaths may occur at home (unrecorded); or where serious illnesses are either not reported at all, are under-reported, or are possibly misdiagnosed by overworked clinic and hospital staff*. There is also a suspicion that certain notifiable diseases are not being reported in the urban areas (as required in terms of the Health Act No. 63 of 1977). There appears to be no (present) cohesive and functional strategy for the comprehensive retrieval of important medical statistics. Compounding the problem is the considerable number of health authorities in South Africa (Walters, 1995)**.

16.5 Infectious and parasitic diseases statistics for the black population

An analysis by the Central Statistical Service*** of patients discharged from hospitals and other medical establishments in South Africa (including the homelands, but excluding the national states) during May and June 1990, revealed that a fair proportion of the total number of discharged black patients had suffered from infectious and parasitic diseases. Of 17 categories of morbidity****, only treatment related to pregnancy, childbirth and the puerperium (the period up to approximately six weeks after childbirth)/accidents,

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* See Botha, J.L. and Bradshaw, D., 1985. African vital statistics - a black hole?, South African Medical Journal, VOL 67(24), p. 977 - 981. See also, Kielkowski, D., Steinberg, M. and Barron, P.M., 1989. Life after death - mortality statistics and the public health, South African Medical Journal, VOL 76(12), p. 672 - 675., as well as McGlashan, N.D., 1985. Death certification of blacks in South Africa as a data-source for geographical epidemiology, South African Journal of Science, VOL 81(9), p. 571 - 578.

** Walters, I., 1995. Personal communication, City Health Department, Pietermaritzburg Corporation, Pietermaritzburg.

*** See Anonymous, 1993. Census of hospitals, community health care centres and other health service establishments, 1990, CSS Report No. 93-01-01 (1990), Central Statistical Service, Pretoria, 176 p. (It is important to note that the discussion generally refers to in-patients, although certain out-patients, namely, those admitted as out-patients to an out-patients' care facility (special bed), appear to be included).

**** According to the ICD ninth revision, infectious and parasitic diseases (as a broad category), are coded as 001 - 139. Individual codes are provided for certain diseases or groups of diseases. The ICD classification system however, has greater relevance for deaths rather than morbidity (in terms of the publication of South African health statistics by the Central Statistical Service).

poisoning and violence/ill defined and unknown conditions/diseases of the respiratory system (all in declining order of the number of patients discharged), ranked higher than infectious and parasitic diseases amongst black patients. On a percentage basis, the relevant statistics were 18,7%; 15,8%; 12,1%; 9,1% and 6,2% respectively of all discharged black patients. If the three categories - accidents, poisoning and violence/ill defined and unknown conditions/mental disorders - are excluded from the analysis, then infectious and parasitic diseases accounted for 9,0% of all discharged black patients in the survey period. The annual rate of discharged (black) patients diagnosed as suffering from infectious and parasitic diseases, was estimated at 5,9 patients per 1 000 of the overall black population. Expressed in another way, black patients constituted 70,1% of all (discharged) patients diagnosed as suffering from infectious and parasitic diseases. For whites, infectious and parasitic diseases ranked 13th in terms of the number of discharged white patients. Asians had the lowest frequency of infectious and parasitic diseases.

The statistics for South Africa *per se* reflect national patterns and include large parts of the country where diseases such as schistosomiasis and malaria are either of minor significance, or are of no local relevance (for example, in the central Karoo). An examination of infectious and parasitic diseases for discharged black patients in Natal/KwaZulu however, revealed that such diseases ranked second after the category - pregnancy, childbirth and the puerperium - with blacks constituting 91% of all discharged patients suffering from infectious and parasitic diseases in Natal/KwaZulu*. By contrast, these diseases ranked 11th amongst discharged black patients in the Orange Free State. The above statistics should be interpreted with caution, given the very limited survey period and the difficulties of obtaining accurate data for the black population. Secondly, the diagnosis may not always reflect initial health problems, where serious secondary complications are evident. (The diagnosis may also be incorrect). Thirdly, problems of definition arise with regard to patient catchment area. For example, many black patients

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* The most common helminthic (parasitic worm) infections especially in children in Natal/KwaZulu, are schistosomiasis (discussed later in the chapter), ascariasis (large roundworm infection), and trichuriasis (whipworm infection). *Taenia* spp. (tapeworms) likewise, are prevalent in many areas. Hookworm infection is much less common and is mainly confined to warm, moist areas. Protozoan infections (mainly due to *Giardia lamblia* and *Entamoeba histolytica*), are also evident in certain districts (Kvalsvig, J. and Connolly, K., 1994. Chapter 5. Health and psychological development among children in poor communities, In: Dawes, A. and Donald, D. (eds), *Childhood and Adversity: Psychological Perspectives from South African Research*, David Philip Publisher, Cape Town, p. 92 - 106). See also, Schutte, C.H.J., Eriksson, I.M., Anderson, C.B. and Lamprecht, T., 1981. Intestinal parasitic infections in black scholars in northern KwaZulu, *South African Medical Journal*, VOL 60(4), p. 137 - 141.

from the Transkei are treated at Natal Provincial Administration facilities in East Griqualand. The data accordingly, reflect trends rather than absolute numbers. Importantly, only some infectious and parasitic diseases are necessarily related to water and/or soil. The true significance of the data for water and soil diseases is unknown. A further complicating factor is the disagreement amongst medical experts on the specific role of water and soil *in the transmission of certain diseases.*

16.6 Death statistics (due to infectious and parasitic diseases) for the black population

The latest Central Statistical Service report on deaths for the black population* provides mortality data for 1990. With regard to infectious and parasitic diseases for all the provinces and homelands, 26,4% of deaths amongst blacks occurred at an age of less than one year; increasing to 34,5% for children of up to one year old and younger. Deaths due to infectious and parasitic diseases per se for all ages, constituted 11,1% of all recorded deaths of blacks (in terms of 17 categories of disease). It is encouraging to note that deaths resulting from infectious and parasitic diseases (as a percentage of all deaths) for the black population, have seemingly declined from a high of 22% recorded in 1978 (Anonymous, 1994)**. More detailed data are presented in the Central Statistical Service report (for the whole country), in terms of various age groups and specific disease categories such as cholera, as well as typhoid and paratyphoid fevers (as per the ICD classification). A breakdown of deaths also by ICD category, is provided for (infant)

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* See Anonymous, 1992. Deaths of blacks: 1990, Report No. 03-10-01 (1990), Central Statistical Service, Pretoria, 255 p. (The data exclude still births).

** See Anonymous, 1994. *Health trends in South Africa 1993, Department of National Health and* Population Development, Pretoria, 96 p.

children in various age groups up to and including 11 months old*. Little purpose is served in discussing such information, given the problems of defining data relevant to water and soil specific diseases, and the difficulties inherent in examining one year only. Of greater relevance are notifiable diseases and deaths (for all population groups) for a longer time period, and mainly with reference to water and soil-related diseases (Table P3). Readers are reminded that detailed information on mortality due to various diseases including notifiable diseases (although not the accompanying morbidity data), can be manually extracted through the careful examination of Central Statistical Service reports on the deaths of blacks as well as whites, Coloureds and Asians. These reports were subsequently combined into one report (as discussed earlier).

Many of the serious diseases which afflict the black population of South Africa are essentially diseases of poverty. While more effective intervention by the health authorities is required - especially in the rural areas and in squatter settlements - of great importance is the provision of improved water supplies and sanitation systems as well as efficient refuse removal. Food security is likewise essential. The "sanitary revolution" of the 18th and 19th centuries in Europe was built on the foundations of public health and a similar programme involving inter alia primary health care (PHC) must be maintained in South Africa.

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* An overall national estimate of infant mortality rates amongst the black population of 94 - 124 deaths per 1 000 live births was derived for 10 large urban areas in South Africa (including Durban and Pietermaritzburg). Mortality rates were found to be variable on a spatial and annual basis. See Yach, D., 1988. Infant mortality rates in urban areas of South Africa, 1981 - 1985, South African Medical Journal, VOL 73(4), p. 232 - 234. In a more recent analysis, an infant mortality rate of 52 deaths per 1 000 live births was estimated for KwaZulu per se for 1993 (Anonymous, 1994 - above). Deaths due to diarrhoeal diseases in South Africa, as a specific sub-set, were examined by Yach, D., Strebel, P.M. and Joubert, G., 1989. The impact of diarrhoeal disease on childhood deaths in the RSA, 1968 - 1985, South African Medical Journal, VOL 76(9), p. 472 - 475. The authors observed that black and Coloured children under one year old were most at risk and that diarrhoea was a major cause of morbidity and mortality. Mortality for black children was highest in the period December - March. The proportion of total mortality in children 0 - 4 years old, due to diarrhoeal diseases, is regarded as a reasonable indicator of socio-economic conditions as well as the effectiveness of primary health services. In this regard, recorded deaths resulting from diarrhoea, as a percentage of all deaths for black children 0 - 4 years old, declined from 42 - 18% in the period 1978 - 1990 in South Africa (excluding the national states) (Anonymous, 1994 - above).

Table P3: Reported cases of illnesses and deaths due to notifiable diseases (mainly in terms of water and soil-related diseases) in South Africa, 1981 - 1987.

Disease	Number of reported illnesses	Number of reported deaths
Cholera	28 182	112
Haemorrhagic fevers of Africa	154	14
Leptospirosis	3	1
Malaria	34 892	87
Poliomyelitis	632	10
Toxoplasmosis	27	0
Trachoma	2 727	1
Trypanosomiasis	4	0
Typhoid fever	26 728	396
Typhus fever	1	0
Viral hepatitis (all types)	11 351	237
Yellow fever	0	0
Total	104 701	858

Source: After Van Pletsen, D. (ed), 1988. Official Yearbook of the Republic of South Africa: South Africa 1988-89, fourteenth edition, Bureau for *Information, Pretoria, 816 p.*

See also:

(i) Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p. (The report provides an informative overview of various health matters in South Africa including notifiable diseases, health indicators and general health trends. The publication should be examined by readers requiring more detailed and longer term information. Four previous editions of the report have been published).

(ii) Slabber, C.F., 1995. Report of the Director-General: Health for the year 1994, Report No. RP 96/1995, Government Printer, Pretoria, 47 p. (The report contains annual data for notifiable diseases in the period 1989 - 1993 inclusive, with respect to reported illnesses and deaths).

(iii) Van Rensburg, H.C.J. and Mans, A., 1987. Profile of Disease and Health Care in South Africa, Academica, Pretoria, 319 p.

(iv) Vlok, M.E., 1986. Manual of Community Nursing and Psychiatry: a Textbook for South African Student Nurses, Juta, Cape Town, 816 p.

Note:

(i) The definition of "South Africa" is not clear. It should be borne in mind that the Transkei was granted independence in 1977, Bophuthatswana in 1978, Venda in 1980, and Ciskei in 1982.

(ii) The classification of a notifiable disease varies over time. Leptospirosis, toxoplasmosis and trypanosomiasis were previously listed as notifiable diseases, although this is currently not the case (see Table P1). Poisoning as a result of any agricultural or stock remedy registered in terms of the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947, is also a notifiable disease. See the chapter on solid waste management.

(iii) Problems of definition are apparent in terms of water and soil-related diseases. The haemorrhagic fevers for example include a broad category of diseases, only a few of which are relevant here (such as Dengue fever and Rift Valley fever - see Table P1)*. Certain statistical difficulties are also evident for the data in respect of deaths assessed on an annual basis.

(iv) Readers requiring data on an annual basis should consult the source listed above as well as other yearbooks. The data are not cumulative however, and the very latest statistics cover a shorter time period. *The annual reports of the Department of National Health and* Population Development should likewise be examined. The incidence of the more serious diseases varies from year to year depending on circumstances such as epidemics (for example, cholera). In the period 1980 - 1987, cholera reached epidemic proportions in certain parts of South Africa (including Natal/KwaZulu).

(v) Some important trends in morbidity notification (infection) rates in South Africa in terms of water and soil-related diseases are given below. Note that the rates fluctuate from year to year.

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* A brief outline of the major African haemorrhagic diseases can be found in Simpson, D.I.H., 1983. Haemorrhagic fevers of central Africa, <u>South African Journal of Science</u>, VOL 79(3), p. 115 - 116. (Other abstracts in the journal issue may be of interest). See also, Gear, J.H.S., 1984. The haemorrhagic fevers of southern Africa, <u>South African Journal of Science</u>, VOL 80(10), p. 449 - 454., *as well as Swanepoel, R., 1987. Viral haemorrhagic fevers in South Africa: history and national strategy,* <u>South African Journal of Science</u>, VOL 83(2), p. 80 - 88.

Disease	Disease notification rate per 100 000 population for the period indicated	Disease notification rate per 100 000 population in Natal and KwaZulu for 1992
Malaria	-	Natal 2,0 KwaZulu 4,0
Trachoma (1972 - 1992 for the black population, excluding the national states. Nearly all cases occur in Venda. The trend presented here is unreliable and is dependent on active case-finding)	2,20 - 0,00	*Not relevant for Natal and* KwaZulu. A total of 459 cases was found in South Africa (including the national states) in 1992
Typhoid fever (1970 - 1992 for the black population, excluding the national states)	26,60 - 4,80	Natal 1,8 KwaZulu 5,7
Viral hepatitis (1980 - 1992 for all population groups, excluding the national states) Hepatitis A	0,05 - 4,33	No data provided
Hepatitis B	0,09 - 1,96	
Unspecified	6,41 - 1,10	
All types (1970 - 1992)	4,48 - 7,39	

Source: After Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p.

(vi) Useful statistics (inter alia on notifiable diseases) are provided in the monthly periodical Epidemiological Comments, which is published by the Department of National Health and Population Development in Pretoria. Relevant statistics for Natal/KwaZulu can be found in the periodical Epidemiological Focus, which is published on a quarterly basis by the Natal Region of the Department.

16.7 Sources of health indicator data

The Department of National Health and Population Development, now (post-1994 election) the (National) Department of Health, with nine provincial Departments of Health, has been involved with a housing and related amenities survey since 1991*. The BBG survey as it is known, is an on-going programme aimed at assessing health conditions in terms of the provision of more effective health services; and for the upgrading of living standards. Various health indicators are used including the state of dwellings, the number of residents per dwelling, and refuse disposal practices as well as sanitation and water facilities. The information obtained with reference to water concerns the source of water, the purification processes (if any), and the distance walked to collect water. Water quality is examined on a periodic grab sample basis, mainly with regard to microbiological determinands. Basic details are also obtained on any reticulation systems. The type and condition of toilets is likewise noted. The programme has concentrated on farms and black freehold settlements, with certain local authorities undertaking surveys in urban areas (at the request of the Department). The survey will be extended to include KwaZulu. A related programme undertaken by the Department in Natal, involves an assessment of the number of pupils and classrooms as well as the availability of electricity, water and sanitation at rural schools.

A primary objective of the programme is to establish baseline data which will be updated at regular intervals in representative areas. The physical survey data are maintained on a Geographic Information System, digitised at the 1 : 50 000 fieldwork (topographic map) scale. Data are available at a national, provincial or magisterial district level (or part thereof). It is envisaged that the information will be correlated with the database of notifiable diseases (and schistosomiasis statistics) maintained by the Department, plus water quality data obtained from the Department of Water Affairs and Forestry as well as water boards. The data-set will be used for epidemiological studies.

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* Discussion after the KwaZulu-Natal Department of Health, Pietermaritzburg, 1995. See also, Grundling, I.D. and Nel, J.J.A., 1991. *Basic subsistence facility indicators: RSA - rural areas January 1991 - March 1991*, Community Health in Southern Africa, VOL 6(3), p. 26 - 28. (For further information contact the Department of National Health and Population Development, Private Bag X54318, Durban, 4000/Private Bag X9067, Pietermaritzburg, 3200).

16.8 A brief overview of poverty in South Africa

Selected statistics on the income distribution of the South African population are available from the Central Statistical Service (the population census series of reports). An abridged version of the data can be found in the new provincial statistics publication series*. *Given the difficulties of accurately determining personal (confidential) information in any* national census, it is nevertheless disturbing that 75,4% of the black population in Natal/KwaZulu was classified as receiving no income in 1991, while a further 2,6% had an annual income of less than R999. According to the 1991 census, blacks constituted 81,5% of the total population of Natal/KwaZulu. Notwithstanding the inaccuracies of census data, it is evident that a significant proportion of the population of Natal/KwaZulu suffers from extreme poverty (however defined). The problems of poverty are compounded by the high dependency ratio, where 42% of the black population of Natal/KwaZulu in 1991 was 14 years old or younger. (This age group accounted for 39,7% of all deaths due to infectious and parasitic diseases in South Africa, amongst the black population in 1990 - refer to Section 16.6).

According to the latest estimates of the Central Statistical Service (Anonymous, 1994)**, the South African population is increasing at an overall rate of 2,2% y^{-1}. While various estimates of the population growth rate are found in the literature, an annual growth rate of 2,2% implies a doubling time of 34 years (assuming that fertility and mortality rates remain the same)***. Unless a high economic growth rate can be

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* See Anonymous, 1994. Provincial statistics 1994, Part 5: KwaZulu/Natal, CSS Report No. 00-90-05 (1994), Central Statistical Service, Pretoria, 99 p.

** See Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p.

*** It has been suggested that high birth rates among poor households is a survival strategy, given the high mortality rate for young children. A low infant mortality rate accordingly, is an important prerequisite for a low fertility level. The Department of National Health and Population Development established a Population Development Programme (PDP) in 1984, although the effectiveness of the policy has been variable, in view of political difficulties. The PDP is now located in the (post-1994 election) Department of Welfare and Population Development. An overview of the Programme is presented in Klugman, B., 1994. Population policy in South Africa: where to from here?, Policy Working Paper No. 31, Development Bank of Southern Africa, Halfway House, 24 p. See also, Hart, T. and Morris, P., 1984. Overpopulation: three juxtapositions examined, South African Journal of Science, VOL 80(9), p. 400 - 403., as well as Sadie, J.L., 1987. The human resources of South Africa, South African Journal of Science, VOL 83(5), p. 289 - 294. (While AIDS has not been discussed in the present publication, it is evident that population projections and hence the demand for *services must be adjusted. The full extent of AIDS - in practical reality - has yet to become* apparent in South Africa).

sustained, it is possible that the sheer depth of poverty could overwhelm the health services - with serious implications for morbidity and mortality (due inter alia to water and soil-related diseases). Demands for necessary infrastructure such as water and sanitation could become insurmountable (especially in urban areas subject to high influx rates). Serious doubts have also been expressed regarding the total population which can be supported by a largely semi-arid country. *(See the chapter on water supply planning)**.

McGrath and Whiteford (1994)** examined the income distribution of the South African population with regard to 1991. Income data were derived from various sources including the 1991 population census as well as income and expenditure surveys in the Transkei, Bophuthatswana, Venda and Ciskei. The analysis revealed that more than two-thirds of the black population of South Africa had incomes lower than the Minimum Living Level (MLL) - calculated for urban black households with reference to household size - and that poverty (so defined) was especially prevalent in the rural areas. In Natal/KwaZulu, 53% of all population group households lived below the MLL (most of whom were black). Although the overall level of poverty amongst black households in South Africa remained fairly constant in the period 1975 - 1991, the poorest 60% of black households (already poverty-stricken in 1975), had sunk even deeper into poverty by 1991. The survey further revealed that nearly all the increased incomes accruing to the black population in general in the period 1975 - 1991, had gone to the richest 20% of black households. The economic situation of the remaining 80% of black households had deteriorated considerably. These households were poorer (in real terms) in 1991 than in 1975. Income inequality in the black population therefore, is increasing.

The income data-set is being upgraded through a detailed analysis of statistics derived from approximately 9 000 representative households across South Africa, which were

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* An up-to-date and rather sobering overview of some implications of South Africa's population growth rate is the following: Haldenwang, B.B. and Boshoff, S.C., 1996. Forecasts of the South African population, 1991 - 2026, Occasional Paper No. 26, Institute for Futures Research, University of Stellenbosch, Stellenbosch, 96 p. (Separate publications by the same authors likewise dated 1996, are also available for each new province of South Africa).

** See McGrath, M. and Whiteford, A., 1994. Inequality in the size distribution of income in South Africa, Stellenbosch Economic Project Occasional Paper No. 10, Centre for Contextual Hermeneutics, University of Stellenbosch, Stellenbosch, 32 p. (The project was undertaken under the auspices of the Human Sciences Research Council, Private Bag X41, Pretoria, 0001). See also, Ardington, E., 1994. Quantitative analysis of socio-economic data from five thousand households in KwaZulu: a secondary analysis of data from an income and expenditure survey conducted in KwaZulu in 1992 by Data Research Africa, CSDS Research Report No. 4, Centre for Social and Development Studies, University of Natal, Durban, 59 p.

surveyed in September 1993*. The latter study is part of the World Bank-funded Project for Statistics on Living Standards and Development, co-ordinated by the Southern Africa Labour and Development Research Unit, University of Cape Town. Other information obtained during the course of the 9 000 household survey included housing and health as well as water and sanitation services data**. (See the chapter on water supply planning)***.

An important implication of income surveys (when viewed from a geographical perspective), is the extent to which specific communities are able to afford improved services and accordingly, the degree of State subsidization required. The locational and economic priority of work relief programmes involving for example, soil conservation and water projects, can also be more accurately assessed. *Geographic Information Systems* (GIS) play a major role in the planning process. It should be noted that the Human Sciences Research Council, P O Box 17302, Congella, 4013, operates a GIS for Natal/KwaZulu, with numerous census and infrastructure data readily available in terms of spatial distribution. Refer to the chapter on maps.

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* For a perspective on poverty in the Durban Metropolitan Area see Cobbledick, J. and Sharratt, M., 1993. A profile of poverty in the Durban region, Project for Statistics on Living Standards and Development, Southern Africa Labour and Development Research Unit, University of Cape Town, Rondebosch, 152 p. (A separate report for Natal/KwaZulu is also available in this series).

** See Anonymous, 1994. South Africa's rich and poor: baseline household statistics, August 1994, Project for Statistics on Living Standards and Development, [Southern Africa Labour and Development Research Unit], University of Cape Town, Rondebosch, 345 p. + app., as well as Reconstruction and Development Programme, 1995. Key indicators of poverty in South Africa, South African Communication Service, Pretoria, 27 p. See also, May, J., Carter, M. and Posel, D., 1995. The composition and persistence of poverty in rural South Africa: an entitlements approach to poverty, LAPC Policy Paper No. 15, Land and Agriculture Policy Centre, Johannesburg, 135 p.

*** Further planning data (presently being processed) will be available in respect of a 6 500 household survey. The survey, initiated in 1996 by the Human Sciences Research Council, Durban and the KwaZulu-Natal provincial authorities, was aimed at achieving a more co-ordinated approach to planning and service delivery in the province. The survey assessed several indicators such as income distribution; the level of urbanization; unemployment; room density; the proximity of a safe water supply; access to a waterborne toilet; the availability of electricity in the home, and refuse removal/disposal practices. Other indicators tested perceptions of the level of satisfaction with, amongst other things, local facilities and services (including infrastructure) and the provision of basic needs. The survey was undertaken throughout the province.

16.9 Two diseases of importance in South Africa

16.9.1 Malaria*

Malaria can be transmitted in four ways, namely: through the bite of an infected mosquito (the main route); by the transfusion of blood from an infected donor and by syringes and needles contaminated with infected blood; congenitally from mother to foetus (rare), and through the bite of a blood-sucking fly acting as a mechanical transmitter. (The latter may theoretically occur, but if evident, is extremely rare). The parasites causing malaria are protozoa of the (class) Sporozoa (suborder) Haemosporidia (genus) Plasmodium. Four species of Plasmodium infect man and all are found in southern Africa. These organisms are firstly, Plasmodium falciparum which results in malignant tertian malaria. The parasite causes the severest forms of the disease (known as pernicious malaria), such as cerebral malaria, which must be promptly treated to prevent death. Secondly, P. vivax (extremely rare in Africa), is the parasite responsible for benign tertian malaria. If the disease is left untreated, the patient may have periodic fever for up to 20 attacks, which gradually lessen in severity and then cease for some 6 - 9 months. Further attacks can occur thereafter. Even if fully treated, relapses are common (at given intervals) within a period of up to seven years. A similar disease pattern is evident as a result of P. ovale, the parasite causing ovale malaria (not common in South Africa). P. malariae (rare in South Africa), is the parasite responsible for quartan malaria. In chronic cases of quartan malaria, the patient becomes anaemic - a condition often associated with so-called "big spleen disease". Big spleen disease may also be evident in cases of chronic P. falciparum infection. Subacute tubular nephritis (a kidney infection) is also common. Patients may in addition, develop oedema and ascites (swelling as a result of blood collecting in the tissues or internal cavities such as the stomach). Attacks due to P. malariae can occur at intervals for several years (often as long as 10 years, but up to 20 - 40 years in some cases).

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* Discussion based on Gear, J.H.S., Hansford, C.F. and Pitchford, R.J., 1981. Malaria in southern Africa, Department of Health, Welfare and Pensions, Pretoria, 49 p. A brief overview of the disease is provided in Anonymous, 1981. Malaria: what you should know about it, Department of Health, Welfare and Pensions, Pretoria, 14 p. See also, Maurel, M., 1994. Malaria: a Layman's Guide, Southern Book Publishers, Halfway House, 115 p. (This section of the source book was reviewed by D. Le Sueur, Medical Research Council, Durban. The author (P.G. Alcock) is however, responsible for any errors in the text).

The mosquito vectors of malaria in southern Africa belong to the (genus) Anopheles of the (family) Culicidae and (subfamily) Anophelinae. Over 30 species of Anopheles are present in southern Africa. The important malaria vectors are members of the Anopheles gambiae Giles complex and the Anopheles funestus group (the latter rarely found in South Africa now, as a result of spraying activities). Several species of the An. gambiae complex are recognized, of which four are common in southern Africa. One of the four species (Anopheles quadriannulatus) feeds on cattle and is not known to transmit malaria to man; while the significance of a second species, Anopheles merus, in the transmission of malaria in southern Africa is uncertain. The two most important malaria vectors of the An. gambiae complex in South Africa are An. gambiae and Anopheles arabiensis (the latter the most common of the complex in South Africa). It should be borne in mind that species of the An. gambiae complex are indistinguishable from each other in a morphological sense. The species spend the aquatic stages of their life cycles in freshwater (with the exception of An. merus which breeds in saline waters).

Mosquitoes of the An. gambiae complex lay eggs in rainwater pools, pools left in river beds after floods have subsided, and in shallow backwaters (including freshwater wetlands). Rainwater pools without vegetation and fully exposed to sunlight, as well as seepages and small puddles left in the hoof marks of livestock at the edges of dams, are favoured breeding sites. Breeding sites due to man include borrow pits and excavations of every description. These breeding sites are temporary (depending on rainfall), becoming more widespread in summer. Irrigation schemes are also important breeding sites. An. gambiae complex mosquitoes are present throughout the year in low-lying areas not subject to frost, spreading up river valleys and into the surrounding countryside following the summer rains. An. funestus larvae are mainly found in warm perennial streams with dense vegetation, deep shade and a slow current. A mean annual rainfall in excess of 750 mm and a mean monthly temperature of over 15°C are prerequisites. An. funestus mosquitoes are confined to perennial streams and do not spread with rain. Heavy falls of rain can reduce numbers by flushing out the larvae. Both An. gambiae and An. funestus are house-frequenting mosquitoes and enter dwellings to feed on human hosts. The mosquitoes may remain inside for 24 hours or longer, while their eggs mature. Several people can be bitten during this period, before the mosquitoes fly away to deposit their eggs in water. An. arabiensis by contrast, feeds indiscriminately on man and after feeding might not remain for long periods in dwellings.

Overview maps illustrating the distribution of the four species of An. gambiae complex mosquitoes which are common in southern Africa were provided by Coetzee, Hunt, Braack and Davidson (1993)*. The maps show that the distribution of An. gambiae (regarded as the most efficient and dangerous malaria vector in the world), is limited in South Africa to Maputaland and border areas near Messina in the Transvaal. In Natal/KwaZulu, An. arabiensis, An. merus and An. quadriannulatus are generally confined to low-lying areas stretching from Maputaland to the environs of Mtunzini; to just north of Durban; and to Durban respectively. In previous times, malarial epidemics were not unknown in Natal/KwaZulu although stringent control measures (which must be maintained), have reduced these dangers (Le Sueur, Sharp and Appleton, 1993)**. Malaria was evident, for example, in Pietermaritzburg earlier this century. During the only epidemic in the city the present author's aunt, as a young child, was revived by the forced ingestion of brandy - an emergency technique learned by the author's grandmother while living in India.

Valuable research work on An. gambiae complex mosquitoes has been undertaken inter alia by the Medical Research Council; with municipal staff as well as staff of the Department of National Health and Population Development plus staff of the KwaZulu Department of Health, responsible for spraying programmes. Incidences of malaria are fairly common in the Natal districts of Hlabisa, Mtunzini, Lower Umfolozi, Lower Tugela, Ngotshe and Eshowe and in the KwaZulu districts of Simdlangentsha, Ingwavuma, Ubombo, Hlabisa, Nseleni, Nongoma, Ongoye and Inkanyezi. Malaria is regarded as endemic in these areas and regular precautions are required (Anonymous, 1990)***.

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* See Coetzee, M., Hunt, R.H., Braack, L.E.O. and Davidson, G., 1993. Distribution of mosquitoes belonging to the Anopheles gambiae complex, including malaria vectors, south of latitude 15°S, South African Journal of Science, VOL 89(5), p. 227 - 231. See also, Le Sueur, D. and Sharp, B.L., 1988. The breeding requirements of three members of the Anopheles gambiae Giles complex (Diptera: Culicidae) in the endemic malaria area of Natal, South Africa, Bulletin of Entomological Research, VOL 78(4), p. 549 - 560.

** See Le Sueur, D., Sharp, B.L. and Appleton, C.C., 1993. Historical perspective of the malaria problem in Natal with emphasis on the period 1928 - 1932, South African Journal of Science, VOL 89(5), p. 232 - 239.

*** See Anonymous, 1990. Malaria in South Africa, 1980 - 1989, Epidemiological Comments, VOL 17(7), p. 3 - 16., as well as Strebel, P.M., Hansford, C.F. and Küstner, H.G.V., 1988. The geographic distribution of malaria in South Africa in 1986, Southern African Journal of Epidemiology and Infection, VOL 3(1), p. 4 - 8. (Readers are reminded that both journals are a source of data on various diseases in South Africa. The South African Medical Journal is a further important source of information).

Sharp, Ngxongo, Botha, Ridl and Le Sueur (1988)* observed that malaria in northern KwaZulu is highly seasonal with a peak during the months of April, May and June. Relatively few cases in the study period occurred in the months July - December inclusive. Recent trends seem to indicate that malaria is on the increase and minor epidemics were noted in the Mahlabathini and Ulundi districts in 1993 (previously regarded as safe areas). *Limited outbreaks of malaria have also recently occurred along the coast between Mtunzini* and Durban, and in Durban itself. Reasons for the apparent increase are varied and may include seasonal factors; the breakdown of control programmes in Mozambique and limited co-operation with neighbouring control programmes in general, as well as greater cross-border traffic and therefore movement of carriers. Other factors are the migration of people from rural areas to large urban centres (such as Durban), and the lack of control programmes in densely populated informal settlements.

Concern has been expressed about the long term health and environmental implications of the spraying of DDT on interior walls and roofs of dwellings in northern KwaZulu, in order to control malaria**. Residents in the area often replaster their walls to cover the DDT. The DDT results in increased bedbug activity which can make conditions in the dwelling unbearable. Householders are also unhappy about the discoloration of walls due to the spraying procedure***. The spraying of interior surfaces in any event may have a limited effect since An. arabiensis mosquitoes appear to avoid DDT-treated surfaces

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* See Sharp, B.L., Ngxongo, S., Botha, M.J., Ridl, F. and Le Sueur, D., 1988. An analysis of 10 years of retrospective malaria data from the KwaZulu areas of Natal, South African Journal of Science, VOL 84(2), p. 102 - 106.

** For a brief overview of DDT concentrations in the fish and sediments of the Kosi system, see Butler, A.C., Sibbald, R.R. and Gardner, B.D., 1983. Gas chromatographic analysis indicates decrease in chlorinated hydrocarbon levels in northern Zululand, South African Journal of Science, VOL 79(4), p. 162 - 163. See also, Bouwman, H., Coetzee, A. and Schutte, C.H.J., 1990. Environmental and health implications of DDT-contaminated fish from the Pongolo Flood Plain, Journal of African Zoology, VOL 104(4), p. 275 - 286. (Note that DDT is no longer commercially available and can only be used, if deemed necessary, by Government spraying teams. The use of DDT in northern KwaZulu is currently under review. These issues are discussed further in the chapter on solid waste management).

*** The National Malaria Research Programme, Medical Research Council, P O Box 17120, Congella, 4013, has established an important GIS database which records the position inter alia of some 600 000 dwellings in northern KwaZulu, thereby enabling malaria-infected households to be accurately identified (with rapid control measures possible). Demographic information is available for the listed households. The database will also be used for the future management of schistosomiasis and other diseases. See: Stuttaford, M.C., 1994. Aspects of a Geographic Information System for medical geographers and malaria control, M. Soc. Sci. Thesis, Department of Geography, University of Natal, Pietermaritzburg, 164 p. The National Malaria Research Programme is in the process of *mapping all malaria risk areas in South Africa (those subject to malaria transmission in the last 10* years). The data will be available on GIS.

(Sharp and Le Sueur, 1991)*. Interior spraying accordingly, will mainly impact on the less common An. gambiae (as well as An. funestus) populations. The spraying of open pools of water (larviciding) is undertaken in the endemic far northern region, where house spraying is insufficient to control malaria transmission. The advent of chloroquine-resistant P. falciparum in South Africa (including northern KwaZulu), has important implications for the control of malaria in this country (Freese, Sharp, Ngxongo and Markus, 1988)**.

16.9.2 Schistosomiasis***

Schistosomiasis (bilharziasis) is a very common disease in many lower-lying parts of southern Africa. The highest prevalence of the disease occurs amongst the rural population, who have direct contact with rivers and dams. Children playing in the water are mainly at risk (especially the 5 - 15 year old group, who have the highest infection rates), while canoeists likewise, may also contract the disease.

Three species of schistosomes of the genus Schistosoma cause disease in man in South Africa. Schistosoma haematobium *(Bilharz) or urinary (bladder) schistosomiasis, has two* intermediate host snails namely, Bulinus africanus (Krauss) and B. globosus (Morelet). S. mattheei Veglia and Le Roux is found in livestock, game, primates and in certain rodents and also occurs in man (in the rectal and urinary tracts). S. mattheei has the same intermediate host snail as S. haematobium and therefore has a similar geographic distribution. S. mansoni (Sambon) or rectal (and urinary) schistosomiasis is found in man,

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* See Sharp, B.L. and Le Sueur, D., 1991. Behavioural variation of Anopheles arabiensis (Diptera: Culicidae) populations in Natal, South Africa, Bulletin of Entomological Research, VOL 81(1), p. 107 - 110.

** See Freese, J.A., Sharp, B.L., Ngxongo, S.M. and Markus, M.B., 1988. In vitro confirmation of chloroquine-resistant Plasmodium falciparum malaria in KwaZulu, South African Medical Journal, VOL 74(11), p. 576 - 578., as well as Freese, J.A., Sharp, B.L., Rossouw, E.J., Gous, E., Fay, S.A. *and Markus, M.B., 1994. The in vitro sensitivity of southern African isolates of* Plasmodium falciparum to amodiaquine, chloroquine, mefloquine, quinine and sulphadoxine/pyrimethamine, South African Journal of Science, VOL 90(7), p. 417 - 420.

*** *Discussion partly based on* Clark, T.E., 1994. Plant molluscicides for snail control in the South African context, Ph.D. Thesis, Department of Zoology and Entomology, University of Natal, Pietermaritzburg, 190 p., as well as Gear, J.H.S. and Pitchford, R.J., 1988. Bilharzia in South Africa, Department of National Health and Population Development, Pretoria, 29 p.

primates and in rodents*. The intermediate host snail is Biomphalaria pfeifferi (Krauss). The most common and widely distributed host snail in South Africa is B. africanus, followed by Biomphalaria pfeifferi. In contrast, B. globosus has a more restricted occurrence in South Africa generally (Appleton, 1995)**. The distribution of the host snails and that of the schistosomes per se in southern Africa is not necessarily the same. It should be noted that it is currently impossible to (reliably) distinguish between B. africanus and B. globosus. Reference is accordingly often made in the literature, to the B. africanus species group. Note also that B. africanus (Krauss) and B. globosus (Morelet) were **previously** known as B. (Physopsis) africanus (Krauss) and B. (Physopsis) globosus (Morelet) - names which will be found in older texts.

The intermediate host snails are found in or along the edges of water bodies, and lay eggs under the surfaces of stones and vegetation as well as on floating matter. The snails prefer shady stretches of water. Downstream river reaches are colonized by snails or eggs attached to debris, or acting as free-floating agents. Cercariae likewise, can be transported some distance in running water. The snails can withstand water purification processes (including chlorination) and are able to pass unharmed through pumps. Cercariae are killed by chlorination, although they can pass through sand and most other physical filters.

Urine and faeces containing schistosome eggs, initiates the disease cycle when man urinates or defecates in or on the banks of dams, canals, shallow river pools and rivers during summer (the rainy season)***. Schistosome eggs may remain alive for up to

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* Urinary schistosomiasis is mainly due to S. haematobium, while rectal schistosomiasis is caused by S. mansoni. However, both can be found in the urine and faeces of infected individuals. S. mattheei is largely confined to animals, although the parasite in man, usually occurs in association with S. haematobium.

** Appleton, C.C., 1995. Personal communication, Department of Zoology and Entomology, University of Natal, Pietermaritzburg. (This section of the source book was reviewed by C.C. Appleton. The author (P.G. Alcock) is however, responsible for any errors in the text).

*** The process described refers to S. haematobium and S. mansoni. In the case of S. mattheei, man is probably not an important host for the maintenance of the parasitic life cycle. Defecation by livestock (and game) directly into the water is therefore of significance. The release of S. mattheei eggs is more or less continuous throughout the year (although the disease is more marked in summer), in contrast to S. haematobium eggs which are released into water in the swimming season, and S. mansoni eggs which are flushed into water bodies by surface runoff (Gear and Pitchford, 1988).

one week if deposited in human faeces on dry land (Vlok, 1986)*. Accordingly, viable S. mansoni eggs can be carried via surface runoff into natural waters. S. haematobium eggs must be released directly into water (by urination) to ensure hatching. The eggs hatch within 15 - 20 minutes (in the case of S. haematobium) and up to one week (for S. mansoni), into the first larval stage (miracidia). The free-swimming miracidia only have a few hours to find host snails. Within the host snails, asexual reproduction from primary sporocysts (the next larval stage) to secondary sporocysts, to cercariae occurs. The cercariae (free-swimming larvae) emerge from the snails after some 4 - 5 weeks in summer (six months in winter), and remain viable for up to 2 - 3 days. Ingestion of, or direct contact with water containing cercariae - the shallow, slow moving water along the vegetation-lined periphery of the water body - results in penetration of the skin or mucous membrane of the human definitive host, and entry to the blood. The cercariae are then carried in the blood and mature in the portal vein, which forms part of the hepatic (liver) system. Migration of worms through the tissues to the pelvic and mesenteric veins (those joining to the intestine) follows.

Sexual reproduction occurs in the pelvic and mesenteric veins of the human host, resulting in the ovipositing (egg laying) of microscopic eggs. The spiked eggs tear through the tissues to penetrate the interior of the bladder, ureters, intestine and rectum. Bleeding, tissue destruction, fibrosis (scarring) and calcification follows such penetration (Vlok, 1986). Eggs may be found in any organ of the body including the brain, eyes and spinal cord, where lesions will result (Appleton, 1995). The incubation period of schistosomiasis is believed to be approximately 40 days (from entry of the cercariae to ovipositing), although several months can elapse before the human host passes eggs, thereby initiating the next cycle of infection. Adult schistosomes can live for a number of years in the human host, occasionally producing eggs in this period (Gear and Pitchford, 1988; Vlok, 1986).

Acute infection with S. haematobium results in haematuria as well as painful and frequent urination. (Haematuria is also evident in bladder infections, kidney disorders and hepatitis). Chronic infection may result in bladder cancer (usually amongst males), urinary tract

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* See Vlok, M.E., 1986. Manual of Community Nursing and Psychiatry: a Textbook for South African Student Nurses, Juta, Cape Town, 816 p.

infection and kidney failure*. Acute infection with S. mansoni is not easily differentiated from other dysentery infections, given that diarrhoea (with or without blood) is a characteristic of dysentery. Chronic infection with S. mansoni can result in ascites, liver damage and jaundice. The clinical effects of S. mattheei are difficult to define as a result of co-occurrence with S. haematobium in man. Symptoms are however, presumed to be similar (Clark, 1994). It has been suggested that scholastic achievement and general activity ("energy") in black children in particular in South Africa is adversely affected by the disease**, although the confounding effects of other parasitic diseases and factors such as nutrition, also need to be considered.

Human schistosomiasis in South Africa is endemic in the northern, eastern, and south eastern Transvaal, Natal/KwaZulu and in north eastern Transkei (generally in waters below 1 200 m in altitude). Water temperature is the main factor determining distribution (Pitchford, 1981)***, although other parameters such as water velocity are also of considerable importance. (The latter reflects the river gradient as well as the flow regime) (Appleton, 1995)****. A comprehensive atlas illustrating the distribution of host snails and schistosome parasites as well as human disease prevalence rates is available.

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* The term "acute" refers to a disease of rapid onset, severe symptoms and brief duration. The term "chronic" refers to a disease of long duration, involving very slow changes and often with a gradual onset. "Subacute" describes a disease that progresses more rapidly than a chronic condition, but which does not become acute.

** See for example, Haycock, D.C. and Schutte, C.H.J., 1983. Schistosoma haematobium infection and scholastic attainment amongst black schoolchildren, South African Journal of Science, VOL 79(9), p. 370 - 373., as well as Kvalsvig, J.D., 1981. The effects of schistosomiasis on spontaneous play activity in black schoolchildren in endemic areas: an ethological study, South African Medical Journal, VOL 60(2), p. 61 - 64.

*** See Pitchford, R.J., 1981. Temperature and schistosome distribution in South Africa, South African Journal of Science, VOL 77(6), p. 252 - 261., as well as Mqoqi, N.P. and Dye, A.H., 1992. Schistosoma haematobium in Transkei: a preliminary survey conducted in the Ngqeleni District, South African Journal of Science, VOL 88(8), p. 445 - 447. See in addition Visser, P.S., 1984. Distribution of human schistosomiasis in the southern Transvaal, South Africa, South African Journal of Science, VOL 80(3), p. 124 - 127. *(The paper by Pitchford (1981) includes several maps with regard to air temperature)*.

**** For a detailed discussion of abiotic parameters affecting host snail distribution, see Appleton, C.C., 1978. *Review of literature on abiotic factors influencing the distribution and life cycles of bilharziasis intermediate host snails*, Malacological Review, VOL 11, p. 1 - 25., as well as Appleton, C.C. and Stiles, G., 1976. Geology and geomorphology in relation to the distribution of snail intermediate hosts of bilharzia in South Africa, Annals of Tropical Medicine and Parasitology, VOL 70(2), p. 189 - 198.

The atlas should be carefully examined by readers requiring a detailed spatial analysis*. The atlas contains a wealth of information and summarizes the results of some 50 years of research in southern Africa (up to 1975). The (now defunct) Snail Research Unit, formerly housed in the Department of Zoology at the Potchefstroom University for Christian Higher Education - and supported by the Medical Research Council - was involved for a number of years in snail research with special reference to schistosomiasis. The Unit was jointly responsible for the compilation of the atlas. Specimen snail as well as reference works collections compiled by the Unit are still available for examination at Potchefstroom University. The Medical Research Council (in 1992) withdrew all funding for schistosomiasis research in South Africa, including projects undertaken by Council staff. Detailed host snail data for Natal/KwaZulu can be obtained from the Centre for Integrated Health Research, Department of Zoology and Entomology, University of Natal, Pietermaritzburg. The Centre is currently in the process of digitising the bilharzia atlas for GIS purposes.

Bhagwandeen (1968, quoted in Clark, 1994)** estimated that 30% of the black and Indian population of Durban suffered from schistosomiasis due to S. haematobium. More recent estimates have suggested a prevalence rate of 25 - 50% in inland parts of Natal/KwaZulu; with more than 70% prevalence along the coastal belt (up to 40 km inland) - mainly with reference to the black population (Clark). Cooppan, Schutte, Mayet, Dingle, Van Deventer and Mosese (1986)*** observed that prevalence rates of less than 5% are evident in endemic areas of South Africa, where piped water supplies and adequate sanitation facilities are available. (Such a trend was confirmed by Visser (1988)****

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* See Gear, J.H.S., Pitchford, R.J. and Van Eeden, J.A. (eds), 1980. Atlas of Bilharzia in Southern Africa, South African Institute for Medical Research, the Medical Research Council and the Department of Health, Pretoria, 93 p. See also, Van Eeden, J.A., Pitchford, R.J., Pretorius, S.J. and Wolmarans, C.T., 1982. Additions to the Atlas of Bilharzia in Southern Africa, Wetenskaplike Bydraes van die Potchefstroomse Universiteit vir Christelike Hoër Onderwys (CHO), Reeks B: Natuurwetenskappe, Nr. 113, Potchefstroom University for Christian Higher Education, Potchefstroom, 2 p. + app. (The latter publication contains data for the period 1975 - 1981).

** See Bhagwandeen, S.B., 1968. The Clinico-pathological Manifestations of Schistosomiasis in the African and the Indian in Durban, University of Natal Press, Pietermaritzburg, 207 p.

*** See Cooppan, R.M., Schutte, C.H.J., Mayet, F.G.H., Dingle, C.E., Van Deventer, J.M.G. and Mosese, P.G., 1986. Morbidity from urinary schistosomiasis in relation to intensity of infection in the Natal Province of South Africa, American Journal of Tropical Medicine and Hygiene, VOL 35(4), p. 765 - 776.

**** See Visser, P.S., 1988. Decreases in schistosomiasis prevalence rates in certain areas of the Transvaal, South African Journal of Science, VOL 84(2), p. 138 - 139.

in the Transvaal). By contrast, prevalence rates in excess of 60% have been found in rural children living under conditions of poor water supplies and inadequate sanitation. It is apparent however, that there is a considerable spatial variation in morbidity, even within a small settlement. Variability depends inter alia on human contact patterns as well as resistance to the disease - which is partly related to gender and age. Environmental factors are also important (Fripp, 1977)*. Chronic cases of infection generally, would seem to be relatively uncommon in South Africa, although further epidemiological surveys are required (Fripp and Keen, 1980; Keen and Fripp, 1980)**.

As noted earlier, canoeists in certain South African rivers may also contract schistosomiasis. Grabow (1993)*** and fellow workers found that numerous participants in the three day Dusi Canoe Marathon (held in January each year on the Msunduze/Mgeni rivers between Pietermaritzburg and Durban), were likely to fall ill due to diseases including schistosomiasis, viral hepatitis type A, and the so-called "Dusi-gut" - a form of gastroenteritis possibly viral in origin. Skin infections and septic infections of wounds as well as respiratory infections have likewise been recorded. Grabow suggested that the incidence of ill health amongst canoeists was directly related to the microbiological quality of the Msunduze/Mgeni rivers. In 1991, the water was highly contaminated following heavy rains which resulted in polluted stormwater runoff from many informal settlements - plus the overflow from at least one sewage works - being flushed into the river. The condition of the river system was much improved during the 1992 marathon and a very much lower incidence of illness was found by comparison with 1991, when roughly 80% of the approximately 1 000 canoeists were reported to have suffered some form of illness (mainly Dusi-gut). While further definitive studies are required (given the

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* See Fripp, P.J., 1977. Bilharzial immunity and its impact on the definitive host, South African Journal of Science, VOL 73(2), p. 50 - 53.

** See Fripp, P.J. and Keen, P., 1980. Bladder cancer in an endemic Schistosoma haematobium area. The excretion patterns of 3-hydroxyanthranilic acid and kynurenine, South African Journal of Science, VOL 76(5), p. 212 - 215., as well as Keen, P. and Fripp, P.J., 1980. Bladder cancer in an endemic schistosomiasis area: geographical and sex distribution, South African Journal of Science, VOL 76(5), p. 228 - 230. (The two papers provide an overview of the occurrence of bladder cancer in the northern and eastern Transvaal, in an area where S. haematobium is endemic. The authors suggested that schistosomiasis in association with dietary and other factors, such as gender, could be the cause of the high incidence of bladder cancer in the area).

*** See Grabow, W.O.K., 1993. Dusi Canoe Marathon: research on infections associated with exposure to polluted river water, SA Waterbulletin, VOL 19(1), p. 4 - 6. (For a more detailed analysis, see Appleton, C.C. and Bailey, I.W., 1990. Canoeists and waterborne diseases in South Africa, South African Medical Journal, VOL 78(6), p. 323 - 326).

difficulties of epidemiological research), it is highly probable that there is a positive relationship between the incidence of diseases and the microbiological quality of the two rivers (a link found in other parts of the world)*. The research illustrates some of the dangers inherent in swimming, playing or washing in contaminated South African rivers, and hence the potential for water-related diseases in rural areas.

Donnelly, Appleton, Begg and Schutte (1984)** found that there is a possibility of contracting schistosomiasis in some 24 "estuaries" (as opposed to the lowest reaches of the rivers) in Natal/KwaZulu (south of the Tugela River). The major factor controlling transmission in estuaries is the salinity of the water, combined with an upstream source of infection. Donnelly et al (1984) observed that the free-living stages of the parasites were better adapted to brackish water than the intermediate host snails of S. haematobium and S. mattheei, thereby extending the areal infectious zone into the estuary itself. Although salinity levels may partially or completely preclude snail breeding in the estuary per se, a permanent reservoir of infection immediately upstream in freshwater, will result in the continual transport of infected snails and viable cercariae into the estuary (with infection possible, albeit at a reduced rate). Donnelly et al noted that a reduction in estuarine salinity would result in an increased disease transmission potential. Importantly, work undertaken by Begg (see the chapter on "estuaries"), has shown that salinity levels in many estuarine systems in Natal/KwaZulu are decreasing due inter alia to sedimentation and the transformation of "estuaries" into river mouths. Estuarine biota are then replaced by riverine biota. A further factor is the substantial movement of sand along the coast by littoral drift, which has resulted in the closure of a number of estuarine systems for considerable periods of time. The building of weirs and causeways in the lowest lying reaches of rivers likewise, can result in reduced salinities beyond a certain point in the river (Donnelly et al, 1984).

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* A maximum of 2 000 faecal coliforms 100 $m\ell^{-1}$ is recommended for recreation (high contact) purposes in South Africa (see the chapter on water quality). This limit was generally exceeded by a wide margin, even for the 1992 marathon. For a Cape perspective (including a discussion of appropriate water quality criteria for direct body contact), see: Harding, W.R., 1993. Faecal coliform densities and water quality criteria in three coastal recreational lakes in the SW Cape, South Africa, Water SA, VOL 19(3), p. 235 - 246.

** See Donnelly, F.A., Appleton, C.C., Begg, G.W. and Schutte, C.H.J., 1984. Bilharzia transmission in Natal's estuaries and lagoons: fact or fiction?, South African Journal of Science, VOL 80(10), p. 455 - 460.

The construction of major impoundments and associated irrigation schemes can have profound effects on the river regime (inter alia through disturbance of flood/drought sequences) and accordingly, the potential for disease transmission. Pretorius, Joubert and De Kock (1989)* observed that generally low snail densities are apparent on the exposed *(as opposed to the vegetation-lined) shores and in the deeper open waters of* impoundments. The potential for infection therefore, is higher in the streams and backwaters of the rivers draining into an impoundment. However, large impoundments - depending on the difference in water depth between the surface and the dam outlet - can raise the temperature of the river water below the dam in winter and reduce the temperature in summer, to a point where a suitable habitat is created for host snails and schistosomes (Pitchford and Visser, 1975)**. In this way, the disease is able to spread to marginal or intermediate regions. The construction of smaller irrigation dams (each in turn altering temperature regimes), can create a suitable habitat for the snails across a fairly broad area. The leakage of water from small irrigation dams and canals results in seepage streams and wetlands which provide a further snail habitat. The inter-basin transport of snails to new areas is also possible via the transfer of infected waters to large *dams in non-endemic areas.*

Schistosomiasis can be controlled through the provision of adequate sanitation and improved water supplies, both of which must be sited away from the contaminated water body. Such a programme would also be most beneficial for combating diseases like cholera and typhoid fever. The construction of small bridges and pathways over and along irrigation canals also prevents direct water contact. It is important to bear in mind that the storage of water for at least 48 hours (preferably longer) in a tank free from intermediate host snails will break the transmission cycle of schistosomiasis due to the death of the cercariae. Storage will likewise result in considerably reduced counts of viruses, bacteria and protozoan cysts. The education of residents living in endemic areas combined with practical assistance is therefore essential. Chemotherapy nevertheless remains the standard medical response to the disease. The identification and testing of chemical or

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* See Pretorius, S.J., Joubert, P.H. and De Kock, K.N., 1989. *A review of the schistosomiasis risk in South African dams*, Water SA, VOL 15(2), p. 133 - 136.

** See Pitchford, R.J. and Visser, P.S., 1975. The effect of large dams on river water temperature below the dams, with special reference to bilharzia and the Verwoerd Dam, South African Journal of Science, VOL 71(7), p. 212 - 213. See also, Pitchford, R.J. and Visser, P.S., 1969. The use of behaviour patterns of larval schistosomes in assessing the bilharzia potential of non-endemic areas, South African Medical Journal, VOL 43(32), p. 983 - 995.

more recently, natural (plant) molluscicides (snail poisons) forms an integral component of potential disease control methods. A number of difficulties are apparent including the cost of molluscicides and the facilities required to undertake the spraying programme. Also problematic is the duration of the effect especially over large areas*. Another factor is the danger of poisoning desirable plant and animal species. In this regard, see Appleton (1985)** and Clark (1994) as well as Pretorius, Joubert and Evans (1988)***. Attention has now shifted away from the unrealistic goal of total disease elimination, to a more practical aim of reducing transmission to manageable levels.

16.10 <u>*Some health aspects of natural wetlands*</u>****

Appleton (1983) observed that natural (as opposed to artificial) wetlands play a limited, although incompletely understood role in the transmission of human parasitic diseases. Appleton stressed that a detailed analysis of the functioning of wetlands in terms of disease is required in South Africa, with special reference to far northern KwaZulu and other sub-tropical areas. In particular, further work is required on the biology of the various pathogens - possibly excluding schistosomes - and their intermediate hosts as well as vectors (where relevant) in the aquatic environment. Appropriate and cost-effective control strategies will only be possible once the full implications of the respective transmission routes have been determined. The importance of the research is evident where rural people use water from wetlands for domestic and potable needs. Appleton suggested that <u>careful</u> field research is necessary especially for cholera, fascioliasis, malaria, Rift Valley fever and typhoid fever. The role of shady, humid riverine environments where neither the pathogen (such as hookworm infection) nor the vector is

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* Since snails are hermaphrodites and a 100% kill rate can seldom be achieved, it is evident that a few snail survivors can repopulate the specific habitat.

** See Appleton, C.C., 1985. Molluscicides in bilharziasis control - the South African experience, <u>South African Journal of Science</u>, VOL 81(7), p. 356 - 360.

*** See Pretorius, S.J., Joubert, P.H. and Evans, A.C., 1988. A re-evaluation of the molluscicidal properties of the torchwood tree, <u>Balanites maughamii</u> Sprague, <u>South African Journal of Science</u>, VOL 84(3), p. 201 - 202.

**** Discussion based on Appleton, C.C., 1983. Wetlands and public health, <u>Journal of the Limnological Society of Southern Africa</u>, VOL 9(2), p. 117 - 122. See also, Appleton, C.C., Sharp, B.L. and Le Sueur, D., 1995. *Problems faced by wetlands. Chapter 15.* Wetlands and water-related parasitic diseases of man in southern Africa, In: Cowan, G.I. (ed), <u>Wetlands of South Africa</u>, South African Wetlands Conservation Programme Series, Department of Environmental Affairs and Tourism, Pretoria, p. 227 - 246.

directly dependent on wetlands per se, also requires attention in densely settled rural areas.

Certain complexities of disease transmission in terms of wetlands have been described by Appleton and Bruton (1979)* as well as by Appleton and Donnelly (1983)**. It has been found, for instance, that various types of water bodies in Lake Sibaya and environs, play different roles in the epidemiology of schistosomiasis. Site specific factors in this regard include temperature, the presence of crocodiles, and possibly inter-trematode competition for the intermediate host snail itself. Appleton (1983) confirmed the potential downstream health implications of water releases (at non-ambient temperatures) from major dams.

Leeches are found in the coastal wetlands and coastal lakes of Natal/KwaZulu in a belt stretching from Durban to the Mozambique border. The best known leech (with nuisance, although occasionally serious health implications) is Limnatis fenestrata Moore 1939, now known as Asiaticobdella buntonensis (Appleton and Porter, 1982)***. An increase in A. buntonensis infestation has been reported in recent years on the Pongola Floodplain (Appleton, 1995)****. Several other leech species also suck human blood. Bites by leeches are seasonal, with a peak in summer.

From an agricultural perspective, economically important livestock diseases associated with wetlands include fascioliasis, paramphistomiasis (caused by conical flukes), and panaritium (footrot). Several poisonous weeds such as Matricaria nigellifolia grow well in wetland conditions (Scotney and Wilby, 1983)*****. Artificially constructed wetlands - see the chapter on sanitation - are now an acceptable technique for the

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* See Appleton, C.C. and Bruton, M.N., 1979. The epidemiology of schistosomiasis in the vicinity of Lake Sibaya, with a note on other areas of Tongaland (Natal, South Africa), Annals of Tropical Medicine and Parasitology, VOL 73(6), p. 547 - 561.

** See Appleton, C.C. and Donnelly, F.A., 1983. Echinostomes as competitors for the schistosomiasis intermediate host snails in Natal, South African Journal of Science, VOL 79(3), p. 120.

*** See Appleton, C.C. and Porter, I.M., 1982. The bite of the leech Limnatis fenestrata Moore 1939, in Natal, Journal of the Limnological Society of Southern Africa, VOL 8(1), p. 21 - 22.

**** Appleton, C.C., 1995. Personal communication, Department of Zoology and Entomology, University of Natal, Pietermaritzburg.

***** See Scotney, D.M. and Wilby, A.F., 1983. Wetlands and agriculture, Journal of the Limnological Society of Southern Africa, VOL 9(2), p. 134 - 140.

treatment of wastewater, which would appear to be in conflict with the role of natural wetlands in disease transmission. It is disturbance of the natural wetland environment by human habitation and related activities however, which largely results in the health problems associated with wetlands.

16.11 <u>The blackfly problem in the Cape Province</u>*

Although not problematic in Natal/KwaZulu, various blackfly species (<u>Simulium</u> <u>chutteri</u> in particular), have reached plague status in the northern Cape. The problem area extends down the Vaal River from Parys to Warrenton, as well as down the Orange River from the H.F. Verwoerd (now the Gariep) Dam to Oranjemund. The release of water from the Verwoerd Dam via the Orange-Fish tunnel into the Fish River system has also resulted in a serious problem developing in the Great Fish River (O'Keeffe, 1985, quoted in Nevill, 1988). Difficulties likewise, are being experienced in the Sundays River downstream of Kirkwood, and along the Gamtoos River. Parts of the Berg, Eerste and Olifants rivers in the western Cape are similarly affected.

Blackflies are blood-sucking flies which irritate livestock and poultry, resulting in a loss of condition and sometimes death, as well as a reduction in lambing and calving rates. Serious economic consequences have been experienced by farmers living up to 80 - 100 km away from the Orange River in particular. Blackflies in sufficient numbers are also an irritant to man. The blackfly plague has been caused by river regulation (the building of dams, weirs and irrigation canals), thereby disrupting seasonal discharge rates which vary from floods to very low flows.

Blackflies require a continuous discharge of fast flowing organically enriched water to flourish. Under conditions of a constant high-volume as opposed to a variable flow, <u>S</u>. <u>chutteri</u> dominates since the larvae are able to attach themselves to many newly submerged rock surfaces - even in the presence of fairly high levels of sediment. The eggs of <u>S</u>. <u>chutteri</u> survive in moist sediment, until released by a fresh flow of water. Colonization therefore, almost immediately follows the passage of water from dams. The

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* Discussion based on Nevill, E.M., 1988. Chapter 13. Veterinary science and the study of disease transmission in southern Africa. *The creation of permanent blackfly problems by the construction of dams*, In: Macdonald, I.A.W. and Crawford, R.J.M. (eds), Long-term Data Series Relating to Southern Africa's Renewable Natural Resources, South African National Scientific Programmes Report No. 157, Foundation for Research Development, CSIR, Pretoria, p. 353 - 355.

pioneer characteristics of S. chutteri give the species a considerable advantage over predators and other blackfly species, which are less able to adapt to the changed regime of the river.

One control method successfully tested at the Vaalharts weir and the P.K. Le Roux (now the Vanderkloof) Dam as well as at the Boegoeberg Dam involved the temporary closure of the impoundments. This was done in order to desiccate the pupae and to cause the larvae to drift (preferably into still pools where the larvae would not survive) (Howell, Begemann, Muir and Louw, 1981, quoted in Nevill, 1988)*. In newer irrigation areas along the Orange River however, the cultivation of winter crops and accordingly, the demand for water throughout the year, plus the need to generate hydro-electric power especially at peak times in winter, virtually precludes water stoppages at dams. Other difficulties of flow regulation include the long distances downstream of impoundments; the time required for the drying-out of rapids, and the impossibility of dam closure during periods of high rainfall (Palmer, 1995 - see composite footnote below). A further factor is the probably detrimental impact of incorrectly timed closure on the recruitment of certain fish species (Cambray, 1984, quoted in Palmer, 1995).

Larvicides are being used in the Orange River in an attempt to control the S. chutteri plague, although concern has been expressed about the possible human health effects as well as damage to the riverine ecology. Investigations are underway to find the most suitable larvicide with the minimum (undesirable) side effects (Palmer, 1993)**. It is

* See Howell, C.J., Begemann, G.J., Muir, R.W. and Louw, P., 1981. The control of Simuliidae (Diptera: Nematocera) in South African rivers by modification of the water flow volume, Onderstepoort Journal of Veterinary Research, VOL 48(1), p. 47 - 49.

** See Palmer, R.W., 1993. Short-term impacts of formulations of Bacillus thuringiensis var. israelensis de Barjac and the organophosphate temephos, used in blackfly (Diptera: Simuliidae) control, on rheophilic benthic macroinvertebrates in the Middle Orange River, South Africa, Southern African Journal of Aquatic Sciences, VOL 19(1/2), p. 14 - 33., as well as Palmer, R.W. and Palmer, A.R., 1995. Impacts of repeated applications of Bacillus thuringiensis var. israelensis de Barjac and temephos, used in blackfly (Diptera: Simuliidae) control, on macroinvertebrates in the Middle Orange River, South Africa, Southern African Journal of Aquatic Sciences, VOL 21(1/2), p. 35 - 55. See likewise De Moor, F.C. and Car, M., 1986. A field evaluation of Bacillus thuringiensis var. israelensis as a biological control agent for Simulium chutteri (Diptera: Nematocera) in the Middle Orange River, Onderstepoort Journal of Veterinary Research, VOL 53(1), p. 43 - 50. Useful background information can be found in Palmer, R.W., 1996. Invertebrates in the Orange River, with emphasis on conservation and management, Southern African Journal of Aquatic Sciences, VOL 22(1/2), p. 3 - 51. An overview publication is the following: Palmer, R.W., 1995. Biological and chemical control of *blackflies (Diptera: Simuliidae) in the Orange River, WRC Report No. 343/1/95*, Water Research Commission, Pretoria, 106 p. (Note that the research programme is being undertaken inter alia by the Onderstepoort Veterinary Institute, and the Directorate of Resource Conservation, Department of Agriculture, Private Bag X120, Pretoria, 0001).

evident that river regulation can have unforseen (and anticipated) consequences, resulting in both negative and positive impacts. (See the section on The conservation status of South African rivers in the chapter on water quality; as well as the section on the Environmental impacts of dams and other works in the chapter on the surface water resources of Natal/KwaZulu).

16.12 A brief overview of some health implications of selected determinands in domestic water

Relevant health and aesthetic information for a number of determinands is presented in a summarized format in Table P4. The following section examines aspects of nitrate contamination (mainly with reference to groundwater). The fluoride content of surface and groundwaters is briefly described thereafter. The possible role of hard versus soft water with respect to cardiovascular disease is then discussed.

16.12.1 Health aspects of nitrates

Tredoux (1993)* in an analysis of groundwater quality data available from the Department of Water Affairs and Forestry in Pretoria (see the chapter on groundwater), found that the median nitrate concentration for 18 827 groundwater sampling points in South Africa was 4,5 mg ℓ^{-1} N**. A further examination of the data revealed that 27% of sources had a nitrate concentration of more than 10 mg ℓ^{-1} N, with 15% of sources exceeding 20 mg ℓ^{-1} N, and 4,3% of sources exceeding 50 mg ℓ^{-1} N. Nitrate levels greater than 20 mg ℓ^{-1} N, although generally more than 50 mg ℓ^{-1} N, were evident in the Gordonia District (adjacent to the Namibian border), in the vicinity of Prieska, on the Ghaap Plateau south west of Vryburg (all in the Cape); on the Springbok Flats (northern Transvaal), and along an 80 km stretch of the Crocodile River (in the north western Transvaal). In the first two instances, high nitrate levels in groundwater are the result of natural nitrate accumulation. High nitrate levels found on the Ghaap Plateau may be due to natural processes and/or man's activities. By contrast, farming operations are responsible for the high nitrate concentrations found on the Springbok Flats and along the

* See Tredoux, G., 1993. A preliminary investigation of the nitrate content of groundwater and limitation of the nitrate input, WRC Report No. 368/1/93, Water Research Commission, Pretoria, 76 p.

** To convert the nitrate (as N) value to a nitrate (as NO_3) value, multiply by 4,43.

Table P4: Some health and aesthetic implications of selected determinands in domestic water.

Determinand concentration	Effect
Aluminium (mg ℓ^{-1} Al) 0 - 0,15	Aluminium intake from water is less than 5% of the total dietary intake of aluminium. No acute or chronic health effects are evident. Generally, no adverse aesthetic effects occur. Very slight discoloration of water may become apparent when iron or manganese is present in association with aluminium at the upper limit of the range
0,15 - 0,5	Aluminium intake from water may exceed 5% of the total dietary intake. No effects on health are expected. Negative aesthetic effects (colour) occur when aluminium is present in association with iron or manganese
>0,5 (*)(**)	Aluminium intake from water exceeds 10 - 15% of the total daily intake. No acute health effects are expected except at very high concentrations. Long term neurotoxic effects are possible (although not proven). Severe aesthetic effects (discoloration of water) occur
Dissolved organic carbon (mg ℓ^{-1} C) 0 - 5	Concentrations of dissolved organics are minimal. No effect on health, aesthetics or trihalomethane formation during treatment is expected
5 - 10	Dissolved organics are present in low concentrations. There may be a slight health risk, depending on dissolved organic carbon composition. Limited aesthetic effects (taste, odour and colour) may occur. Some formation of trihalomethanes during treatment may be expected
10 - 20	Dissolved organics are present in significant concentrations. There may be a health risk, depending on dissolved organic carbon composition. Significant aesthetic effects may be evident. Trihalomethanes will be formed during treatment
>20	High concentrations of dissolved organics occur. Aesthetic effects and the formation of trihalomethanes during treatment can be expected. Health risks may be marked (depending on the composition of dissolved organic carbon)
Fluoride (mg ℓ^{-1} F) 0 - 1,0	The fluoride concentration in water necessary to meet requirements for healthy tooth structure, is a function of the daily water intake and varies with the annual maximum daily air temperature. A concentration of some 0,75 mg ℓ^{-1} F corresponds to a maximum daily temperature of approximately 26 - 28°C
1,0 - 1,5	Generally well tolerated, although slight mottling of dental enamel may occur in sensitive individuals. No other health effects are expected and no tooth damage occurs
1,5 - 3,5	The threshold for marked dental mottling is 1,5 mg ℓ^{-1} F. Above this concentration, mottling will probably be evident in most continuous users of the water

Table P4: Some health and aesthetic implications of selected determinands in domestic water (continued).

Determinand concentration	Effect
3,5 - 4,0 (*)	Threshold concentration for chronic effects of fluoride exposure (manifested as skeletal effects). Effects are detected mainly by radiological examination
4,0 - 6,0 (*)	Skeletal fluorosis occurs after long term exposure
6,0 - 8,0 (*)	Pronounced skeletal fluorosis occurs after long term exposure
>8,0 (*)	Crippling skeletal fluorosis is likely to appear following long term exposure
>100 (*)(**)	Threshold concentration for the onset of severe acute fluoride poisoning (marked by vomiting and diarrhoea)
>2 000 (**)	The lethal concentration of fluoride is approximately 2 000 mg ℓ^{-1} F
Iron (mg ℓ^{-1} Fe) 0 - 0,1	No taste, health or aesthetic effects are evident
0,1 - 0,3	Very slight effects on taste and marginal other aesthetic effects are experienced. No health effects occur and the water is generally well tolerated
0,3 - 1,0	Aesthetic effects gradually increase. No health effects occur
1,0 - 10,0	Pronounced aesthetic effects are apparent. Slight health effects may be expected in sensitive individuals (such as young children)
10 - 30 (*)	Severe aesthetic effects occur in this range. Slight iron overload is possible in some individuals. Chronic health effects may occur in sensitive individuals in the range 10 - 20 mg ℓ^{-1} Fe. Acute effects may occasionally be found towards the upper end of the range
30 - 100 (*)	Aesthetic effects are severe. Long term health effects gradually increase
100 - 300 (*)(**)	Aesthetic effects are severe, while chronic health effects are evident. Acute toxicity may begin to appear
300 - 3 000 (*)(**)	Aesthetic effects are severe. Chronic and acute health effects occur. Accidental iron poisoning from water is extremely rare, since very high concentrations of iron do not occur naturally in water
3 000 - 30 000 (**)	Aesthetic effects are severe. Lethal toxicity occurs
Manganese (mg ℓ^{-1} Mn) 0 - 0,05	No effects on health or aesthetics occur in general. Marginal aesthetic problems may occasionally be found in the range 0,020 - 0,05 mg ℓ^{-1} Mn

Table P4: Some health and aesthetic implications of selected determinands in domestic water (continued).

Determinand concentration	Effect
0,05 - 0,10	Concentrations in this range are tolerable, although slight aesthetic effects (staining) may occur. No health effects are evident
0,10 - 0,15	Threshold for the appearance of significant staining and taste problems. No health effects occur
0,15 - 1,0	Staining and taste problems become increasingly severe. No health effects are apparent
1,0 - 2,0	Very severe staining occurs. No danger to health
2,0 - 5,0	Extreme staining evident, which is likely to be aesthetically unacceptable to a large proportion of users. No health effects occur
5,0 - 14,0	Unacceptable levels of aesthetic effects occur. No health effects are expected
14,0 - 20,0 (*)	Very severe, aesthetically unacceptable staining occurs. There is some risk of manganese toxicity under unusual conditions. However, it is unlikely that the water will be used for domestic purposes due to aesthetic effects
>20,0 (*)(**)	Extreme aesthetic effects are evident and chronic toxicity occurs. At high concentrations, possible acute effects may be experienced, although it is unlikely that the water will be accepted for domestic use (due to severe aesthetic effects)
Mercury (mg ℓ^{-1} Hg) 0 - 0,005	No health effects associated with mercury are expected. At 0,002 mg ℓ^{-1} Hg, water provides up to 13% of the safe daily intake of mercury; and at 0,005 mg ℓ^{-1} Hg, water provides 33% of the safe daily intake. A very slight risk of neurotoxicity due to organic mercury may exist for sensitive individuals (at the upper limit of this range). Risk to the general population is unlikely
0,005 - 0,020 (*)	Brief, episodic exposure is unlikely to have adverse effects. There is some risk of chronic neurotoxic effects due to organically complexed mercury
0,020 - 10,0 (*)(**)	There is a long term risk of neurotoxicity with continuous exposure, particularly to organic mercury compounds. Acute effects may occur, especially with organic mercury compounds
>10,0 (*)(**)	In addition to chronic effects, acute poisoning (with damage to the nervous system), may occur
>100 (**)	Fatal mercury poisoning becomes likely, particularly with repeated or continuous exposure

Source: After Anonymous, 1993. South African water quality guidelines, VOL 1, Domestic use, Department of Water Affairs and Forestry, Pretoria, 216 p. (References quoted in the original table have been removed in the above version, but with one exception, are listed below).

See also:

(i) Aucamp, P.J. and Vivier, F.S., 1990. Water quality criteria in South Africa, Technology SA, June 1990, p. 21 - 27.

(ii) Kempster, P.L., Hattingh, W.H.J. and Van Vliet, H.R., 1980. Summarized water quality criteria, Technical Report No. TR 108, Department of Water Affairs, Forestry and Environmental Conservation, Pretoria, 45 p.

(iii) Kempster, P.L. and Smith, R., 1985. Proposed aesthetic/physical and inorganic drinking-water criteria for the Republic of South Africa, CSIR Research Report No. 628, National Institute for Water Research, CSIR, Pretoria, 51 p.

Note:

(i) An asterisk within a bracket indicates concern regarding chronic health effects in the general population (due to long term exposure). A double asterisk within a bracket indicates the possibility or reality of acute health effects in the general population as a result of short term exposure. No such information is available for dissolved organic carbon due to a lack of epidemiological evidence.

(ii) Some health and aesthetic effects of drinking water with excessively high electrical conductivity, pH and turbidity are described in Anonymous (1993). Most consumers would however, be able to determine objectionable concentrations by sight and/or taste.

(iii) Aluminium is the third most abundant element and is accordingly found in air, water and food. Aluminium enters natural waters through erosion, the leaching of minerals and soil, the deposition of atmospheric dust and precipitation. Industrial wastes are a site specific source. It appears that aluminium is not an essential element for man, and has a low acute toxicity in healthy people. A link between adverse (human) health effects and aluminium in drinking water has yet to be conclusively demonstrated, although aluminium has been implicated in neurological disorders such as Alzheimer's disease*. The aesthetic effects of aluminium in drinking water may be of some concern (Anonymous, 1993).

(iv) Dissolved organic carbon provides a measure of the organic content of raw water. Chlorine added to water during purification reacts with organic matter to produce trihalomethanes, which are believed to be carcinogenic. The presence of dissolved organic carbon is regarded as indicative of the potential for the formation of trihalomethanes. Dissolved organic carbon may in addition, be

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* One such compound is believed to be alum (aluminium sulphate) which is used in the purification of drinking water (Walters, I., 1994. Personal communication, City Health Department, Pietermaritzburg Corporation, Pietermaritzburg).

associated with toxic organic compounds as well as certain odours, tastes and colour. Toxic organic compounds are found in industrial wastes and sewage, while organic carbon from natural sources is of little importance. High dissolved organic carbon levels in natural waters may indicate the availability of nutrients for the growth of microorganisms.

(v) Fluorine is a fairly common element, existing as fluoride in several minerals including fluorspar, cryolite and fluorapatite. Fluorides are found in a number of industrial goods and in a wide range of pharmaceutical products. Although industrial wastes are occasionally implicated, most of the fluoride in raw water is due to natural processes. High concentrations may be present in groundwater in particular. Fluoride has no significant aesthetic effects. Fluoride is required for the proper hardening of dental *enamel and also increases the resistance of tooth enamel to bacterial* acid attack. There is however, a small difference between fluoride levels required for health needs and the onset of dental problems at slightly higher concentrations. Health effects include discoloration of dental enamel, with mottling of teeth at greater concentrations (prevalent in children up to seven years old). Higher doses of fluoride interfere with lipid, vitamin, protein, carbohydrate, mineral and enzyme metabolism. At advanced concentrations, health problems include skeletal fluorosis (deformation of the bone structure), nephritis, haemorrhagic gastroenteritis and damage to liver and heart muscles. Initial symptoms of fluoride toxicity are nausea, vomiting, abdominal pain, diarrhoea and convulsions.

(vi) Iron is the fourth most common element and is found in raw waters as a result of the natural processes of weathering and leaching. Other important sources include acid mine drainage, sewage, landfill leachates, the burning of coke and coal, iron-related industries and the corrosion of iron and steel. Although iron is an essential element necessary for the formation of haemoglobin and other proteins and enzymes in the body, excessive concentrations and hence accumulation can damage many organs (a condition known as haemochromatosis). Iron present in water distribution systems (in sufficient concentrations) supports iron bacteria, resulting in a slimy coating on pipes. Microorganisms (possibly with health implications), can use the bacterial coating as a nutrient source. Any health risks however, are usually very limited*. Water with a high iron concentration is unlikely to be ingested as a result of the very unpleasant metallic taste. Aesthetic considerations therefore predominate (Anonymous, 1993).

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* See Augoustinos, M.T., Kfir, R. and Venter, S.N., 1992. Assessment of water quality problems due to microbial growth in drinking water distribution systems, WRC Report No. 252/1/92, Water Research Commission, Pretoria, 25 p. + app.

(vii) Manganese in raw water is derived from metamorphic and sedimentary rocks as well as sediment and soil. Manganese and its alloys and compounds are extensively used in the steel and chemical industries. Industrial effluents discharged into water as well as into the atmosphere (with consequent deposition), contribute significant amounts of the manganese found in natural waters. Acid mine drainage and iron and steel industries are especially important in this regard. Manganese in surface waters generally has a low concentration of less than 0,2 mg ℓ^{-1} Mn, although considerably higher concentrations may be evident in groundwater due to reducing conditions. Manganese is an essential element and deficiencies can result in growth impairment, skeletal abnormalities and anaemia. Neurotoxic effects can occur at high concentrations, although toxicity is generally low. There is a possible link between manganese and Parkinson's disease. Manganese is regarded as one *of the least toxic elements. Poisoning therefore results from* industrial processes. Aesthetic effects are of importance. Taste, odour and turbidity problems in treated (distributed) water are possible, since manganese supports the growth of certain nuisance organisms. Manganese in greater concentrations imparts an unpleasant taste to water.

(viii) Heavy metals (including mercury) are highly poisonous. Mercury is a chronic neurotoxin which causes neurological and renal disturbances. Both inorganic and organic forms are toxic (the latter particularly so). Mercury bioaccumulates in the food chain and is responsible for horrific effects on the human body. An infamous example occurred in Japan in the 1950s when fish containing methyl mercury - the latter originally derived from factory effluent - was eaten by residents in the coastal town of Minimata (hence Minimata disease). Mercury from natural sources is unlikely to be found in water in dangerous concentrations. High levels of mercury are accordingly site specific and are due to industrial contamination. Mercury is used in the pulp and paper industry; and for the manufacture of electrical equipment and paint. Mercury is likewise used in dentistry and in the chlor-alkali industry (which produces hydrogen, chlorine and sodium hydroxide) (Anonymous, 1993).

Crocodile River. Very little published groundwater quality information is available for Natal/KwaZulu. The limited data suggest that there is a slightly elevated nitrate concentration in the drier northern regions (by comparison with the rest of the province) - a trend noted in part by Van Wyk (1963)*.

Tredoux (1993) observed that the "internal" nitrogen cycle is almost closed in the top soil (under natural conditions). However, the leaching of nitrate - dependent on vegetation, soil, geology, rainfall, hydrology and temperature - can result in a natural accumulation in groundwater, as found in many parts of South Africa. Tredoux suggested that fertilizer and manure application on agricultural land is the main (diffuse) source of groundwater nitrate pollution due to man's activities. Such a pattern has been noted overseas, although confirmation is required in this country. The problem is exacerbated in dry land cultivation as a result of droughts and erratic rainfall, and accordingly, variable fertilizer application rates and unpredictable plant cover. The nett effect is a reduced nitrate uptake by vegetation, and considerable leaching following significant rainfall. Heaton (1985)** working on the Springbok Flats, found that the increased areal extent of cultivation per se (the change in cultivated land as a proportion of total agricultural land over time), was responsible for nitrification of the soil, with the consequent leaching and accumulation of nitrate in groundwater. Using isotopic techniques, Heaton established that groundwater nitrate concentrations were not related to rainwater, artificial fertilizers or animal wastes. This finding applies to the Springbok Flats which have a considerable expanse of Arcadia Form ("black turf") soils. These soils are largely underlain by basalt. (See the chapter on soils and soil erosion).

Isolated site specific instances of high nitrate concentrations in groundwater in South Africa (30 - 50 mg ℓ^{-1} N or more) are evident in rural areas where boreholes, wells and springs are subject to contamination by feedlots, animal assembly points and pit latrines (Tredoux, 1993). Urban sources of nitrate include the land application of sewage sludge and effluent, the disposal of waste by landfill, and on site sanitation systems in high density settlements. There is accordingly, a marked potential for surface and groundwater contamination. Tredoux stressed that increased groundwater nitrate concentrations are

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* See Van Wyk, W.L., 1963. Ground-water studies in northern Natal, Zululand and surrounding areas, Memoir No. 52, Geological Survey, Department of Mines, Pretoria, 135 p. and map.

** See Heaton, T.H.E., 1985. Isotopic and chemical aspects of nitrate in the groundwater of the Springbok Flats, Water SA, VOL 11(4), p. 199 - 208.

apparent in many parts of the world - either due to man per se - or as a result of man's activities in areas with naturally high groundwater nitrate levels. Tredoux further observed that many years or even decades may elapse before remedial measures aimed at reducing groundwater nitrate levels, become effective. A recently completed map identifying areas susceptible to groundwater contamination in South Africa will facilitate forward planning and will hopefully lead to measures being taken to reduce, or at least contain pollution generally (where feasible and where caused or exacerbated by man)*. In order to safeguard South Africa's precious groundwater resources in the longer term, it is vitally important that a national groundwater quality sampling and assessment programme be instituted (Parsons and Tredoux, 1993)**. (See the chapter on water quality). Problematic localities in terms of high nitrate groundwaters could then be identified, and appropriate action taken.

Some of the health implications of nitrate in drinking water have been discussed by Adam (1980)***; Kempster (1981)****; Tredoux (1993), and Terblanche (1991)*****. Excessively high nitrate levels in drinking water may have serious implications for both man and domestic livestock. According to the South African Bureau of Standards specifications for water for (human) domestic supplies, a nitrate (+ nitrite) concentration of 10 mg ℓ^{-1} N is the maximum allowable limit. Pieterse (1989)****** in a further analysis of potable water quality proposed a three tier system with a (second) maximum permissible limit (the maximum limit for insignificant risk) of 10 mg ℓ^{-1} N, and a (third) crisis limit (the maximum limit for low risk) of 20 mg ℓ^{-1} N. (Refer to the chapter on water quality). Based on data provided by Tredoux (1993),

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* See Lynch, S.D., Reynders, A.G. and Schulze, R.E., 1994. Preparing input data for a national-scale groundwater vulnerability map of southern Africa, Water SA, VOL 20(3), p. 239 - 246.

** See Parsons, R. and Tredoux, G., 1993. The development of a strategy to monitor groundwater quality on a national scale, WRC Report No. 482/1/93, Water Research Commission, Pretoria, 50 p. + app.

*** See Adam, J.W.H., 1980. Health aspects of nitrate in drinking water and possible means of denitrification (literature review), Water SA, VOL 6(2), p. 79 - 84.

**** See Kempster, P.L., 1981. Nitrite, iron deficiency anaemia and methemoglobinemia, Water SA, VOL 7(1), p. 61.

***** See Terblanche, A.P.S., 1991. Health hazards of nitrate in drinking water, Water SA, VOL 17(1), p. 77 - 82.

****** See Pieterse, M.J., 1989. Drinking-water quality criteria with special reference to the South African experience, Water SA, VOL 15(3), p. 169 - 178.

it is evident that many areas in South Africa (especially the drier parts) are potentially at risk. Site specific problems are possible at individual households and settlements.

Besides water, certain vegetables such as beetroot, celery, lettuce and spinach contain high levels of nitrate, although nitrite levels are mainly low. Cured meats likewise, contain high concentrations of nitrate and nitrite (which are used as preservatives). Tredoux (1993) observed that less than 30% of the total dietary nitrate intake comes from drinking water. The significance of water as a source of nitrate is apparent at concentrations in excess of 10 mg ℓ^{-1} N.

It is important to bear in mind that nitrate per se has a low primary toxicity and is readily excreted at reasonable concentrations (Rohmann and Sontheimer, 1985, quoted in Tredoux, 1993). However, when reduced to nitrite through microbial action in the intestine or during food preparation, it becomes an oxidising agent and following absorption, combines with the red blood pigment haemoglobin to form methaemoglobin. Methaemoglobin is more stable and is unable to transport oxygen. The first signs of cyanosis (blue discoloration due to low blood oxygen levels) are evident where blood methaemoglobin is present in concentrations of 5 - 10% (Knotek and Schmidt, 1964, quoted in Terblanche, 1991). Concentrations of 50% or more result in death due to suffocation (Shuval and Gruener, 1977 quoted in Terblanche, 1991). A number of workers including Shuval and Gruener (1977), have confirmed a direct relationship between the presence of methaemoglobin in infants and nitrate concentrations in excess of 10 mg ℓ^{-1} N in drinking water. While infants are susceptible to methaemoglobinaemia (as the condition is known), a high nitrate concentration in water is not the only pathological determinant or variable causing the disease. According to Ross and Desforges (1959, quoted in Terblanche, 1991), additional factors include age (more prevalent in children less than one year old and especially less than three months old); the presence of nitrate reducing bacteria in the gastrointestinal tract; a gastric acidity usually exceeding a pH of 4; gastrointestinal disturbances, and the type of powdered milk used. Other factors are a high fluid intake; the effect of nutrition (nitrate-rich foods); foetal haemoglobin composition, and methaemoglobin reduction factors. Kempster (1981) stressed the importance of iron deficiency anaemia in infants, which predisposes such children to nitrate-induced methaemoglobinaemia. Research has shown that a diet rich in vitamin C, helps to prevent iron deficiency anaemia and susceptibility to methaemoglobinaemia resulting from nitrate. Goodman and Gilman (1965, quoted in

Kempster, 1981) found that infants are also very susceptible to high concentrations of iron salts.

The only detailed South African (epidemiological) study to-date, was undertaken by *Hesseling, Toens and Visser (1991)** at Rietfontein in the far northern Cape. Hesseling et al (1991) were unable to find a statistical correlation between the groundwater nitrate content and methaemoglobin blood levels in infants less than one year old. Boreholes in the area had a median nitrate concentration of 11,6 mg ℓ^{-1} N (within the range 4,8 - 22,8 mg ℓ^{-1} N)**. A correlation was evident however, in an epidemiological survey undertaken in Namibia where much higher nitrate concentrations, with a maximum of 56 mg ℓ^{-1} N, were measured in the groundwater (Super, Heese, MacKenzie, Dempster, Du Plessis and Ferreira, 1981, quoted in Tredoux, 1993).

Other health implications of high nitrate waters may include possible carcinogenic, teratogenic (causing prenatal defects) and mutagenic (producing genetic changes) properties of nitrosamines. The latter can form in food or in the digestive tract if nitrates and nitrites are exposed to secondary and tertiary amines under specified acidic conditions (Shuval and Gruener, 1977, quoted in Tredoux, 1993). The World Health Organization (1985, quoted in Tredoux, 1993) concluded that no definitive evidence was available for a relationship between drinking water nitrate levels of up to 10 mg ℓ^{-1} N or more, and gastric cancer. Similar conclusive evidence was not available with respect to birth defects. High nitrate levels in drinking water have also been implicated in disturbance of the Central Nervous System amongst children (Petukhof and Ivanov, 1970, quoted in Terblanche, 1991); and hypertension (Fraser and Chilvers, 1981, quoted in Terblanche). No conclusive proof, given the many other factors operating, has been forthcoming.

Waters with a high nitrate concentration may likewise pose a danger to animals. It would appear that non-ruminants and poultry can tolerate high nitrate levels. Ruminants (especially cattle) however, may be severely affected due to the rapid biological reduction

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* See Hesseling, P.B., Toens, P.D. and Visser, H., 1991. An epidemiological survey to assess the effect of well-water nitrates on infant health at Rietfontein in the northern Cape Province, South Africa, South African Journal of Science, VOL 87(7), p. 300 - 304.

** It is interesting to note that the high nitrate levels were partly due to faecal contamination of the groundwater (with accompanying bacteriological pollution).

of nitrate to nitrite in the rumen (Anonymous, 1993)*. Kempster, Hattingh and Van Vliet (1980)** suggested a maximum nitrate (+ nitrite) concentration for livestock watering of 100 mg ℓ^{-1} N. (See the chapter on water quality). A slightly lower guideline threshold of 90,3 mg ℓ^{-1} N has been recommended for dairy cattle in South Africa (Baard, 1992, quoted in Tredoux, 1993), although detrimental effects could occur at much lower concentrations for dairy herds. Davison, Hansel, Krook, McEntee and Wright (1964, quoted in Tredoux, 1993) noted that cattle subject to sub-lethal nitrate concentrations have a reduced growth potential, a shorter lifespan, and a higher incidence of abortion and infertility. Stock losses (on some scale) due to high nitrate concentrations in groundwater have occurred in Namibia and Bophuthatswana. In the former instance however, adult (human) inhabitants of the farm concerned, appeared to suffer no ill-effects (Tredoux, 1993).

It is possible that the negative impacts of high nitrate waters are more widespread in South Africa than appears to be the case at present, although many potentially affected areas are rural, where diagnostic services (if available), are limited. Further instances of health problems may become evident following an increased emphasis on the importance of groundwater resources and accordingly, the quality of these resources. Epidemiological studies may be required in medium to high density informal settlements in semi-arid and arid areas which are totally reliant on untreated groundwater sources.

Several techniques are available for the denitrification of drinking water. Denitrification procedures can be divided into two broad categories, namely, physico-chemical processes and biological processes. The former include ion exchange, reverse osmosis, chemical reduction, freezing of the water, electrodialysis and solar distillation***. Biological methods encompass algal ponds and bacterial denitrification (Adam, 1980). Difficulties either of cost or practicality however, preclude the use of many of these techniques in

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* See Anonymous, 1993. South African water quality guidelines, VOL 4, Agricultural use, Department of Water Affairs and Forestry, Pretoria, 286 p.

** See Kempster, P.L., Hattingh, W.H.J. and Van Vliet, H.R., 1980. Summarized water quality criteria, Technical Report No. TR 108, Department of Water Affairs, Forestry and Environmental Conservation, Pretoria, 45 p.

*** A small solar distillation unit is discussed in Sanderson, R.D., Vreugde, M. and Schoeman, D.W., 1994. *Provision of point-source water by enhanced solar distillation*, WRC Report No. 468/1/94, Water Research Commission, Pretoria, 78 p.

rural areas. Letimela (1993)* suggested that bacterial denitrification may prove to be a cost effective method for rural settlements in Bophuthatswana, where high nitrate levels in groundwater are problematic. Finally, it should be borne in mind that nitrogen is an important plant nutrient. Excessive concentrations in surface waters may result in eutrophication (see the chapter on water quality).

16.12.2 The fluoride content of surface and groundwaters

High fluoride concentrations in surface and groundwaters are of concern in parts of the northern Cape, the northern Transvaal, Bophuthatswana and in certain areas of the Orange Free State. Grobler and Dreyer (1988)** examined fluoride levels in numerous towns and villages in South Africa in the very dry (1983) and wetter (1984/85) period. Grobler and Dreyer found that boreholes had significantly higher fluoride concentrations than rivers and dams. Importantly, fluoride concentrations usually declined in both surface and groundwaters due to dilution factors in high rainfall periods (by comparison with dry periods). Fluoride concentrations in the 37 localities examined in Natal/KwaZulu, varied *from less than* 0,05 *mg* ℓ^{-1} F *in areas such as Pietermaritzburg and Amanzimtoti, to* 0,04 - 0,64 mg ℓ^{-1} F in Utrecht. By contrast, both Kenhardt and Pofadder (in the northern Cape), had high fluoride values ranging between 2,40 - 2,66 mg ℓ^{-1} F. The low fluoride concentrations in Natal/KwaZulu generally (well within required health limits) as well as seasonal variations, were noted in previous research undertaken by the CSIR in association with the Natal Town and Regional Planning Commission. (Refer to the chapter on water quality).

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* See Letimela, O.N., 1993. Denitrification of groundwater for potable purposes, WRC Report No. 403/1/93, Water Research Commission, Pretoria, 49 p.

** See Grobler, S.R. and Dreyer, A.G., 1988. Variations in the fluoride levels of drinking water in South Africa: implications for fluoride supplementation, South African Medical Journal, VOL 73(4), p. 217 - 219. See also, Dreyer, A.G. and Grobler, S.R., 1984. Die fluoriedgehalte in die drinkwater van Suid-Afrika en Suidwes-Afrika, Journal of the Dental Association of South Africa, VOL 39(12), p. 793 - 797. For further data examine Bond, G.W., 1946. A geochemical survey of the underground water supplies of the Union of South Africa with particular reference to their utilisation in power production and industry, Memoir No. 41, Geological Survey, Department of Mines, Pretoria, 216 p., as well as Van Wyk, W.L., 1963. Ground-water studies in northern Natal, Zululand and surrounding areas, Memoir No. 52, Geological Survey, Department of Mines, Pretoria, 135 p. and map.

16.12.3 The hardness of water and cardiovascular disease*

Derry, Bourne and Sayed (1990) examined the incidence of cardiovascular disease mortality for the white population in 43 major urban areas in South Africa. A statistically significant negative correlation was established between cardiovascular disease mortality and the total hardness (as $CaCO_3$) of treated (potable) domestic water. Significant negative correlations were also found for sulphate, chloride and potassium. The survey was a first approximation and the results need to be confirmed in a more detailed and longer term study. The research findings reflect overseas studies, where several programmes have provided evidence for an inverse relationship between the total hardness of water and cardiovascular disease mortality**. Soft water accordingly, appears to be strongly implicated in cardiovascular disease (other factors such as diet and stress being excluded). The results of epidemiological studies however, are often extremely difficult to interpret in a definitive sense and alternative explanations are certainly possible.

16.13 Poisons***

A Poisons Information Centre operates on a 24 hour basis at the Red Cross War Memorial Children's Hospital in Cape Town (phone 021-6895227). Other poison information centres are found in Parow Vallei (Tygerberg Hospital); in Kimberley (Kimberley Hospital); East London (Frere Hospital); Port Elizabeth (Livingstone Hospital and the Port Elizabeth Provincial Hospital); Bloemfontein (University of the Orange Free State Medical School and the Universitas Hospital), and in Ga-Rankuwa (Medunsa Hospital). The only (24 hour) poison information centre in Natal/KwaZulu is at the St Augustine's Hospital in Durban,

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* Discussion based on Derry, C.W., Bourne, D.E. and Sayed, A.R., 1990. The relationship between the hardness of treated water and cardiovascular disease mortality in South African urban areas, South African Medical Journal, VOL 77(10), p. 522 - 524. See also, Van Staden, D.A., 1990. Absence of cardiovascular disease in a rural community using soft water, South African Medical Journal, VOL 78(4), p. 219.

** It has likewise been suggested that manganese in drinking water is inversely related to cardiovascular disease mortality (Anonymous, 1993. South African water quality guidelines, VOL 1, Domestic use, Department of Water Affairs and Forestry, Pretoria, 216 p.).

*** Agrichemicals - as a specific category of poisons - are discussed in the chapter on solid waste management.

phone (toll free) 0800-333444*. The two cellphone service providers operate a general 24 hour emergency number, and can supply the phone number of the nearest poison centre. **If any difficulties are experienced, phone 10177 (no area code) at any time.**

16.14 Some primary publications on health in South Africa

16.14.1 Bacteriological and viral diseases

- Anonymous, 1993. South African water quality guidelines, VOL 1, Domestic use, Department of Water Affairs and Forestry, Pretoria, 216 p.

- Anonymous, 1993. South African water quality guidelines, VOL 4, Agricultural use, Department of Water Affairs and Forestry, Pretoria, 286 p.

- Coetzer, J.A.W., Thomson, G.R. and Tustin, R.C. (eds), 1994. Infectious Diseases of Livestock With Special Reference to Southern Africa, VOL 1, 729 p. + app., and VOL 2, p. 733 - 1605 + app., Oxford University Press, Cape Town.

- Coovadia, H.M. and Loening, W.E.K. (eds), 1992. Paediatrics and Child Health: a Handbook for Health Professionals in the Third World, Oxford University Press, Cape Town, 630 p.

- Fripp, P.J., 1983. An Introduction to Human Parasitology With Reference to Southern Africa, second edition, Macmillan South Africa (Publishers), Johannesburg, 168 p. (The book is concise and is highly recommended).

- Grabow, W.O.K., 1992. Navorsing oor menslike virusse in water, WRC Report No. 265/1/92, Water Research Commission, Pretoria, 43 p. + app.

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* Data on the safe use of medicines as well as information on adverse drug reactions and the interactions of drugs are available from the University of Cape Town: Ciba-Geigy Medicines Safety Centre located in the Department of Pharmacology, Medical School, University of Cape Town, Observatory, 7925. (Most of the data are on a computer databank). Similar information can be obtained from the World Health Organization Collaborating Centre for Drug Policy, School of Pharmacy, University of the Western Cape, Private Bag X17, Bellville, 7535. See: Directory of Poison and Drug Information Services in South Africa Including Snake Parks, Supplement to the South African Pharmaceutical Journal, 1987, VOL 54(8), 8 p.

- Grabow, W.O.K., 1996. Waterborne diseases: update on water quality assessment and control, Water SA, VOL 22(2), p. 193 - 202.

- Grabow, W.O.K. and Nupen, E.M., 1968. The role of water in the transmission of pathogenic microorganisms from animals to man and man to animals - a review, File No. W 6/206/3, Code No. 6201/6206, National Institute for Water Research, CSIR, Pretoria, 62 p.

- Grabow, W.O.K., Taylor, M.B. and Wolfaardt, M., 1996. Research on human viruses in diffuse effluents and related water environments, WRC Report No. 496/1/96, Water Research Commission, Pretoria, 25 p. + app.

- Mönnig, H.O. and Veldman, F.J., 1989. Handbook on Stock Diseases, Tafelberg, Cape Town, 408 p. (The book is a somewhat dated, although still useful general text).

- Vlok, M.E., 1986. Manual of Community Nursing and Psychiatry: a Textbook for South African Student Nurses, Juta, Cape Town, 816 p.

- Von Schirnding, Y., Yach, D. and Mathee, A., 1993. Health aspects of sanitation, with special reference to South Africa, CHASA Journal of Comprehensive Health, VOL 4(3/4), p. 73 - 79.

16.14.2 Wastewater reuse (for potable purposes) and health implications

Note: The topic is not discussed in this publication. Further useful references are listed at the end of the chapter on sanitation. (See documents relating to conventional sewerage systems).

- Anonymous, 1981. Manual for water renovation and reclamation, second edition, CSIR Technical Guide No. K42, National Institute for Water Research, CSIR and the Water Research Commission, Pretoria, 330 p.

- Anonymous, 1986. Management of the Water Resources of the Republic of South Africa, Department of Water Affairs, Pretoria, various pages.

- Beekman, H.G., Klopper, D.N., Fawcett, K.S. and Novella, P.H., 1990. Construction and operation of the Cape Flats water reclamation plant and the surveillance of the reclaimed water quality, WRC Report No. 75/1/90, Water Research Commission, Pretoria, 106 p. + app.

- Bourne, D.E., Sayed, A.R., Watermeyer, G.S. and Klopper, J.M.L., 1987. Epidemiological studies pertaining to the possible reclamation and reuse of purified sewage effluent in the Cape Peninsula, WRC Report No. 74/1/87, Water Research Commission, Pretoria, 155 p. and map.

- *Hattingh, W.H.J. and Nupen, E.M., 1976. Health aspects of potable water* supplies, Water SA, VOL 2(1), p. 33 - 46.

- Hodgkiss, M., Moodie, J.W. and Hattingh, W.H.J., 1989. Virological studies of water from the Cape Flats reclamation plant, South African Medical Journal, VOL 76(1), p. 11 - 13.

- Isaäcson, M., Sayed, A.R. and Hattingh, W.H.J., 1987. Studies on health aspects of water reclamation during 1974 to 1983 in Windhoek, South West Africa/Namibia, WRC Report No. 38/1/87, Water Research Commission, Pretoria, 77 p.

16.14.3 Sources of epidemiological information and data

Note: (i) Due to the number of Central Statistical Service reports listed below, it is not possible to cite each report individually. Bibliographic details can be obtained by examining the following publication - and earlier editions: Anonymous, 1995. User's guide March 1995, Central Statistical Service, Pretoria, 62 p. The guide is published each quarter. A more comprehensive *document is the following: Anonymous, 1995. Statibib: list of CSS* publications as from 1978, Central Statistical Service, Pretoria, 179 p. Alternatively, the Government Publications section of any of the five copyright (legal deposit) libraries in South Africa, namely: the Natal Society Library (Pietermaritzburg); the State Library (Pretoria); the Library of Parliament (Cape Town); the South African Library (Cape Town), and the

Public Library (Bloemfontein) should be contacted in order to examine Central Statistical Service reports. The Central Statistical Service in Pretoria as well as the Johannesburg Public Library are further sources. The same procedure should be used for other reports such as the South African life tables. The responsible agency was initially known as the Bureau of Census and Statistics subsequently the Bureau of Statistics, then the Department of Statistics, and is now the Central Statistical Service.

Mortality data for the black population were first made available for the years 1968 - 1971 inclusive. The data were published in one volume in 1974 (Report No. 07-03-04). Thereafter, annual reports were issued for the years 1972 - 1990 inclusive (Reports No. 07-03-06/07/08/12/14/15; 07-05-01 (for the year 1978); 07-05-02/03/04/05/06/07/08; 03-10-01 (1986); 03-10-01 (1987); 03-10-01 (1988); 03-10-01 (1989), and 03-10-01 (1990)). Data for the years 1968 - 1977 inclusive, were only in respect of urban areas in 34 selected magisterial districts. Information is available from 1978 onwards for the whole country, excluding the national states (from date of independence).

Mortality data for whites (1935 - 1958); Coloureds (1938 - 1958), and Asians (1938 - 1958) were first published in 1961 in two volumes (Reports No. UG 26/1961 and RP 17/1961). A later report in two volumes covered the years 1959 - 1962 (Reports No. RP 45/1965 and RP 63/1965). Combined data for 1963 - 1966 inclusive were published in one volume (Report No. 07-03-01); for 1967 (Report No. 07-03-02), and for 1968 - 1971 inclusive (Report No. 07-03-03). Thereafter, annual reports were published for the period 1972 - 1990 inclusive (Reports No. 07-03-05/09/10/11/13/16/17/18/19/20/21/22/23/24; 03-09-01 (1986); 03-09-01 (1987); 03-09-01 (1988); 03-09-01 (1989), and 03-09-01 (1990)). Mortality data for 1991, published in 1993 (Report No. 03-09-01 (1991)) and 1992, also published in 1993 (Report No. 03-09-01 (1992)) do not differentiate between the various population groups. This is now standard Government policy which applies to all agencies and departments.

(ii) Morbidity data for all population groups were (apparently) first published in 1978, in respect of 1976 (Report No. 20-06-01). Annual reports were then issued for the period 1977 - 1983, although excluding 1982 (Reports No. 20-06-02/03/04/05/06/07). Thereafter, a report was made available for the year 1987 (Report No. 93-01-01 (1987)), and for 1990 (Report No. 93-01-01 (1990)). No further reports have been issued thus far (August 1995).

(iii) The monthly publication Epidemiological Comments, produced by the Department of National Health and Population Development in Pretoria, contains numerous statistics inter alia on notifiable diseases. Similar data for Natal/KwaZulu can be found in Epidemiological Focus, which is published on a quarterly basis by the Natal Region of the Department.

- Anonymous, 1985. South African life tables 1979 - 81, Report No. 02-06-03, Central Statistical Service, Pretoria, 28 p.

- Anonymous, 1992. Deaths of blacks: 1990, Report No. 03-10-01 (1990), Central Statistical Service, Pretoria, 255 p.

- Anonymous, 1992. Deaths: whites, Coloureds and Asians, 1990, Report No. 03-09-01 (1990), Central Statistical Service, Pretoria, 559 p.

- Anonymous, 1993. Census of hospitals, community health care centres and other health service establishments, 1990, CSS Report No. 93-01-01 (1990), Central Statistical Service, Pretoria, 176 p.

- Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p. (The publication is updated at given intervals. The latest issue should be consulted for current information).

- Botha, J.L. and Bradshaw, D., 1985. African vital statistics - a black hole?, South African Medical Journal, VOL 67(24), p. 977 - 981.

- Bourne, D.E. and Coetzee, N., 1996. An atlas of potentially water-related diseases in South Africa, VOL 1: mortality 1990, WRC Report No. 584/1/96, Water Research Commission, Pretoria, 48 p. (See also, Coetzee, N. and Bourne, D.E., 1996. An atlas of potentially water-related diseases in South Africa, VOL 2: bibliography, WRC Report No. 584/2/96, Water Research Commission, Pretoria, 49 p.).

- Bourne, D.E., Sayed, A.R. and Klopper, J.M.L., 1990. A data base for use in the epidemiological surveillance of potential changes in drinking water quality in South Africa, WRC Report No. 186/1/90, Water Research Commission, Pretoria, 81 p.

- Dorrington, R.E., 1987. African mortality rates - an initial estimate, Transactions of the Actuarial Society of South Africa, VOL 7(1), p. 169 - 202.

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- Katzenellenbogen, J., Joubert, G. and Yach, D., 1991. Introductory manual for epidemiology in southern Africa, Medical Research Council, [Tygerberg], 166 p. + app.

- Sadie, J.L., [1976]. Projections of the South African population 1970 - 2020, Industrial Development Corporation of South Africa Ltd, Johannesburg, 66 p.

- Slabber, C.F., 1995. Report of the Director-General: Health for the year 1994, Report No. RP 96/1995, Government Printer, Pretoria, 47 p. (The report is produced each year. The latest issue should be consulted for up-to-date information inter alia on notifiable diseases. Such data are sometimes not continuous).

- Van Pletsen, D. (ed), 1988. Official Yearbook of the Republic of South Africa: South Africa 1988-89, fourteenth edition, Bureau for Information, Pretoria, 816 p.

(The publication, in more recent times, is produced each year usually by a different editor. Retrospective searches may be required to derive time series data, which are however, seldom continuous. The yearbooks are an important source of information on notifiable diseases).

- Yach, D., 1988. Infant mortality rates in urban areas of South Africa, 1981 - 1985, South African Medical Journal, VOL 73(4), p. 232 - 234.

- Yach, D., Strebel, P.M. and Joubert, G., 1989. The impact of diarrhoeal disease on childhood deaths in the RSA, 1968 - 1985, South African Medical Journal, VOL 76(9), p. 472 - 475.

16.14.4 Services and health implications

- African National Congress, 1994. The Reconstruction and Development Programme: a Policy Framework, Umanyano Publications, Johannesburg, 147 p.

- Anonymous, 1994. Provincial statistics 1994, Part 5: KwaZulu/Natal, CSS Report No. 00-90-05 (1994), Central Statistical Service, Pretoria, 99 p.

- Anonymous, 1994. South Africa's rich and poor: baseline household statistics, August 1994, Project for Statistics on Living Standards and Development, [Southern Africa Labour and Development Research Unit], University of Cape Town, Rondebosch, 345 p. + app.

- Anonymous, 1996. South African health review 1996, Health Systems Trust and the Henry J. Kaiser Family Foundation, Durban, 232 p. (The review, published annually since 1995, deals with a number of health policy issues. Data are also provided on communicable diseases in South Africa).

- Emmett, T. and Rakgoadi, S., 1993. Water supply and sanitation services in South Africa, Project for Statistics on Living Standards and Development, Southern Africa Labour and Development Research Unit, University of Cape Town, Rondebosch, 218 p. + app.

- Genthe, B. and Seager, J., 1996. The effect of water supply, handling and usage on water quality in relation to health indices in developing communities, WRC Report No. 562/1/96, Water Research Commission, Pretoria, 63 p. + app.

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- Palmer Development Group, 1994. Water and sanitation in urban areas: financial and institutional review, Report 3. Meeting the demand for water and sanitation *services: getting it right in the transition*, WRC Report No. 571/3/94, Water Research Commission, Pretoria, 101 p. + app.

- Palmer, I. and Eberhard, R., 1994. Evaluation of water supply to developing urban communities in South Africa, Phase 1 - overview, WRC Report No. KV 49/94, Water Research Commission, Pretoria, various pages.

- Reconstruction and Development Programme, 1995. Key indicators of poverty in South Africa, South African Communication Service, Pretoria, 27 p.

16.14.5 Malaria

- Anonymous, 1981. Malaria: what you should know about it, Department of Health, Welfare and Pensions, Pretoria, 14 p.

- Anonymous, 1990. Malaria in South Africa, 1980 - 1989, Epidemiological Comments, VOL 17(7), p. 3 - 16.

- Coetzee, M., Hunt, R.H., Braack, L.E.O. and Davidson, G., 1993. Distribution of *mosquitoes belonging to the* Anopheles gambiae *complex, including malaria* vectors, south of latitude 15°S, South African Journal of Science, VOL 89(5), p. 227 - 231.

- Gear, J.H.S., Hansford, C.F. and Pitchford, R.J., 1981. Malaria in southern Africa, Department of Health, Welfare and Pensions, Pretoria, 49 p.

- Jupp, P.G., 1996. Mosquitoes of Southern Africa: Culicinae and Toxorhynchitinae, Ekogilde Publishers, Hartbeespoort, 156 p. (The book concentrates on the identification and characteristics of various mosquitoes. Useful geographical distribution data are provided. The book has an extensive bibliography).

- Le Sueur, D., Sharp, B.L. and Appleton, C.C., 1993. *Historical perspective of the* malaria problem in Natal with emphasis on the period 1928 - 1932, South African Journal of Science, VOL 89(5), p. 232 - 239.

- Maurel, M., 1994. Malaria: a Layman's Guide, Southern Book Publishers, Halfway House, 115 p.

- Sharp, B.L., Ngxongo, S., Botha, M.J., Ridl, F. and Le Sueur, D., 1988. An analysis of 10 years of retrospective malaria data from the KwaZulu areas of Natal, South African Journal of Science, VOL 84(2), p. 102 - 106.

- Strebel, P.M., Hansford, C.F. and Küstner, H.G.V., 1988. The geographic distribution of malaria in South Africa in 1986, Southern African Journal of Epidemiology and Infection, VOL 3(1), p. 4 - 8.

- Stuttaford, M.C., 1994. Aspects of a Geographic Information System for medical geographers and malaria control, M. Soc. Sci. Thesis, Department of Geography, University of Natal, Pietermaritzburg, 164 p.

16.14.6 Schistosomiasis

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- Appleton, C.C., 1985. Molluscicides in bilharziasis control - the South African experience, South African Journal of Science, VOL 81(7), p. 356 - 360.

- Appleton, C.C., 1996. Freshwater Molluscs of Southern Africa With a Chapter on Bilharzia and its Snail Hosts, University of Natal Press, Pietermaritzburg, 64 p.

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- Fripp, P.J., 1977. Bilharzial immunity and its impact on the definitive host, South African Journal of Science, VOL 73(2), p. 50 - 53.

- Gear, J.H.S. (ed), 1977. Medicine in a Tropical Environment: Proceedings of the International Symposium South Africa/1976, A.A. Balkema, Cape Town, 817 p. (The publication contains papers on a wide range of tropical diseases).

- Gear, J.H.S. and Pitchford, R.J., 1988. Bilharzia in South Africa, Department of National Health and Population Development, Pretoria, 29 p.

- Gear, J.H.S., Pitchford, R.J. and Van Eeden, J.A. (eds), 1980. Atlas of Bilharzia in Southern Africa, South African Institute for Medical Research, the Medical Research Council and the Department of Health, Pretoria, 93 p.

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- Kvalsvig, J.D., 1981. The effects of schistosomiasis on spontaneous play activity in black schoolchildren in endemic areas: an ethological study, South African Medical Journal, VOL 60(2), p. 61 - 64.

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- Visser, P.S., 1984. Distribution of human schistosomiasis in the southern Transvaal, South Africa, South African Journal of Science, VOL 80(3), p. 124 - 127.

16.14.7 Wetlands and health

- Appleton, C.C., 1983. Wetlands and public health, Journal of the Limnological Society of Southern Africa, VOL 9(2), p. 117 - 122.

- Appleton, C.C. and Bruton, M.N., 1979. The epidemiology of schistosomiasis in the vicinity of Lake Sibaya, with a note on other areas of Tongaland (Natal, South Africa), Annals of Tropical Medicine and Parasitology, VOL 73(6), p. 547 - 561.

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16.14.8 The blackfly plague (as one example of ecosystem disturbance resulting in health problems)

- De Moor, F.C. and Car, M., 1986. A field evaluation of Bacillus thuringiensis var. israelensis as a biological control agent for Simulium chutteri (Diptera: Nematocera) in the Middle Orange River, Onderstepoort Journal of Veterinary Research, VOL 53(1), p. 43 - 50.

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16.14.9 Inorganic determinands and health

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- Derry, C.W., Bourne, D.E. and Sayed, A.R., 1990. The relationship between the hardness of treated water and cardiovascular disease mortality in South African urban areas, South African Medical Journal, VOL 77(10), p. 522 - 524.

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For further information contact:*

- Actuarial Society of South Africa, c/o the Department of Actuarial Science, University of the Witwatersrand, Private Bag 3, Wits, 2050. (Actuarial science can be studied at three other universities, namely, the Rand Afrikaans University, the University of Cape Town and the University of Stellenbosch. Actuarial science involves the calculation inter alia of life expectancy data in terms of specific age groups, using complicated mathematical modelling procedures. The Actuarial Society has developed an AIDS model to try and assess the impact of the disease on the South African population).

- Africa Centre for Population Studies and Reproductive Health, c/o the Medical School, University of Natal, Private Bag 7, Congella, 4013. (The Centre is a recent, joint research initiative involving the Medical School, the Medical Research Council, and the University of Durban-Westville. Research projects include population studies and reproductive health. The impact of AIDS, amongst other diseases, will be assessed with regard to population dynamics. A considerable amount of demographic information will be available for the study area which is situated in the Hlabisa District).

- Bureau of Market Research, University of South Africa, P O Box 392, Pretoria, 0001 (with reference to population data).

- Central Statistical Service, Private Bag X44, Pretoria, 0001.

- Centre for Health Policy, University of the Witwatersrand, Private Bag 3, Wits, 2050.

- Centre for Health and Social Studies/Industrial Health Unit, Medical School, University of Natal, Private Bag 7, Congella, 4013.

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* The larger municipalities in South Africa have an environmental health inspectorate as well as community health staff who can be called upon for advice and assistance where necessary. Community health likewise, is an important part of the service/training provided by major hospitals and medical schools.

- Centre for Integrated Health Research, Department of Zoology and Entomology, University of Natal, Private Bag X01, Scottsville, 3209.

- Centre for Social and Development Studies, University of Natal, Private Bag X10, Dalbridge, 4014 (with regard to income and poverty statistics for Natal/KwaZulu).

- Chief Directorate: Occupational Safety, Department of Manpower/Advisory Council for Occupational Safety, Private Bag X117, Pretoria, 0001.

- Chief Directorate: Veterinary Services, Department of Agriculture, Private Bag X138, Pretoria, 0001.

- Dental Association of South Africa, Private Bag 1, Houghton, 2041.

- Department of Biological Services, South African Bureau of Standards, Private Bag X191, Pretoria, 0001.

- Department of Community Health, Medical School, University of Natal, Private Bag 7, Congella, 4013.

- Department of Community Health/University of Cape Town: Ciba-Geigy Medicines Safety Centre, c/o the Department of Pharmacology, Medical School, University of Cape Town, Observatory, 7925.

- Department of National Health and Population Development, Private Bag X54318, Durban, 4000. (The Department provides a health inspectorate service for areas where no local authority exists. The Department is the major central Government organization concerned with health issues in South Africa).

- *Department of Zoology, Potchefstroom University for Christian Higher Education,* Private Bag X6001, Potchefstroom, 2520.

- Directorate of Resource Conservation, Department of Agriculture, Private Bag X120, Pretoria, 0001.

- Division of Water Technology, CSIR, P O Box 395, Pretoria, 0001.
- Environmental Health Officers' Association of Southern Africa, P O Box 2520, Pietermaritzburg, 3200/P O Box 17174, Sunward Park, 1470.
- Epidemiological Society of Southern Africa, c/o the Medical Research Council, P O Box 19070, Tygerberg, 7505.
- Health Services Branch, Natal Provincial Administration, Private Bag X9037, Pietermaritzburg, 3200.
- Health Systems Trust, P O Box 808, Durban, 4000.
- Human Sciences Research Council, P O Box 17302, Congella, 4013.
- Industrial Health Research Group, University of Cape Town, Private Bag, Rondebosch, 7701.
- Infectious Diseases Society of Southern Africa, c/o the South African Institute for Medical Research, P O Box 1038, Johannesburg, 2000.
- Institute for Futures Research, University of Stellenbosch, Private Bag X1, Matieland, 7602 (with reference to population data and scenario planning).
- Institute for Water Quality Studies, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001.
- KwaZulu Department of Health, Private Bag X10, Ulundi, 3838.
- Medical Association of South Africa, P O Box 20272, Alkantrant, 0005.
- National Malaria Research Programme, Medical Research Council, P O Box 17120, Congella, 4013. (Other programmes of the Medical Research Council may also be relevant. The head office address of the Medical Research Council is P O Box 19070, Tygerberg, 7505).

- Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort, 0110.
- Pharmaceutical Society of South Africa, P O Box 31360, Braamfontein, 2017.
- Population Training and Research Centre, University of Bophuthatswana (now the University of North-West), Private Bag X2046, Mmabatho, 2735. (The Centre undertakes research on population issues and sustainable development).
- South African Institute for Medical Research, P O Box 1038, Johannesburg, 2000.
- South African Medical and Dental Council, P O Box 205, Pretoria, 0001.
- South African Pharmacological Society, c/o the Department of Pharmacology, Rhodes University, P O Box 94, Grahamstown, 6140.
- South African Pharmacy Council, P O Box 40040, Arcadia, 0007.
- Southern Africa Labour and Development Research Unit, University of Cape Town, Private Bag, Rondebosch, 7701 (in terms of household survey data).
- World Health Organization Collaborating Centre for Drug Policy, School of Pharmacy, University of the Western Cape, Private Bag X17, Bellville, 7535.

Note: In order to avoid repetition, non-government and other organizations mainly concerned with primary health care are listed at the end of the chapter on sanitation. Certain other agencies with an interest in the environment and accordingly health issues, are listed at the end of the chapter on solid waste management.

NOTES:

CHAPTER 17: SOLID WASTE MANAGEMENT IN SOUTH AFRICA

The consequences of irreversible destruction...

"What is man without the beasts?
If all the beasts were gone,
man would die from a great loneliness of spirit.
For whatever happens to the beast
also happens to the man.
All things are connected.
Whatever befalls the earth
befalls the sons of the earth".

Chief Seathl. A North American Indian in a letter to the President of the United States of America - 1855, quoted in Furlonger, D. (ed), 1989. Financial Mail Survey: SA Nature Foundation, Supplement to Financial Mail, 18 August 1989, 64 p.

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17.1 Introduction

The chapter provides an overview of selected aspects of solid waste management (including municipal effluent disposal) in South Africa. Pollution of the sea is briefly described. Some emphasis has been placed on the legal implications of waste and pollution in order to provide relevant background data, and to enable the reader to assess the current waste situation in this country. Certain important waste statistics are likewise presented. Guidelines for the land disposal of sewage sludge and effluent are then examined, before hazardous waste is discussed. The final part of the chapter reviews a special category of hazardous chemicals, namely, agrichemicals (pesticides)*.

17.2 Some implications and definitions of waste

Manufactured chemicals are necessary for comfort and survival in the modern world. However these chemicals, if not used with great care, can have a profound impact on life in general. Man is exposed to chemical substances (hazardous or otherwise) through emissions to air, water and soil. Sources of chemical contamination include industrial activities; accidents and spillage during transport, storage and use; household applications; inadequate waste disposal procedures, and ingestion of contaminated foodstuffs and water. The effects of chemicals on human and animal health depend on a variety of parameters, not least of which is the considerable number of manufactured chemicals available (Fourie, 1989)**. Roberts (1982, quoted in Fourie, 1989), calculated that there are approximately five million known chemical substances (with numerous new chemicals being formulated each year), of which only some 7 000 (0,14%) have been tested for carcinogenicity. Of the 7 000 chemicals, 1 500 have been found to be carcinogenic in animal studies, of which 30 have been clearly linked to cancer in man. Approximately 2 221 organic compounds have been identified in the aquatic environment - of which some 765 compounds may be found in drinking water. According to Bedding and co-workers (1983, quoted in Fourie, 1989), 43 of the latter are suspected carcinogens, 56 are mutagenic contaminants (causing genetic changes), and 18 are

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* The terms "agrichemical" and "agrochemical" are both used in the literature. The former has been used in this publication.

** See Fourie, H.O., 1989. An estimation of the health implications of chemical contaminants in food and water: a total diet ("market basket") study, WRC Report No. 173/1/89, Water Research Commission, Pretoria, 43 p. + app.

carcinogenic promoters. Many other forms of illness may occur due to exposure to man-made chemicals per se, or to chemicals resulting from the degradation of processed substances.

Fourie (1989) observed that waste disposal (especially involving hazardous materials), could well be **the major** constraint to life on earth - to which overpopulation and hence the generation of further waste could be added. Wastes can be regarded as potential or actual contaminants which have, or may have, poisonous properties. A waste product can be further defined as a substance which has become redundant, and which differs in its physical or chemical properties from its original or natural occurrence in the environment. Included in this definition of waste is a variety of chemicals simply not found in nature (Fourie, 1989). Waste also includes material with possible or actual microbiological dangers. The definition of waste in many cases is somewhat subjective in that certain categories of waste constitute valuable raw materials. An important survey on waste management and pollution control in South Africa, undertaken by the CSIR (Anonymous, 1991)*, defined waste as any substance having no perceived use for the organism or system that produced the substance. Pollution was defined as the introduction of any substance to the environment, which causes or results in harmful or undesirable effects on man and the environment. Pollution control includes any activity or procedure which controls waste production in order to meet (or set) standards. Waste management in turn, was defined as any activity influencing the quantity, quality or effects of waste. Hazardous waste was described as any waste (excluding radioactive material), which as a result of its chemical reactivity or explosive, toxic, corrosive or other properties causes - or is likely to cause - dangers to health or the environment.

A similar definition of hazardous waste was provided by the Department of Water Affairs and Forestry (Anonymous, 1994)**. The Department of Water Affairs and Forestry definition is more specific, and also includes risks associated with one or more of the following: infections, pathogens, parasites or their vectors; cancer, mutations or birth

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* See Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

** See Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p. (It is important to note that toxic waste is a sub-category of hazardous waste).

defects; fire; damage to ecosystems or natural resources and accumulation in biological food chains; as well as persistence in the environment, or other multiple environmental effects. Hazardous waste therefore requires special attention and cannot be released untreated into the environment, or stored in a site open to the air or from which leachates can escape. The basic concept of hazardous waste accordingly, is material which represents a direct or indirect threat to health and the environment. The official South African definition of hazardous waste (as described by the Department of Water Affairs and Forestry), complies with the United Nations Environment Programme definition (Anonymous, 1994).

In terms of the Environment Conservation Act No. 73 of 1989 (discussed below), waste refers to any matter (whether solid, liquid or gaseous, or any combination of these states), which is derived from any agricultural, residential, commercial or industrial area - and which is designated by notice in the Republic of South Africa Government Gazette by the Minister of Environment Affairs - as an undesirable or superfluous by-product, emission, residue or remainder of any process or activity. Wastes so identified include matter discarded, or accumulated and stored for eventual disposal (with or without further treatment); as well as matter stored for recycling, reuse or for the extraction of a usable product therefrom. The latter definition excludes building rubble used for levelling or in-fill purposes, as well as any minerals, mine tailings, waste rock or slimes resulting from processes at mines or works, as identified in the Mines and Works Act No. 27 of 1956/Minerals Act No. 50 of 1991. Also excluded is ash resulting from any electricity generating plant as per the Electricity Act No. 41 of 1987. Likewise excluded, is any matter entering a French drain or septic tank or any effluent (including industrial effluent) discharged in accordance with the Water Act No. 54 of 1956, plus water used for industrial purposes, as well as radioactive material discarded in terms of the Atomic Energy Act No. 90 of 1967/Nuclear Energy Act No. 92 of 1982 (Lombard, Botha and Rabie, 1992)*. Lombard et al (1992) stressed that several problems are inherent in the legal definition of waste. Litter (an integral part of waste) is defined by Act No. 73 of 1989 as any matter or object discarded (or left behind) by the person who previously controlled or possessed it (Lombard et al). Various other definitions of litter and waste are found in the scientific literature, as well as in provincial ordinances and municipal by-laws.

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* See Lombard, R., Botha, L. and Rabie, M.A., 1992. Chapter 19. Solid waste, In: Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Juta, Cape Town, p. 493 - 522.

17.3 Some legal aspects of solid waste management on land in South Africa

Numerous Acts, provincial ordinances and municipal by-laws control the disposal of waste on land, in water and in the air. The overall management of waste disposal is complicated by the various legal requirements and responsible authorities. The survey undertaken by the CSIR (Anonymous, 1991) revealed that provisions relating to land disposal alone, were to be found in some 37 key Acts, 16 provincial ordinances and several municipal by-laws. (A number of Acts have subsequently been repealed). Lombard et al observed that in the past, solid waste legislation mainly addressed refuse removal and the problems of littering, while law enforcement was largely undertaken by local authorities. The promulgation of the Environment Conservation Act No. 73 of 1989, which replaced the repealed Environment Conservation Act No. 100 of 1982, however, was a major advance in achieving a more comprehensive approach to the management and control of solid waste in South Africa (Lombard et al). The 1989 Act is briefly discussed here only with reference to solid waste, although the Act deals with a number of issues*. Both the Departments of Environment Affairs as well as Water Affairs and Forestry are involved in administering the Act for waste control purposes.

17.3.1 The Environment Conservation Act No. 73 of 1989**

In terms of Section 20(1) read with Section 29(4) of the Environment Conservation Act, no person may establish, provide or operate any waste disposal site without a permit issued by the Minister of Water Affairs and Forestry, and subject to its conditions. The Minister may alter or cancel any permit or condition in a permit, or refuse to issue a permit. He may also exempt any person from obtaining a permit (under specific conditions). The Minister is empowered to issue directions relating to the control and management of disposal sites, by placing a notice in the Republic of South Africa Government Gazette (Section 20(5)). Subject to the provisions of any other law, no person may discard waste

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* For a more detailed examination see Rabie, M.A., 1992. Chapter 7. Environment Conservation Act, In: Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Juta, Cape Town, p. 99 - 119. (Other chapters dealing with particular aspects of the Act should also be consulted. Note that certain changes to the Act have been effected by the Environment Conservation Amendment Act No. 79 of 1992 and the Environment Conservation Second Amendment Act No. 115 of 1992. A few of the changes have been included in the discussion, with regard to Act No. 79 of 1992).

** Discussion based on Anonymous (1991 - above), as well as Anonymous (1994 - above), plus Lombard, Botha and Rabie (1992 - above).

or dispose of it in any other manner, except at a disposal site for which a permit has been issued; or in a manner or by means of a facility or method and subject to conditions prescribed by the Minister of Environment Affairs (Section 20(6) of the Environment Conservation Act).

Landfill site permitting (as the process is termed), applies to new and existing sites as well as all sites closed after August 1990. Unpermitted closed sites are controlled either in terms of Section 31A of the Act, or with regard to Sections 22A and B of the Water Act No. 54 of 1956. The conditions of the permit are based on the minimum requirements published in 1994 by the Department of Water Affairs and Forestry (discussed later in the chapter). Section 20(3) of the Environment Conservation Act empowers the Minister of Water Affairs and Forestry to demand further information from the landfill applicant - such as certain operational aspects of the proposed site (which in turn must also be based on the minimum requirements).

An Environmental Impact Assessment (EIA) may be required for proposed sites, although only if the Minister of Environment Affairs declares waste disposal to be an identified activity (Section 21(2)(i) read with Section 22(1) and (2) of the Environment Conservation Act). In terms of the minimum standards formulated by the Department of Water Affairs and Forestry however, it is now a requirement that all applications for a permit to operate a waste disposal site must automatically include an EIA of the proposed (or existing) site.

Section 31A of the Environment Conservation Act empowers the Minister of Environment Affairs, the Administrator of a province, or the local authority or the Government institution concerned, to take action against any person undertaking any activity or failing to undertake any activity which results in environmental damage. Costs incurred in repairing the damage can be recovered from the offender. Similar powers are conferred on the Minister of Water Affairs and Forestry in terms of the Water Act. The Minister of Environment Affairs by virtue of Section 24 of the Environment Conservation Act may make regulations for various aspects of waste management such as the handling, storage, transport and disposal of waste; the classification of different types of waste, and the submission of relevant waste statistics. Further aspects involve the reduction of waste by modifications to manufacturing processes, and the use of alternative products, plus changes in the design and marketing of products. Other issues are the reuse, recovery or further processing of waste, and control over the management of waste disposal sites, as well as equipment used for the disposal of waste. Regulations may also encompass the prevention, control and removal of litter (Section 24A).

It is an offence in terms of Section 19(1) of Act No. 73 of 1989 to discard, dump or leave any litter on any land or water surface, street, road or site; and in or on any public place (except in a container or at a specified locality). It is therefore the duty of every person or authority in charge of, or responsible for the maintenance of public areas to ensure that containers or appropriate places are provided for litter disposal. Litter must be removed by such a person or authority or someone acting for them, within a reasonable time period (Section 19A).

The regulations provided for in the Act have yet to be finalized, although two sets of draft regulations on waste disposal were produced in terms of the (previous) Environment Conservation Act No. 100 of 1982. Certain draft regulations have also been issued in terms of the Environment Conservation Act No. 73 of 1989. One of the main problems of controlling waste through any regulations issued by virtue of Act No. 73 of 1989, concerns already existing legislation (discussed below), which to varying degrees, addresses some of the topics covered by Act No. 73 (Lombard et al).

17.3.2 Other Acts relevant to waste management on land

Reference has already been made to the Water Act No. 54 of 1956. The Act will not be examined here, although further details can be found in the chapter on the surface water resources of Natal/KwaZulu, and in the chapter on water quality. Pollution of the sea (especially by oil) as well as emergency procedures on land are discussed later in the chapter.

Another important Act is the Hazardous Substances Act No. 15 of 1973 which is administered by the Department of National Health and Population Development. The Act refers inter alia to dumping and other forms of disposal of numerous hazardous substances. The Act also controls the transportation of hazardous material (including hazardous waste) by road*. Other Acts relevant to the transportation of hazardous

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* Act No. 15 of 1973 deals with four groups of hazardous substances, namely, Groups I and II (chemicals), III (electronic products), and IV (radioactive material).

substances or waste include the Fire Brigade Services Act No. 99 of 1987 (flammable materials) and the Explosives Act No. 26 of 1956 (explosives). The disposal of radioactive waste is controlled by the Atomic Energy Act No. 90 of 1967/Nuclear Energy Act No. 92 of 1982. The Mines and Works Act No. 27 of 1956/Minerals Act No. 50 of 1991 deals with various aspects of mining waste. The Department of Mineral and Energy Affairs is the responsible authority for waste generated on mines. (See the chapter on the laws of South Africa).

Agrichemicals are controlled under the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947, with the Department of Agriculture as the relevant agency. The Agricultural Pests Act No. 36 of 1983 is of some significance for agrichemicals with regard to the control of pathogens and insects on important agricultural plants. Maximum permissible pesticide residue levels in foodstuffs are specified in terms of the Foodstuffs, Cosmetics and Disinfectants Act No. 54 of 1972. The Act is administered by the Department of National Health and Population Development. The Conservation of Agricultural Resources Act No. 43 of 1983 is applicable to certain wastes or pollutants (primarily sediment), resulting from agricultural activities. The Forest Act No. 122 of 1984 - also administered by the Department of Water Affairs and Forestry - refers to solid waste in State forests (forests and adjacent grasslands); as well as in vital catchment areas, private forests and along the national hiking way system.

The Sea-shore Act No. 21 of 1935 (outlined later in the chapter), which is administered by the Department of Environment Affairs, has been used to authorize local authorities to make regulations for the control of waste on the sea-shore or in the sea. Similar powers in respect of the sea-shore and the sea, plus lakes, rivers and "estuaries" within certain protected lake areas (national parks), have been conferred on the National Parks Board in terms of the Lake Areas Development Act No. 39 of 1975. (The Act is applied in the Cape Province only). The National Parks Board is likewise responsible for waste disposal and management in other protected areas controlled by the Board (with reference to the National Parks Act No. 57 of 1976).

The control of waste on roads (including abandoned vehicles and machinery), has been addressed by the Advertising on Roads and Ribbon Development Act No. 21 of 1940; the

National Roads Act No. 54 of 1971, and the Road Traffic Act No. 29 of 1989*. Health aspects of waste are managed in terms of the Health Act No. 63 of 1977; the Atmospheric Pollution Prevention Act No. 45 of 1965, and the Medicines and Related Substances Control Act No. 101 of 1965 (which deals with - amongst other things - the disposal or destruction of undesirable medical products). A further Act is the International Health Regulations Act No. 28 of 1974. The latter Act requires inter alia that each seaport and airport must have an efficient removal and disposal system for sewage, refuse, wastewater, condemned food and other waste. The four Acts are administered by the Department of National Health and Population Development. Also of relevance to health is the Animal Slaughter, Meat and Animal Products Hygiene Act No. 87 of 1967/Abattoir Hygiene Act No. 121 of 1992, which refers to the proper disposal of carcasses, animal products and waste.

The Occupational Health and Safety Act No. 85 of 1993 (which replaced the since repealed Machinery and Occupational Safety Act No. 6 of 1983) is applicable to the health and safety of employees. The Act - which covers the effects of industrial accidents and the incorrect handling of machinery and waste - is administered by the Department of Manpower. The Act does not apply to the mining and fishing industries. The health considerations of such employees are however, covered by the Minerals Act No. 50 of 1991 and the Merchant Shipping Act No. 57 of 1951.

Several other Acts are pertinent to the disposal or control of waste on land. An apparently unrelated Act, namely, the Income Tax Act No. 58 of 1962 provides for tax deductions on new or unused machinery or plant which is used by the taxpayer to manufacture goods, or to undertake a recognized business activity (excluding farming and mining). Accordingly, a scrap metal dealer is entitled to the deduction where machinery is purchased to process scrap metal (Lombard, Botha and Rabie, 1992 - above). Provincial legislation of relevance in Natal includes the Prevention of Environmental Pollution Ordinance No. 21 of 1981; the Local Authorities Ordinance No. 25 of 1974; the Town Planning Ordinance No. 27 of 1949; the Roads Ordinance No. 10 of 1968, and the Nature

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* A number of powers have been delegated to provincial administrations or other agencies, with regard to several Acts listed here. Where relevant, further details have been provided elsewhere in this publication. Several central Government departments accordingly, may only be partly responsible for overall control.

Conservation Ordinance No. 15 of 1974. (Refer to the chapter on the laws of South Africa).

Lombard et al (1992) observed that the control of solid waste at provincial level in South Africa, has mainly been undertaken with regard to solid waste along roads (in terms of Ordinance No. 10 - in Natal - and the Road Traffic Act which is administered at provincial level). Local authorities have used provincial ordinances and by-laws to control littering in public places, streets, private property and in various waters. The dumping of refuse is controlled in a similar manner. Local authorities are also concerned with the keeping of certain animals, the disposal of dead animals, and the regulation of offensive trades. The main function of local authorities in terms of solid waste, involves the collection and disposal of refuse and litter with particular reference to the protection of health and the prevention of nuisances. The management of solid waste at local government level however, is not being properly addressed (Lombard et al).

It is evident from the brief discussion that there is a plethora of legislation and regulatory authorities. Both Anonymous (1991 - above) and Lombard et al emphasized that there is at present, no national waste management and pollution control policy for South Africa. An attempt was made in 1980 by the central Government to examine policy issues and to obtain public comment by means of a White Paper*. The White Paper referred to the need to co-ordinate the activities of organizations involved in the control of solid waste and littering; as well as the need for appropriate public awareness campaigns; and the necessity for incentives and measures to promote the reuse, recycling and reclamation of suitable packaging material - in order to conserve natural resources and to prevent pollution. Other topics examined, included the need to establish guidelines for the evaluation of packaging material and containers. Attention was drawn to the necessity for the cost effective recovery, recycling and reuse of urban solid waste in general, inter alia through the design of machinery and facilities. The development of new methods and processes to enable the sorting of urban solid waste to be undertaken at source (for example the household), was stressed. The possible use of waste for other purposes such

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* See Anonymous, 1980. Department of Water Affairs, Forestry and Environmental Conservation, White Paper on a National Policy Regarding Environmental Conservation, Report No. W.P.O - 1980, Government Printer, Pretoria, 13 p. (The White Paper was preceded by a Commission of Inquiry on the broader aspects of littering and the disposal of solid waste. The Commission then prepared a Bill based on its findings. The Bill was not passed into law. See: Hoon, J.H., 1978. Report of the Commission of Inquiry into the Disposal of Containers Bill (W111-77), Report No. RP 121/1978, Government Printer, Pretoria, 18 p.).

as electricity generation was also put forward. Measures and procedures to regulate the production of solid waste in the first instance, were identified as an important aspect of waste management (Lombard et al). The question of solid waste in South Africa received further attention in a President's Council report, where similar concerns and issues were raised*. A more recent White Paper published in 1993 emphasized the need for a national waste management policy for South Africa**.

Despite the good intentions of the White Papers and associated reports as well as those of the Environment Conservation Act, there are still no real incentives for a large scale reduction in solid waste generation. In addition, specific controls designed to ensure the optimum use of waste (if formulated), have not been put into practice. Lombard et al noted that current waste legislation does not specifically address issues such as the avoidance or separation of solid waste at source, or the reuse or recycling of waste (possibly due to a lack of understanding of the economic factors governing waste generation and disposal). The gathering of routine data on solid and other waste produced in South Africa, which is an important component of any national waste management policy, is a further problem. Provision has however, been made by the Environment Conservation Act for the submission of statistics on waste. The CSIR investigation (Anonymous, 1991 - above) attempted to obtain some overall estimates on the solid and liquid waste generated in this country; while improved estimates especially for hazardous waste were provided in a Department of Environment Affairs report released in 1992 (both discussed later in the chapter). Lombard et al observed that penalties specified in the legislation are often not appropriate or sufficiently stringent, are not uniformly applied, and are sometimes not applied at all. This is hardly surprizing in that no standard set of by-laws for waste management have been promulgated at the important local authority level. One implication is that "dirty" industries may be able to locate or expand in towns or cities with "soft" by-laws.

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* See Anonymous, 1991. Report of the Three Committees of the President's Council on a national environmental management system, President's Council Report No. P.C. 1/1991, Government Printer, Cape Town, 350 p.

** See Anonymous, 1993. Department of Environment Affairs White Paper, Policy on a National Environmental Management System for South Africa, Report No. WP E - 1993, Government Printer, Pretoria, 25 p.

A most important development was the set of minimum requirements inter alia for landfill operation, as stipulated by the Department of Water Affairs and Forestry (Anonymous, 1994: Documents Nos. 1, 2 and 3)*. The minimum requirements were primarily designed to prevent problems at future landfill sites, and to remedy past neglect at existing or recently closed sites. Readers should bear in mind that the three documents are in the process of being revised. The revised documents will be discussed in any second edition of this source book.

A further significant advance - in respect of hazardous waste - was the publication of General Notice Gen N 1064/94 in the Republic of South Africa Government Gazette in September 1994 (see later in this chapter). The purpose of the General Notice was to invite public comment on a proposed hazardous waste management policy as envisaged by the Department of Environment Affairs. It is interesting to note that the Minister of Environment Affairs as well as the Minister of Water Affairs and Forestry, the Administrator of a province or any local authority, is obliged by virtue of Section 32(1 and 2) of the Environment Conservation Act No. 73 of 1989, to ask for public comment before policy or regulations or certain other matters are finalized in terms of Act No. 73. The General Notice was regarded by the Department of Environment Affairs (with input from the Departments of Agriculture/National Health and Population Development/Water Affairs and Forestry), as the first step in a comprehensive programme to develop a national holistic Integrated Pollution Control and Waste Management (IPC & WM) system for South Africa. Current initiatives have included conferences at both national and provincial level, in order to ensure public participation in the IPC & WM programme.

A number of observers have suggested that a single comprehensive Act which regulates all aspects of waste including solid waste, is required to properly address waste management in South Africa. Lombard et al (1992) stressed that such an Act must supplement, co-ordinate (and where feasible) consolidate all waste legislation at all levels of Government. Other requirements are the formulation of a national policy for waste reduction which would focus on the avoidance, reuse and recycling of waste, plus the

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* See Anonymous, 1994. Minimum requirements for waste disposal by landfill, Document No. 1, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 181 p., and Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p., plus Anonymous, 1994. Minimum requirements for monitoring at waste management facilities, Document No. 3, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 49 p.

correct disposal of residual waste. Most importantly, such an Act would enable a model set of regulations (on all aspects of waste management) to be formulated and enforced. The Act should in addition, standardize approaches to waste management and waste terminology. The latter issue is to some extent covered by Documents 1, 2 and 3 above - although only for the land disposal of waste. The Act should also give regional and local authorities the power to regulate waste on a regional or local basis, in accordance with regional/local conditions. The proposed Act likewise, should incorporate effective financial and other incentives especially to reduce the amount of waste in the first instance, and to encourage the reuse and recycling of waste. Penalties must also be appropriate. The Act should provide for public education on environmental issues involving all aspects of waste from generation to disposal (cradle to the grave) (Lombard et al).

17.4 The process of solid waste management*

More than 95% of all waste generated in South Africa is disposed of on land (Blight, 1987)**. The discussion therefore, is mainly concerned with the land disposal of waste, with special emphasis on urban waste. According to Tchobanoglous (1977, quoted in Lombard, Botha and Rabie, 1992) waste management can be divided into six components, namely: waste generation, storage, collection, transfer/transportation, processing/recovery, and final disposal. Every activity generates its own particular waste which must be properly managed and disposed of in an environmentally acceptable manner. Viewed in terms of disposal, it is evident that there are two waste stream categories, specifically, a formal waste stream and an informal waste stream. Formal waste streams refer to wastes which follow a recognized path of disposal, and which can be identified and regulated. The informal waste stream by contrast, is difficult and expensive to control, and includes the illegal dumping of industrial/household waste, litter, and sometimes human faecal waste. The latter may be problematic in certain informal settlements without proper services. This chapter concentrates on formal wastes.

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* A useful discussion of the techniques used in the handling and disposal of waste (with special reference to hazardous waste), is the following: Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 2: Technologies, Department of Environment Affairs, Pretoria, 106 p. See also, Anonymous (1994 - above: Document No. 2).

** See Blight, G.E., 1987. Site and method selection in the disposal of mining, industrial and domestic waste: state of the art, In: Wates, J.A. and Brink, D. (eds), Proceedings of the International Conference on Mining and Industrial Waste Management, VOL 1, Division of Geotechnical Engineering and the Division of Urban Engineering, South African Institution of Civil Engineers (Transvaal Branch), 17 - 19 August 1987, Johannesburg, p. 41 - 46.

An important procedure governing waste management and pollution control in South Africa, is the "Best Practicable Means" or BPM. The BPM approach has been formally applied with regard to the Atmospheric Pollution Prevention Act No. 45 of 1965, and informally in a number of guidelines and policies (Anonymous, 1991 - CSIR). The purpose of BPM is to prevent pollution in the first instance and secondly, to try and contain any damages where pollution cannot be avoided. All relevant factors are considered in deciding upon a course of action, although weights are not assigned to the different factors. Other parameters which must be examined include the level of development of the control technology; the financial implications; the current understanding of the effects of pollutants; the contribution of the manufacturing/disposal plant or process to the total pollutant load, and local conditions and circumstances. The BPM procedure is not an absolute doctrine and requires "trade-offs" between various competing components. A major difficulty is that BPM does not consider the effects of a given pollutant in other environmental media (air/land/water) (Anonymous, 1991 - CSIR).

A more recent approach (although similar to BPM) is the "Best Available Technology Not Entailing Excessive Cost" or BATNEEC philosophy, which has been adopted by the European Union. The BATNEEC approach encompasses the best available acceptable and demonstrated option for a particular situation (excluding any alternatives which are very much more expensive). A further method is the "Best Available Technology" (BAT) or "Best Demonstrated Available Technology" (BDAT), which describes the best available option for the prevailing circumstances, with a proven technology which is likely to produce the most favourable result in terms of health, safety and the environment - irrespective of cost (Noble, 1992)*. A new standard has been defined in the United Kingdom, namely, the "Best Practicable Environmental Option" (BPEO). The latter standard is an integrated consultative decision making process which considers the environment in all spheres (air, land and water). That option which is the most beneficial or least damaging to the environment as a whole in the short and long term, and has an acceptable cost, is regarded as the best option for a specific set of objectives. The CSIR report (Anonymous, 1991) made the important point that consolidation of key South African environmental legislation with only a few or preferably one controlling Government department, would enable a standard policy (for example, the BPEO) to be jointly applied

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* See Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 4: Legislative options, Department of Environment Affairs, Pretoria, 72 p.

to the air, land and water components of the environment. It is encouraging that the BPEO approach has been used in the minimum requirements for waste handling and disposal, as published by the Department of Water Affairs and Forestry.

The extent of waste generated at a particular locality depends on the size and type of human settlement as well as industrial activities. The evaluation of waste and the formulation of appropriate management strategies both require a definitive classification system. Many different classification systems are used throughout the world, although three broad categories of urban solid waste can be identified*. Inert wastes include building rubble, tyres, cover and spoil. These wastes are not generally regarded as problematic unless disposed of in an unacceptable manner (Lombard et al, 1992). Concern has however been expressed regarding tyres, which can constitute a severe air pollution hazard if set alight, and which are not especially biodegradable. Household, garden and commercial refuse together with inert industrial waste is defined as general waste, which can result in environmental pollution (including the leaching of degradation products into water sources). A third category, namely, special wastes may or will have a severe impact on the environment and/or human morbidity (disease) and mortality. Wastes are classified as special wastes on the basis of quantity, concentration, or chemical, physical or infectious properties. The wastes may be corrosive, toxic, volatile, explosive, radioactive or inflammable. Special wastes can pose an immediate or potential threat if not correctly treated, stored, transported and disposed of. These wastes must therefore be carefully managed (Lombard et al). It follows that the long distance or repeated transport of special waste increases the possibility of accidents and spillage.

Lombard et al observed that on site waste storage and handling systems at apartment buildings, office blocks and factories are seldom well planned. Factors which need to be considered include the type of internal collection system, as well as site specific methods to reduce the volume of waste, to treat the waste, and to recover material. Waste storage and collection at many factories is highly mechanized due to the bulk nature of the waste. Important parameters for the design of industrial waste collection and transport systems are: the volume and characteristics of the waste (liquid or solid); the size and type of containers; specific vehicles and manpower required to remove the waste; internal factory

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* A different classification system for urban wastes adopted by the Department of Water Affairs and Forestry is discussed later in the chapter.

architecture; municipal by-laws, and aesthetic requirements. Similar design considerations apply to the formal removal and transport of domestic waste.

The design of intermediate (halfway) transfer stations depends on the planned capacity of the stations, the nature of the waste, the containers used, the transport network and the materials handling system. Initial processing such as compaction may be desirable at certain stations. Regional waste disposal sites serving a number of local authorities in metropolitan areas are becoming popular in South Africa, due to financial factors (primarily the high costs of complying with relevant legislation), and the problems of finding suitable landfill sites. More transfer stations accordingly, may be required. An important strategy aimed inter alia at increasing the lifespan of landfill sites involves the sorting and processing of items of waste, especially at the waste source itself. Benefits of this policy include the recovery of usable materials; the transformation of waste to reduce volumes and to ensure lower transport and disposal costs (or to facilitate disposal), and general environmental considerations (Lombard et al). Attempts however, to introduce kerb-side recycling (the sorting of household waste by the householder), have not been successful on any scale in South Africa.

Waste disposal procedures essentially involve six options. One method is the recycling (or resource recovery) of materials such as paper, cardboard, glass, plastics, metal and rubber, which in the case of domestic waste, can result in an approximately 30 - 40% reduction in waste volumes. Incineration of waste with a marked reduction in mass and volume is a further possibility. Incineration may take several forms including the controlled "open burning" of limited amounts of waste (up to 40 m^3 or 5 - 10 t day^{-1}) at small disposal sites. Waste residues are then buried (Lombard et al). Open incineration (for whatever purpose) is no longer acceptable, and simply converts solid waste into gaseous waste ("landfills in the sky"). Advanced technology incineration involves costly and specialized equipment such as rotary kilns, fluidized bed combustors, double chamber incinerators and plasma arc furnaces. This technology is used to treat intractable waste such as organic chemical waste, for example dichloro-diphenyl-trichloroethane or DDT, as well as infectious waste from medical sources. The disadvantages of this method include the high costs of the incinerator, and the sophisticated gas cleaning and monitoring equipment required. Strict controls are necessary to prevent the release of incompletely burnt toxic gases (including heavy metals) and particulate matter. The precise and continuous identification of all stack constituents however, is seldom possible in terms of current technology.

Disposal of the final solid waste, specifically ash, is also problematic. High technology incineration is not widely used in South Africa. Guidelines for the operation of medical incinerators are currently being finalized (Lombard, 1995)*. In future, incinerators - as with landfill sites - will have to be licensed. A method applied in Europe is that of burning waste for domestic energy and heating. Two sources are used, namely, unprocessed urban solid waste (termed Waste-derived Fuel or WDF) and Refuse-derived Fuel or RDF. Refuse-derived Fuel consists of urban solid waste which has been processed to extract the combustible fraction. Similar problems of toxic or harmful gases and ash residues may be evident. The pyrolysis of wastes (chemical decomposition by heat) is a further possibility, although the technology is not yet proven. The procedure involves the heating of waste in an oxygen-deficient chamber to convert the waste into gaseous, liquid and solid fractions which could be used as sources of energy (Lombard et al).

A third (somewhat costly) option for the disposal of selected wastes is that of encapsulation in reinforced concrete. The method is used for hazardous wastes which cannot be safely disposed of in landfill sites. Another method of isolating wastes from the environment concerns the stabilization, solidification and chemical fixation of the wastes. The procedures involve inter alia the blending of the wastes with fly ash, or vitrification (conversion to a glass-like substance) (Lombard et al). The non-reactive or encapsulated waste is then stored in a landfill designed to accept hazardous material (discussed later in the chapter).

Other methods of waste disposal include physico-chemical treatment of the waste (such as oxidation, reduction and neutralization) as well as biological treatment (bioremediation). The latter involves the use of microorganisms to bioaccumulate substances and to break wastes down into their component parts. Bioremediation is of particular importance in

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* Lombard, R., 1995. Personal communication, Lombard and Associates, Link Hills. According to Lombard, some 1 400 t of medical waste is generated every month in South Africa (over half of which, is from the Pretoria-Witwatersrand-Vereeniging area). Medical waste includes disposable items such as bandages, swabs, syringes, rubber gloves and medicines as well as human tissue. It is a legal requirement in terms of the Human Tissue Act No. 65 of 1983, that all human anatomical waste must be incinerated. Infectious animal anatomical waste must likewise be incinerated. Certain types of cytotoxic pharmaceutical waste (with a deleterious effect on cells - used for instance in the treatment of cancer), must also be incinerated wherever possible. On site incineration is the preferred method of disposal for most (but not all) categories of medical waste. Criteria for the segregation, collection, movement, storage and on site disposal of waste materials at health care and biological research facilities, are outlined in the relevant South African Bureau of Standards (SABS) document. See SABS Code of Practice 0248-1993 (Handling and disposal of waste materials within health care facilities). Note that incineration per se is not discussed therein. The disposal of medical waste once it has been removed from the health care/research site is similarly not examined.

sewage and wastewater treatment*. Notwithstanding the above methods however, the final or residual waste disposal practice is that of storage in a sanitary landfill site, or disposal (in the case of certain treated sewage sludges) on the land surface. It is therefore of great importance that landfill sites are carefully selected and operated to the best achievable standards. A sanitary landfill involves the disposal of waste in thin layers, which are then compacted to the highest practical density. The waste is covered with soil or other acceptable material at the end of each working day. The identification of suitable landfill sites is problematic. Landfill sites are not popular "neighbours" and the NIMBY (Not In My Back Yard!) principle is often invoked. A major constraint in any event, is the world-wide shortage of sites which meet both technical and social requirements.

Landfills constitute the cheapest method of disposal and will have a minimal impact on the environment, provided that numerous precautions and scientific principles are fully observed, and that aquifer contamination is avoided or at least contained (Lombard et al). It follows that properly designed and accessible landfill sites are essential to avoid the indiscriminate dumping of waste, particularly hazardous waste. Landfill sites function as large anaerobic bioreactors which produce methane gas and carbon dioxide, with lesser volumes of water vapour and nitrogen as well as trace component gases. The methane gas is a valuable by-product and has an economic value, although untapped, could well be dangerous (Letcher, Daneel and Senior, 1994)**. Landfill sites can be used for a variety of recreational purposes after closure - provided that the facility has been correctly operated. It is not uncommon in South Africa however, to find informal settlements in very close proximity to operational as well as redundant landfills.

It is evident from the above discussion that the earth is essentially a closed system and that wastes once generated (especially hazardous wastes) have to be disposed of somewhere - be it on land, in the air, or in water. There is no real escape from man's desire and his ability to contaminate his own life support system. This theme is reinforced

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* See for example: Brady, D., Letebele, B., Duncan, J.R. and Rose, P.D., 1994. Bioaccumulation of metals by Scenedesmus, Selenastrum and Chlorella algae, Water SA, VOL 20(3), p. 213 - 218., as well as Duncan, J.R., Brady, D. and Stoll, A.D., 1994. The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from wastewater, WRC Report No. 464/1/94, Water Research Commission, Pretoria, 121 p., plus Oellermann, R.A. and Pearce, K., 1995. Bioaugmentation technology for wastewater treatment in South Africa, WRC Report No. 429/1/95, Water Research Commission, Pretoria, 52 p.

** See Letcher, T.M., Daneel, R.A. and Senior, E., 1994. Preliminary appraisal of the hazards posed by landfill gas in South Africa, South African Journal of Science, VOL 90(10), p. 503 - 506.

in the next section which briefly examines pollution of the sea with special reference to oil. The following section provides some general statistics on waste in South Africa. Thereafter, municipal sewage sludges and effluents are discussed.

17.5 Chemical (mainly oil) spillages at sea*

Distress and emergency messages and requests for assistance involving ships at sea are usually directed in the first instance, to the nearest port captain. Such requests may concern the spillage of chemicals (mainly oil), which threaten the sea and coastline including beaches and "estuaries". It is compulsory for all ships to report all incidents of the spillage of oil or dangerous chemicals within the Prohibited Zone (a maximum of 50 nautical miles off the South African coast). Action could also be taken up to the 200 nautical mile limit (the extent of South Africa's Exclusive Economic Zone comprising some 1,1 x 10^6 km^2 - a concept defined by the 1982 Law of the Sea Convention - and as claimed for fishing purposes by the Territorial Waters Act No. 87 of 1963). Note that the 12 nautical mile limit defines the extent of South Africa's territorial waters. The overall area of South African jurisdiction stretches from the Orange River to Kosi Bay, and includes the Marion and Prince Edward islands.

Two departments are involved in combating oil pollution at sea, namely, the Department of Transport (Chief Directorate: Shipping) and the Department of Environment Affairs (Chief Directorate: Sea Fisheries). The Department of Transport is responsible for any oil or dangerous chemicals remaining on board damaged, sinking or abandoned ships (and which may present a pollution hazard), while the Department of Environment Affairs is responsible for oil in the sea. The four Kuswag oil pollution patrol vessels monitor, contain and disperse oil in the sea. A spotter aircraft is also available. Parties (local authorities) named in the coastal contingency plan** act when oil has reached the shore (for example, the Natal Parks Board). The cost of clean-up operations is borne by the Department of Environment Affairs. The Department of Transport acts in terms of the

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* Discussion after the Department of Transport, Durban, 1993.

** See Anonymous, 1987. Coastal oil spill contingency plan, VOL 1 - 26, various pages, Department of Environment Affairs, Pretoria. (The publication is regularly updated). The 3 000 km long South African coastline has been divided into a total of 26 MPERSS (Marine Pollution Emergency Response Support System) areas, with defined emergency plans and stocks of oil dispersant. For a brief discussion of the emergency oil spill procedure, see Moldan, A., 1992. Response plans save the day, Conserva, VOL 7(4), p. 4 - 6.

Prevention and Combating of Pollution of the Sea by Oil Act No. 6 of 1981; the International Convention for the Prevention of Pollution from Ships Act No. 2 of 1986, and the International Convention Relating to Intervention on the High Seas in Cases of Oil Casualties Act No. 64 of 1987. The Department of Environment Affairs (with more of a supervisory role), advises the Department of Transport in the event of oil incidents at sea. Portnet is responsible for prevention and control measures for oil and other chemical spillages (including waste in general) in South African harbours, in terms of the South African Transport Services Act No. 65 of 1981/Legal Succession to the South African Transport Services Act No. 9 of 1989*. The pollution of fishing harbours per se is controlled under the Sea Fishery Act No. 12 of 1988. Act No. 12 is administered by the Department of Environment Affairs. The International Health Regulations Act No. 28 of 1974 - discussed earlier - also has relevance to waste in harbours. Operational oil pollution from "dry" cargo ships and tankers on the high seas is controlled by the 1973 International Convention for the Prevention of Pollution from Ships, which was updated by the 1978 Protocol (known as MARPOL 73/78). Both agreements were formulated under the auspices of the International Maritime Organization.

A coding system similar to the HAZCHEM method (see later in this chapter), operates for hazardous cargoes transported by sea**. The International Maritime Dangerous Goods Code (IMDG-code) compiled by the International Maritime Organization categorizes dangerous goods in terms of various hazard groups, for example, explosives, flammable goods and poisons. Goods posing a threat to the environment are in addition, classified as marine pollutants. The document is given legal status in South Africa by virtue of the Merchant Shipping Act No. 57 of 1951, and Annexure III to the International Convention for the Prevention of Pollution from Ships Act No. 2 of 1986. The Department of Environment Affairs controls the dumping of substances at sea (up to 12 nautical miles

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* The CSIR investigation of waste in South Africa (Anonymous, 1991 - above), revealed that oil spillages in Durban Harbour amount to some 8 m^3 day^{-1}.

** See Barrie, G.N., 1990. International law and the safe transport of hazardous material, Tydskrif vir die Suid-Afrikaanse Reg, No. 3, p. 426 - 433.

from the coast), in terms of the Dumping at Sea Control Act No. 73 of 1980*. The Hazardous Substances Act No. 15 of 1973 is likewise applicable. Also of relevance is the Sea Fishery Act No. 12 of 1988 which controls the dumping of substances harmful to fish or fish food or aquatic plants, or the ecology of the sea. The Sea-shore Act No. 21 of 1935 makes provision for the protection of human health against pollution of the sea-shore or the sea. The (Natal) Nature Conservation Ordinance No. 15 of 1974, prohibits the deposition or discharge of any substance injurious to fish or fish food in the sea. The latter two Acts plus the Ordinance also apply to "estuaries".

Cloete (1979)** in a first approximation estimation (for 1978) of petroleum hydrocarbon emissions into the sea along the coast of South Africa, suggested that oil refineries were responsible for some 0,02 x 10^3 t y^{-1} of hydrocarbon inputs in "estuaries", the surf zone and the nearshore area. Other industrial and domestic hydrocarbon discharges of the order of 0,5 x 10^3 t y^{-1} were also present in estuaries, the surf zone and the nearshore area. Urban and land runoff contributed 0,3 x 10^3 t y^{-1} of petroleum hydrocarbons to the load in estuaries and the surf zone. Accidental hydrocarbon losses from vessels in the nearshore, offshore (the deeper waters beyond the surf zone), and the ocean were approximately 20 x 10^3 t y^{-1}. Oil discharges from tankers and other vessels (not restricted to South African territorial waters) amounted to some 40 - 600 x 10^3 t y^{-1} in the nearshore, offshore and ocean. Further sources of hydrocarbons include atmospheric deposition and offshore exploration.

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* See Rabie, A., 1981. South African legislation with respect to the control of pollution of the sea, South African National Scientific Programmes Report No. 46, Cooperative Scientific Programmes, CSIR, Pretoria, 73 p. See also, Lusher, J.A. and Ramsden, H.T., 1992. Chapter 18. Water pollution, In: Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Juta, Cape Town, p. 456 - 492., as well as Oosthuizen, A.J., 1987. The application of the Sea-shore Act and related legislation on the Natal Coast, Natal Town and Regional Planning Commission Supplementary Report, VOL 6, Pietermaritzburg, 113 p.

** See Cloete, C.E. (ed), 1979. The transfer of pollutants in two southern hemispheric oceanic systems: proceedings of a workshop held at Plettenberg Bay, South Africa, 23 - 26 April 1979, South African National Scientific Programmes Report No. 39, Cooperative Scientific Programmes, CSIR, Pretoria, 188 p. See also, Chapman, P. and Watling, R.J., 1980. Oil pollution studies in South Africa, South African Journal of Science, VOL 76(12), p. 534 - 535., plus Moldan, A. and Dehrmann, A., 1989. Trends in oil spill incidents in South African coastal waters, Marine Pollution Bulletin, VOL 20(11), p. 565 - 567. See in addition: Schumann, E.H., 1986. Assessing oil pollution potentials for the South African coast, South African Journal of Science, VOL 82(5), p. 240 - 242., and Lusher, J.A. (ed), 1984. Water quality criteria for the South African coastal zone, South African National Scientific Programmes Report No. 94, Foundation for Research Development, CSIR, Pretoria, 25 p. + app. A further important publication which classifies the vulnerability of the shoreline to oil pollution is Jackson, L.F. and Lipschitz, S., 1984. Coastal sensitivity atlas of southern Africa, 1984, Department of Transport, Pretoria, 34 p. (See also the chapter on "estuaries", elsewhere in this publication).

It should be noted that M. Gerber, Department of Applied Mathematics, University of Stellenbosch, Private Bag X1, Matieland, 7602, is in the process of developing a mathematical model in order to predict the occurrence of freak (episodic) waves off the eastern South African coastline*. These waves pose a grave threat to shipping, particularly oil tankers, with consequent dangers of severe oil contamination of beaches and "estuaries". Freak waves (more than 20 m in height) develop under specific conditions when rough seas meet the fast-flowing Agulhas current. The energy combination of the large waves and the Agulhas current results in the formation of the freak waves. The most dangerous part of the coast is from Richards Bay to Port Elizabeth. The mathematical model may be able to predict the probability of freak waves developing within a 12 hour period, thereby allowing shipping to move away from the danger zone. The sinking of the Chinese-registered bulk ore carrier the Apollo Sea, in gale force (although not freak wave) conditions off the Cape Coast on the 20th of June 1994, with oil spillage on Dassen and Robben islands and the death of many penguins - plus contamination of Cape Town beaches - is a sobering case-in-point. The damage was caused by a relatively minor fuel oil leak of some 2 500 t**. It is a legal requirement that laden oil tankers must maintain a distance of not less than 12 nautical miles off the South African coast unless entering a port. The consequences nevertheless of a large oil tanker sinking off the coast of Maputaland with horrendous damage _inter alia_ to the St Lucia Estuary, are best left to the imagination. The potential for such a disaster however, is ever-present.

For further information contact:

- Chief Directorate: Sea Fisheries, Department of Environment Affairs, Private Bag X2, Rogge Bay, 8012.

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* See Mallory, J.K., 1984. Abnormal waves off the south-east coast of South Africa, _The Marine Observer_, VOL 54(283), p. 29 - 37., as well as Shillington, F.A., 1978. The giant wave syndrome, _South African Journal of Science_, VOL 74(6), p. 199. Examine likewise Gründlingh, M. and Rossouw, M., 1995. Wave attenuation in the Agulhas current, _South African Journal of Science_, VOL 91(7), p. 357 - 359.

** See Moldan, A., 1994. Impact of a major oil spill, _Conserva_, VOL 9(5), p. 8 - 11., as well as Gubb, A., 1994. Coast of death: oil spills on the South African coastline - the Wildlife Society's viewpoint, _African Wildlife_, VOL 48(5), p. 6 - 7., and Yeld, J., 1994. Of penguins and people, _African Wildlife_, VOL 48(5), p. 5. See in addition: Brown, A.C., 1985. The effects of crude oil pollution on marine organisms - a literature review in the South African context: conclusions and recommendations, South African National Scientific Programmes Report No. 99, Foundation for Research Development, CSIR, Pretoria, 33 p.

- Chief Directorate: Shipping, Department of Transport, Private Bag X193, Pretoria, 0001.

- Durban Port Captain, Portnet, P O Box 1027, Durban, 4000.

- Richards Bay Port Captain, Portnet, P O Box 181, Richards Bay, 3900.

<u>**The following publications dealing with various aspects of sea navigation (and hence potential dangers) in South African coastal waters may be relevant**</u>:

- Anonymous, 1901. <u>Africa Pilot: Part 2. Containing Sailing Directions for the West Coast of Africa from the River Cameroon to the Cape of Good Hope, Including the Islands of Ascension, St Helena, and Gough, and the Tristan da Cunha Groups,</u> Hydrographic Office of the Admiralty, London, 394 p. (Later editions are available).

- Anonymous, 1905. <u>The Africa Pilot: Part 3. South and East Coasts of Africa from the Cape of Good Hope to Ras Asir (Cape Guardafui), Including the Comoro Islands,</u> Hydrographic Office of the Admiralty, London, 630 p. (Later editions are available).

- Anonymous, 1975. <u>South African Sailing Directions, VOL 1. General Information,</u> The Hydrographer, South African Navy, Cape Town, 95 p. (The publication, which is being updated, contains useful information on South African coastal climatology).

- Anonymous, 1979. <u>South African Sailing Directions, VOL 2. The Coasts of South West Africa and the Republic of South Africa from the Kunene River to Cape Hangklip,</u> The Hydrographer, South African Navy, Cape Town, 219 p.

- Anonymous, 1985. <u>South African Sailing Directions, VOL 3. The Coasts of the Republic of South Africa from Table Bay to Great Kei River and Marion and Prince Edward Islands,</u> The Hydrographer, South African Navy, Cape Town, 207 p. (Revised edition).

- Anonymous, 1982. <u>South African Sailing Directions, VOL 4. The Coasts of the Republic of South Africa and Transkei from East London to the Mocambique Border,</u> The Hydrographer, South African Navy, Cape Town, 160 p.

17.6 The solid waste stream in South Africa*

17.6.1 Overall estimates

Estimates of the total solid waste stream in South Africa are difficult to derive and may vary considerably amongst different studies. According to an assessment by the Chemical Marketing and Consulting Services (Laing, 1990), the 1990 figure was more than 280×10^6 t y^{-1}, while Malan in 1987 suggested an amount of approximately 300×10^6 t y^{-1} (both authors quoted in Anonymous, 1991). Noble (1992)** suggested a value (based on 1990/91 data), of almost 400×10^6 t y^{-1}. The main components of the South African solid waste stream are outlined in Table Q1. Data on the relative contribution of various types of industrial activities to the solid waste stream are provided for Natal/KwaZulu in Table Q2.

Table Q1: The estimated composition of the solid waste stream in South Africa.

Type of waste	Percentage of the total according to Malan (1987)	Percentage of the total according to the Chemical Marketing and Consulting Services (Laing, 1990)
Mining tailings and discards	74	79,5
Pulverized fuel ash	9	7,4
Metallurgical slags	7	1,9
Urban waste	6	5,3
Chemical waste (including phosphogypsum)	3	4,3
Other waste	1	1,6

Source: After Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

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* Discussion based on Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

** Additional and more comprehensive data on the types and amounts of waste generated in South Africa can be found in Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 1: Situation analysis, Department of Environment Affairs, Pretoria, 96 p.

Table Q2: Important sources of solid waste as estimated by industrial category, for Natal/KwaZulu in 1990.

Type of industry	Percentage contribution to the solid waste stream
Pulp and paper industry	67
Paint manufacturing industry	35
Water management chemicals	33
Household products	30
Industrial cleaning products	30
Electronics manufacturing	25
Leather industry	25
Fabricated metal products	18
Pharmaceutical industry	18
Saw milling and timber	18
Dry cleaning	15
Inks and printing paste	15
Plastics and rubber processing	15
Printing and publishing	15
Metallurgical industry	12
Adhesives and sealants	10
Agriculture, fishing, food and beverages	10
Process chemical industry	4,9
Mining	2,5
Generation of electricity	1

Source: After Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

Note: Most waste and most hazardous waste is generated in the Transvaal, specifically in the Pretoria-Witwatersrand-Vereeniging complex which is the industrial heart of South Africa.

17.6.2 Main components of the solid waste stream in South Africa

(a) Mining and mineral waste

Some 294,35 x 10^6 t y^{-1} of mineral ore is removed by the South African mining industry, 40,8% of which is contributed by the gold and uranium sectors, with the coal industry responsible for 38,4% of the waste (Laing, 1990). Low grade coal and duff coal disposed of on dumps, amounts to approximately 44,2 x 10^6 t y^{-1}. The estimated accumulated coal mine waste (in 1990) was of the order of 283 x 10^6 t and covered 10,2 km^2 (Barnard, 1990, quoted in Anonymous, 1991). Many coal mine dumps constitute a serious water pollution hazard, which is of considerable importance in northern Natal/KwaZulu (see the chapter on water quality).

(b) Pulverized fuel ash and metallurgical slags

Pulverized fuel ash is mainly produced by power stations, with an estimated figure for 1990, of 26 x 10^6 t rising to some 35 x 10^6 t in 1997. The total metallurgical waste generated in South Africa is of the order of 5 533 x 10^6 t y^{-1} (Anonymous, 1991).

(c) Urban waste

The total urban waste (including non-hazardous trade waste) generated in South Africa annually is estimated to be 15 x 10^6 t (Anonymous, 1991). More recent estimates suggest a figure approaching 25 x 10^6 t y^{-1}. The Johannesburg City Council alone, disposes of more than 1 x 10^6 t y^{-1} of solid waste (Du Plessis, 1992)*. Packaging as a single component, forms a significant proportion of urban solid waste. Approximately 1 260 x 10^3 t of packaging/container waste is discarded each year in South Africa, which is either directly removed to a landfill site, or is disposed of by littering (Anonymous, 1991). Packaging/container waste consists of paper (51,6%), glass (21,4%), plastic (15,1%) and tinplated steel (11,9%). Approximately 29% of paper and board**, 14%

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* See Du Plessis, G.J., 1992. The impact of urbanization on solid waste management in South Africa and the development of regional standards, Afrotech Workshop on Regional Urban Standards, 14 - 19 June 1992, Johannesburg, 7 p.

** A useful source of statistics is the following: Lombard, R., 1994. The South African market for recyclable paper, Lombard and Associates, Link Hills, 5 p.

of glass, 21% of tinplate and 36% of aluminium (mainly food and beverage cans) were recycled in 1990*. Relatively little plastic (only 11%) was recycled. On an overall basis, some 23% of such materials were recycled in 1990 in South Africa (Anonymous, 1991). Other substances for instance used oil can also be recovered from the waste stream**.

Increasing attention is being paid to the recycling of urban waste materials***. The theme "Reduce, reuse, refill, recycle, repair, remake, resell, respond" is gaining ground with the growing realization that valuable materials are present in the urban waste stream; and that suitable landfill sites are at a premium in metropolitan areas****. While schools and charities have an important role to play in recycling urban waste, direct financial (market) incentives for companies provide the best means of ensuring the recovery of selected materials. As part of this process, deposit-refund systems should be broadened and possibly made compulsory. Higher recovery rates are likely in the future, aided by the increasing public awareness of environmental issues. Paper and bottle banks, for example, are now widely distributed in many urban areas including a number of townships. A recent innovation is the collection of litter and solid waste along the shoreline of Natal/KwaZulu on a specified day once a year. The programme, which is undertaken by volunteers from all walks of life, is organized by the Natal Parks Board, P O Box 17090, Congella, 4013. Environmental and business organizations encouraging the recycling of urban waste materials include the following:

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* An interesting paper on the corrosion of two piece (tinplated steel/aluminium) beverage cans in the marine environment is the following: Cockcroft, V.G., Dutton, T.P. and Bulbring, S., 1995. Discarded beverage cans and the environment, South African Journal of Science, VOL 91(3), p. 141 - 143. (The authors observed that some 2 800 million beverage cans are made in South Africa every year).

** Of the estimated 148 000 t of used engine/machinery oil which could be recycled each year in South Africa, only about 10% was actually recycled in 1995. Used oil - which has an economic value - contains several important pollutants. Lead is a primary contaminant where leaded fuel is used. The careless dumping of used oil can have marked environmental implications (Hunter, D., 1996. Personal communication, FFS Refiners Ltd, Durban).

*** Commonly quoted recovery figures include the following: 1 t of recycled paper = 15 pine trees; 59 aluminium cans = 1 kg aluminium; 27 tinplate cans = 1 kg tinplate, and 1 000 plastic bags = 12 kg of plastic. Some background information on the environmental awareness of the various sectors involved in packaging, can be found in Spence, J.L. and Ogg, D.A., 1994. The importance of environmental aspects of packaging, South African Journal of Business Management, VOL 25(3), p. 118 - 125.

**** See Goeschl, R., 1988. Waste management without recycling is wasted management, Municipal Engineer, VOL 19(8), p. 36 - 41.

- Aluminium Can Recycling Association, P O Box 14976, Wadeville, 1422*.
- Collect-a-Can, P O Box 43304, Industria, 2042.
- Council for the Environment/Department of Environment Affairs, Private Bag X447, Pretoria, 0001.
- Earthlife Africa (Pietermaritzburg Branch), P O Box 100468, Scottsville, 3209.
- Glass Recycling Association, P O Box 562, Germiston, 1400.
- Institute of Packaging (South Africa), P O Box 56145, Pinegowrie, 2123.
- Institute of Waste Management (Southern Africa), P O Box 1378, Pinegowrie, 2123.
- Keep South Africa Beautiful Association (and related organizations), P O Box 1514, Randburg, 2125.
- KwaZulu-Natal Recycling Forum, c/o the Wildlife Society of Southern Africa, P O Box 2985, Durban, 4000.
- Kimberly-Clark of SA Ltd, P O Box 555, Umhlanga Rocks, 4320.
- Mondi Recycling, P O Box 29074, Maydon Wharf, 4057.
- Nampak Paper Recycling, P O Box 20527, Durban North, 4016.
- National Recycling Forum, P O Box 1378, Pinegowrie, 2123.

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* A number of organizations have provincial branches or branches in different cities. Only one address is provided here. The first private sector total waste recycling facility in South Africa was established in Randburg in 1991. Four types of waste were recycled, namely, domestic/commercial waste, general "public" waste, garden waste and building rubble. Benefits of the project included the creation of employment opportunities and extension of the lifespan of the Randburg municipal landfill site, thereby to some extent moderating future increases in rates. (Every tonne of recycled paper, for instance, saves approximately 3 m^3 of landfill space). The plant was subsequently forced to close down due to the lack of a suitable market for its products. The same problem - with the same result - was evident for a similar plant in Johannesburg and one in Durban (Lombard, R., 1996. Personal communication, Lombard and Associates, Link Hills).

- Plastics Federation of South Africa, Private Bag X68, Halfway House, 1685.

- Sappi War on Waste, P O Box 41040, Rossburgh, 4072.

- Wildlife Society of Southern Africa, P O Box 394, Howick, 3290.

- World Wide Fund for Nature South Africa/The Green Trust, P O Box 456, Stellenbosch, 7599.

Litter is a manifestation of modern civilization where few areas are free of the problem. Litter is unsightly and has serious consequences for livestock and aquatic or marine life if plastic objects (packets) are ingested. Litter in addition, can clog stormwater drains, ultimately ending up in watercourses and the sea. Litter introduced into sewers can result in blockages, and imposes an additional burden on wastewater treatment plants. Discarded material may also damage irrigation systems as well as raw water pipelines and pumps (Anonymous, 1991). Health problems due to the breeding of flies, mosquitoes and rats often result from accumulated piles of litter and general household rubbish. The removal of litter is a relatively expensive process per unit volume, where funds could be better allocated to more deserving projects. It is interesting to note, for example, that the 1994/95 street cleaning budget of the Pietermaritzburg City Engineer's Department was R3,6 million*. Local citizens may argue that such funding is insufficient, given the steadily increasing volume of litter inter alia in the Central Business District (CBD) of the city. Litter is regularly removed from the popular hiking routes of the Natal Drakensberg, while major difficulties are experienced in many formal and informal settlements throughout South Africa.

Approximately 95 t day^{-1} of litter (mainly packaging material) is removed from the municipal area of the City of Johannesburg, of which some 25 t is removed each day from the CBD and environs (constituting less than 2% of the total municipal area) (Du Plessis, 1992). Street bin refuse and litter can be a major problem where hawkers and vendors are active. Du Plessis observed that seven of the 25 t removed every day from the

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* Natal Witness, 3 August 1994, p. 7. The amount of money spent on removing litter in Pietermaritzburg is limited by comparison with Johannesburg, where approximately R30 million was allocated for the 1992/93 financial year in order to remove litter from the streets and public open spaces of Johannesburg (Du Plessis, 1992 - above). Du Plessis estimated the cost of removing litter not placed in proper containers, at R1 300 t^{-1}.

Johannesburg CBD was generated in close proximity to hawking areas. On an overall basis, some 200 000 t of litter are discarded annually in South Africa (Anonymous, 1991). Du Plessis estimated the total annual cost of clearing litter in South Africa to be of the order of R150 million*. The disposal of litter especially plastic by incineration - unless properly undertaken - results in the emission of toxic and/or mutagenic fumes including fused polycyclic aromatics, dioxins (suspected potent carcinogens)** and carbon monoxide, as well as sooty particulates***. The degradation of litter in landfill sites is a slow process which releases toxic compounds into the soil profile and ultimately, the groundwater. The end products of litter in aquatic and marine systems likewise, may be toxic or at best, undesirable (Anonymous, 1991).

Differences in the types and volumes of urban (municipal) waste are evident depending on socio-economic circumstances. Useful data for the Johannesburg area were provided by Wiseman (1987, quoted in Malan, 1988)****. The survey revealed that the main component of waste in Dube (an unelectrified part of Soweto), consisted of fines and ash (Table Q3). Pimville, a more affluent and electrified suburb of Soweto, also had a high

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* A national survey of litter, undertaken at selected urban sites across South Africa in 1994, revealed the following average litter stream composition: cigarette butts (21%); miscellaneous paper (17%); organic matter (7%); bottle tops (6%), broken glass (6%) and match sticks (6%); ring pulls (4%); plastic strapping (3%), straws (3%) and sweet wrappers (3%); beverage cans (2%), cardboard boxes (2%), ice-cream sticks (2%), newspapers (2%) and shopping bags (2%); polystyrene items (1,5%); beer cartons (1%), cigarette boxes and matchboxes (1%), and till slips (1%). Other minor items formed the balance of the waste stream. The survey was conducted by means of a photometric index, which is a technique used for measuring litter accumulation by spatial distribution, namely, according to visual perception (Keep South Africa Beautiful Association, Randburg, 1994).

** Dioxins consist of a group of some 75 closely related substances. The most well known dioxin is 2,3,7,8 - tetrachlorodibenzo-para-dioxin (TCDD). Dioxins mainly occur as contaminants in industrial processes involving chlorinated phenols. TCDD is the infamous contaminant in Agent Orange, which was used as a defoliant in the Vietnam war. There is considerable debate about the effects of TCDD on human health due to conflicting medical studies (Walters, I., 1995. Personal communication, City Health Department, Pietermaritzburg Corporation, Pietermaritzburg).

*** Plastics in common household use include high density polyethylene (HDPE), for instance, opaque household detergent bottles and milk bottles; low density polyethylene (LDPE), for example, plastic bags and soft packaging; polyethylene terephthalate - such as plastic Coke bottles; polypropylene (plastic crates); polystyrene (cups and food trays), and polyvinyl chloride (vinegar and cooking oil bottles). A brief overview of some economic and environmental implications of plastic bags can be found in Ryan, P.G., Swanepoel, D., Rice, N. and Preston, G.R., 1996. The 'free' shopping-bag debate: costs and attitudes, South African Journal of Science, VOL 92(4), p. 163 - 165. (According to the authors, some six billion plastic bags were made in South Africa in 1993. Approximately 20% of the production was for the export market).

**** See Malan, J.J., 1988. The future of waste management in the RSA, Environmental Issues in Waste Management, Ninth Biennial Congress and Equipment Exhibition of the Institute of Waste Management (Southern Africa), 9 - 11 August 1988, Durban, 10 p.

Table Q3: The composition of municipal solid waste in three suburbs of Johannesburg (equivalent dry mass as a percentage of total mass).

Waste component	Dube	Pimville	Yeoville
Putrescibles	8,4	14,6	17,0
Kraft paper	1,7	3,3	9,8
Newsprint	1,6	7,1	13,9
Common paper	2,5	4,1	14,0
Plastics	1,7	4,9	8,5
Glass	3,1	21,3	14,1
Ferrous materials	2,6	4,3	8,9
Aluminium objects	0,2	0,4	1,1
Other metal objects	0,0	0,0	0,1
Rags, rubber and leather	0,5	1,0	2,1
Fines and ash	46,4	16,6	1,7
Unclassified	31,3	22,4	8,8

Source: After Wiseman (1987, quoted in) Malan, J.J., 1988. The future of waste management in the RSA, Environmental Issues in Waste Management, Ninth Biennial Congress and Equipment Exhibition of the Institute of Waste Management (Southern Africa), 9 - 11 August 1988, Durban, 10 p.

Note:

(i) Residents of Soweto and similar areas generate some 1 kg capita^{-1} day^{-1} of domestic waste or approximately 3,5 kg day^{-1} for a given household; with 0,5 kg day^{-1} per house of street bin refuse and litter (Malan, 1988). A study undertaken by the consulting engineering firm Van Wyk and Louw Inc. (1991)* in the Durban Functional Region, revealed that refuse generated in the informal (squatter) settlements of Inanda, KwaMashu and Ntuzuma was of the order of 25 ℓ per house per week. In the formal settlements of the three areas by contrast, a figure of 40 ℓ per house per week of solid waste was calculated for design purposes. The volume of solid waste in informal settlements can vary considerably. An important factor is the number of people resident at individual sites (yards).

(ii) Du Plessis (1992 - above) suggested that residents in formal western-style accommodation generate approximately 1 kg capita^{-1} day^{-1} of solid waste, which will increase to 1,5 kg capita^{-1} day^{-1} by

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* See Anonymous, 1991. RSA-KwaZulu Development Project: Department of Development Aid on behalf of the South African Development Trust, Inanda solid waste disposal site design report, RKDP Project No. Z907 - Z165, Project No. 478/52, Van Wyk and Louw Inc., Pinetown, 21 p. + app.

the year 2000. Various other "guesstimates" are evident in the literature.

(iii) The approximate degradation rate of common urban waste materials on the soil surface and which are exposed to sunlight, is as follows:

Material	Condition of material		
	>1 year	>5 years	>10 years
Aluminium cans[1]	Paint has peeled off; can still intact	Can is flatter and begins to sink into the soil	Can gradually begins to decompose due to contact with the soil
Glass bottles[1]	Virtually no change	Bottle breaks up into large pieces	Bottle has broken up into small segments which sink into the soil
Plastic bottles[1]	Virtually no change	Bottle partially decomposed by sunlight	The condition of the bottle depends on environmental factors. Small segments may still be present on the soil surface with the remainder below ground
Plastic supermarket bags[2]	Degradation occurs within approximately six months		
Organic waste[1] (food scraps and garden cuttings - readily biodegradable)	Conversion to compost occurs within a two year period		
Paper/cardboard[1] - biodegradable	Decomposes in 1 - 5 years. The rate of degradation depends on the type of paper/cardboard and climatic parameters. Decomposition is much slower in a dry environment		

<u>**Source**</u>: (i) After the Department of Environmental Affairs and Tourism, Pretoria, 1996. (Reference 1).

(ii) After the Percy FitzPatrick Institute of African Ornithology, University of Cape Town (unpublished, quoted in) Ryan, P.G., Swanepoel, D., Rice, N. and Preston, G.R., 1996. The 'free' shopping-bag debate: costs and attitudes, South African Journal of Science, VOL 92(4), p. 163 - 165. (Reference 2).

proportion of ash in the waste stream. By contrast, Yeoville, which is a high density middle income area had a larger proportion of plastic, paper and putrescibles (decomposing matter). A similar waste composition trend (low income versus middle income) was found in a study undertaken in the Cape Town area by Palm and Loots (1991, quoted in Du Plessis, 1992).

While the larger municipalities follow established solid waste disposal procedures, smaller local authorities may still resort to outdated methods. Verrier (1986, quoted in Anonymous, 1991) examined urban waste disposal methods in the smaller cities and towns in South Africa in 1975. For Natal, Verrier found that only 55% of the 96 local authorities assessed, disposed of urban waste in a landfill site, while 3% provided no service whatsoever. Uncontrolled disposal occurred in 28% of cases; with burning (7%), partial recycling (4%), and composting (2%) also evident. Of the 815 local authorities studied in South Africa as a whole, 42% disposed of urban waste in landfill sites, 3% did not operate any service, with uncontrolled disposal, burning, partial recycling and composting apparent in 28%, 21%, 3% and 4% of cases respectively. An interesting study would involve an examination of the current situation, especially following the introduction of the permit system in terms of the Environment Conservation Act. Such a study would reveal the extent to which smaller local authorities were complying with the Act. Problems however, are still likely to be evident in small villages in rural areas.

Very few waste disposal studies have been undertaken in black settled peri-urban and rural areas. Alcock (1984, unpublished material, quoted in Alcock, Rivett-Carnac and Fourie, 1988)* in a survey of 121 households in the Inadi Ward, Vulindlela District of KwaZulu (near Pietermaritzburg), found that 60% of households disposed of all their refuse in pits, the maize patch/flower bed or overgrowth, usually situated below the main house. Thirty-one percent of respondents disposed of their rubbish outside the yard, in the adjacent grazing area or in a donga. The latrine was used as a disposal site by 7% of households, while 2% of respondents threw refuse into a nearby stream. Deep trenching of small vegetable plots using biodegradable matter may be a partial solution to the difficulties of household waste disposal in peri-urban and rural areas. Brief data on domestic refuse

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* See Alcock, P.G., Rivett-Carnac, J.L. and Fourie, K.J., 1988. Current status of water supply and sanitation in rural and peri-urban areas of KwaZulu, Paper No. 2.2, Seminar on Water Supply and Sanitation - KwaZulu, South African National Committee of the International Water Supply Association, the Division of Water Technology of the CSIR, the KwaZulu Government and the Department of Development Aid, 28 - 30 June 1988, Durban, 32 p.

disposal, as per housing category in black residential areas of Natal/KwaZulu, are provided in Table P2 in the chapter on health.

A number of possible solutions have been proposed to address the solid waste problems of townships and informal settlements*. One method which has been used for several years in some large (formal) townships of KwaZulu involves the removal and disposal of waste by private firms specializing in waste technology, and/or the management of waste operations by consulting engineering firms. It is possible that a number of smaller municipalities in South Africa generally, will privatise or amalgamate their waste services in the future - especially where regional landfill sites are funded by Joint Services Boards and Regional Services Councils**.

Attempts have been made on a small scale to encourage the collection of waste in informal settlements by exchanging food for bags filled with refuse. One trial undertaken by Van Wyk and Louw Inc. involving 100 - 200 households at Doornkop in the Transvaal, worked reasonably well at first. It is unlikely that the "food for refuse" scheme can be applied on a large scale due to logistical problems and possible abuse (Crawford, 1994)***. A different approach currently being tested in five areas in the Transvaal involves the selection of an unemployed and literate resident of an informal settlement, who is contracted to work and train with an established refuse removal agency for a specified period. The person is then assisted inter alia through business loans to establish his/her

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* Guidelines on solid waste management for black urban areas can be found in the following: Anonymous, 1988. Towards guidelines for services and amenities in developing communities, Department of Development Aid, Pretoria, various pages. Similar information (with brief cost data) is presented in Anonymous, 1994. Guidelines for the provision of engineering services and amenities in residential township development, Department of National Housing and the National Housing Board, Pretoria, various pages. (The latter publication was compiled by the Division of Building Technology, CSIR, Pretoria). The minimum requirements of the Department of Water Affairs and Forestry have effectively replaced these guidelines. Data on householder perceptions of solid waste disposal problems in six townships in South Africa including Clermont, can be found in Palmer Development Group, 1994. Water and sanitation in urban areas: survey of on-site conditions, WRC Report No. 561/1/94, Water Research Commission, Pretoria, 63 p. + app.

** A useful case study is the following: Ahrens, H.P.L. and Roberts, M.R., 1991. Report on solid waste disposal for the Southern Natal Joint Services Board, Campbell Bernstein and Irving in association with Stewart Sviridov and Oliver, Durban and Pietermaritzburg, 32 p. + app. and maps.

*** See Crawford, D.J., 1994. Report on a workshop attended by D.J. Crawford: community based cleansing services, Council for the Environment, 29 March 1994, Johannesburg, INR Occasional Paper No. 139, Institute of Natural Resources, University of Natal, Pietermaritzburg, 5 p. + app. See also, Palmer Development Group, 1996. Evaluation of solid waste practice in developing urban areas in South Africa, WRC Report No. 629/1/96, Water Research Commission, Pretoria, 163 p. (An executive summary of the report is available, namely, WRC Report No. 629/2/96, 23 p.).

own small waste removal business. The entrepreneur recruits a few residents of the informal settlement as staff, with each household paying a fee of R4 - R6 a month for a regular home refuse removal service. The scheme has achieved considerable success (Hattingh, 1994, quoted in Crawford, 1994). Innovative methods and equipment are required to deal with solid waste, especially in the rapidly growing informal settlements of South Africa*. The high levels of in-migration to the major metropolitan areas and the resulting demands for infrastructure including waste removal, represent major challenges which must be overcome to ensure adequate standards of living, and to protect the environment. The quality of our water resources in particular, must be preserved through the careful control of all forms of waste. (See the chapter on water quality).

(d) Chemical waste

Chemical waste generated by the chemical industry in South Africa amounts to approximately $12{,}3 \times 10^6\ t\ y^{-1}$ (Laing, 1990, quoted in Anonymous, 1991 - above). Most of the waste consists of coal ash (69,9%) and phosphogypsum (24,4%) - with considerably lesser amounts of sodium nitrate, hydrogen fluoride, coal fines, sulphur dioxide, ethane, coal tar, methane, coal tar pitch, propane, iron oxide, lime, propylene, ethylene, hydrocarbon sludge, and sodium chloride respectively.

(e) Agricultural waste and sewage sludges

Biomass waste generated by agriculture and forestry consists of a variety of materials including reject fruit and vegetables, sugar cane bagasse, maize stalks and cobs, sawdust and tree-felling trimmings (amounting to some $20 \times 10^6\ t\ y^{-1}$); as well as manure from

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* The Clean and Green Campaign was recently initiated in response to the problems of effective waste management in townships and informal settlements. The Campaign - which is funded by the private and public sectors - is based on two approaches devised by the Keep South Africa Beautiful Association. The two projects are the One Person Contract Programme and the Tidy Town Programme. The former is a community-driven waste management system, while the latter is a community education programme. The One Person Programme which is much the same as the procedure described above, involves the appointment of suitable contractors and supervisors who live in the area concerned. The selection of contractors/supervisors is via a representative community committee. The contractors and supervisors are trained by the Keep South Africa Beautiful Association. Each contractor is responsible for servicing 250 homes in the immediate vicinity. Domestic refuse is removed from the houses on a weekly basis. Litter in the streets is likewise removed. The refuse (in plastic bags) is placed in skips or at an agreed site for collection by the local authority or a cartage contractor. The Tidy Town Programme concentrates on schools, charities and clubs. Participants are encouraged to make toys and other useful items from waste materials. The finished articles can be sold, thereby demonstrating that waste has an economic value (Department of Environmental Affairs and Tourism, Pretoria, 1996).

feedlots (Anonymous, 1991). Data on typical vegetable and animal wastes generated on an annual basis were provided by Tshiteya (1985, quoted in Kolbe, 1990)*. Not all the waste is problematic however, and crop residues are often used for mulch, for the feeding of livestock, or for other farm purposes. Sewage sludges (discussed below), constitute a major disposal problem, especially sludges containing a high proportion of industrial waste.

17.6.3 Freshwater waste streams

Laing (1990, quoted in Anonymous, 1991) estimated the total water (effluent) waste stream in South Africa in 1990, to be of the order of 779 890 t y^{-1} (Table Q4). Best (1987)** calculated that some 500 000 t y^{-1} of mineral salts from industrial effluents (excluding the power generation and mining sectors), was discharged into freshwater systems in 1983. Sewage effluent is an important component of the total wastewater stream and is also discussed below.

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* The relevant data for vegetable wastes (dry tonnes ha^{-1} y^{-1}) are: barley (0,99 - 4,69); maize (1,48 - 8,65); oats (0,99 - 3,21); peanut hay (0,49 - 3,95); rice straw (4,45 - 6,92); sorghum (1,48 - 5,93); soya beans (1,24 - 2,72) and wheat (0,74 - 5,93). Animal wastes (t $animal^{-1}$ y^{-1}) are as follows: cattle (0,63 - 0,73); chickens and ducks (0,038); geese and turkeys (0,040); horses (0,35 -0,39); pigs (0,100) and sheep (0,035). (See Kolbe, F.F., 1990. Waste management as an alternative energy source, Technology SA, March 1990, p. 45 - 51. Note that the references are not listed at the end of the paper, but can be obtained from Crown Publications Ltd, P O Box 140, Bedfordview, 2008). It is not stated whether the animal data refer to wet or dry mass or faeces/faeces and urine. The estimate for cattle at least, appears to be low. Further data can be found in the chapter on sanitation.

** See Best, H.J., 1987. Management and industrial waste management: state of the art, In: Wates, J.A. and Brink, D. (eds), Proceedings of the International Conference on Mining and Industrial Waste Management, VOL 1, Division of Geotechnical Engineering and the Division of Urban Engineering, South African Institution of Civil Engineers (Transvaal Branch), 17 - 19 August 1987, Johannesburg, p. 3 - 15.

Table Q4: **The total identified freshwater waste stream in South Africa in 1990.**

Sector	Amount ($t\ y^{-1}$)
Agriculture	134 200
Pulp and paper	122 200
Consumables	
Soaps and detergents	227 000
Laundry additives/other	114 000
Toiletries and cosmetics	102 000
Cleaning solvents	11 000
Textiles	34 461
Metallurgical	16 449
Leather processing	9 807
Transportation	4 090
Photographic processing	2 321
Process chemicals	1 538
Formulated	
Paints	365
Household products	168
Water treatment	98
Adhesives and sealants	85
Pharmaceuticals	26
Fabricated metal products	78
Electronic	5
Total	779 890

Source: After Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

Note:

(i) The above data refer to actual identified contaminants and not to the volume of wastewater per se.

(ii) Further details on the disposal of effluents inter alia in terms of permits from the Department of Water Affairs and Forestry, are provided in the chapter on water quality.

(iii) No accurate (overall) estimates are available of non-point liquid waste loads in South Africa.

17.7 The disposal of municipal sewage sludge and wastewater (effluent)

17.7.1 Introduction

Municipal sewage sludge which includes waste from toilets, bathrooms and kitchens as well as trade and industrial wastes can be disposed of in several ways, namely: by incineration, burial in municipal sanitary landfill sites, by land application (in raw or composted form), and by disposal at sea (Smith and Vasiloudis, 1989)*. The spreading of municipal sewage sludge on agricultural land is generally the cheapest method of disposal, and has many beneficial effects. Land application is also the most popular procedure for the disposal of manure from farms and feedlots. Sludge has soil conditioning properties and contains important plant nutrients such as phosphorus and nitrogen as well as calcium, magnesium, potassium and several trace elements. In this regard, Du Plessis (1977, quoted in Nell, Engelbrecht, Smith and Nupen, 1981)** calculated that the demand for inorganic fertilizers in South Africa would decline by some 10% if all sewage sludges produced in this country, were sold as fertilizer. However, there is a limit to the volume of sludge which can be applied to a particular site. Problems can include an accumulation of pathogens, nutrients (especially nitrogen), heavy metals and organic compounds in the soil profile, in plants and in water - with consequent environmental and health implications. Some of these difficulties can be avoided through the burial of municipal sludge along with domestic waste in landfill sites (termed co-disposal). Such co-disposal is not common in South Africa. A disadvantage of the latter method is that the positive effects of agricultural land application are lost. Easton (1983)*** in a study of a sandy soil showed that sludge application - with particular reference to the organic

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* See Smith, R. and Vasiloudis, H., 1989. Inorganic chemical characterization of South African municipal sewage sludges, WRC Report No. 180/1/89, Water Research Commission, Pretoria, 179 p.

** See Nell, J.H., Engelbrecht, J.F.P., Smith, L.S. and Nupen, E.M., 1981. Health aspects of sludge disposal: South African experience, Water Science and Technology, VOL 13(6), p. 153 - 170. (This paper is also cited as appearing in: Progress in Water Technology, 1980, VOL 13, p. 153 - 170, which was the previous title of the journal).

*** See Easton, J.S., 1983. Utilization and effects of anaerobically digested sludge on a red sandy soil of Natal, Water SA, VOL 9(2), p. 71 - 78.

matter content - had a number of beneficial results. Improvements were found in the cation exchange capacity; the total organic carbon; soil acidity; buffer capacity; bulk density, and the water holding capacity. An altered plant wilting time was also evident due to the greater water holding capacity of the soil. Easton observed that sludge applied to heavy clay soils will make these soils more friable and manageable, thereby reducing compaction caused by large farm machinery. (See the chapter on soils and soil erosion).

The land disposal of municipal wastewater and feedlot wastewater (manure water and wash water), has similar advantages and disadvantages. Benefits may include the prevention of pollution of surface and groundwaters; the recycling of nutrients and minerals; a reduction in the need for supplementary fertilizers, and the conservation of high quality natural waters (Van der Riet, Kfir and Van Vliet, 1992)*. The reuse of wastewater for low grade industrial requirements (where permitted), likewise represents a saving in terms of freshwater intake and the overall demand for water. The artificial recharge of aquifers by means of stormwater and treated domestic as well as industrial effluents is undertaken at the town of Atlantis on the Cape West Coast (Tredoux, 1987, quoted in Campbell, Parker-Nance and Bate, 1992)**. The domestic wastewater undergoes activated sewage sludge treatments - involving both nitrification and denitrification processes - before being pumped into maturation ponds. Seepage from the ponds then recharges the aquifer. Recharge using stormwater is via a number of detention ponds leading to a final infiltration pond in the recharge zone.

Estimates of the total amount of municipal sewage sludge produced in South Africa annually, are difficult to derive. Best (1987 - above) suggested that the total sludge production for the whole country in 1983 was of the order of 12×10^6 t; with manure from livestock feedlots amounting to approximately 10×10^6 t each year. Nell, Engelbrecht, Smith and Nupen (1981) observed that over 60% of the municipal sludge produced in South Africa is disposed of through land application (a method which is becoming increasingly popular). Detailed (current) data on the various methods of disposal used in different parts of South Africa are not easily obtained, although a survey in the

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* See Van der Riet, W.B., Kfir, R. and Van Vliet, B.M., 1992. How water quality standards ensure safe food, South African Journal of Science, VOL 88(2), p. 80 - 84.

** See Campbell, E.E., Parker-Nance, T. and Bate, G.C., 1992. A compilation of information on the magnitude, nature and importance of coastal aquifers in southern Africa, WRC Report No. 370/1/92, Water Research Commission, Pretoria, 192 p.

Cape Province revealed that more than half of the municipal sludge (including composted sludge) was disposed of on land. A proportion was "stored" (allowed to dry during summer for possible agricultural use). Small amounts were buried or were left in oxidation ponds, while only a fraction was incinerated or heat treated (Engelbrecht, Nell and Steer, 1981)*. A useful case study on the land disposal of sludge is that of Van Niekerk, Richards and Duvenhage (1988)**.

The volumes of municipal wastewater which are reused for irrigation purposes in South Africa range from less than 1% up to 100%, with a mean reuse factor of some 24,3%. Most of the wastewater is sprayed on pastures (67,7% by volume), followed by trees (13,9%), crops (12,4%), sports fields (5,4%) and parks (0,6%). In Pietermaritzburg, approximately 25% of the sewage wastewater is reused (confined to the watering of trees) (Anonymous, 1986)***.

The CSIR provided valuable data on the volumes and waste loads of industrial and domestic effluents and sludges discharged into "estuaries", the surf zone and the offshore area along the coast of South Africa (Anonymous, 1991)****. There are 11 major pipelines discharging into estuaries along the coast of Natal/KwaZulu, with a further eight pipelines discharging to the surf zone. Seven pipelines discharge effluent into the offshore area. The relevant data are presented in Table Q5.

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* See Engelbrecht, J.F.P., Nell, J.H. and Steer, A.G., 1981. 'n Opname van bestaande rioolslykbeskikkingspraktyke in die Kaapprovinsie, CSIR Special Report No. WAT 61, National Institute for Water Research, CSIR, Pretoria, 23 p.

** See Van Niekerk, A.M., Richards, J.C. and Duvenhage, J.A., 1988. Land disposal of anaerobic digested sludge: the Krugersdorp experience, Symposium on Sludge Handling, Geological Survey, Division of Water Technology, CSIR, Water Institute of Southern Africa, Water Research Commission and the Department of Water Affairs, 15 November 1988, Pretoria, 19 p.

*** See Anonymous, 1986. Management of the Water Resources of the Republic of South Africa, Department of Water Affairs, Pretoria, various pages.

**** See Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app. (The report contains some data on stormwater runoff volumes and waste loads).

Table Q5: Effluent/sludge volumes (10^3 m^3 day^{-1}) discharged into "estuaries", the surf zone and the offshore area of Natal/KwaZulu, 1991.

Locality	Type of industry							Domestic sources			Grand total
	fertilizers	pulp	chemicals	oil	fish/food	textiles	total	raw	treated	total	
"Estuaries"											
North Coast (4 pipelines)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,5	2,5	2,5
Central (2 pipelines)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	25,4	25,4	25,4
South Coast (5 pipelines)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,6	3,6	3,6
Total for "estuaries"	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	31,5	31,5	31,5
The surf zone											
North Coast (2 pipelines)	0,0	7,0	0,0	0,0	0,0	3,6	10,6	0,0	0,0	0,0	10,6
Central (1 pipeline)	0,0	0,0	3,0	0,0	0,0	0,0	3,0	0,0	0,0	0,0	3,0
South Coast (5 pipelines)	0,0	0,0	1,8	0,0	0,0	0,0	1,8	0,0	2,8	2,8	4,6
Total for the surf zone	0,0	7,0	4,8	0,0	0,0	3,6	15,4	0,0	2,8	2,8	18,2
The offshore area											
North Coast (2 pipelines)	24,1	95,0	15,5	0,0	0,0	0,0	134,6	10,0	0,0	10,0	144,6
Central (4 pipelines)	0,0	30,0	5,0	6,5	1,5	0,0	43,0	170,0	0,0	170,0	213,0
South Coast (1 pipeline)	0,0	80,0	0,0	0,0	0,0	0,0	80,0	0,0	0,0	0,0	80,0
Total for the offshore area	24,1	205,0	20,5	6,5	1,5	0,0	257,6	180,0	0,0	180,0	437,6

Source: After Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

See also:
(i) Botes, W.A.M., 1994. Dilution studies on large offshore pipelines, WRC Report No. 364/1/94, Water Research Commission, Pretoria, 73 p.

(ii) Lord, D.A., Anderson, F.P. and Basson, J.K. (eds), 1984. Pipeline discharges of effluents to sea: proceedings of a workshop held at Hermanus, South Africa, 24 - 26 May 1983, South African National Scientific Programmes Report No. 90, Foundation for Research Development, CSIR, Pretoria, 108 p.

(iii) Lord, D.A. and Geldenhuys, N.D., 1986. Richards Bay effluent pipeline, South African National Scientific Programmes Report No. 129, Foundation for Research Development, CSIR, Pretoria, 30 p.

Note:
(i) Industrial zones in the North Coast area are Richards Bay/Empangeni, Felixton and Tongaat; and Durban, Umlazi and Umbogintwini (the central area), with Umkomaas and Sezela in the South Coast area.

(ii) Data on regional suspended solids and chemical oxygen demand loads (t day^{-1}) for industrial and domestic effluents discharged into "estuaries" in Natal/KwaZulu in 1991 are provided below:

Determinand	North Coast	Central area	South Coast	Total for Natal/KwaZulu
Regional suspended solids loads				
Industrial sources (fish/food factories)	0,00	0,00	0,00	
Domestic sources (treated effluent)	0,16	1,60	0,23	
Total	0,16	1,60	0,23	1,99
Regional chemical oxygen demand loads				
Industrial sources (fish/food factories)	0,00	0,00	0,00	
Domestic sources (treated effluent)	0,30	3,04	0,44	
Total	0,30	3,04	0,44	3,78

Source: After Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

(iii) The total nutrient load (in terms of phosphorus and nitrogen) discharged into South African "estuaries" is less than 2 t day^{-1}, and is mainly derived from treated sewage and fish factories in the Cape Province. The total toxic inorganic material load (cyanide, fluoride and heavy metals) discharged into estuaries in this country is less than 10 kg day^{-1}, approximately equally divided between the Cape and Natal/KwaZulu. Further data relating to the offshore area and the surf zone can be found in Anonymous (1991).

(iv) It should be noted (with respect to offshore areas, for example), that the settleable fraction of suspended solids can form sludge deposits near the mouth of the pipe, thereby smothering the benthic environment (including the feeding grounds of fish species). Decomposition of the deposits results in an oxygen demand in the water. The non-settleable fraction causes turbidity, which in areas of poor circulation, may reduce light penetration to a point where primary production is affected (around the mouth of the outfall pipeline). Phosphogypsum in large volumes likewise, results in turbidity as well as the clogging of fish gills plus a reduction in aesthetic values. The substance has a smothering effect on the ocean floor (near the pipeline), following final settlement. A phosphogypsum load of some 5 000 - 8 000 t y^{-1} is discharged to the offshore area by the fertilizer factory at Richards Bay (Anonymous, 1991). The use of phosphogypsum as a soil amendment is being investigated*.

17.7.2 Health aspects

Raw domestic sewage and even partially treated effluents contain a high proportion of problematic waste, especially pathogens. The type and concentration of pathogenic organisms in sewage is indicative of the general health of the community in the area. The faeces of children is particularly dangerous, in view of the number of infectious diseases to which children are prone. It follows that incorrectly treated sludge and effluent can have serious health implications as a result of direct human contact, the consumption of contaminated foodstuffs (crops/meat), and entry into surface and groundwaters. (See the chapter on water quality).

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* See for example, Smith, H.J.C., Levy, G.J. and Shainberg, I., 1990. Water-droplet energy and soil amendments: effect on infiltration and erosion, Soil Science Society of America Journal, VOL 54(4), p. 1084 - 1087.

Helminthic ova (eggs) concentrate in the sludge fraction of sewage - given their relatively high density - and may survive in soil for a number of years (Smith, 1977, quoted in Nell, Engelbrecht, Smith and Nupen, 1981 - above)*. Of particular concern are Ancylostoma duodenale; Ascaris lumbricoides; Enterobius vermicularis; Hymenolepis nana; Necator americanus; Taenia solium, and Trichuris trichiura. A. lumbricoides ova are the most resistant to treatment, and the presence/absence of such ova is a useful indicator of the hygienic quality of treated domestic sewage sludge and effluent (Steer and Windt, 1978)**. Pathogenic bacteria of significance include Salmonella spp. and Shigella spp. Important protozoa are those which cause diseases such as amoebic dysentery and other dysenteries (see the chapter on health). Bacteria and protozoa in sewage sludge applied on land are likely to be concentrated on the surface of the soil, and are therefore in direct contact with crops and animals. Vegetative bacteria are rapidly destroyed by sunlight as well as by desiccation and filtration through the soil. Spore-forming bacteria however, can remain viable for more than a year in soil (Engelbrecht, 1978, quoted in Nell et al, 1981).

Viruses present in sewage include those causing hepatitis A, poliomyelitis and rotaviral enteritis. Of increasing concern are viruses and other pathogens derived from hospital waste. Viruses can be adsorbed to clay particles and accordingly, are able to survive for several weeks or even months. Adsorption depends on various factors including soil pH, the cation exchange capacity, and rain (Nupen, 1980, quoted in Nell et al, 1981). The survival of pathogens (including viruses) on plant surfaces in turn, depends on a number of parameters such as temperature, humidity, sunlight, rainfall, pH, protection by foliage, and competition from other microorganisms (Pescod, 1987, quoted in Van der Riet, Kfir and Van Vliet, 1992). It has been shown, for example, that the polio virus can survive from 14 - 36 days on radishes and lettuces grown under field conditions (Bitton, 1980, quoted in Van der Riet et al, 1992). Pathogens can also enter plant root systems through lesions (Bitton, 1980). Fruit can be contaminated in the same way, although to a lesser extent than vegetables (Rose, 1986, quoted in Van der Riet et al).

Heavy metals and organic compounds (including agrichemicals) can also pose a serious health risk. Environmental impacts are likewise of concern following bioaccumulation in

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* See also, Engelbrecht, J.F.P. and Nell, J.H., 1988. Die gesondheidsrisiko van mikro-organismes in rioolslyk vir die mens, Water Sewage and Effluent, VOL 8(3), p. 31 - 34.

** See Steer, A.G. and Windt, C.M., 1978. Composting and the fate of Ascaris lumbricoides ova, Water SA, VOL 4(3), p. 129 - 133.

soil and aquatic organisms*. Organic compounds can have long term carcinogenic, mutagenic and teratogenic (causing prenatal defects) implications. The nature and concentration of heavy metals and organic compounds in sludge and effluent will vary depending on the industrial component vis-a-vis domestic sources - reflecting the type of industry, the level of technology, and the extent to which industrial wastes are discharged into sewers. Organic compounds of particular significance are the organochlorines as well as chlorinated phenolic compounds, polyaromatic ring compounds, phthalates and sulfonates (Fourie, 1979, quoted in Nell et al, 1981). Many of these substances tend to be concentrated in sludge in view of their limited solubility in water (Nell et al).

There is some debate on the toxicity to crops of heavy metals present in sludge (Nell et al, 1981). Pahren, Lucas, Ryan and Dotson (1979, quoted in Nell et al) suggested that toxicity is of a temporary nature, given that heavy metals become increasingly inactive due to chemical processes within the soil. In some cases, heavy metals are not taken up by plants to any extent (although they may be phytotoxic at low concentrations). According to Viitasalo (1978, quoted in Nell et al) only a few instances of livestock poisoning have been caused by the presence of copper, molybdenum, selenium and zinc as a result of sludge applied to soils. Viitasalo concluded that these metals constitute a very minor risk for humans. However, Hyde, Page, Bingham and Mahler (1979, quoted in Van Niekerk, Richards and Duvenhage, 1988) observed that cobalt, molybdenum and selenium can reach harmful concentrations in plants and will accordingly damage human health. There is agreement nevertheless on the dangers of cadmium, since cadmium is readily absorbed and stored by many crops. In humans, cadmium accumulates in the kidneys with possible serious consequences (Hyde, Page, Bingham and Mahler, 1979; Pahren, Lucas, Ryan and Dotson, 1979). Cadmium therefore poses a threat and is the most likely heavy metal limiting sludge application rates (Van Niekerk et al, 1988). Severe cadmium poisoning in humans can lead to so-called Itai-itai disease (Easton, 1983 - above).

Smith and Vasiloudis (1989)** investigated the inorganic and nutrient content of municipal sludges at 77 sewage works in South Africa (mainly those serving over 25 000

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* See Pearce, K., Snyman, H., Van Heerden, H., Greben, H. and Oellermann, R.A., 1995. Bioremediation technology for the treatment of contaminated soil in South Africa, WRC Report No. 543/1/95, Water Research Commission, Pretoria, 60 p. + app.

** See Smith, R. and Vasiloudis, H., 1989. Inorganic chemical characterization of South African municipal sewage sludges, WRC Report No. 180/1/89, Water Research Commission, Pretoria, 179 p.

people). The researchers found that the major inorganic contaminants in sewage sludge are arsenic, boron, cadmium, chromium, copper, fluoride, lead, mercury, molybdenum, nickel, selenium and zinc. Minor contaminants include antimony, beryllium, cobalt, silver, thallium, tin, tungsten and vanadium. The results of the sampling programme are presented in Table Q6. Smith and Vasiloudis proposed certain guidelines for the maximum permissible concentration of 13 inorganic determinands in sewage sludges intended for agricultural land application. The guidelines were based on their survey as well as overseas data, and other guidelines formulated by Vivier, Pieterse and Aucamp (1988)* for the Department of National Health and Population Development. On the basis of the guidelines suggested by Smith and Vasiloudis, 58% of the 77 sludges met the recommended concentrations, while the balance exceeded one or more determinand concentration/s. Smith and Vasiloudis observed that sludges in many parts of South Africa are probably not as contaminated by dangerous substances (heavy metals and organic compounds), as sludges in highly industrialized countries. It is possible however, that concentrations for a number of determinands in certain industrial towns in the Pretoria-Witwatersrand-Vereeniging complex are <u>currently</u> approaching or will soon reach those found in some European cities.

17.7.3 <u>Guidelines for the land disposal of sewage sludge</u>

Before 1970, the control of sewage sludge treatment, disposal and utilization was the sole responsibility of local authorities. Following the general recognition that sewage sludge requires careful handling and disposal, the then Department of Health instituted a research programme - undertaken by the then National Institute for Water Research of the CSIR - in order to establish relevant South African guidelines. While larger municipalities have the required technical expertise to properly treat and dispose of sewage sludges according to

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* See Vivier, F.S., Pieterse, S.A. and Aucamp, P.J., 1988. Guidelines for the use of sewage sludge, Symposium on Sludge Handling, Geological Survey, Division of Water Technology, CSIR, Water Institute of Southern Africa, Water Research Commission and the Department of Water Affairs, 15 November 1988, Pretoria, 13 p.

Table Q6: The results of an inorganic and nutrient chemical analysis of municipal sludges derived from 77 sewage works in South Africa, 1983 - 1987.

Determinand	Unit	Sewage sludge concentration		
		median	mean	range
Arsenic	mg kg^{-1} dry basis	6	7	<1 - 34
Boron	mg kg^{-1} dry basis	28	31	6 - 78
Cadmium	mg kg^{-1} dry basis	3	12	<1 - 122
Calcium	g kg^{-1} dry basis	29,3	31,8	11,4 - 79,3
Chromium	mg kg^{-1} dry basis	220	551	25 - 10 015
Copper	mg kg^{-1} dry basis	355	654	80 - 17 217
Fluoride	mg kg^{-1} dry basis	97	128	32 - 1 260
Lead	mg kg^{-1} dry basis	214	452	67 - 10 137
Magnesium	g kg^{-1} dry basis	5,4	5,7	1,9 - 13,2
Mercury	mg kg^{-1} dry basis	3	5	<1 - 22
Molybdenum	mg kg^{-1} dry basis	5	6	1 - 24
Nickel	mg kg^{-1} dry basis	55	154	6 - 2 660
Potassium	g kg^{-1} dry basis	1,9	2,5	0,7 - 10,9
Selenium	mg kg^{-1} dry basis	2	4	<1 - 107
Total Kjeldahl nitrogen	g kg^{-1} dry basis	28,9	31,0	16,7 - 58,4
Total phosphorus	g kg^{-1} dry basis	13,5	15,6	4,1 - 41,0
Zinc	mg kg^{-1} dry basis	1 432	2 054	237 - 17 680
pH	pH units	6,8	6,8	5,4 - 7,8

<ins>Source</ins>: After Smith, R. and Vasiloudis, H., 1989. Inorganic chemical characterization of South African municipal sewage sludges, WRC Report No. 180/1/89, Water Research Commission, Pretoria, 179 p.

<ins>See also</ins>: Smith, R. and Vasiloudis, H., 1991. Importance, determination and occurrence of inorganic chemical contaminants and nutrients in South African municipal sewage sludges, <ins>Water SA</ins>, VOL 17(1), p. 19 - 30. (The paper is a summary of the Water Research Commission report).

<ins>Note</ins>: (i) Results for cadmium, calcium, chromium, copper, lead, magnesium, nickel, potassium, zinc and pH are the average of four measurements. For the other determinands, the results are of the composite of four samples.

(ii) Typical sources of heavy metals in sewage sludge are the electroplating, pigment and chemical industries (cadmium); the electroplating and chemical industries (copper); the electroplating, tanning and dyestuff industries (chromium); the battery, printing and paint industries, plus petrol additives washed from road surfaces (lead); the electrical, explosives, pharmaceutical, agrichemical and chemical industries as well as laboratory wastes and wastewaters (mercury); the electroplating, motor vehicle, aircraft, printing and chemical industries (nickel); and domestic wastes, the galvanizing, cosmetics, pharmaceutical and rubber industries (zinc). The importance of recovering economically valuable heavy metals from the industrial waste stream, and thereby preventing contamination of the environment, is evident.

(iii) Readers seeking data on determinand levels at various sewage works (and accordingly, the influence inter alia of industrial processes), should carefully examine Smith and Vasiloudis (1989).

(iv) Data on the general chemical composition of raw domestic sewage was provided by the then Institute of Water Pollution Control (1984, quoted in Moldan and Lusher, 1992)*. Of interest is that mean pesticide residues in raw sewage are typically of the order of $<20\ \mu g\ \ell^{-1}$. See the chapter on sanitation.

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international standards, the same may not necessarily be true for smaller local authorities. It was therefore considered necessary for the Department to compile a standard set of guidelines for use throughout the country. An early version of the guidelines was provided by Smith (1977/1978)**. Thereafter, more comprehensive guidelines were compiled by Vivier, Pieterse and Aucamp (1988). The revised guidelines represented a compromise between (a) banning the agricultural and horticultural use of any sewage sludge not specifically derived from domestic sources (and not fully stabilized or disinfected), (b) the strict application of comprehensive regulations (as opposed to guidelines), and (c) the previous ad hoc approach. The guidelines were slightly revised (incorporating research undertaken inter alia by Smith and Vasiloudis, 1989 - above), and are currently in final

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* See Moldan, A.G.S. and Lusher, J.A., 1992. Part 3: Effluent, pollution and risk. Chapter 5. Effluent characteristics, In: McGlashan, J.E. (ed), Guide for the Marine Disposal of Effluents Through Pipelines, WRC Report No. TT 58/92, Water Research Commission, Pretoria, p. 43 - 47.

** See Smith, L.S., 1977/1978. Can sludge be used hygienically?, Imiesa, VOL 3(1), p. 27.

draft form (Van der Merwe and Vivier, 1994)*. Further refinements are likely. The guidelines provide for essential requirements and conditions only (for various types of sludges), thereby minimizing potential or actual human health and environmental impacts. Full protection however, cannot be guaranteed. The guidelines represent the best practical method of standard control throughout South Africa, with regard to cost as well as technical expertise and equipment.

It is a requirement in terms of Section 20 of the Health Act No. 63 of 1977, that local authorities must take all lawful and practical measures to maintain the area under their jurisdiction in a hygienic condition; and to prevent nuisances as well as offensive conditions from arising which will or could damage human health locally or regionally. These duties also refer to sewage purification and sludge treatment, storage, processing, utilization and disposal. The guidelines therefore, are in accordance with the Act.

The guidelines were drawn up in consultation with the Department of Agriculture; the Institute for Soil, Climate and Water (of the Agricultural Research Council); the Department of Environment Affairs; the Department of Water Affairs and Forestry; the Water Research Commission; the Division of Water Technology of the CSIR, and other interested organizations (Van der Merwe and Vivier, 1994). The guidelines will be used by the Department of Water Affairs and Forestry to grant exemptions for sewage sludge in terms of Section 21 of the Water Act No. 54 of 1956 (pertaining to effluent or wastewater disposal - refer to the chapter on water quality). The guidelines will also be used by the Registrar: Act No. 36 of 1947 (Department of Agriculture) for the registration of Type D sludge. (See the section dealing with agrichemicals later in this chapter). As with many other legal and official notifications however, the success of the guidelines will depend on mutual cooperation amongst all parties.

In terms of the guidelines, sewage sludges can be classified into four categories, namely, Types A, B, C and D (Table Q7). The classification operates on a declining scale with regard to the potential for odour nuisances and fly breeding, as well as the transmission

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* See Van der Merwe, W. and Vivier, F.S., 1994. Healthy sewage sludge, Water Sewage and Effluent, VOL 14(3), p. 27 - 32. See also, Oberholster, G., 1983. South African practice in land disposal of sludge, including legislation and health aspects: an overview, Water Science and Technology, VOL 15(1), p. 151 - 155. A most useful publication is the following: Murray, K.A., 1987. Wastewater Treatment and Pollution Control, Water Research Commission, Pretoria, 367 p.

Table Q7: The classification of sewage sludges to be used or disposed of on land.

Type of sewage sludge	Origin/treatment (examples)	Characteristics/quality of sewage sludge
Type A sludge	Raw sludge; cold digested sludge; septic tank sludge; oxidation pond sludge	Usually unstable and can cause odour nuisances and fly breeding; contains pathogenic organisms and has a variable metal and inorganic content
Type B sludge	Anaerobic digested sludge (heated digester); surplus activated sludge; humus tank sludge	Fully or partially stabilized (should not cause significant odour nuisances or fly breeding); contains pathogenic organisms and has a variable metal and inorganic content
Type C sludge (If not certified this sludge is regarded as a Type B sludge)	Pasteurised sludge; heat treated sludge; lime stabilized sludge; composted sludge; irradiated sludge	• Certified to comply with the following quality requirements: - Stabilized (should not cause odour nuisances or fly breeding) - Contains no viable Ascaris lumbricoides ova per 10 g dry sludge - Maximum zero Salmonella spp. organisms per 10 g dry sludge - Maximum 1 000 faecal coliforms per 10 g dry sludge immediately after treatment (disinfection/ sterilization) • Has a variable metal and inorganic content

Table Q7: The classification of sewage sludges to be used or disposed of on land (continued).

Type of sewage sludge	Origin/treatment (examples)	Characteristics/quality of sewage sludge
Type D sludge (A sludge produced for unrestricted use on land with or without the addition of plant nutrients or other materials. This product must be registered in terms of the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947)	Pasteurised sludge; heat treated sludge; lime stabilized sludge; composted sludge; irradiated sludge	• Certified to comply with the following quality requirements: - Stabilized (should not cause odour nuisances or fly breeding) - Contains no viable Ascaris lumbricoides ova per 10 g dry sludge - Maximum zero Salmonella spp. organisms per 10 g dry sludge - Maximum 1 000 faecal coliforms per 10 g dry sludge immediately after treatment (disinfection/ sterilization) • The maximum metal and inorganic content (mg kg^{-1} dry sludge) is as follows: Metals Cadmium 20 Chromium 1 750 Cobalt 100 Copper 750 Lead 400 Mercury 10 Molybdenum 25 Nickel 200 Zinc 2 750 Inorganic content Arsenic 15 Boron 80 Fluoride 400 Selenium 15

Source: After Van der Merwe, W. and Vivier, F.S., 1994. Healthy sewage sludge, Water Sewage and Effluent, VOL 14(3), p. 27 - 32.

See also: (i) Ekama, G.A. (ed), 1993. Sewage sludge utilization and disposal: information document, Sludge Management Division Executive Committee, Water Institute of Southern Africa, Johannesburg, 201 p. (See also Ekama, G.A., 1992. Sludge management for land disposal, Water Sewage and Effluent, VOL 12(3), p. 19 - 27).

(ii) Funke, J.W., 1975. Metals in urban drainage systems and their effect on the potential reuse of purified sewage, Water SA, VOL 1(1), p. 36 - 44.

(iii) Gopo, J.M. and Chingobe, N., 1995. Salmonella contamination of recycled effluent of treated sewage and urban waste water, Water SA, VOL 21(3), p. 245 - 250.

(iv) Korentajer, L., 1991. A review of the agricultural use of sewage sludge: benefits and potential hazards, Water SA, VOL 17(3), p. 189 - 196.

(v) Nell, J.H., Dowdles, D.R. and Louw, J.M., 1987. Chemical, physical and microbiological quality of domestic refuse compost, Biennial Conference and Exhibition of the Institute of Water Pollution Control (Southern African Branch), VOL 1, 12 - 15 May 1987, Port Elizabeth, 21 p. (The paper provides data inter alia on the quality of compost produced by six wastewater treatment plants in the western Cape).

(vi) Steyn, C.E., Van der Watt, H.v.H. and Claassens, A.S., 1996. On the permissible nickel concentration for South African soils, South African Journal of Science, VOL 92(8), p. 359 - 363.

Note: (i) The user must be informed about the moisture as well as the nitrogen, phosphate and potassium content, in respect of Type D sludge.

(ii) The user must be warned (also for Type D sludge), that not more than 8 t ha^{-1} y^{-1} (dry sludge) may be applied to the soil and that the pH of the soil should preferably be greater than 6,5.

(iii) The terms "metal" and "inorganic content" used in the above table and in the following table (Table Q8), should not be confused with the terminology used by Smith and Vasiloudis (1989 - above).

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of pathogenic organisms. Type A and B sludges accordingly, are problematic. Type D sludge which is produced for unlimited land use has a similar hygienic quality (by comparison with Type C sludge), but has a lower metal and inorganic content. The required indicators of the hygienic quality of Type C and D sludges are the number of Ascaris lumbricoides ova, Salmonella spp. organisms and faecal coliforms. This is due to cost and technical considerations (Van der Merwe and Vivier, 1994). The permissible methods for the land disposal of sludge, as per sludge type, are outlined in Table Q8. Severe restrictions are applied for uses such as vegetable growing, with no restrictions for example, for sludge composting with other organic material. Provision is made in the guidelines for contractual agreements between the local authority or agency supplying the

Table Q8: Permissible methods of sewage sludge disposal, according to land use and agricultural/domestic crops.

Disposal site or method	Type A sludge	Type B sludge	Type C sludge	Type D sludge
Sale or alienation of sludge	Permissible - restriction 1	Permissible - restriction 1	Permissible - restriction 1	Permissible - no restriction
Public gardens and traffic islands only for beautifying, with minimum human contact	Not permissible	Permissible - restriction 6	Permissible - restriction 6	Permissible - recommendation 6
Public parks, recreational areas, lawns at schools, swimming pool surrounds and sports fields	Not permissible	Permissible - restriction 2,6	Permissible - restriction 2,6	Permissible - recommendation 6
Instant lawn cultivation	Not permissible	Permissible - restriction 3,5	Permissible - restriction 3,5	Permissible
Stabilizing of mine dumps - grass or other plants	Not permissible	Permissible - restriction 6,7	Permissible - restriction 6,7	Permissible - recommendation 6, 7
Nurseries: shrubs, trees and other plants	Not permissible	Permissible - restriction 3,5	Permissible - restriction 5	Permissible
Natural veld and tree plantations	Permissible - restriction 4,5, 6,8	Permissible - restriction 3,4, 6	Permissible - restriction 6	Permissible
Land application - ploughed in repeatedly: disposal and co-disposal on disposal site	Permissible - restriction 4,5, 6,8,9 (soon not permissible)	Permissible - restriction 4,5, 6,8,9 (soon not permissible)	Permissible - restriction 6,8, 9 (soon not permissible)	Permissible - restriction 9
Composting with other organic material	Permissible (see Type C sludge)	Permissible (see Type C sludge)	Permissible	Permissible
Household vegetables consumed raw or cooked; tobacco	Not permissible	Not permissible	Not permissible	Permissible - recommendation 2, 6
Private gardens: lawns, shrubs, trees and vegetables	Not permissible	Not permissible	Not permissible	Permissible - recommendation 6

Table Q8: **Permissible methods of sewage sludge disposal, according to land use and agricultural/domestic crops (continued).**

Disposal site or method	Type A sludge	Type B sludge	Type C sludge	Type D sludge
Vineyards and fruit trees (excluding private gardens)	Not permissible	Permissible - restriction 3,6	Permissible - restriction 6	Permissible - recommendation 6
Cereal and sugar cane cultivation	Not permissible	Permissible - restriction 3,6	Permissible - restriction 6	Permissible - recommendation 6
Grazing for milk, meat and egg-producing animals	Not permissible	Permissible - restriction 2,6	Permissible - restriction 6	Permissible - recommendation 6
Crops not for grazing, but utilized as dry fodder	Not permissible	Permissible - restriction 3,4, 6	Permissible - restriction 6	Permissible - recommendation 6
General requirements and precautionary measures according to the type of sludge	Maximum slope of site 1 : 25 (4%)	Maximum slope of site 1 : 17 (6%)	-	-
	Depth of aquifer: >5 m	Depth of aquifer: >2 m	-	-
	>500 m from dwelling	>200 m from dwelling	-	-
	>200 m from river, dam or borehole	>200 m from river, dam or borehole	>100 m from river	-
	Soil pH >6,5	Soil pH >6,5	Soil pH >6,5	Soil pH preferably >6,5

<u>Source</u>: After Van der Merwe, W. and Vivier, F.S., 1994. Healthy sewage sludge, <u>Water Sewage and Effluent</u>, VOL 14(3), p. 27 - 32.

<u>Note</u>: (i) The restrictions/recommendations referred to in the above table are as follows:

1. Only as per contract for Type A, B and C sludges. The following essential items must be included in any contractual agreement: Supplier/producer Name and address; type of sewage sludge; quality (hygienic - stability and micro-organisms), moisture content, nitrogen, phosphate and potassium content, and maximum metal and inorganic content; limiting metal and maximum application rate in dry t ha^{-1} y^{-1}; recommended maximum application rate in t ha^{-1} y^{-1} in terms of nitrogen demand of the crop, and notification of the local authorities involved. Receiver/user Name and address; name of transporter of sludge; name of farm or site where the sludge will be stored and used; date of application as well as the size and exact locality of the sludge application area; crops to be fertilized or alternative use; previous sewage sludge application - annual rate and frequency; metal and inorganic content in soil, and details of sewage sludge processing, addition of other materials or chemicals, and quality of the final product (if produced for sale). Agreement Sewage sludge to be used in terms of this guide; inspection of user's activities by the local authority, and breach of contract - termination of sewage sludge supply and punitive measures
2. Application only during planting
3. Application only with planting and during the period subsequent to harvesting, and prior to the next growing season (in order to minimize sewage sludge contact with crops to be harvested)
4. Application permissible only if the area is effectively fenced to keep out unauthorized persons as well as milk, meat and egg-producing animals
5. No subsequent sale or alienation of sludge or any mixture containing such sludge is allowed by the user
6. All sludge must be mixed or covered with soil wherever possible
7. Soil pH and slope requirements could be relaxed on condition that no contaminated runoff and seepage water pollutes any surface or groundwater
8. Application of excessive quantities of sewage sludge on land will result in the site being declared unfit for any other purpose during the operation and for a minimum period of two years after termination thereof. (Waste disposal site, see 9). No nuisance or any other condition posing a potential health hazard or which may cause pollution of any water source will be tolerated at such a site. Use of the site for any other purpose will only be permitted after the necessary investigation has proved that it is safe to do so
9. Disposal of sludge and co-disposal with domestic waste and other waste in disposal sites. Permit requirements in terms of the Environment Conservation Act No. 73 of 1989 must be met. The minimum requirements for landfills as per the Department of Water Affairs and Forestry are likewise applicable

(ii) The total maximum permitted metal and inorganic contaminant accumulation in soil specifications, and the maximum permissible contaminant application rate are given below:

Metal/inorganic content	Maximum permissible metal and inorganic content in soil (mg kg^{-1})	Maximum amount of metal and inorganic contaminants that can be applied to soil		Main reason why metals and inorganic contaminants are restricted	
		kg ha^{-1} 25 y^{-1}	g ha^{-1} y^{-1}	phytotoxicity (toxic to plants)	zootoxicity (toxic to animals)
Cadmium	Cd 2	4	160		Yes
Chromium	Cr 80	350	14 000	Yes	
Cobalt	Co 20	20	800		Yes
Copper	Cu 100	150	6 000	Yes	
Lead	Pb 56	80	3 200		Yes
Mercury	Hg 0,5	2	80		Yes
Molybdenum	Mo 2,3	5	200		Yes
Nickel	Ni 15	40	1 600	Yes	
Zinc	Zn 185	550	22 000	Yes	
Arsenic	As 2	3	120	Yes	
Boron	B 10	16	640	Yes	
Fluoride	F 50	80	3 200		Yes
Selenium	Se 2	3	120		Yes

(iii) The maximum application rate of sewage sludge must be in accordance with the sludge metal and inorganic contaminant concentration, and the maximum permitted application rate. Some examples of the maximum sludge application rate in terms of the corresponding total maximum metal and inorganic content are outlined below. The frequent user of sludge for agricultural purposes should have the soil tested to maximize plant growth and to avoid excessive concentrations of metals and inorganic constituents. It is important to bear in mind that many soils (especially in the higher rainfall areas), are acidic or can easily be acidified due to a poor buffering capacity. The mobility and availability of heavy metals is much increased at soil pH (water) values of 6,5 and less - with the exception of arsenic, chromium (certain valence states) as well as molybdenum, selenium and vanadium. Accordingly, most heavy metals are more available for plant uptake at low soil pH values. Soils receiving sludge containing heavy metals must therefore be monitored and treated with lime to keep the pH above 6,5 (Van der Merwe and Vivier, 1994).

Application rate for sludge t ha^{-1} y^{-1} (dry mass)	Maximum metal and inorganic contaminant concentrations in sludge permitted for the corresponding sludge application rate (mg kg^{-1} dry mass)												
	Cd	Cr	Co	Cu	Pb	Hg	Mo	Ni	Zn	As	B	F	Se
0,5	320	28 000	1 600	12 000	6 400	160	400	3 200	44 000	240	1 280	6 400	240
1,0	160	14 000	800	6 000	3 200	80	200	1 600	22 000	120	640	3 200	120
1,5	107	9 333	533	4 000	2 133	53	133	1 067	14 667	80	427	2 133	80
2,0	80	7 000	400	3 000	1 600	40	100	800	11 000	60	320	1 600	60
2,5	64	5 600	320	2 400	1 280	32	80	640	8 800	48	256	1 280	48
3,0	53	4 667	267	2 000	1 067	27	67	533	7 333	40	213	1 067	40
3,5	46	4 000	229	1 714	914	23	57	457	6 286	34	183	914	34
4,0	40	3 500	200	1 500	800	20	50	400	5 500	30	160	800	30
4,5	36	3 111	178	1 333	711	18	44	356	4 889	27	142	711	27
5,0	32	2 800	160	1 200	640	16	40	320	4 400	24	128	640	24
6,0	27	2 333	133	1 000	533	13	33	267	3 667	20	107	533	20
7,0	23	2 000	114	857	457	11	29	229	3 143	17	91	457	17
8,0	**20**	**1 750**	**100**	**750**	**400**	**10**	**25**	**200**	**2 750**	**15**	**80**	**400**	**15**

(iv) The application rate of sewage sludge should (ideally) be based on the phosphate content rather than the nitrogen content of the sludge (given the relatively low nitrogen content of sludge). It should be noted that the plant available (total) nitrogen in sludge is some 30% in the first year after application, 15% in the second year, and 5% in the third year. Agricultural users should determine the amount of nitrogen required for optimum plant growth, the amount of available nitrogen from the sludge, and the balance required from artificial fertilizers. A professional soil analysis is advisable. Excessive nitrogen application rates must be avoided to prevent surface and groundwater pollution (see the chapter on health). A general guide for the nitrogen demand of a number of crops is given below:

Crop	Nitrogen demand ($kg\ ha^{-1}$)
Asparagus	45 - 75
Cabbages	160
Cotton	40 - 70
Dry beans and soya beans	12 - 40
Maize	30 - 50
Onions	150
Pastures and fodder crops	30 - 40
Potatoes	15 - 40
Sunflowers	30 - 50
Sweet peppers	180
Tobacco	30 - 80
Tomatoes	40 - 50
Other vegetables	80 - 120
Wheat (summer rainfall area)	10 - 30
Wheat (winter rainfall area)	30 - 50
Lawns	80 - 100

(v) Care should be exercised where sewage sludges contain (or are suspected of containing) a high proportion of organic compounds - such as agrichemicals. Special attention should be paid to Type D sludges. As a general guide, the United States Environmental Protection Agency maximum annual loading limits for selected organic compounds are listed below. Some of the compounds are no longer manufactured or have been withdrawn from sale.

Contaminant	Dry mass basis (mg kg^{-1})
Aldrin/dieldrin (total)	2,7
Benzene	16 000
Benzo(a)pyrene	15
Chlordane	86
DDD, DDE, DDT (total)	1,2
Heptachlor	7,4
Hexachlorobenzene	29
Hexachlorobutadiene	600
Lindane	84
N-nitrosodimethylamine	2,1
Pentachlorophenol	30
Polychlorinated biphenyls	4,6
Toxaphene	10
Trichloroethylene	10 000

sewage sludge, and all other parties handling, transporting, treating, selling, using or disposing of the sludge. The parties are jointly responsible for complying with the guidelines. The stipulation applies to Type A, B and C sludges. Details of the required agreements are provided in Table Q8.

It should be borne in mind that the repeated use of an area for sewage sludge disposal (more than the specified application rate), will in effect, change the area into a waste disposal site. Agencies or individuals operating a waste disposal site require a permit (in terms of the Environment Conservation Act No. 73 of 1989), which is issued by the Department of Water Affairs and Forestry. The minimum requirements of the Department - discussed later - are then applicable.

No sampling frequency and methods for chemical analyses are specified in the guidelines. The producer of the sludge accordingly, must make the required arrangements with a reputable laboratory. Various restrictions have been placed on the use of sewage sludge (drawn from domestic and industrial sources) in terms of metal and inorganic contaminants

(Table Q8). Restrictions on the nitrogen application rate also apply (Table Q8). No specific South African guidelines are available for organic chemicals in sewage sludges. The United States Environmental Protection Agency maximum annual loading limits for certain organic compounds - as reported by Van der Merwe and Vivier (1994) - are presented in Table Q8. A computer program to assist users (Sludge Land Application Decision Support software - SLADS) will be released in due course by the Water Research Commission.

A useful strategy which could provide employment in certain circumstances (such as in informal settlements), and which helps to protect the environment was investigated by La Trobe and Associates (1994)*. The strategy involves the forced aeration co-composting of primary sewage, particularly night soil or activated sludge, with unsorted and unpulverized domestic refuse. The refuse is used as a bulking and filtering agent. The procedure could be a cost effective method for the integrated stabilization, disinfection and resource recovery for the two polluting waste streams. The final product can be used as a soil conditioner, as landfill cover, or as a solid fuel. More high technology semi-automated processes using the same basic principles (although with wood chips and not refuse), are used at certain sites in South Africa.

17.7.4 Guidelines for irrigation with reclaimed municipal wastewater

Treated wastewaters are classified on the basis of guidelines for reuse, as drawn up by the Department of National Health and Population Development (in terms of the Health Act No. 63 of 1977). The guidelines are applied by the Department of Water Affairs and Forestry (Section 21 of the Water Act No. 54 of 1956), and also by the Department of Agriculture. The guidelines refer to five types of treated wastewaters (Table Q9). It should be noted that wastewater resulting from the use of water for industrial

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* See La Trobe and Associates, 1994. Forced aeration composting of sewage sludge for rural communities, WRC Report No. 341/1/94, Water Research Commission, Pretoria, 62 p. See also, Nell, J.H. and Ross, W.R., 1987. Forced-aeration composting of sewage sludge: prototype study, WRC Report No. 101/1/87, Water Research Commission, Pretoria, various pages.

Table Q9: Guidelines for wastewater irrigation in South Africa.

PS	Primary and secondary treatment; humus tank effluent
PST	Primary, secondary and tertiary treatment
STD	Final effluent must comply with the General Standard
SP-STD	Advanced treatment, with the final effluent meeting the Special Standard. Quality must compare favourably with general drinking water standards
OD	Oxidation ponds with a final effluent having less than 1 000 E. coli organisms 100 $m\ell^{-1}$

Use category	Wastewater treatment method				
	PS	PST	STD	SP-STD	OD
Crops eaten raw	No	No	No	Yes	No
Crops not eaten raw	No	No	Yes	Yes	Restricted
Fruit trees and vines	No	Restricted	Yes	Yes	Restricted
Dry fodder crops	Restricted	Yes	Yes	Yes	Restricted
Seed production	Restricted	Yes	Yes	Yes	Restricted
Pastures (not for milk cows)	No	Restricted	Yes	Yes	Restricted
Pastures (for milk cows)	No	No	Yes	Yes	No
Nurseries	Restricted	Yes	Yes	Yes	Restricted
Timber plantations	Restricted	Yes	Yes	Yes	Restricted
Cut flowers	No	Restricted	Yes	Yes	Restricted
Lawns (associated with children)	No	No	No	Yes	No
Public sports fields					
Development stage	Restricted	Yes	Yes	Yes	Restricted
Non-recreational areas	Restricted	Restricted	Restricted	Yes	Restricted
Recreational areas	No	Restricted	Restricted	Yes	Restricted
School sports fields	No	Restricted	Restricted	Yes	Restricted
Parks					
Development stage	Restricted	Yes	Yes	Yes	Restricted
Non-recreational areas	Restricted	Restricted	Restricted	Yes	Restricted
Recreational areas	No	Restricted	Restricted	Yes	Restricted

Source: After Anonymous, 1986. Management of the Water Resources of the Republic of South Africa, Department of Water Affairs, Pretoria, various pages.

See also:

(i) Murray, K.A., 1987. Wastewater Treatment and Pollution Control, Water Research Commission, Pretoria, 367 p. (The publication contains a more detailed analysis of wastewater disposal options, and should be examined if in-depth information is required).

(ii) PGJ Meiring and Partners, 1982. A guide for the planning, design and implementation of a water reclamation scheme, Water Research Commission, Pretoria, various pages.

(iii) Smith, L.S., 1978. Health considerations in prescribing microbiological quality of effluents, Conference of the Institute of Water Pollution Control (Southern African Branch), 13 - 17 March 1978, Port Elizabeth, 13 p. + app.

(iv) Van der Riet, W.B., Kfir, R. and Van Vliet, B.M., 1992. How water quality standards ensure safe food, South African Journal of Science, VOL 88(2), p. 80 - 84.

(v) Van Rooyen, D.J., 1975. Some soil hydraulic considerations in liquid waste disposal, Water SA, VOL 1(2), p. 83 - 89.

Note:

(i) The terms "No, Yes and Restricted" indicate that wastewater cannot be used for the specified purpose; that wastewater can be used for the specified purpose and thirdly, that wastewater irrigation is permitted, although with certain restrictions.

(ii) Refer to the chapter on water quality for information on the General and Special Standard for the discharge of effluent or wastewater.

(iii) Treated wastewater may not be used in the food industry. Use is permitted with certain restrictions for general industrial/mining purposes, for example for cooling machinery. Disposal to rivers, canals, "estuaries", dams, lakes and the sea (the surf zone), is only permitted subject to treatment up to the General/Special Standard. Further restrictions can be applied such as the Special Standard for Phosphate (see the chapter on water quality). In certain circumstances (excluding the surf zone), the discharge of wastewater treated to primary, secondary and tertiary level may be allowed in some water bodies. Discharge beyond the surf zone will depend on the merits of each case, where all types of treated wastewater could be considered.

(iv) Treated wastewater may not be used for the flushing of toilets, on roads, or for dust abatement unless the wastewater has been treated by primary, secondary and tertiary processes, and/or to the General/Special Standard. Wastewater cannot be used for personal hygiene (unless purified to the Special Standard). Other restrictions may also apply in all cases (Smith, 1978).

purposes* - including municipal wastewater and water from intensive animal feedlots - is public water by virtue of the Water Act. A permit is accordingly required from the Department of Water Affairs and Forestry for the general reuse of this water for watering parks and for similar local authority purposes. The reuse of wastewater by local authorities is limited to the actual vegetation requirements only.

An exemption may be granted by the Department to allow the disposal of treated wastewater by irrigation, in cases where economic or practical difficulties preclude the return of the treated wastewater to the stream of origin. Smaller local authorities (those with a total average dry weather sewage flow of less than 750 m^3 day^{-1} - equivalent to a population of some 5 000 people), are allowed to use oxidation ponds for treatment purposes. The wastewater from oxidation ponds does not usually comply with the General/Special Standard and disposal of the wastewater by irrigation is therefore compulsory (Anonymous, 1986)**.

The salinity and sodium content of treated wastewater requires careful monitoring***, while acid sulphate effluent derived from the mining industry is highly toxic (unless neutralized) to virtually all plants. Synthetic detergents in sufficient concentrations may cause a build-up of phosphate in the soil. The continual use of wastewater containing suspended solids for irrigation purposes will clog the pores of heavy clay soils. In contrast, irrigation of light sandy loam soils also with wastewater containing suspended solids, will improve the soil organic content with limited clogging of pores evident. It is therefore

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* According to Kilani (1985, quoted in) Kilani, J.S., 1993. A compatibility study of the effects of dairy and brewery effluents on the treatability of domestic sewage, Water SA, VOL 19(3), p. 247 - 252., industrial effluents/wastewaters can generally be classified in terms of four main categories, namely: those derived from food and drink industries (such as dairies); effluents produced by industries using animal/vegetable materials as the raw product (for example, tanneries); effluents derived from metal industries (iron and steel works), and effluents from chemical industries (such as petroleum refineries). Only the first two effluent categories are generally biodegradable and are therefore suitable (in certain circumstances), for land disposal.

** See Anonymous, 1986. Management of the Water Resources of the Republic of South Africa, Department of Water Affairs, Pretoria, various pages.

*** See Thompson, J.G., 1985. Guidelines for the disposal of effluent on land in South Africa, SIRI Information Bulletin No. B1/1, Soil and Irrigation Research Institute, Department of Agriculture, Pretoria, 11 p. (The report discusses the suitability of various soils for the land disposal of four types of effluent, including that derived from municipal sources). See also, Anonymous, 1993. South African water quality guidelines, VOL 4, Agricultural use, Department of Water Affairs and Forestry, Pretoria, 286 p., as well as the chapter on water quality.

important to assess local soil conditions when using wastewater containing suspended matter (Anonymous, 1986).

17.8 Hazardous wastes in South Africa

17.8.1 Overview

Numerous issues are relevant in any discussion of hazardous wastes. Only some of the main points are briefly examined here. Readers requiring a more detailed analysis should refer to the following primary documents:

- Anonymous, 1993. Clean production: a preliminary assessment of the need and potential for the introduction of clean technology in some industrial sectors in South Africa, Environmental Monitoring Group: Western Cape, Cape Town, 193 p.

- Anonymous, [1993]. Suggested guidelines for the transport and disposal of hazardous waste: a self-regulatory approach, the Fraser Alexander Group, the Institute of Waste Management and the Southern African Nature Foundation, [Stellenbosch], 15 p.

- Anonymous, 1994. Minimum requirements for waste disposal by landfill, Document No. 1, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 181 p.

- Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p.

- Anonymous, 1994. Minimum requirements for monitoring at waste management facilities, Document No. 3, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 49 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa: executive summary, Department of Environment Affairs, Pretoria, 19 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 1: Situation analysis, Department of Environment Affairs, Pretoria, 96 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 2: Technologies, Department of Environment Affairs, Pretoria, 106 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 3: Policy, Department of Environment Affairs, Pretoria, 61 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 4: Legislative options, Department of Environment Affairs, Pretoria, 72 p.

- Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 5: Impact assessment, Department of Environment Affairs, Pretoria, 114 p.

Note: Papers of relevance to waste management in general can be found in the regular conference proceedings of the Institute of Waste Management (Southern Africa). Not all these papers are published in the formal journals. Readers requiring pertinent information should carefully examine the proceedings. Example: Wastecon '92: Waste Management in a Changing Society, Eleventh Congress, Institute of Waste Management (Southern Africa) and the South African Chemical Institute, 3 - 5 November 1992, Rand Afrikaans University, Johannesburg, various pages. Also of interest are papers presented at anaerobic digestion symposia. The first symposium was held in 1986. The Third Anaerobic Digestion Symposium was held in 1992. For further details contact the International Centre for Waste Technology (Africa), c/o the Department of Microbiology and Plant Pathology, University of Natal, Private Bag X01, Scottsville, 3209.

The final section of the chapter deals with agrichemicals (as a broad component). A number of classification systems are outlined, before some health and environmental implications of agrichemicals in food and especially water are examined. Agrichemicals form an important and special category of hazardous chemicals, and are used extensively in many parts of the world. Agrichemicals moreover, can have unforeseen effects in different ways and over fairly large areas. Certain agrichemicals such as DDT are persistent and may result in long term health and environmental damage, while other substances can cause sudden illness or even death. A significant factor, sometimes overlooked, is that a few of the more dangerous agrichemicals are available to the (untrained) man-in-the-street, while many other types of hazardous chemicals are usually confined to factory (or specialist) premises and waste disposal sites. It is often only when industrial accidents occur, or wilful negligence is evident, that the latter chemicals become problematic in the wider environment. Any consideration of hazardous waste therefore, must include agrichemicals as an inherently dangerous group of commodities, used by many.

17.8.2 Some primary management concepts for hazardous waste*

Several guiding principles were put forward in terms of General Notice 1064/94 for the management of hazardous and other waste in South Africa. The relevant principles involve a number of aspects such as sectoral regulation; allocation of authority; health, safety and environmental protection; affordability; the principle of no bad legacy; the principle that the polluter pays, and self regulation. Further components are the principle of cradle to the grave management; the precautionary principle; public participation and consultation; State remediation and sanction to repair environmental damage, and financial liability for the closure of facilities. An important concept is the recognition that the control of hazardous waste is best undertaken at the lowest level of authority, specifically by provincial and local authorities who are aware of immediate circumstances and problems. Health, safety and environmental issues are of major significance, notwithstanding the recognition of differences between various economic (industrial) and therefore waste sectors, and the need for minimum standards and practices applicable on a sector-by-sector basis.

The waste management and regulation system must be affordable. A balance is required, in order to ensure that the present generation does not leave the following generation with a poor legacy, in respect of contaminated sites and degraded community health. It is accordingly important that the polluter should pay (and not society), for the negative environmental and health effects caused by the polluter himself. Recovery of the direct

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* Discussion based on General Notice 1064/94 (Determination of policy on hazardous waste management in terms of the Environment Conservation Act, 1989 (Act No. 73 of 1989)), as issued by the Department of Environmental Affairs and Tourism and as contained in the Republic of South Africa Government Gazette No. 15987 of the 30th September 1994, Government Printer, Pretoria, p. 16 - 31.

costs of pollution from the polluter is therefore necessary*. The "big stick" approach is not always the best method of control, and it is recognized that a partnership between the public, commerce and industry is essential for successful waste management. Those industries achieving set waste objectives by using a partnership approach may be exempted from certain administrative requirements. Self regulation (a somewhat optimistic concept), however, does not imply an absence of statutory controls, even where public awareness and involvement in waste management is at a maximum.

Successful waste management requires an holistic approach to the waste cycle, beginning with the (envisaged) generation of waste and ending with the recycling, destruction or safe disposal of the waste (cradle to the grave control). Allowance must be made for the transfer of responsibility for waste handling, treatment and disposal to various other parties or agencies involved in the waste cycle, namely, the transporters, brokers and disposers. The latter group includes both treatment plant and disposal site operators. It follows that an important responsibility is borne by the waste generator - who must ensure that his manufacturing process and the resulting products are as environmentally friendly and safe as possible. (Importers of waste, in effect, become generators once the waste has been landed in South Africa). A conservative or precautionary approach to the regulation of waste has been specified to safeguard environmental and health standards. Hazardous waste of unknown composition or hazard must therefore be classified and

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* Landfill services provided by most of the larger local authorities in South Africa are no longer free, in terms of the polluter pays principle. At the New England Road landfill site (owned by the Pietermaritzburg Corporation), the following tariffs are applicable (all per 250 kg load or part thereof), with effect from September 1995:

Builders' rubble and garden refuse	R 2,75
Cardboard and paper; windscreens and glass, and leather trimmings	R 8,25
Condemned food	R11,00
Fine soil and ash	R 1,25
Mixed waste	R 8,25
Industrial ash and clinker; industrial sludges; industrial waste plastics, and industrial wood shavings and sawdust	R 8,25
Tyres (complete casings)	R16,50
Tyres (shredded)	R 8,25

Occasional loads of builders' rubble and domestic as well as garden refuse delivered in a 1 t (or smaller) light delivery vehicle are free, as a service to ratepayers. All wastes generated by industrial and commercial firms are charged for, at the specified tariffs. A standard monthly charge of R18 per house, R15,25 per flat/simplex and R51,75 per factory or commercial site is levied for refuse removed from the premises by the Waste Management Branch of the City Engineer's Department. The levy refers to a weekly maximum of 240 ℓ of waste (three plastic refuse bags or three rubbish bins). In the CBD of Pietermaritzburg, one 240 ℓ Otto bin (a plastic bin on wheels which facilitates mechanization) is allowed per commercial site per week. The New England Road landfill is a Class G:L:B^+ site (see Section 17.13.1). An average of some 430 t day^{-1} of domestic and industrial/commercial waste (excluding liquids) is delivered to the site (data for 1995).

treated on the assumption that the waste is extremely hazardous. The precautions required - and particularly the costs involved - should encourage waste generators, transporters, brokers and disposers to accurately determine the composition of their own waste streams. The recommendation was made in General Notice 1064/94 that regulatory authorities should be involved in planning appropriate waste management systems in association with waste generators and others, in order to reduce or contain environmental and health problems. (This is easier said than done, especially in view of the wide variety of hazardous wastes, and the detailed knowledge essential for the handling and disposal of this waste).

An innovative concept is the recognition that all Interested and Affected Parties should be given the opportunity to help formulate and to review official policy - a procedure authorized by the Environment Conservation Act No. 73 of 1989. Public participation must however, be balanced and a danger exists that policy formulation could be halted or diverted by extremist groups (of any given persuasion), or groups with "impossible" agendas. Allowance in terms of the proposed policy is made for State intervention to remedy environmental degradation caused by contaminated sites or other sources of pollution, with costs recoverable from the responsible parties. The State (in terms of the policy) should also prosecute offenders. Provision has in fact been made by virtue of the Environment Conservation Act and other Acts including the Water Act No. 54 of 1956, for State intervention to clean up the environment and to charge offenders, although a much stricter application of the law is necessary. A welcome addition with regard to policy formulation is the proposed requirement that waste generators, transporters, brokers and disposers of waste will be required (under certain circumstances), to assume financial liability for the rehabilitation and closure of their facilities.

17.8.3 Goals for regulatory authorities

According to General Notice 1064/94 four long term goals must be met by the authorities regulating hazardous and other waste in South Africa. These goals are the maintenance of environmental quality; the effectiveness of management and administrative procedures; international acceptability, and the attainment of minimum standards. It is vital that ambient environmental quality standards for air, water and soil (and which are conducive to health and environmental protection), be attained. The standards should be acceptable to the population of South Africa as well as to those involved in waste generation, management and disposal. The standards must also be based on sound scientific principles and should provide adequate protection for man and the environment, bearing in mind the need for economic development. The efficient management of the waste cycle requires an effective regulatory system and accordingly, the avoidance of duplication with consequent high administrative costs.

There is a growing realization amongst the international community that strict measures are required to protect the environment. In order to avoid international pressures and possible trade embargoes, it is essential that South Africa and many other smaller nations actively support international initiatives aimed at safeguarding the environment. An efficient and internationally acceptable waste regulatory system must not only be applied in South Africa, but must also be seen to be operating properly. An important international agreement, namely, the (Basel) Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, came into operation in May 1992*. The provisions of the Convention (ratified by over 64 countries), came into force in South Africa on the 3rd of August 1994. A feature of the Convention is the commitment of member countries to limit and/or eliminate the production of hazardous wastes, and to reduce the danger to health and the environment by using suitable waste technology. Residual waste must likewise be properly treated. The Convention provides for strict international controls over the cross-border movement of hazardous waste, which is only permissible if required as a raw material for recycling purposes, or if the country of export cannot properly treat or dispose of the waste. The Basel Convention is a major advance in terms of the international management, movement and disposal of hazardous waste. The Convention therefore, has many important ramifications. Other international agreements (formulated under the auspices of the United Nations Environment Programme - UNEP) are the Cairo Guidelines on Environmentally Sound Management of Hazardous Waste (1985); the International Register of Potentially Toxic Chemicals (1985); the Guidelines for Hazardous Waste Management in Asia and the Pacific (1986), and the UNEP Code of Practice (1993) (Anonymous, 1994: Document No. 2)**.

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* A brief examination of the Basel Convention can be found in the following: Cameron, C., 1994. Safe management of hazardous waste products, RSA Review, VOL 7(8), p. 20 - 27. See also, Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 4: Legislative options, Department of Environment Affairs, Pretoria, 72 p.

** See Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p.

In order to achieve international acceptability, prescribed minimum standards must form part of the regulatory system. Minimum standards may be performance based or method orientated. Minimum standards must be applicable to waste generators, transporters, brokers and disposers as well as to their processes and facilities. The minimum standards must be drawn up by a competent organization such as the South African Bureau of Standards. Reference has been made earlier in the chapter to the minimum requirements published by the Department of Water Affairs and Forestry, and which meet international criteria.

17.8.4 Policy and regulatory strategies

General Notice 1064/94 placed considerable emphasis on "pro-active" regulation, in association with self regulation as well as command and control methods. The onus therefore falls on generators, transporters, brokers and disposers who must develop their own specific waste management strategies. Pro-active procedures include waste avoidance and minimization measures; recycling; special treatment and disposal needs; rehabilitation and closure techniques; financial provisions; exemptions from statutory requirements, and additional non-statutory obligations. Pro-active control measures require extra manpower for administration purposes. Accordingly, these methods will initially be applied to waste brokers, disposal site operators and waste generators who dispose of, or who intend to dispose of their hazardous waste in landfills other than those already approved or licensed by virtue of the Environment Conservation Act No. 73 of 1989. In due course, pro-active methods will be expanded to include all generators of specific classes of hazardous waste.

In terms of the proposed policy on hazardous waste management, all generators, brokers, transporters and disposers of prescribed classes of waste will be required to submit relevant waste statistics at selected intervals, to the regulatory authorities. The data will be available to the public - excluding trade secrets or essential business information likely to be used to advantage by a competitor. Official approval for the generation, transport, sale, treatment or disposal of waste will be necessary for some classes of waste which require further control (subject to certain exemptions). Transporters will be regarded as the agents of generators or brokers, and will be jointly responsible for ensuring that the waste is in fact, delivered to the agreed destination. A manifest system will be introduced for the most hazardous classes of waste to ensure delivery compliance. Hazardous wastes must also be classified (as noted above), and will be subject to regulations to control all aspects of the waste cycle. Additional legislation and the use of minimum standards will be introduced to control processes which destroy or alter the composition of waste (for example, through incineration).

The importance of integration was stressed, where regulatory authorities (especially Government departments), must co-operate with each other to ensure the efficient control and regulation of waste. The point was acknowledged that greater efficiency would result from the consolidation of administrative functions on waste management. The need was recognized for a few Acts or preferably one Act which would empower a single department to prescribe waste management policies. The primary regulatory authority must provide a mechanism to deal with conflicts between socio-economic considerations and environmental impacts on air, water and land. Conflicts between regulatory authorities and Interested and Affected Parties must likewise be catered for.

There is currently a general, although not all-encompassing ban on the importation into South Africa, of hazardous or other waste for the purposes of destruction or final land disposal. Much debate has centred on the admission in General Notice 1064/94 that it is not in South Africa's interest to ban all transboundary movement of hazardous or other waste. Two main reasons were given, namely, that neighbouring countries in southern Africa who are unable to effectively treat or dispose of their hazardous waste, should be able to have the waste treated or possibly disposed of in this country. Such a scenario would prevent regional threats to health and the environment through poor waste management practices. The claim was made that South Africa has the resources and infrastructure to establish treatment and disposal facilities, and to operate the facilities according to advanced standards. (If this is so, then why was it necessary to publish General Notice 1064/94? Should South African expertise not be provided "on loan" or at no cost, to other southern African countries in order to solve problems locally in those countries?). The second reason advanced, was that certain items classified as wastes by the Basel Convention are valuable raw materials and are traded internationally. An all-embracing ban on the transboundary movement of waste would have economic and socio-economic implications for specific industries reliant on imported waste. Increased costs to the consumer necessitated by the use of (original) raw materials would be evident. The overall trend towards reuse and recycling would be impaired. (The key to the dilemma would seem to involve the careful selection of waste which can be safely - itself a problematic concept - used in the production processes of this country).

A subregion was envisaged in terms of the proposed policy on hazardous waste, within which a general ban on the transboundary movement of waste to and from South Africa would not apply - although the movement of waste would be subject to regulatory control. It was recommended that a ban be placed on the importation into South Africa of all hazardous waste or other waste intended only for final destruction or disposal. Such a ban would exclude the subregion (the latter was not defined). The export of hazardous waste by South Africa to countries not signatory to the Basel Convention, or to those countries where the importation of hazardous waste has been banned, will not generally be permitted. Any exports of hazardous waste from South Africa will require regulatory authority approval, and must meet the conditions of the Basel Convention. The policy document re-affirmed the role of central Government departments in retaining responsibility for national policy on waste issues.

Further research on both managerial and technological aspects is required for the effective control of the waste cycle, and the point was made that sufficient research funding must be forthcoming*. Finally, General Notice 1064/94 acknowledged that the institutional capacity required to implement the entire hazardous waste management policy (as envisaged) is not currently available, and that an incremental approach should be adopted in South Africa. An incremental approach will also reduce financial demands on the Treasury. The next section provides some brief statistics on the amount of hazardous waste generated in South Africa, before the all important concept of a standard

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* Funding for research on waste management in South Africa has not been adequate in the past, notwithstanding the activities of the Waste Management Programme which formed part of the National Materials Programme. The latter programme was a component of the Cooperative Scientific Programmes/Foundation for Research Development research effort, which was administered by the CSIR in the 1970s and 1980s. (See for example, Cooperative Scientific Programmes, 1984. Environmental research perspectives in South Africa, South African National Scientific Programmes Report No. 84, Cooperative Scientific Programmes, CSIR, Pretoria, 77 p.). CSIR Environmental Services have continued waste management research (albeit under rather different circumstances), and were responsible for the five volume report on hazardous waste as well as the earlier first report on waste management in South Africa. Three main centres of research expertise in Natal/KwaZulu are the Centre for Water and Wastewater Research, Department of Biotechnology, Technikon Natal, P O Box 953, Durban, 4000; the International Centre for Waste Technology (Africa), c/o the Department of Microbiology and Plant Pathology, University of Natal, Pietermaritzburg, and the Pollution Research Group, Department of Chemical Engineering, University of Natal, Private Bag X10, Dalbridge, 4014.

classification system for hazardous waste, which is central to hazardous waste management, is discussed.

17.9 Overall estimates of the hazardous waste generated in South Africa

Noble (1992)* for the period 1990/91, estimated the total industrial and mining hazardous waste stream in South Africa to be of the order of 1,89 x 10^6 t y^{-1} (Table Q10). The data exclude the water content of the waste, or the water with which the waste was discharged or emitted. Waste was defined by Noble (1992) in terms of five categories, with Groups 1 - 3 constituting hazardous waste. Group 4 was allocated to potentially hazardous waste, while Group 5 was for non-hazardous waste. Wastewater accounted for 59,2% of hazardous waste, air emissions 18% and sludges 16,9%, with considerably lesser amounts for solids, slurries, liquids, tars and emulsions respectively. Some 94% of the hazardous waste found in wastewater, consisted of cyanide-containing effluents from the gold mining industry. Inorganic slurries, sludges and solids likewise contained cyanide as well as mercury, arsenic and other heavy metals (which are toxic and mobile). These wastes require chemical treatment and/or immobilization to prevent entry into the environment, before final disposal in a landfill site. Certain organic hazardous wastes are not suitable for disposal by landfill, where alternatives to incineration may be unsatisfactory or extremely expensive. Organic wastes which could be treated by incineration include organic solids, organic sludges and organic liquids as well as tars. Noble (1992) suggested that incineration could also be applied to emulsions, organic wastewaters and organic gases (subject to regulatory permission).

* See Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 1: Situation analysis, Department of Environment Affairs, Pretoria, 96 p.

Table Q10: **The estimated amount of hazardous and non-hazardous industrial/mining waste generated annually in South Africa (assessed for the period 1990/91).**

Type of waste	Hazardous waste (Groups 1 - 3)		Total waste (Groups 1 - 5)	
	$t\ y^{-1}$	percentage	$t\ y^{-1}$	percentage
Air emissions				
Inorganic	136 725	7,2	1 756 505	0,4
Organic	204 943	10,8	215 704	0,05
Wastewater				
Inorganic	1 081 876	57,2	1 882 703	0,5
Organic	34 505	1,8	36 704	0,1
Mixed	3 393	0,2	259 796	0,06
Liquids (organic)	14 606	0,8	17 567	0,004
Emulsions (organic)	1 840	0,1	2 340	0,0006
Tars (organic)	5 005	0,3	77 605	0,02
Slurries				
Inorganic	24 812	1,3	15 501 695	3,7
Organic	0	0	2 000	0,0005
Sludges				
Inorganic	296 412	15,7	317 960	0,08
Organic	925	0,05	36 049	0,01
Mixed	20 846	1,1	76 971	0,02
Solids				
Inorganic	30 066	1,6	1 114 177	0,3
Organic	36 727	1,9	181 087	0,04
Slags	0	0	5 248 458	1,3
Ash	0	0	29 331 200	7,0
Tailings	0	0	275 221 477	65,7
Rubble/spoil	0	0	87 525 000	20,9
Total	1 892 681	100	418 804 998	100

<u>Source</u>: After Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 1: Situation analysis, Department of Environment Affairs, Pretoria, 96 p.

Note:

(i) Group 1 wastes were defined by Noble (1992) as high hazard wastes which contain significant concentrations of very toxic constituents. These constituents are mobile, persistent in the environment, and bioaccumulative. Group 2 wastes are moderately hazardous wastes which have highly dangerous properties and are very explosive, flammable, corrosive, reactive or infectious. Group 2 wastes may also contain high concentrations of constituents which are potentially very toxic, but which are only moderately mobile, persistent or bioaccumulative; or which are moderately toxic although very mobile/persistent or bioaccumulative. Group 3 (low hazard) wastes were defined as moderately explosive, flammable, reactive or corrosive; or which contain significant concentrations of constituents potentially very harmful to human health or to the environment. Group 4 wastes (often found in large quantities), were defined as potentially hazardous wastes, which contain potentially harmful constituents in concentrations which generally represent only a limited threat to health or to the environment. Group 5 wastes were regarded as non-hazardous wastes which at most, contain only insignificant concentrations of harmful constituents. Readers should note that the categories used in Noble (1992) refer to the report series in question, and should not be confused with the South African Bureau of Standards hazardous waste categories discussed below.

(ii) The estimated amount of hazardous waste (excluding water) generated on a sectoral basis for certain mines and industries in South Africa in 1990/91 was as follows: gold mining (1×10^6 t y^{-1}); other mining - excluding coal ($0{,}05 \times 10^6$ t y^{-1}); non-metallurgical manufacturing industries ($0{,}45 \times 10^6$ t y^{-1}); metal and metallurgical industries ($0{,}33 \times 10^6$ t y^{-1}); power generation ($< 0{,}01 \times 10^6$ t y^{-1}), and other service industries ($0{,}03 \times 10^6$ t y^{-1}) (Noble, 1992).

(iii) Data were also provided by Noble (1992) on the amount of hazardous waste generated annually in South Africa, based on waste definitions outlined in the Basel Convention. As indicated in the relevant table (Table 29, VOL 1 - Noble, 1992), hazardous waste does not necessarily only involve waste generated by industries and mines. Certain household items, once disposed of, are hazardous. Examples include batteries (especially mercury batteries); agrichemicals and their containers (see later in the chapter); paint; paint strippers and thinners; oil; brake fluid; fibreglass resins; disinfectants, and medicines.

In commenting on the problems surrounding the investigation of hazardous and other wastes in South Africa, Noble (1992) made the truly chilling point that waste generators themselves (with few exceptions), were not able to provide detailed statistics on the composition or extent of wastes in their own firms. Accurate figures on the cost of waste management and even for materials bought and sold - and energy used in the production process - were likewise seldom available. Waste generators in addition, were very reluctant to provide information on their hazardous waste backlogs being stored (on site or elsewhere), pending treatment or disposal. Viewed holistically, the survey undertaken by CSIR Environmental Services revealed a pervasive lack of knowledge on numerous aspects of waste management in the formal industrial and mining sectors of South Africa. For many firms, the request for data for the survey apparently prompted the first comprehensive assessment of the total waste stream at site level, and the implications thereof (termed life cycle analysis)*. It was evident that many of the waste generators only seriously began to consider internal waste management in 1990 or 1991 (when the survey interviews were conducted). It is not surprizing therefore, that data on the composition and extent of hazardous waste (in particular), should be viewed as conservative. The true nature of hazardous waste in South Africa (with some exceptions), must still be determined.

It is probable that a later survey will provide more detailed data due to a growing awareness of environmental issues. In this regard it should be noted that the Responsible Care Initiative promoted by the Chemical and Allied Industries' Association, Private Bag 34, Auckland Park, 2006 - specifically for the chemical industry - has been adopted by some 104 companies in South Africa (Lotter, 1996)**. The Responsible Care Initiative began in Canada in 1984 and was first applied in South Africa in 1994. The aim of the Initiative is to improve company performance in health and safety, as well as waste management and pollution control, plus community awareness and emergency responses to accidents.

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* Life cycle analysis or assessment involves an examination of the environmental implications of a product or activity. Both direct as well as indirect impacts must be identified for the lifetime of the product/activity. The objective is to quantify the environmental burden, where possible. The life cycle of a product in particular encompasses the extraction, processing and transport of the raw materials plus the manufacture, transport, consumption, reuse (if any), and final disposal of the product. The resources - including energy - used at every stage are an integral part of the analysis. The precise methodology for life cycle analyses has yet to be agreed upon. Some subjectivity is inherent in the procedure (Le Hanie, S., 1996. Personal communication, Department of Environmental Affairs and Tourism, Pretoria).

** See Lotter, L., 1996. The chemical industry: a new way of doing business - Responsible Care, Earthyear, International edition No. 14, November 1996, p. 14 - 15.

Other aims include the safe storage, distribution and transport of chemicals, and product stewardship. The Chemical and Allied Industries' Association is a member of a larger organization, namely, the Industrial Environmental Forum of Southern Africa, P O Box 1091, Johannesburg, 2000. The broad objectives of the Forum similarly, are to increase environmental awareness and performance amongst members.

In 1994, the World Wide Fund for Nature South Africa (formerly the Southern African Nature Foundation), P O Box 456, Stellenbosch, 7599, initiated an annual award for the best environmental report by a South African company. The aim of the award is to promote an understanding of environmental issues amongst firms, and to encourage firms to report on their environmental policies. The overall objective is to improve accountability to the South African population*. Also of relevance is the ISO 14000 series of international environmental management standards (see Chapter 20). Much however, remains to be done with regard to waste management - especially in the smaller centres of South Africa - and by numerous companies who have not made a formal environmental commitment**.

17.10 The classification of hazardous waste according to the South African Bureau of Standards

Wastes vary in nature, composition, appearance, size, volume and the extent of hazard. In order to manage hazardous waste, it is necessary to classify waste using a commonly accepted system, thereby establishing inherent danger. The classification system for hazardous waste presently used in this country is the South African Bureau of Standards (SABS) Code of Practice 0228-1990 (The identification and classification of dangerous substances and goods)***, which is based on the International Maritime Dangerous

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* The Department of Accounting, University of Pretoria, Pretoria, 0002, undertakes an annual review of environmental reporting data provided by companies listed on the Johannesburg Stock Exchange. The information is abstracted from the annual reports of the companies concerned. The first review was published in 1993. See: De Villiers, C.J., 1996. Green reporting in South Africa, fourth edition, Research Report No. 97, Department of Accounting, University of Pretoria, Pretoria, 64 p.

** See Anonymous, 1993. Clean production: a preliminary assessment of the need and potential for the introduction of clean technology in some industrial sectors in South Africa, Environmental Monitoring Group: Western Cape, Cape Town, 193 p.

*** SABS Code of Practice 0228 was first issued in 1990. The Code is currently being updated and extensively revised. The revised version will be made available at a later stage. Readers should contact the South African Bureau of Standards, Private Bag X191, Pretoria, 0001, for further information on the latter document.

Goods Code (IMDG-code). The latter Code compiled by the International Maritime Organization, was developed to control the international transport (by sea) of pure hazardous substances. The Code is based on the chemical properties and toxicity of the substances. The Code was accepted for use in South Africa in 1986 with certain important modifications - such as the inclusion of ecotoxicity and environmental fate as relevant factors. It was also recognized that wastes are mixtures of substances in various proportions. The SABS Code is divided into nine classes ranging from explosives to miscellaneous dangerous substances (Table Q11). The classes are grouped with regard to properties such as toxicity, reactivity, flash point, corrosivity and flammability. Wastes are allocated to a class in terms of their most dangerous constituent. The SABS Code is a comprehensive document which should be carefully examined by those requiring detailed information. A brief explanation of the Code can be found in Anonymous (1994: Document No. 2).

The SABS classification system is an inclusive hazardous waste list which specifically identifies some 4 000 hazardous substances. Each substance family or group has been given a unique identification number. The presence of a listed substance in a waste stream automatically results in regulatory control (Anonymous, 1994: Document No. 2). The absence of a substance from the list however, does not necessarily mean that the substance in question is not hazardous. The SABS Code incorporates a degree of hazard approach to determine whether a waste is hazardous or non-hazardous, and also differentiates between the degree of hazard and therefore disposal methods and site options.

A hazard rating (for all classes of waste) is provided in Class 6 of the Code (Table Q11), where a compound or waste stream is ranked according to the inherent mammalian and ecological (acute and chronic) toxicity of compounds*, as well as environmental fate and

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* The term "acute" refers to a disease of rapid onset, severe symptoms and brief duration. The term "chronic" refers to a disease of long duration, involving very slow changes and often with a gradual onset. "Subacute" describes a disease that progresses more rapidly than a chronic condition, but which does not become acute.

Table Q11: The classification of hazardous waste, in terms of the South African Bureau of Standards Code of Practice 0228-1990 (The identification and classification of dangerous substances and goods).

Class	Description
Class 1	Explosives
Class 2	Gases: compressed, liquified, dissolved under pressure or deeply refrigerated
Class 2.1	Flammable gases
Class 2.2	Non-flammable gases
Class 2.3	Poisonous gases
Class 3	Flammable liquids
Class 3.1	Low flashpoint group of liquids with a closed-cup flashpoint below -18°C
Class 3.2	Intermediate flashpoint group of liquids with a closed-cup flashpoint of -18°C up to, but not including 23°C
Class 3.3	High flashpoint group of liquids with a closed-cup flashpoint of 23°C up to, and including 61°C
Class 3.4	Very high flashpoint group of liquids with a closed-cup flashpoint of more than 61°C up to, and including 100°C
Class 4	Flammable solids or substances
Class 4.1	Flammable solids
Class 4.2	Substances liable to spontaneous combustion
Class 4.3	Substances which emit flammable gases when in contact with water
Class 5	Oxidizing substances and organic peroxides
Class 5.1	Oxidizing agents
Class 5.2	Organic peroxides
Class 6	Poisonous (toxic) and infectious substances
Class 6.1	Poisonous (toxic) substances
Class 6.2	Infectious substances
Class 7	Radioactive substances
Class 8	Corrosives
Class 9	Miscellaneous dangerous substances. (Any substance not covered by the other classes, but which has been or may be shown by experience, to be of such a dangerous character that the provisions of this section should be applicable)

<u>Source</u>: After Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p.

<u>Note</u>:

(i) The Class 1: Explosives category has been further divided into five classes, namely: Class 1.1 Substances/articles which have a mass explosion hazard; Class 1.2 Substances/articles which have a projection hazard (but not a mass explosion hazard); Class 1.3 Substances/articles which have a fire hazard and either a minor projection hazard or a minor blast hazard or both, but not a mass explosion hazard; Class 1.4 Substances/articles which present no significant hazard, and Class 1.5 Substances which are very insensitive, but which have a mass explosion hazard. (Note: Anonymous (1994 - above) refers to divisions, for example, Division 1.1 whereas SABS Code of Practice 0228-1990 refers to Class 1.1).

(ii) Class 6.1 substances are divided into two further classes. Class 6.1(a) refers to all poisonous (toxic) substances including pesticides (agrichemicals) in Hazard Group 1 (as defined by SABS Code 0228). Class 6.1(b) refers to all poisonous (toxic) substances including pesticides (agrichemicals) in Hazard Group 3 (as defined by SABS Code 0228).

(iii) Class 9 has been allocated for compounds difficult to classify according to the definitions contained in SABS Code 0228. Examples of such compounds include acenapthene, acetylaminofluorene, adipic acid, aerosol dispensers and anthracene. If wastes contain Class 9 compounds or products and the compounds are listed in SABS Code 0228, then the Department of Water Affairs and Forestry must be notified before classification according to hazard (as specified by criteria outlined in Class 6). Written approval must be obtained from the Department before disposal. It is also a requirement that the Department should be consulted before the classification of any substances which are <u>not listed</u> in SABS Code 0228.

(iv) Substances/goods listed in SABS Code 0228 have been allocated to one of four danger groups, on the basis of the degree of danger/hazard of the primary property of the substance/good. Danger Group 1 substances/goods accordingly, pose a very severe risk; Danger Group 2 a serious risk, and Danger Group 3 a relatively low risk. Danger Group 4 substances/goods constitute a very low risk. Substances/goods in Classes 1, 2, 6.2 and 7 have not been assigned to a danger group.

the Estimated Environmental Concentration (EEC) principle*. The EEC is used to provide a concentration level and assimilation capacity, where compounds above a certain threshold concentration are regarded as hazardous. Four hazard groups have been specified, namely: Hazard Group (or Rating) 1 - extreme hazard; Hazard Group (or Rating) 2 - high hazard; Hazard Group (or Rating) 3 - moderate hazard, and Hazard Group (or Rating) 4 - low hazard.

The Code also incorporates a delisting by exemption approach, where waste generators are allowed to undertake tests to prove that their wastes are either less hazardous or are non-hazardous. If acceptable proof can be provided, then these wastes may be exempted from disposal in a hazardous waste site, and can be disposed of in a general landfill site equipped with a leachate management system. It is important to note that the SABS Code is to be expanded to include a no effect or no risk level. A list of substances will be made available in due course, which will specify chemicals in given concentrations (or quantities) which do not pose a danger to health and the environment. Such a listing will simplify waste management in general. Of particular importance is a planned extension to the Code which will provide a convenient means of identifying and classifying substances for waste disposal purposes. The Code therefore, is not a fixed or static document and will be updated from time-to-time according to circumstances (Anonymous, 1994: Document No. 2).

17.10.1 The identification of a probable hazardous waste

The identification of hazardous waste is an important process. Identification is required where permit conditions as stipulated by the Department of Water Affairs and Forestry must be met. Identification is likewise essential where illegal waste operations have taken

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* Environmental fate refers to the persistence and accumulation potential of waste in the broader environment and especially in the soil profile and in groundwater. The Estimated Environmental Concentration is defined as the concentration of a substance in the aquatic environment where the substance is introduced directly into the water body (the worst case scenario). The EEC is used to indicate possible risk, by comparison with the minimum estimated concentration which would adversely affect aquatic life, or which would result in unacceptable concentrations in biota, sediment or water.

place in the past, or where waste has been carelessly dumped. As outlined earlier in the discussion, it is a prerequisite that any unknown waste suspected or believed to be harmful to man and/or the environment, must be regarded as hazardous (pending confirmation). The origin of the waste stream or substance, namely the industrial activity, process (or waste stream itself) provides the first important clue - especially if specific industries known to be handling hazardous materials can be identified. The waste in question should be carefully examined to determine its properties as well as possible source/s, either in terms of a group of industries or a particular factory or industrial process. The Basel Convention definitions of waste should also be consulted (Anonymous, 1994: Document No. 2).

The next step involves the physical and chemical confirmation that the waste is hazardous. It is essential that the various constituents of the waste are carefully identified during testing. If the properties of a constituent or compound in the waste conform to the list of hazardous characteristics of the Basel Convention; or the constituent or compound is listed in SABS Code 0228, then the waste is hazardous. If however, the constituent or compound is not mentioned in the SABS Code, although its properties conform to the Basel Convention (or to one or more of the nine SABS classes), then the waste must be regarded as a probable hazardous waste. In the latter instance, the Department of Water Affairs and Forestry should be approached for technical assistance to establish whether the waste is hazardous, and to confirm the disposal class (discussed later) and hazard rating. Waste which has been positively identified as non-hazardous can be regarded as general waste.

Determination of the hazard rating is an important part of hazardous waste management, and refers specifically to the treatment and final disposal of the waste (excluding gases and radioactive waste). The hazard rating will also indicate whether the waste can be disposed of without danger to health or the environment. The hazard rating of a waste is undertaken in terms of the SABS Class 6 category (as described above). More restrictive conditions apply for very hazardous wastes. The hazard rating is not fixed and can change following appropriate treatment of the waste (in effect, treatment of the most hazardous component of the waste - as per the precautionary principle). It is entirely feasible therefore, for the waste to be placed in a less hazardous class, or even to reclassify "hazardous" waste as general waste for final disposal purposes. The minimum requirements for waste treatment and disposal published by the Department of Water

Affairs and Forestry are set according to the classification and hazard rating of wastes. Although the minimum requirements may specify certain classes of waste which must be treated prior to final disposal, the precise treatment methods are often not prescribed. Treatment methods are dependent on the nature of the wastes plus available technology and current practice, as well as suitable treatment/disposal facilities and the cost effectiveness of various options. The updated SABS Code 0228 will provide a guide to preferred, allowed and unacceptable treatment technologies for numerous hazardous compounds and wastes (Anonymous, 1994: Document No. 2).

17.11 Waste handling, storage and transportation*

The Department of Water Affairs and Forestry has specified a number of minimum requirements for waste handling, storage and transport (Anonymous, 1994: Document No. 2). All wastes must be accumulated at the point of origin, and must not be mixed or stored with other wastes which have a different nature or composition (in order to avoid violent reactions or fire or other dangerous events). Waste placed in a container for temporary storage must be correctly identified before storage. Temporary storage sites must be properly designed with a firm waterproof base which is protected from surface runoff, and which has an effective drainage system to cater for spillage. The waste generator must take all possible measures to recover any hazardous waste and polluted water which escapes from the storage site as a result of storm damage or for any other reason. Hazardous material must not be allowed to enter watercourses, sewers or stormwater drains. Where spillage cannot be contained on site, both the Department of Water Affairs and Forestry as well as the local authority must be promptly informed so

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* Several SABS codes of practice and specifications dealing with the handling, storage and transport of hazardous substances (including waste), are available. The most important documents which should be carefully examined where relevant, include the following: SABS Code of Practice 0229-1990 (Packaging of dangerous goods for road and rail transportation in South Africa); SABS Code of Practice 0230-1992 (Transportation of dangerous goods - inspection requirements for road vehicles); SABS Code of Practice 0231-1992 (Transportation of dangerous goods - operational requirements for road vehicles); SABS Code of Practice 0232-1:1995 (Transportation of dangerous goods - emergency information system for road transportation); SABS Code of Practice 0233-1992 (Intermediate bulk containers for dangerous substances), and SABS Specification 1560-1992 (Corrugated fibreboard boxes for dangerous goods). Codes of practice and specifications can only be legally enforced in terms of Section 33 of the Standards Act No. 30 of 1982, or where incorporated by regulation into a specific Act. Numerous changes are underway with regard to hazardous substances control in South Africa and further SABS codes of practice and specifications are being prepared, or are being updated (such as SABS Code of Practice 0228). Note that SABS Code of Practice 0232-1:1995 namely, Part 1, deals with road transportation. Part 2 of the same document (yet to be published) will address transportation by rail. Part 3 (also still to be published), will specify initial emergency action to be taken by the first responder (usually the traffic police) at the scene of an accident.

that remedial action can be taken to minimize adverse effects. Any waste generator who treats or stores for more than 90 days or who disposes of hazardous waste on site, must obtain a permit in terms of Section 20(1) of the Environment Conservation Act. The site is then regarded as a waste disposal site and must comply with all the necessary requirements (discussed later in the chapter). The amount of hazardous waste which can be stored on site for less than 90 days without a permit, has been strictly defined in Document No. 2. Various storage requirements are likewise described in Document No. 2.

Hazardous waste must be properly contained (as per the nature of the waste) during handling, storage and transport to avoid risks to health and the environment. Containers must be able to withstand both the hazardous waste and the handling process, and must also be correctly labelled with regard to SABS procedures. Intermediate bulk containers are necessary for larger quantities of waste and must likewise be labelled in terms of SABS requirements. Warning (HAZCHEM) signs on vehicles transporting bulk containers (discussed below), should be prominently displayed and must be designed in accordance with SABS stipulations.

An important concept is the duty of care principle where the waste generator or his appointed agent (the transporter), must ensure that the hazardous load is safely carried and delivered to the specified final disposal site (as per the cradle to the grave principle), or to the factory premises, if recycling is to be undertaken. A hazardous substances manifest describing inter alia the nature of the substance/s, accompanies each load to the point where the material is correctly and legally disposed of. A copy of the manifest is then returned to the waste generator. The purpose of the manifest is to guard against illegal dumping or disposal in an unauthorized site.

The leakage or spillage of hazardous materials on roads as well as railways creates special circumstances. The driver of the vehicle has a primary responsibility to ensure the safety of other road users, to contact his company or the nearest emergency services office, and to control traffic. Although it is the duty of the waste generator or the transporter to clean up the spillage, to remove contaminated soil or vegetation (where relevant) and to prevent further damage, this is sometimes undertaken by emergency services staff in view of the urgency of the situation. A waste disposal contractor may be appointed to complete the task after emergency services personnel have withdrawn. All road accidents involving hazardous materials must be reported in writing to the Department of Transport and the Department of Water Affairs and Forestry (Anonymous, 1994: Document No. 2).

17.12 Emergency hazardous materials procedures in Natal/KwaZulu

Local authority emergency services consist of traffic police and the fire brigade, who should be able to deal with most "routine" spillages. Requests for further on site assistance by local authority emergency services in the Natal Midlands and northern Natal are directed to the Pietermaritzburg Fire and Emergency Services; while the Durban Fire and Emergency Services will provide assistance in the North Coast, Zululand, Port Natal, southern Natal and East Griqualand areas. A HAZMAT (hazardous materials) response team is then sent to the site. The specialized HAZMAT response teams called in by local authority emergency services unable to cope on their own, consist of a team commander, a traffic control section, a chemicals section, a fire section, a medical section, and an environmental section composed inter alia of Department of Water Affairs and Forestry and/or Umgeni Water personnel. A number of large companies such as Spoornet and AECI Ltd, have HAZMAT teams for the areas or premises under their control. Company HAZMAT teams (if available locally), may be required to help at the scene of road (or rail) accidents involving very hazardous substances transported by company vehicles.

Regional Natal Provincial Administration Ambulance and Emergency Medical Services (AEMS) Metro centres in Pietermaritzburg, Ladysmith, Empangeni and Port Shepstone, or the AEMS Metro Natal headquarters in Durban, will co-ordinate medical services (if necessary) for the treatment of victims at hazardous chemicals incident sites. AEMS personnel may also be required to treat any injuries sustained by emergency services staff. It should be borne in mind that AEMS is the provincial co-ordinator for emergency medicine and rescue, which includes major disturbances such as fires, floods, civil unrest and mass poisoning*.

An analysis of HAZMAT incidents attended to by the Pietermaritzburg Fire and Emergency Services within the city limits as well as per agreed attendance areas - see above - revealed that approximately two call-outs a month were undertaken in the period July

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* South African Airforce helicopters based in Durban (15 Squadron) will airlift casualties to hospitals in Durban and Pietermaritzburg if required.

1992 - May 1995*. Besides petrol, diesel, paraffin and oil, other road/rail spillages and leaks from premises or the contamination of premises involved the following substances: acetone (Class 3.1); creosote (Class 9); ethyl mercaptan (Class 3.1); ferric sulphate (liquid) (Class 9); hydrochloric acid (Class 8); liquified petroleum gases (Class 2.1); methamidophos (Class 6.1); methyl ethyl ketone (Class 3.2); methylene chloride (Class 6.1); nitric acid (Class 8); phenol (liquid) (Class 6.1), and sodium hydrosulphite (Class 4.2). No serious (chemical) injuries resulted from such incidents, although several people were treated for substance inhalation, with particular reference to leaking containers of methamidophos (an organophosphate insecticide).

Approximately four HAZMAT call-outs a month were undertaken by the Durban Fire and Emergency Services within the municipal boundary as well as in other parts of Natal/KwaZulu, during the period March 1993 - November 1995. Substances which required attention (excluding chemicals already listed above) were the following: ammonium hydroxide (Class 9); caustic soda (Class 8); chlorine (gas) (Class 2.3); cresols (Class 6.1); ethyl acrylate (Class 3.2); ethylenediamine (Class 8); hydrogen peroxide (Class 5.1); isopentane (gas) (Class 3.1); methanol (Class 3.2); methylated spirits (Class 3.2); phosphoric acid (Class 8); propanol (various types) (Class 3.2); propyl alcohol (Class 3.2); propylene (Class 2.1); sulphuric acid (Class 8), and tetrachloromethane (Class 6.1).

TO REPORT HAZARDOUS MATERIALS INCIDENTS OR ANY OTHER EMERGENCY PHONE 10177 (NO AREA CODE) AT ANY TIME.

For further information contact:

- Ambulance and Emergency Medical Services, Private Bag X01, Dalbridge, 4014.

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* Data provided by the Pietermaritzburg Fire and Emergency Services as well as by the Durban Fire and Emergency Services refer to incidents attended to by the respective Services. The data do not reflect all incidents in the given areas (some of which were not reported, or were attended to by in-house staff or waste disposal contractors). A few call-outs concerned suspected rather than actual incidents, where no action was required. The data provide an indication of some of the chemicals encountered in HAZMAT situations. A conservative estimate of approximately five million litres a day for hazardous chemicals carried in tankers along the N3 freeway at Mariannhill, was derived in a field survey undertaken in May 1996 by the Pietermaritzburg Fire and Emergency Services. This volume includes about 900 000 ℓ of petrol or derivative products as well as 450 000 ℓ of liquified petroleum gases.

- Durban Fire and Emergency Services, P O Box 625, Durban, 4000.

- Pietermaritzburg Fire and Emergency Services, Private Bag 321, Pietermaritzburg, 3200.

17.12.1 The HAZCHEM system*

The HAZCHEM (hazardous chemicals) system is a British system of identifying chemical loads carried on land, and became compulsory in South Africa in June 1987 (in terms of the Hazardous Substances Act No. 15 of 1973). The system provides a method for the rapid identification of families or groups of hazardous substances (gases, solids and liquids), and accordingly the remedial action to be taken to prevent loss of life or damage to health and/or the environment. An example of a HAZCHEM sign attached to the back of road or rail tankers is given below. The sign is divided into five parts. The HAZCHEM code indicating procedures required to deal with any incidents is interpreted by means of a scale card (see below) carried by emergency services personnel. The UN (United Nations) number identifies the particular chemical being transported. Emergency services personnel can obtain further information on the properties of the chemical from their operational control, by quoting the UN number. The sign also gives the name of the chemical, which is primarily intended for control purposes in factories during the filling and emptying of the container. A telephone number is provided should specialist advice from the manufacturer or supplier be required. The manufacturer or supplier's name or logo is likewise indicated.

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* Discussion based on Coucom, B.A., 1988. The transportation of hazardous substances, Environmental Technology Workshop, South African Chemical Institute (Natal Branch), 22 - 26 August 1988, Durban, 24 p. See also, Partridge, A., 1991. SABS action on transporting hazardous products, ChemSA, VOL 17(6), p. 139 - 140.

The HAZCHEM sign

<table>
<tr><td>HAZCHEM
2X</td><td colspan="2" rowspan="2">POISON</td></tr>
<tr><td>UN No.
2312
Phenol Molten</td></tr>
<tr><td colspan="2">Specialist advice
Phone number</td><td>Company
logo</td></tr>
</table>

The hazard (warning) diamond (not shown in the example), indicates the nature of the hazard associated with the cargo through a combination of words, colours and pictograms, for example, corrosive (black and white) or toxic (white). Where multi-loads are transported, the hazard diamond will display a large exclamation mark, if various hazards are evident. In the case of multi-loads, the UN number is omitted and is replaced by the word "multi-load". It should be noted that the HAZCHEM signs as well as the hazard diamonds currently in use, are being changed.

The use of the HAZCHEM scale card is relatively simple. The card is divided into several parts, where the numbers 1 - 4 indicate the correct fire fighting medium to be used if the vehicle is on fire. In cases where more than one medium can be used, only the most suitable method is given.

The HAZCHEM scale card

1	Jets
2	Fog
3	Foam
4	Dry agent

HAZCHEM	◇
UN No.	

P	V	FULL	DILUTE
R			
S	V	BA	
S		BA for FIRE only	
T		BA	
T		BA for FIRE only	
W	V	FULL	CONTAIN
X			
Y	V	BA	
Y		BA for FIRE only	
Z		BA	
Z		BA for FIRE only	

E	CONSIDER EVACUATION

FOG
In the absence of fog equipment a fine spray may be used

DRY AGENT
Water must not be allowed to come into contact with the substance at risk

V
Can be violently or explosively reactive

FULL
Fullbody protective clothing with BA

BA
Breathing apparatus and protective gloves

DILUTE
May be washed to drain with lots of water

CONTAIN
Keep spillage out of drains or watercourses

CHEMICAL EMERGENCY INFORMATION CENTRE PHONE: JHB CITY FIRE DEPT. (011) 331-2947

The numbers are self-cancelling. Where for instance the numeral 2 appears, medium No. 3 and 4 could be used, but never No. 1. The letters P to T indicate that the spillage may be diluted and flushed away, while the letters W to Z indicate that the material must be contained until further advice is available. The letters P, S, W and Y warn of the risk of a violent reaction occurring. The letters S, T, Y and Z may be orange-on-black, instead of black-on-orange, and will then indicate that only personnel involved in active fire fighting need to wear breathing apparatus. The letter E indicates that consideration must be given to the evacuation of the area. The code 3YE for example, denotes that emergency services personnel should wear breathing apparatus, that the substance may present a risk of violent or even explosive reaction, that it should not be washed into drains, that the extinguishing medium is foam, and that there is a risk which might require evacuation of the surrounding area. If the letter Y is orange-on-black, then emergency services personnel other than those involved in fire fighting need not wear breathing apparatus.

Lists of HAZCHEM codes and UN numbers are published in relevant issues of the Republic of South Africa Government Gazette*. UN numbers can also be found in SABS Code of Practice 0228-1990 (the primary source document). Fire departments of major local authorities in South Africa (including Pietermaritzburg and Durban) maintain computerized databases of UN numbers. The AEMS Metro headquarters in Durban likewise, has a computerized database of UN numbers. With reference to Natal/KwaZulu, chemical manufacturers, transport firms and depot companies must ensure that their product information is available in one of the three main databases. Reputable road hauliers also carry a Tremcard (Transport Emergency Card) containing product and other information specific to the load being transported, and which may be necessary for remedial action by emergency services personnel. Tremcards are now being replaced by Material Safety Data Sheets (MSDS), which provide more detailed information.

Anyone witnessing a chemicals incident should report, if possible, the UN number or if trained in chemistry, the particular substance as indicated on the HAZCHEM sign attached to the vehicle. The SOS telephone boxes situated along part of the N2 and N3 freeways can be used to report the spillage of chemicals on those freeways. The next part of the chapter examines the classification and permitting of landfill sites in South Africa.

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* For a listing of the various substances and HAZCHEM codes plus signs, see Cooper, W.E., 1985. Road Transport: Commentary on and Text of Road Transportation Act and Regulations, Juta, Cape Town, various pages. (The publication contains inter alia the regulations governing the conveyance of hazardous substances by road tankers, namely, Government Regulation Notice GN R73/85, as amended by GN R1554/85, both issued in terms of the Hazardous Substances Act No. 15 of 1973). The revised HAZCHEM signs and hazard diamonds for road transport are illustrated in SABS Code of Practice 0232-1: 1995. Similar information for rail transport will be provided in Part 2 of the latter document (yet to be published).

17.13 Landfill site classification in South Africa

The landfill site classification system used in South Africa was changed in 1994. Landfill sites were previously classified according to the types of wastes which could be safely received, and the permeability of the underlying strata (whether natural or man-made) at the site. Four classes of landfill sites were designated. Class 1 sites consist either of containment lagoons for liquids and certain industrial sludges; or containment landfills for dry wastes, industrial sludges and limited volumes of liquid waste, co-disposed with general urban solid waste (Lombard, Botha and Rabie, 1992)*. Class 1 sites are specifically designed to contain and isolate special wastes from the environment. The underlying unsaturated zone of suitable thickness should have a permeability in the range of $k \leq 10^{-6}$ to 10^{-8} cm s^{-1}. Any synthetic materials used should have a permeability of $k \leq 10^{-28}$ cm s^{-1}. Particular care must be taken in the selection of Class 1 waste disposal sites where a low water table, low permeability soils and a weathered rock strata - combined with the use of a suitable synthetic barrier membrane - must preclude the seepage of leachate into the underlying layers during operation and after closure. Poorly located or managed Class 1 sites can result in severe health and environmental hazards. Rehabilitation of these sites is both difficult and expensive, and the land cannot be used for any other purpose.

Class 2 sites are of two types, namely: Class 2 domestic sanitary landfill sites for domestic, garden and commercial wastes; and Class 2 co-disposal sanitary landfill sites, where municipal solid waste is co-disposed with certain industrial wastes (of a given chemical nature). The permeability of the unsaturated zone in Class 2 sites should be of the order of $k \leq 10^{-5}$ cm s^{-1}. Class 3 and 4 sites, although in use in South Africa, are not acceptable for environmental reasons and should be closed and rehabilitated as soon as possible. Class 3 sites comprise land such as seasonal wetlands, where the waste comes into contact with the water table in the rainy season (and not during the dry months). A "pulsed" groundwater pollution plume is then evident downstream of the site. Class 4 sites - often found in permanent wetlands, "estuaries" and in certain quarries - are those where the waste is constantly in contact with the water table. A well developed and continuous groundwater pollution plume is accordingly present below the site (Lombard et al, 1992). Both Class 3 and Class 4 sites are especially common along the coast of

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* See Lombard, R., Botha, L. and Rabie, M.A., 1992. Chapter 19. Solid waste, In: Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Juta, Cape Town, p. 493 - 522.

Natal/KwaZulu and are still (in some cases), being used to dispose of garden waste and builders' rubble.

The new landfill classification system for South Africa, as approved by the Department of Water Affairs and Forestry, provides for 10 different landfill classes (Anonymous, 1994: Document No. 1). Waste in terms of the new system is divided into two types, namely, general waste and hazardous waste. General waste is defined as all urban waste produced within a local authority area and consists of domestic and garden waste, as well as rubble, plus commercial and general (dry) industrial waste. Small amounts of hazardous substances (for example, batteries, agrichemicals and medical waste) derived from domestic and commercial premises, are found in general waste. General waste can be disposed of in any permitted site. Hazardous waste by contrast, can only be disposed of in selected landfill sites. The new landfill classification system defines the disposal method and identifies the type of landfill which would be most suitable for the specific category of waste (general or hazardous). Also defined is the size of the waste stream and accordingly the size of the landfill operation; as well as the potential for water pollution by leachate (the latter with respect to general sites only).

17.13.1 General landfill sites

The size of general landfills depends on the population served as well as industrial/commercial activities, and therefore the daily rate of waste deposition*. In order to ensure that the minimum requirements apply to the final envisaged size of the landfill, it is necessary to determine the Maximum Rate of Deposition (MRD), which is the projected maximum mean annual rate of waste deposition (t day^{-1}) during the expected life of a landfill site**. The MRD is then used to establish four general landfill size classes, namely: communal (MRD less than 1 t day^{-1}); small (MRD more than 1 t day^{-1}, but less than 25 t day^{-1}); medium (MRD more than 25 t day^{-1}, but less than 500 t day^{-1}),

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* An important factor affecting the amount of industrial/commercial waste is the state of the local economy. A depressed economy results in a reduced volume of waste. Also relevant - as discussed earlier - is the impact of recycling programmes.

** In order to calculate the MRD, the Initial Rate of Deposition (IRD) must first be determined, namely, the existing waste stream (t day^{-1}). The IRD is then escalated at a rate which is usually based on the projected growth in population for the design life of the site. The maximum mean daily rate of deposition (usually achieved in the final year of operation) represents the MRD. Both the IRD and the MRD are based on a five-day week, adjusted if necessary from a seven-day week.

and large (MRD in excess of 500 t day^{-1}). In borderline cases, the higher size class must be used. It follows that more stringent minimum requirements are applicable at larger landfill sites (Anonymous, 1994: Document No. 1).

General landfill sites are further classified on the basis of their potential for leachate generation and therefore water (especially groundwater) pollution. Leachates may be generated on a sporadic or seasonal/annual (significant) basis. Sporadic leachate generation occurs in certain abnormal circumstances, for example, during periods of high rainfall or due to poor site drainage. A leachate containment system consisting of a very low permeability geomembrane liner and/or a low permeability soil or clay liner placed along the base of the site - as well as a series of drains leading to a collection sump and containment dam - would not usually be necessary in this regard. The site must however, be correctly managed.

Significant leachate generation requires an effective management system, where the site must be carefully designed and controlled to reduce leachate production in the first instance. A good quality leachate is also important. Containment of the leachate is essential. All leachate collected, must be treated to an acceptable standard (prior to release in the environment), as specified by the Department of Water Affairs and Forestry. Determination of the need for advanced leachate management (in cases of anticipated or actual significant leachate generation), depends on the climatic water balance of the site in question. The water balance in turn, is a function of climate (seasonal rainfall and evaporation rate)*; the moisture content of the waste; surface or groundwater entry to the site, and poorly located, designed or managed landfills. The climatic water balance is used to establish whether water deficit or water surplus conditions apply at the site, and therefore whether sporadic or significant leachate generation will occur. General landfill sites with sporadic leachate generation are classified as B^- sites, with significant leachate generation resulting in a B^+ classification. No advanced leachate management programme (or containment system) is regarded as necessary at B^- sites - provided that the minimum requirements for the siting, design and operation of these sites are met, and that only dry waste is disposed of at the site. Functional leachate management and containment is a minimum requirement however, at B^+ sites (excluding communal sites), with increasing

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* The primary factors in calculating the water balance at a landfill site are rainfall and evaporation. Only a simplified calculation is needed. Refer to the chapter on rainfall elsewhere in this publication for sources of relevant data available inter alia from the Weather Bureau.

complexity according to the size of the site. Calculation of the climatic water balance (as specified in Anonymous, 1994: Document No. 1), is conservative and ignores runoff from the surface of the landfill site, as well as the moisture storage capacity of the waste body. In the event of an inconclusive investigation to determine a B^- or B^+ classification, it is necessary to reassess the climatic water balance by means of a suitable computer program such as the Hydrologic Evaluation of Landfill Performance (HELP) Model.

Additional factors influencing the water balance, for example surface or groundwater inflow, may result in the classification of the general landfill site (as determined by rainfall and evaporation) being changed from B^- to B^+. Circumstances could include sites where the excavation is too deep with consequent penetration of the water table, or where groundwater is at or near the ground surface. Significant leachate generation may also be evident in landfill sites situated across watercourses or drainage lines - effectively forming a dam with entry of water to the waste body. Other conditions resulting in significant leachate generation can include sites where surface ponding is apparent (with consequent infiltration of water), and the failure of drainage systems allowing runoff to enter the site. The co-disposal of waste with a high moisture content as well as liquid waste imposes a hydraulic loading on the site. Accordingly, more detailed water balance calculations may be required, where the site is usually classified as B^+.

General (G) landfill sites can be classified in terms of eight classes, namely: G:C:B^- or G:C:B^+ (communal sites); G:S:B^- or G:S:B^+ (small sites); G:M:B^- or G:M:B^+ (medium sites), and G:L:B^- or G:L:B^+ (large landfill sites). Once existing or proposed landfill sites have been categorized according to the landfill classification system, the various minimum requirements which apply to the particular site must be identified and put into practice. (See Anonymous, 1994: Documents Nos. 1 - 3).

17.13.2 Hazardous landfill sites

The classification of hazardous (H) landfill sites is based only on the Hazard Rating of the waste (discussed earlier in the chapter). Any landfill which receives considerable quantities of liquid or solid hazardous waste per se, or significant amounts of such waste plus general waste, is a hazardous landfill site. Sites receiving all types of hazardous waste (Hazard Rating 1 - 4) must be designed, engineered and operated to the most exacting standards, where the waste and leachate must be fully contained and prevented from entering the environment at any point. A sophisticated liner and an advanced leachate collection/management system is essential. Very hazardous (Hazard Rating 1 - 2) wastes must be disposed of in H:H sites. Sites receiving Hazard Rating 3 and 4 (less hazardous) wastes are termed H:h sites. Note that Hazard Rating 3 and 4 wastes can be disposed of in H:H sites. The designation of a given landfill site (whether general or hazardous) is not fixed for all time, and may change as a result of circumstances. The appropriate minimum requirements then become applicable.

17.13.3 Current landfill site conditions

No overall statistics are available on the exact number of waste disposal sites in South Africa, although the Department of Water Affairs and Forestry has identified approximately 1 400 sites, of which 210 have been permitted (as at December 1995). Five H:H sites (three in the Cape Province and two in the Transvaal) are found in South Africa*. There are three H:h sites in Natal/KwaZulu (all in the Durban Functional Region). Parsons (1992)** estimated that it will take approximately 50 years at the current rate of processing, to issue fully operational permits for all presently identified waste disposal sites in this country. The implications of slow progress remain to be seen.

Few landfill sites in South Africa meet the minimum requirements for their class, especially in terms of liner design, operational needs, and the final cover or layer of soil applied when the site is closed (Anonymous, 1994: Document No. 1). Noble (1992)*** observed that poor waste management practices as well as the illegal disposal of waste are apparent in all industrialized countries. The bad legacy principle therefore applies, where present (and future) generations are required to rehabilitate or to isolate dangerous disposal sites;

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* The three sites in the Cape are found near Cape Town, Mossel Bay and Port Elizabeth. The two sites in the Transvaal are in the vicinity of Germiston (closed at the end of 1995), and Springs. The three H:h sites in Natal/KwaZulu are located at Chatsworth, Shongweni and Umlazi. The latter site is nearing the end of its lifespan and will be closed in the near future. Some 200 t of Hazard Rating 1 and 2 waste is generated in Natal/KwaZulu every year. The waste is sent to H:H landfills outside the province.

** See Parsons, R., 1992. Monitoring and assessment. Preventing groundwater contamination by waste disposal activities: are we doing enough?, Wastecon '92: Waste Management in a Changing Society, Eleventh Congress, Institute of Waste Management (Southern Africa) and the South African Chemical Institute, 3 - 5 November 1992, Rand Afrikaans University, Johannesburg, 14 p.

*** See Noble, R.G. (ed), 1992. Hazardous waste in South Africa, VOL 1: Situation analysis, Department of Environment Affairs, Pretoria, 96 p.

and to decontaminate factory premises and sometimes the landscape (which may now be a residential area, or in very close proximity to a residential area)*.

A first assessment of the possible extent of landfill problems in South Africa was undertaken by Noble (1992). Noble found that conditions likely to result in environmental contamination were evident at more than half of the 542 open and 42 closed sites examined in the study. Most of the sites assessed were not designed to receive hazardous or potentially hazardous waste, although industrial waste had been dumped at many of these sites in the past. Groundwater contamination in particular, is clearly possible in such circumstances.

17.14 Minimum requirements for the treatment and disposal of hazardous waste

The objectives of these minimum requirements are to ensure that certain classes of hazardous waste are pre-treated prior to disposal, and that hazardous wastes are correctly disposed of. This is essential to safeguard health and the environment both in the short and long term**. A brief outline of the relevant minimum requirements is presented in Table Q12. Further particulars can be found in Anonymous (1994: Document No. 2).

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* An infamous example is the Love Canal in the town of Niagara, USA, where approximately 80 different chemicals were disposed of in a would-be canal, over a 30 year period. The excavation (known as the Love Canal), was then covered (in 1953) with a shallow layer of soil. Houses and a primary school were subsequently built on the land. Severe human health impacts such as liver abnormalities and birth defects first became apparent some 23 years after the cessation of dumping (domestic pets were similarly affected). Trees and gardens likewise, showed symptoms of gross chemical poisoning. The area had to be abandoned (Lombard, R., 1995. Personal communication, Lombard and Associates, Link Hills).

** It has been estimated that up to 50% of the hazardous waste generated in South Africa is illegally dumped. Sites include open veld, old mine shafts and sewer networks (Bredenhann, L., 1996. Personal communication, Department of Water Affairs and Forestry, Pretoria).

Table Q12: Minimum requirements for the treatment and disposal of hazardous waste.

Waste class	Minimum requirements
Class 1	Class 1 wastes must be pre-treated and the residues landfilled. The direct disposal of Class 1 wastes is prohibited
Class 2	Flammable gases must be thermally destroyed. Non-flammable gases to be released to the atmosphere, unless in contravention of the Atmospheric Pollution Prevention Act No. 45 of 1965. The controlled destruction of poisonous gases must be undertaken
Class 3	The landfilling of flammable liquids (flashpoint <61 °C) is prohibited. Flammable liquids must therefore be treated to a flashpoint >61 °C. Flammable liquids with a flashpoint of >61 °C or the residues after treatment, must be given a Hazard Rating
Class 4	The landfilling of flammable solids is prohibited. Flammable solids must be treated to non-flammability and must then be Hazard Rated
Class 5	The landfilling of oxidizing substances and organic peroxides is prohibited. Treatment to neutralize the oxidation potential must be undertaken. Treated Class 5 substances must be Hazard Rated
Class 6	Infectious substances must be sterilized. Residues of infectious substances to be Hazard Rated. Toxic substances (Hazard Rating 1 - 2) must be disposed of at permitted H:H sites. Toxic substances (Hazard Rating 3 - 4) to be disposed of at H:H or H:h sites
Class 7	Radioactive substances with specific activity <74 Bq g^{-1}, and total activity <3,7 kBq to be incinerated or landfilled. The disposal of radioactive substances with specific activity >74 Bq g^{-1}, and total activity >3,7 kBq is prohibited. Consult the Department of National Health and Population Development
Class 8	The disposal of corrosive substances (pH <6 and/or pH >12) by landfill is prohibited. Corrosive substances must be treated to pH 6 - 12. Corrosive substances must be given a Hazard Rating after treatment
Class 9	Refer to Footnote (iii) of Table Q11

<u>Source</u>: After Anonymous, 1994. Minimum requirements for the handling and disposal of hazardous waste, Document No. 2, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 124 p.

<u>See also</u>:

(i) Baldwin, D.A., 1987. Disposal of hazardous chemical waste generated by teaching and research, <u>South African Journal of Science</u>, VOL 83(8), p. 457 - 464.

(ii) Scott, P.D., 1980. The treatment and disposal of toxic and hazardous waste, Conference of the Institute of Water Pollution Control (Southern African Branch), 2 - 5 June 1980, Pretoria, 19 p. + app. (The paper was formally published as: Scott, P.D., 1980. The treatment and disposal of toxic and hazardous wastes, <u>Imiesa</u>, VOL 5(10), p. 43 - 47).

Note: (i) Disposal volumes or the total load capacity of a site for Hazard Groups or (Rating) 1 - 4 wastes must be in accordance with the calculated Estimated Environmental Concentration (EEC), multiplied by a factor determined by the Department of Water Affairs and Forestry.

(ii) The above table is highly simplified and addresses a very complex topic.

17.15 Minimum requirements for landfill site selection

Several procedures are necessary once a clearly defined need exists for a new landfill site which can accommodate specified volumes and types of waste. The first step involves the consideration of a number of possible sites. Identification of the various candidate landfill sites is based on economic*, environmental and social (public acceptance) factors (Anonymous, 1994: Document No. 1). All candidate sites are then evaluated and ranked with regard to social and environmental impacts as well as the safety and cost factors inherent in the acquisition, construction, operation and closure of the sites. Top ranking sites must be further investigated to confirm the ranking. A feasibility study - involving a preliminary Environmental Impact Assessment (EIA) and a geohydrological investigation - must be undertaken for the most likely site (excluding communal sites), in order to

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* Economic factors include economies of scale; possible incorporation of the site into a regional waste system; transport costs (the distance of the site from waste generation areas); accessibility of the site; the local availability of soil for cover purposes; the quality of soil at the site for containment requirements; land availability, and current use of the land. Environmental parameters are numerous and mainly involve the pollution potential of the site according to soil, locality and hydrological constraints. Public acceptance parameters relate to impacts on the residential quality of life (nuisances due to traffic, noise, litter, odour, general inconvenience and visual "blight"); as well as property values and therefore, public resistance.

establish whether the site is acceptable in terms of environmental parameters*. Following such confirmation, all people who will be affected by the new site (or who will possibly be affected) as well as the local authority - termed the Interested and Affected Parties (IAPs) - must be consulted. Failure to secure community approval for the landfill and the ultimate end use of the site may result in rejection of the site, and consideration of the second best option. Assuming environmental and community acceptance, the next step involves submission of all documents to the Department of Water Affairs and Forestry. The site selection procedure is completed following written acceptance of the proposal by the Department (discussed further in the next section).

It is a minimum requirement that no landfill site can be developed in any area which has an inherent Fatal Flaw (which virtually precludes the landfill for environmental or social reasons). Accordingly, no landfill site will be allowed within 3 km of the end of any airport runway or landing strip (in the direct line of the flight path), or within 500 m of the boundary of an airport or landing strip - in order to prevent aircraft bird-strikes. Prohibitions also apply in areas in close proximity to land uses incompatible with landfills. No landfill site may be established where the required buffer zones cannot be implemented between the landfill site and surrounding land uses such as residential suburbs. (Buffer zones of at least 200 m for communal sites, and 500 m or more for other sites are

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* The objectives of the Environmental Impact Assessment, undertaken according to the Integrated Environmental Management (IEM) principles as specified by the Council for the Environment - see the chapter on "estuaries" - are to identify the various ways in which a proposed, existing or closed landfill site will impact on the receiving environment; and secondly to specify design measures aimed at reducing impacts. Accordingly, the environmental consequences of (design) failure due to damage of the liner, for example, must be considered. Response action (contingency) plans which will contain or prevent health and environmental damage (especially at H sites) must be compiled. An Environmental Impact Control Report (EICR) incorporating the EIA, the environmental consequences of failure, and the response action plan must be submitted. The EICR report refers to the actual design and operation of the site. More detail is required when a particular site has been decided upon. A comprehensive investigation is then necessary (discussed later in the chapter). A useful checklist of design and environmental considerations for landfill sites is presented in Anonymous (1994: Document No. 1). The checklist can be used to ensure that all design aspects and all possible environmental impacts have been examined. The checklist can also be used to identify interactions between site selection, design and operation and accordingly, all potential impacts on the environment. See also, Beaumont, R.D., 1988. Environmental study and its relevance to the planning, approval and management of waste-disposal sites, Municipal Engineer, VOL 19(11), p. 28 - 37. A computer-based decision support system known as the Municipal Landfill Site - Selection Advisory System (MuLaSSAS), which will assist in the scientific identification, selection and evaluation of potential municipal landfill sites is being developed for use under South African conditions. The software system comprises various programs (expert systems) including landfill site selection; surface and groundwater contamination potential; annual waste load and waste volume estimation; operational cost estimates, and on site soil suitability assessment. See Murphy, K.O'H., 1994. Development of a method for the selection of suitable landfill sites and of guidelines for sanitary landfill in municipal areas: extended executive summary, WRC Report No. 352/1/94, Water Research Commission, Pretoria, 41 p.

necessary). Any land immediately upwind of the prevailing wind direction/s of a residential area is likewise not suitable. Constraints will also apply in areas where rezoning for a landfill site is simply not possible, or where important water, electricity and gas servitudes are found (Anonymous, 1994: Document No. 1).

Fatal Flaws incorporate environmental parameters such as land below the 1 : 50 year flood line (including wetlands and floodplains); and areas in close proximity to watercourses and dams, or forming part of a major catchment. Also prohibited are areas of groundwater recharge (due to topography and/or highly permeable soils), and areas overlying or adjacent to important aquifers, as well as areas with shallow or emergent groundwater. Unstable land where sinkholes or ground subsidence is possible, and land with very shallow soils overlying bedrock (sometimes found on steep slopes), is similarly not suitable for landfills. Areas of special ecological, cultural or historical interest (for instance, protected nature areas), plus all areas with any characteristics which would result in exorbitant landfill costs, must be avoided. It follows that economic, environmental and public acceptance criteria may become Critical Factors (factors which can impose severe constraints on the development or operation of landfills). An unresolved Critical Factor therefore, can become a Fatal Flaw if certain minimum requirements cannot be met, for example, if widespread public rejection of the proposed site is evident.

17.16 The permitting of landfill sites

The formal permit application procedure begins once a specific site has been selected and the feasibility thereof, has been approved by the Department of Water Affairs and Forestry. A detailed site investigation (discussed below), forms an integral part of the permit application. The main aim of permitting is to ensure that a given set of specifications (minimum requirements) is applied to landfill sites, thereby ensuring that landfills are properly designed, prepared, operated, monitored and closed. Permitting applies to new and operating landfill sites as well as to all sites closed after August 1990 (in terms of the Environment Conservation Act No. 73 of 1989). Prior to the promulgation of Act No. 73, concept permits were issued for new and existing sites by virtue of the since repealed Environment Conservation Act No. 100 of 1982. Provision has been made by the Department for the upgrading of concept permits to full permits as per the minimum requirements.

Confirmation of the feasibility of the site by the Department of Water Affairs and Forestry involves several documents (as described in the previous section), as well as a **permit application form.** The permit application form and supporting documentation provides the Department with much of the data necessary to decide on the feasibility or future of the site. A decision is made in consultation with the Department of Environment Affairs, the Department of National Health and Population Development, and the local authority. (The latter must also authorize the site in terms of town planning regulations). Following a site inspection by representatives of the three Departments and the applicant, a decision is then made to authorize the applicant to begin drawing up a **permit application report** (if the new site is feasible); or to consider the next best candidate site (if the new site is not acceptable). Additional details may be specified for inclusion in the permit application report. The Department of Water Affairs and Forestry may decide that an existing unpermitted or concept permitted site must be closed (with consequent permitting requirements - see Section 17.21).

The permit application report - where authorized for new and existing sites - must then be submitted to the Department of Water Affairs and Forestry. A formal report is not required for communal and G:S:B$^-$ sites where the permit application form and accompanying documentation will suffice. In all other cases the application report must include the permit application form and an overall executive summary as well as data relating to the site classification; plus the detailed geohydrological investigation report, the comprehensive Environmental Impact Assessment, and the Environmental Impact Control Report. Carefully assessed information on the design, construction, operation and monitoring of the landfill - together with plans for the rehabilitation, closure, end use and long term monitoring of the site - must be included in the permit application report. If the proposed or existing landfill can meet the minimum requirements, then a duly authorized permit specifying a number of conditions will be issued by the Department to the Permit Holder. The Permit Holder retains full legal responsibility for the site during operation and closure, regardless of the use of waste contractors*. Provision is made for an appeal to the Minister of Water Affairs and Forestry against the permit conditions, as specified by the Department. If the appeal is successful then the permit conditions will be changed in accordance with the ruling. If the appeal is rejected, then the original permit conditions must be accepted or the project must be abandoned. If an application for the continued

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* If the site is sold then the new Permit Holder, who must be approved by the Department of Water Affairs and Forestry, becomes legally responsible for the site.

use of an existing site is turned down, and on appeal is again turned down, then the site must be closed in terms of the minimum requirements (Anonymous, 1994: Document No. 1).

It is important to bear in mind that the permit is a major legal document which controls all aspects of the landfill site including the preparation of a new site. Any minimum requirements not expressly stated in the permit conditions must nevertheless be adhered to. Periodic inspections of the site will be undertaken by staff of the Department of Water Affairs and Forestry. Minor infringements of the permit conditions, or non-compliance with certain minimum requirements must be rectified. Major transgressions could result in prosecution, or closure of the site by the Department and the recovery of all costs thereby incurred. The Department must be informed of any changes associated with the site which may affect the environment. The permit conditions will then be amended by the Department where necessary. The permit accordingly, is a dynamic document which (in many cases), will need to be updated or revised in terms of the life cycle of the site.

17.17 Minimum requirements for the final site investigation

The objectives of the detailed site investigation plus the detailed Environmental Impact Assessment are to ensure that no Critical Factors or Fatal Flaws were ignored or overlooked in the preliminary investigation. Secondly, a re-examination of the site will provide comprehensive data for landfill design and operation. The extent of the site investigation for a new landfill depends on the class of the site. For closed, unpermitted or concept permitted sites, the information required will depend on the specific conditions prevailing at the site in question. Three major topics must be addressed in the site investigation, namely, the observable features of the site (the physical geography), the sub-surface aspects of the site, and any other issues of importance. Relevant maps as well as a written report must be submitted to the Department of Water Affairs and Forestry. The latest data are required (Anonymous, 1994: Document No. 1).

The observable features which must be examined refer specifically to the physical characteristics of the site and the surrounding area up to 1 km away. These include the topography and drainage patterns (seasonal/perennial streams), as well as the distances to the nearest important watercourses, dams, springs and wetlands. The 1 : 50 year flood line must be indicated on the map/s accompanying the written report. Data on rock *outcrops and the soil must also be recorded.* Surface water quality studies (both upstream and downstream of the proposed site) are essential to assess any subsequent pollution caused by the landfill. Similar upstream and downstream data are necessary in the case of already operating or closed sites under investigation. Present water usage likewise, must be considered. All infrastructure including roads, railways, airports, wastewater treatment plants, cemeteries and existing waste dumps - either within or immediately adjacent to the proposed landfill boundary - are of importance in determining the possible or actual impacts of the site. Any earthworks or excavations similarly, may have negative or positive implications (for example, disturbance of the drainage patterns, or a readily available supply of soil for cover purposes). Information on rainfall, wind speed and direction as well as evaporation constitutes vital input data. Details of existing vegetation and land use as well as any cultural, historical and archaeological sites of interest must also be provided.

Sub-surface features of the site are of particular significance and must be assessed by means of inspection pits, auger samples and the drilling of at least one borehole at smaller sites, and three boreholes at larger sites. Soil data of relevance include depth and accordingly the quantity available on site, as well as soil properties (especially permeability, shear strength and compaction characteristics). Geological information is crucial to the design and operation of the site and must be carefully recorded. All water-bearing features such as fractures, faults, dykes and geological contacts must be clearly identified and assessed. Close examination is also required of the depth of the main water table - particularly the wet season elevation - and the presence of any perched water tables, as well as the gradient and general flow directions of the groundwater. Data on groundwater quality both upgradient and downgradient of the proposed landfill site is also required, to assess the later impact of the landfill on the quality of the groundwater. A similar sampling programme for existing or closed landfills will likewise indicate the groundwater implications of the site. A hydrocensus of existing boreholes and wells within a distance of 1 km from the site boundary must be undertaken where abstraction rates, yield, depth to the water table, and groundwater usage data are recorded. Close attention must be paid to any important aquifers which could be regarded as strategic water bodies - especially in the drier parts of South Africa where no practical alternative sources of supply may exist. The Department of Water Affairs and Forestry must be informed of any aquifer yields in excess of 5 $\ell\ s^{-1}$. Further testing of the yield will then be necessary. It follows that the presence of a strategic aquifer constitutes a Fatal Flaw which will prevent the construction of a landfill site. Special care is therefore required in the site investigation of landfills to be located in areas where important aquifers are found or are believed to exist, or where groundwater is the primary source of water. An absolute minimum thickness of 2 m must separate the waste at the base of a landfill from any underlying groundwater (assuming very impermeable soil). A most important minimum requirement at all sites accordingly, involves the risk assessment of aquifer contamination (discussed in more detail later in the chapter).

Miscellaneous issues which might need investigation include the risks of mining-induced earth tremors (for example, in the Witwatersrand area) and the number of mines in the locality, which could result in subsidence or interference with groundwater flow. Sinkholes or subsidence zones which are a feature of the landscape constitute a Fatal Flaw, thereby precluding the construction of landfills. Existing landfill sites located in unstable areas may have to be closed. Gas (largely consisting of methane) is a potential hazard at many landfill sites. The site investigation therefore, must examine the possibility of gas migrating from the landfill to adjacent land. Migration paths can include porous soil or rock strata, sewers and pipelines. Wide buffer zones will reduce the risk of gas seepage and explosions (Anonymous, 1994: Document No. 1).

The disposal of mining wastes in slimes dams or dumps (and therefore the selection and management of suitable sites) can be especially problematic - given the sheer volume of semi-permanent or permanent waste involved - and the potential fire hazard of low grade (reject) coal and duff coal tailings*. The disposal of asbestos mine waste can pose major health problems, with radionuclides of concern in uranium ore tailings (albeit in trace amounts)**. The contamination of surface and groundwaters by mining waste may be

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* In terms of the Mines and Works Act No. 27 of 1956/Minerals Act No. 50 of 1991, the owner of every mine and quarry in South Africa is required to submit and obtain approval for an Environmental Management Programme, before prospecting or mining/quarrying operations can commence. The relevant documentation is referred to as the Environmental Management Programme Report (EMPR). A set of guidelines on the compilation of EMPRs can be obtained from the Department of Mineral and Energy Affairs, Private Bag X59, Pretoria, 0001.

** The possible impact of radionuclides associated with the mining industry in South Africa (underground, in process plants, in tailings, and especially in seepage and wastewater) does not appear to have received much attention in the formal scientific literature. One source of expertise is the South African Radiation Protection Society, c/o S. Van der Woude, Council for Nuclear Safety, P O Box 7106, Centurion, 0046. A Water Research Commission report is available. See: Bain, C.A.R., Schoonbee, H.J., De Wet, L.P.D. and Hancke, J.J., 1994. Investigations into the concentration ratios of selected radionuclides in aquatic ecosystems affected by mine drainage effluents with reference to the study of potential pathways to man, WRC Report No. 313/1/94, Water Research Commission, Pretoria, 95 p.

severe, while large dumps are a major aesthetic intrusion in the landscape*. Dumps (unless stabilized) are also a source of dust which can cause respiratory illnesses. The disposal of mining waste is not specifically discussed in this publication. The interested reader is referred to useful papers by Blight (1981); Caldwell and Robertson (1983); Lyell (1989), and Smith and Caldwell (1983)**. The rehabilitation of open cast mines is described inter alia by Collins (1989). Further references can be found in the bibliographic database including literature on the revegetation of mine dumps.

17.18 The design of landfills

Following final site selection, the actual design of the landfill must be addressed. The main purpose of landfill design is to ensure that an environmentally-sound site is constructed, with the absolute minimum pollution of surface and groundwaters. The site design must also be cost effective. Depending on circumstances, the (design) upgrading of operating or closed landfill sites may be necessary. All landfill design procedures must be in accordance with the minimum requirements.

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* Certain implications both above and below ground of the flooding of abandoned mines are discussed by Scott, R., 1995. Flooding of Central and East Rand gold mines: an investigation into controls over the inflow rate, water quality and the predicted impacts of flooded mines, WRC Report No. 486/1/95, Water Research Commission, Pretoria, 238 p. An important series of documents on mine water quality and related issues was released by the Water Research Commission. See Pulles, W., Howie, D., Otto, D. and Easton, J., 1996. A manual on mine water treatment and management practices in South Africa, WRC Report No. TT 80/96, various pages, Appendix, VOL 1: Literature reviews, WRC Report No. 527/1/96, various pages, Appendix, VOL 2: Coal mine site visit reports, WRC Report No. 527/2/96, various pages, Appendix, VOL 3: Gold mine site visit reports, WRC Report No. 527/3/96, various pages, Appendix, VOL 4: Overseas study tour report, WRC Report No. 527/4/96, various pages, and Appendix, VOL 5: Catalogue of relevant WRC research projects, WRC Report No. 527/5/96, various pages, Water Research Commission, Pretoria. (A publication of related interest is the following: Herold, C.E., Pitman, W.V., Bailey, A.K. and Taviv, I., 1996. Lower Vet River water quality situation analysis with special reference to the OFS goldfields, WRC Report No. 523/1/96, Water Research Commission, Pretoria, various pages. Some pollution aspects in terms of ecosystems are discussed in Schoonbee, H.J., Adendorff, A., De Wet, L.M., De Wet, L.P.D., Fleischer, C.L., Van der Merwe, C.G., Van Eeden, P.H. and Venter, A.J.A., 1996. The occurrence and accumulation of selected heavy metals in fresh water ecosystems affected by mine and industrial polluted effluent, WRC Report No. 312/1/96, Water Research Commission, Pretoria, 148 p.).

** See Blight, G.E., 1981. Assessment for environmentally acceptable disposal of mine wastes, Civil Engineer in South Africa, VOL 23(10), p. 489 - 499., as well as Caldwell, J.A. and Robertson, A. Mac G., 1983. Selection of tailings impoundment sites, Civil Engineer in South Africa, VOL 25(10), p. 537 - 553. See also, Lyell, K., 1989. Principles involved in modern tailings disposal, South African Mechanical Engineer, VOL 39(7), p. 327 - 333., plus Smith, A. and Caldwell, J., 1983. Waste disposal without degrading the environment, South African Mining World, VOL 2(8), p. 60 - 67, 73. The following paper provides a brief, non-specialist overview of some rehabilitation measures required for open cast mines: Collins, G.B., 1989. Technical aspects of surface-mined land rehabilitation, Landscape Southern Africa, VOL 3(1), p. 9 - 13. Checklists are provided in Blight (1981), Caldwell and Robertson (1983), and Collins (1989).

Two design stages are usually required, namely, the conceptual design and the technical design (Anonymous, 1994: Document No. 1). The conceptual design refers to the principles of the proposed design which will affect the operation and final closure of the site. Of fundamental significance is the site classification and accordingly, the relevant minimum requirements and associated design parameters. The site classification - as discussed earlier in the chapter - depends on the type and quantity of waste and the resulting leachate, and hence the required leachate management system. A most important factor to be considered is the airspace of the site, namely, the void that will be filled by waste and cover (and which determines the potential lifespan of the site). Other factors include the site lay-out which must be designed inter alia to facilitate the ultimate closure and end use of the site (for example, as a park). The site lay-out includes the design of roads, surface drainage and stormwater drains as well as the monitoring systems for surface and groundwaters. Gas management and gas monitoring systems may be needed if landfill gas migration and accumulation is likely to be problematic at the new site; or where an operating or already closed site is situated less than 250 m away from a residential or industrial area. The lay-out plan must include a 1 : 1 000 scale map indicating relevant items such as infrastructure, screening berms and vegetation as well as site access and drainage. A progressive rehabilitation plan and a preliminary closure plan (including an end use plan) must be compiled.

More specific testing of the underlying soil and/or rock strata at the site may be necessary to establish design constraints - especially where the site is sub-optimal in terms of geohydrology and/or other impacts on the environment. Soil intended for cover purposes may likewise need further on site analysis to determine suitability. Any artificial liners to be used at the new site may need to be examined to ensure that the liners can accommodate the type of waste and leachate which will be present, or is likely to be present. The strength and durability of the liners, as well as any artificial membranes to be used in the capping layer* might require further investigation in view of the site conditions (Anonymous, 1994: Document No. 1).

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* The 0,5 m thick capping layer is the final top layer of soil which isolates the waste body from the environment. An additional near-surface artificial membrane is required in the case of G:L:B$^+$, H:h and H:H sites. The capping layer controls the entry of rainwater to the waste body and accordingly leachate generation, as well as regulating evapotranspiration and passive landfill gas emissions.

The technical design is based on the conceptual design and quantifies all relevant aspects of the conceptual design. The technical design is a minimum requirement for permitting at all B^+ and H landfill sites. At other sites, a technical design may be needed for practical reasons. Technical design components of particular significance include (a) the upslope cut-off drains which prevent mixing of unpolluted runoff and contaminated water found on the site, (b) the unsaturated zone between the waste body and any groundwater, (c) the lining layer, and (d) the leachate detection, collection and treatment system. Gas management requirements, where relevant, must be considered in detail in the technical design. The stability of excavated and artificial slopes at the site should likewise be carefully evaluated. The design of the capping layer is of marked importance (as the surface equivalent of the lining layer). Specific attention must be paid to the erosion potential of the capping layer particularly on steep surfaces. The collection and removal of surface runoff (polluted or otherwise) from the site also requires attention in the technical design, in order to avoid surface ponding and seepage into the waste body.

17.19 The operation of landfill sites

The new landfill can legally begin operating once the site preparation and construction phases have been completed, and have been approved by the Department of Water Affairs and Forestry. A number of minimum requirements must be met for successful landfill operation. The minimum requirements will depend on the site classification and the permit conditions, with the maximum number of requirements for H:H sites. The control of nuisances such as fires, litter, odours, noise, rats and flies as well as dust at all landfills is essential (Anonymous, 1994: Document No. 1).

The landfill must be properly signposted indicating inter alia the site classification and the type of wastes which can be accepted. It is of particular importance that sites classified as G receive only general waste (as per the minimum requirements), and that all hazardous waste is delivered to the appropriate H site. Care must be taken especially at landfills located near or within an industrial area to ensure that only general waste is accepted at G sites. Similar safeguards are required at H sites, where deliveries of waste from a hitherto unknown source must be accompanied by representative samples and the appropriate waste data. Consignments of such waste must be tested at intervals to ensure that the waste complies with the samples and information originally provided. Discrepancies must be reported to the Department of Water Affairs and Forestry as well as to the waste generator. All suspect waste must be properly identified prior to disposal at the site. Where the waste cannot be identified, the precautionary principle (discussed earlier in the chapter) must be enforced. The precautionary principle states that any unidentified waste must be classified in terms of the most hazardous category.

Caution is especially necessary at H:h sites which may only accept Hazard Rating 3 and 4 waste and general waste. Any Hazard Rating 1 and 2 waste must be diverted to the nearest H:H landfill. Quarterly returns on the type of waste and the disposal method must be submitted to the Department of Water Affairs and Forestry, in respect of all H:h and H:H sites. It follows that security arrangements must be appropriate for the given landfill site, in order to control access. Strict security is essential at all H sites.

All permitted landfills require a site specific operating plan (which must be regularly updated), and which forms an integral component of the permit application. The plan describes all aspects of daily and longer term operation at the landfill, according to the classification of the site. Very comprehensive plans including the response action plan (discussed earlier), are necessary for H sites. Other minimum requirements for landfill operation include the necessary infrastructure, plant and equipment as well as staff. An on site laboratory is a minimum requirement at H:H landfills. Each landfill site must be under the control of a Responsible Person who has relevant expertise (including an appropriate university degree at all H sites).

It is a minimum requirement that waste at general and hazardous landfills must be compacted and covered with suitable material (soil, builders' rubble, ash or some other acceptable substance) at the end of the working day. The cover depth must be equivalent to 150 mm of compacted soil, or more in the case of poor quality cover. A special landfill compactor should be used at all Class G:M, G:L and H sites. Other machinery can be used to compact the waste at certain existing small sites. At small landfills with a severe shortage of cover material the waste need not be covered each day - subject to approval by the Department of Water Affairs and Forestry - although waste exposure is not desirable. It is a minimum requirement for all new sites however, that sufficient cover material must be available for the lifespan of the site. A reserve supply of cover sufficient for three days must be maintained at all sites in case of emergencies (Anonymous, 1994: Document No. 1).

Further minimum requirements apply to the methods of landfilling, which must be in accordance with the design parameters, the operating plan and the permit. At Class G:C and G:S sites handling fairly small amounts of waste, trenches are often used and must be excavated on a continuous basis to ensure that at least one week's waste can be accommodated at any particular time. Care must be taken in the design of the trenches in order to prevent people or vehicles falling into the trench. The common method of disposal at larger general waste sites involves the use of standard cells, which are usually formed by 1,5 - 2,0 m high berms constructed of soil, rubble or sloped covered waste. Waste is deposited at the working face and is then spread out over the cell, before being compacted and covered at the end of the day. A reserve cell capacity equivalent to one week's waste is required. At certain sites, a readily accessible wet weather cell must be constructed for use in extreme weather conditions. The cell should also have a one week reserve capacity. Special cells to cater for putrescible wastes may be necessary, where the waste should be covered as soon as possible with a 0,5 m thick layer of soil. Such wastes could also be buried at the base of the working face. The practice of "end tipping" is allowed at some Class G:C, G:S and H sites where waste must be disposed of (end tipped) into trenches. End tipping involves the deposition of waste directly over the edge of an advancing face. The resultant slopes however, are unstable and little compaction is possible. The method is therefore only used in specific circumstances. A further procedure, known as the area method, can be used at certain sites. The area method refers to the disposal of large volumes of dry, non-putrescible general waste where compaction is of less importance. The waste is spread over a large area in a 0,5 m thick layer (Anonymous, 1994: Document No. 1).

The disposal of hazardous waste at landfill sites is problematic and great caution must be exercised. As briefly discussed earlier in the chapter, it is a minimum requirement that numerous hazardous wastes must first be treated to render them less hazardous, before final disposal of the residues in a landfill. Certain very hazardous wastes must be encapsulated and completely isolated from the environment. The methods of disposal of hazardous waste must be specified in the operating plan as well as in the permit application. The hazardous waste load allocation of the site likewise, as outlined in the operating plan and the permit application, must be carefully observed. At landfills where Hazard Rating 3 and 4 wastes are co-disposed with general waste, it is a minimum requirement that the sites must conform to Class H:h landfill criteria (particularly in terms of the lining system and leachate collection/treatment). It is important that no incompatible wastes are co-disposed at the site. Where only a portion of the site is to be used for hazardous purposes, it is essential that properly constructed and specially lined engineered cells be provided for the hazardous waste. If the whole site is used for co-disposal, then the solid hazardous waste (depending on the type of waste) can be mixed with general waste at the working face. The hazardous waste can also be spread out over the existing waste, or mixed in trenches excavated in soil or waste. Liquid hazardous waste can be end tipped into engineered cells or trenches and is then covered with sufficient dry, solid general waste so that cover material can be mechanically applied at the end of the working day. It is the duty of the Responsible Person to ensure that the appropriate operating standards are met and that all safety precautions are adhered to.

Even more stringent standards apply at Class H:H sites where the need for pre-treatment of hazardous wastes and isolation from the environment, is of paramount importance. General waste is often co-disposed with very hazardous waste at H:H sites and serves as a substrate for the excavation of trenches designed to accept liquid hazardous waste. Hazardous waste at H:H sites can likewise be disposed of in a series of engineered cells or in cells excavated in existing waste. The Responsible Person plays a major role at Class H:H sites in ensuring that the operating procedures are fully observed.

Reference has previously been made to the necessity for proper upslope drainage of the site, plus the separation of polluted and clean runoff, as well as the need for on site storage and treatment of contaminated water and leachate. All surfaces including cells and trenches must be constructed so that water drains away from the waste. Landfill site water per se and leachate can only be discharged to the external environment if the quality of the water/leachate complies with the General/Special Standard in terms of the Water Act No. 54 of 1956. (See the chapter on water quality). All leachate and gas management systems (as specified), must be correctly operated and maintained.

In parts of the landfill where no further deposition will occur, it is a minimum requirement that rehabilitation processes must be undertaken as soon as possible after the final cover has been applied, and site conditions allow. Completed slopes should not exceed 1 : 2,5 inter alia to prevent soil erosion. Suitable vegetation should be planted to bind the soil layer and to improve the aesthetics of the site. Rehabilitation must be undertaken in accordance with the landfill design and the envisaged end use of the site (Anonymous, 1994: Document No. 1).

17.20 The monitoring of landfill operations

17.20.1 Overall monitoring

The purpose of monitoring is to ensure that the landfill site has been properly designed, and is being operated and maintained according to the permit conditions and the relevant minimum requirements. The monitoring process also attempts to quantify certain environmental impacts of the site, especially with regard to water resources. Accordingly, monitoring (if correctly undertaken), serves as an early warning mechanism in the event of unforeseen or unplanned environmental hazards. Problems may include ineffective or blocked drainage systems as well as leaking liners and poor cover compaction, with resulting surface and groundwater contamination. Landfill monitoring therefore, is a valuable management technique.

Landfill operators are responsible for the monitoring (waste auditing) of their own sites. However, monitoring is also undertaken by a number of different agencies. Reference has already been made to routine inspections by Department of Water Affairs and Forestry staff. In reality, only the most important sites (mainly Class H sites) and those sites with serious problems are likely to be inspected on a routine basis. Waste generators whose hazardous waste is disposed of by commercial site operators may themselves audit landfill management procedures (in terms of the duty of care principle). Members of the Institute of Waste Management (Southern Africa) as well as other consultants can likewise be approached to audit sites on behalf of the landfill operators per se or their own duly appointed contractors. The extent and frequency of monitoring operations depends on the site classification and the permit conditions. Audits must be undertaken once a year at G:S sites, once every six months at G:M sites, once every three months for G:L sites, and monthly at all H sites (with possible later amendments by the Department of Water Affairs and Forestry). It is the primary duty of the Responsible Person to ensure that all monitoring is in accordance with the specific site in question (Anonymous, 1994: Document No. 1).

An audit committee must be established at all landfills, possibly excluding communal sites. The committee at H sites consists of the Permit Holder, the Responsible Person, a representative of the Directorate of Water Quality Management of the Department of Water Affairs and Forestry, and where necessary, one or more consultants. A smaller audit committee is acceptable at G sites, subject to approval by the Department of Water Affairs and Forestry. Numerous factors must be considered in any audit including site infrastructure such as access and security and the condition of roads; as well as the all-important waste disposal operation, for example, cell construction and the spreading, compaction and covering of the waste. Other items which must be assessed are inter alia drainage, the leachate management system, litter control and aesthetics. An examination of the degree of compliance with the permit conditions is an essential part of the auditing programme. The Department must be notified of any problems as well as the remedial measures to be applied.

A number of on-going monitoring procedures are necessary at landfill sites (over and above the periodic audit process). Routine monitoring requirements - as described in the operating plan - refer to the collection and analysis of data on important aspects of the landfill operation. All data obtained must be in accordance with the site classification. Information which must be collated includes the origin, type and amount (volume/mass) of waste entering the site (gate or weighbridge data). Daily and cumulative waste load data must therefore be available. Hazardous waste at H sites must be classified in terms of the appropriate Hazard Rating. Accurate records are essential for hazardous waste, and must also reflect the place and method of disposal at the site. Three dimensional locality data are required for hazardous waste. The precise co-ordinates of all encapsulated (Hazard Rating 1) waste must be recorded. Periodic assessments must be undertaken to determine the remaining landfill airspace. The use of land surveying equipment is a minimum requirement at G:M, G:L and H sites (Anonymous, 1994: Document No. 1).

Testing for landfill gas is required at all sites where gas accumulation or migration could be problematic. Monitoring equipment must be installed if necessary, and must be maintained for the lifespan of the site (and possibly also after closure). Air quality monitoring to reduce odour nuisances (including landfill gas) may be needed at certain Class G sites. Monitoring of the air is especially important at H sites to prevent the airborne transmission of gaseous and particulate substances. Scientific instrumentation must be maintained in good order at all sites. The monitoring of progressively rehabilitated parts of the landfill must be undertaken at regular intervals. The vegetation cover should be checked at the same time. Any cracks, depressions, or erosion gullies in the final capping layer of the rehabilitated land must be attended to. A vitally important aspect of waste auditing and on-going monitoring concerns leachate as well as surface and especially groundwater quality.

17.20.2 Water quality monitoring

Water quality monitoring is an essential component of landfill investigation as well as design, operation and closure (Anonymous, 1994: Document No. 1). Leachate escaping from landfills, existing industrial/mining areas or industrial/mining waste disposal sites can have serious consequences for animal, human and plant life, and the environment in general. The exact relationship between dangerous leachates and human health in particular, is virtually impossible to predict with any degree of accuracy. It follows that the damage has already been done by the time health effects become evident. Concise estimates of the period during which leachates will continue to be harmful in the future, are also very difficult to derive. No man-made liner can be guaranteed to last forever and partial failure at some stage (perhaps 40 years hence), is virtually assured. The long term consequences for important aquifers can be severe in terms of chemical and microbiological contaminants (especially the former) (Engelbrecht, 1993)*. Problems may be particularly acute at sites where a high proportion of hazardous wastes have been disposed of. Leaking underground petrol/diesel (and other chemical) storage tanks are likewise of concern (Roe, Lacy, Stuart and Robbins, 1989, quoted in Engelbrecht, 1993).

The type and chemical nature of leachate depends on a variety of factors. These factors include the type and volume of waste per se; the proportion of hazardous waste; the disposal method; the extent of waste compaction; the passage of time; climatic parameters (primarily seasonal and mean annual rainfall); complex chemical and biological processes; soil, liner and rock characteristics, and depth to the water table. Very little is known about the microbiology of groundwater, although it is recognized that aquifers are just as liable to microbiological contamination as surface waters (Engelbrecht, 1993). The degree of microbiological pollution will vary according to the nature and number of pathogenic organisms found in the landfill. Sources of contamination include discarded

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* See Engelbrecht, J.F.P., 1993. An assessment of health aspects of the impact of domestic and industrial waste disposal activities on groundwater resources: a literature review, WRC Report No. 371/1/93, Water Research Commission, Pretoria, 46 p. A useful publication is the following: Senior, E. (ed), 1990. Microbiology of Landfill Sites, CRC Press, Boca Raton, 220 p. (The book, a second edition of which was published in 1995, is available at the Life Sciences Library, University of Natal, Pietermaritzburg).

foodstuffs, disposable nappies and pharmaceutical products. Also significant is the ability of the organisms to survive or to retain their infectious properties, and the extent to which these organisms reach the groundwater (Engelbrecht and Amirhor, 1975, quoted in Engelbrecht, 1993). A number of environmental parameters including the nature of the leachate will determine survival rates in the landfill. Both organic and inorganic compounds reaching the groundwater can be directly transformed by microbiological processes. Microbiological organisms in sufficient numbers can also cause clogging and may change the permeability of the aquifer material. A change in pH may likewise be induced by microorganisms with important consequences for the oxidation-reduction potential of the aquifer system (McCarty, Rittmann and Bouwer, 1984, quoted in Engelbrecht, 1993). Changes in pH can result in the dissolution or precipitation of heavy metals and phosphates, as well as the oxidation or reduction of sulphur salts and iron. The chemical and microbiological properties of leachates and hence their potential or actual impacts vary considerably, and are specific to a given site (Engelbrecht, 1993).

Municipal leachate data for a landfill near Cape Town are presented in Table Q13. Readers should bear in mind that South African leachate information is not readily available in formally published sources (partly for reasons of confidentiality and partly because few detailed long term studies have been undertaken in this country). A useful research project would involve the collation and analysis of South African leachate statistics for similar types of landfills (especially those containing industrial wastes) in various climatic regions, with a view to policy formulation and future planning*. Such a project could form part of the current research programme on waste management with special reference to groundwater contamination and aquifer protection. The research is being funded by the Department of Water Affairs and Forestry and the Water Research Commission**.

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* Useful background information on the types of industrial waste produced in local authority areas could include sewage sludge characteristics provided by Smith and Vasiloudis (1989) - see Table Q6. Procedures for obtaining information on industries present in a particular area are outlined in the chapter on water quality.

** Several research reports on waste management with regard to aquifers are in the process of being released by the Water Research Commission, Pretoria. Readers requiring further details should contact the Commission.

Table Q13: Leachate concentrations in Cell No. 1 at the Coastal Park landfill site, Cape Town, 1986 - 1989.

Parameter	Unit	Stabilization time (months)				
		5 (86-08-07)	12 (87-03-11)	21 (87-12-21)	29 (88-08-23)	42 (89-09-12)
Total solids (105°C)	mg ℓ^{-1}	-	-	-	16 860	10 133
Total dissolved solids (105°C)	mg ℓ^{-1}	33 750	39 450	31 980	16 480	10 133
Total volatile solids (600°C)	mg ℓ^{-1}	-	-	-	8 700	2 708
Chemical oxygen demand (COD)	mg ℓ^{-1}	38 100	56 373	49 000	19 300	2 000
Ammonia nitrogen (N)	mg ℓ^{-1}	197	1 483	1 340	1 140	1 340
Organic nitrogen (N)	mg ℓ^{-1}	47	263	250	150	110
Nitrate + nitrite (N)	mg ℓ^{-1}	16	6	1	46	30
Total phosphates (P)	mg ℓ^{-1}	13	2	75	2	9
pH	pH units	5,9	6,3	6,2	7,5	7,8
Conductivity (25°C)	mS m^{-1}	1 902	2 620	2 580	1 827	1 251
Chloride (Cl)	mg ℓ^{-1}	3 660	3 600	2 400	2 400	2 400
Sulphate (SO_4)	mg ℓ^{-1}	98	886	460	119	37
Alkalinity ($CaCO_3$)	mg ℓ^{-1}	7 969	7 500	6 750	6 150	8 500
Sodium (Na)	mg ℓ^{-1}	1 690	1 941	1 490	1 345	1 413
Potassium (K)	mg ℓ^{-1}	1 780	2 077	1 627	1 591	1 800

Table Q13: Leachate concentrations in Cell No. 1 at the Coastal Park landfill site, Cape Town, 1986 - 1989 (continued).

Parameter	Unit	Stabilization time (months)				
		5 (86-08-07)	12 (87-03-11)	21 (87-12-21)	29 (88-08-23)	42 (89-09-12)
Calcium (Ca)	mg ℓ^{-1}	-	-	-	471	112
Magnesium (Mg)	mg ℓ^{-1}	-	-	-	262	274
Copper (Cu)	μg ℓ^{-1}	142	103	94	<25	42
Chromium (Cr)	μg ℓ^{-1}	<25	364	160	<25	101
Zinc (Zn)	μg ℓ^{-1}	13 790	4 616	490	529	319
Cadmium (Cd)	μg ℓ^{-1}	80	61	30	12	13
Nickel (Ni)	μg ℓ^{-1}	730	824	595	217	249
Lead (Pb)	μg ℓ^{-1}	1 500	393	890	<50	106
Lithium (Li)	μg ℓ^{-1}	-	-	-	255	231
Volatile acids (as acetic)	mg ℓ^{-1}	-	11 580	3 740	940	<1
Volatile acids (total)	mg ℓ^{-1}	-	22 500	-	3 825	<1

<u>**Source**</u>: After Stow (1989, quoted in) Ross, W.R., 1990. Factors influencing the chemical characteristics of landfill leachates, <u>Water SA</u>, VOL 16(4), p. 275 - 280.

See also:

(i) Ball, J.M. and Blight, G.E., 1986. Groundwater pollution downstream of a long-established sanitary landfill, Municipal Engineer, VOL 17(9), p. 17 - 23.

(ii) Ball, J.M. and Blight, G.E., 1988. The fate of leachate from a landfill site, Environmental Issues in Waste Management, Ninth Biennial Congress and Equipment Exhibition of the Institute of Waste Management (Southern Africa), 9-11 August 1988, Durban, [20 p.]. (The paper provides further information on the Coastal Park landfill site. This landfill has been extensively investigated and is a useful case study. Relevant data are also presented in Meyer, Duvenhage, Coetsee and Weaver (1994) as well as in Myburg and Britz (1993), and in Novella, Ross, Lord, Greenhalgh, Stow and Fawcett (1996) - see immediately below).

(iii) Meyer, R., Duvenhage, A.W.A., Coetsee, V. d A. and Weaver, J.M.C., 1994. The evaluation and development of geophysical techniques for characterizing the extent and degree of ground water pollution, WRC Report No. 267/1/94, Water Research Commission, Pretoria, 115 p. + app.

(iv) Myburg, C. and Britz, T.J., 1993. Influence of higher organic loading rates on the efficiency of an anaerobic hybrid digester while treating landfill leachate, Water SA, VOL 19(4), p. 319 - 324.

(v) Novella, P.H., Ross, W.R., Lord, G.E., Greenhalgh, M.A., Stow, J.G. and Fawcett, K.S., 1996. The co-disposal of waste-water sludge with refuse in sanitary landfills, WRC Report No. 391/1/96, Water Research Commission, Pretoria, various pages.

(vi) Stern, D.J., 1980. Landfill leachates: origin and consequences, Conference of the Institute of Water Pollution Control (Southern African Branch), 2 - 5 June 1980, Pretoria, 16 p.

Note:

(i) The data in the above table refer to a control cell (commissioned in March 1986), and used as part of an investigation into the co-disposal of hazardous and municipal waste. The study was undertaken inter alia by the Cape Town Municipality and the Division of Earth, Marine and Atmospheric Science and Technology, CSIR, Stellenbosch. The landfill site in the study period mainly received municipal solid waste. The landfill is situated adjacent to the Cape Flats wastewater treatment works.

(ii) The primary objective of a landfill site is to stabilize the waste body from raw refuse to an end product which is acceptable in terms of health and environmental parameters. The land disposal of waste accordingly, is a dynamic treatment procedure. The decomposition of waste is a complex attenuation process involving chemical, physical and biological mechanisms. Major chemical processes include neutralization, precipitation, oxidation, reduction, complexation, ionisation and acid-base reactions. Physical processes are ion exchange, absorption, adsorption, filtration, evaporation, extraction and encapsulation. Biological processes of importance are aerobic, anaerobic, hydrolytic and fermentative biodegradation. Rainfall, especially prolonged or high intensity rainfall, plays a significant role in leachate formation (Ross, 1990) along with the entry of surface or groundwater due to inadequate design features.

(iii) Leachate concentrations vary over time reflecting different phases in the stabilization procedure (a well-documented process reported in many case studies). Landfill stabilization (waste decomposition) can essentially be divided into five phases, namely: Phase 1 (initial deposition); Phase 2 (transition); Phase 3 (acid formation); Phase 4 (methane fermentation), and Phase 5 (final maturation - typically some five years later when several leachate determinand concentrations have declined) (Pohland, Dertein and G[h]osh, 1983, quoted in Ross, 1990). Other classification systems are also used in the literature. Each phase of the stabilization process has a characteristic leachate composition (with some degree of overlapping of the phases). Ross observed that the age of a landfill does not necessarily reflect the degree of stabilization of the waste body (due to numerous factors specific to the site in question). Secondly, no landfill has a single age but rather a "family" of different ages indicative of the deposition schedule.

A most important aspect of landfills and their environmental and health implications is the period during which leachates will continue to be generated after site closure. Stone (1991, quoted in Parsons and Jolly, 1994)*, with reference to the waste situation in the USA, argued that waste disposal sites will always need a certain degree of management - given inter alia the very slow rate of leachate migration. Myburg and Britz (1993) dated municipal landfills to 6000 - 3000 BC, while Stone referred to 2 000 year old Roman landfills which are currently still producing leachate. Stone (1991) disputed the belief that leachate generation will stabilize over an approximately 30 year period. Stone emphasized that landfill design and engineering procedures will merely, at best, delay the impacts of landfills, and stressed that landfills and aquifers are mutually incompatible. Stone as well as Parsons (1994)** and Lee and Jones (1992, quoted in Parsons and Jolly, 1994), warned against a false sense of security when leachate is not detected in collection systems and in monitoring boreholes, where many years may pass before the site reaches its optimum leachate generating capacity. It is quite possible therefore, for leachate generation to assume serious proportions after the long term post closure monitoring programme has ceased. Since leachate migration (in the

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* See Parsons, R. and Jolly, J., 1994. The development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria, WRC Report No. 485/1/94, Water Research Commission, Pretoria, 79 p. + app.

** See Parsons, R., 1994. A review of approaches and methodologies for determining leachate generation at waste disposal sites and groundwater recharge, WRC Report No. 564/1/94, Water Research Commission, Pretoria, 69 p. + app.

USA) only began to be comprehensively studied in the 1970s, it is evident that science cannot yet provide definitive answers in respect of leachate movement. Rimmer and Theron (1990, quoted in Engelbrecht, 1993 - above)*, referred to a study undertaken in Germany which revealed that contamination of an aquifer was detected 1,5 km downstream of a landfill site, 25 years after the site was opened. Contamination continued for a period of nine years after closure. A further 18 years elapsed before leachate concentrations in the groundwater dropped to background levels. Site specific factors however (perhaps not understood or even investigated), may (fortuitously) prevent or contain the long term migration of leachate at a particular landfill. Such good fortune cannot be relied upon in the same, or in any other locality. It is apparent that potential or actual contamination problems can be anticipated as long as waste is present in the ground.

(iv) Useful indicators of the extent of municipal waste decomposition include parameters such as COD; alkalinity-volatile fatty acid-pH relationships; the degree of mineralization; the conversion of organic phosphorus and nitrogen to inorganic forms, and the rate of gas production (Ross, 1990). Ross found that the leachate chemical characteristics at the study landfill were very similar to those reported for other "young" landfill sites.

(v) Ross (1990)** made the innovative suggestion that municipal wastewater treatment works should be sited immediately adjacent to landfills (where feasible), in order to promote a comprehensive waste management strategy, and to facilitate the exchange of leachates and secondary sludges. The siting of both facilities in one locality would also concentrate negative impacts, which might then be easier to control. (The converse however, depending on site conditions, is also true).

(vi) Typical leachate chemical data, mainly drawn from studies in the USA, are presented in Engelbrecht (1993). According to reports examined by Engelbrecht, groundwater contaminants such as benzene, chlorinated phenols, organic solvents, polychlorinated biphenyls, arsenic, selenium and various heavy metals - depending on the types of waste disposed of - have been detected some distance away from industrial landfill sites in the USA. A number of these compounds are inter alia carcinogenic, with potential or real dangers if ingested via contaminated groundwater or a poorly maintained surface water supply. Robinson and Maris (?1979/1985, quoted in Engelbrecht, 1993) found that leachate from domestic solid waste usually contains high concentrations of both soluble organic matter as well as inorganic ions. Major cations found in

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* See Rimmer, R. and Theron, P.F., 1990. Experience in monitoring of ground water at sanitary landfills, Imiesa, VOL 15(5), p. 25 - 29.

** See Ross, W.R., 1990. Co-disposal of sewage sludge and refuse in a sanitary landfill bioreactor, Municipal Engineer, VOL 21(6), p. 40 - 45.

leachates in the United Kingdom (in order of decreasing concentration) are sodium, calcium, potassium and magnesium. The leachate composition for domestic wastes in the United Kingdom is much in accordance with leachates examined at domestic sites in the USA, Canada and in other countries. Health implications will depend on the specific concentrations present in surface or groundwater.

(vii) Several factors control and influence the persistence of microorganisms in landfills and in leachates. These factors include heat generated through waste decomposition, the chemical properties and moisture content of the waste, and the antagonistic action of various organisms in the microflora (Geldreich, 1990, quoted in Engelbrecht, 1993). Engelbrecht stressed the difficulties of obtaining representative samples of microorganisms for a detailed survey, in view of the different types of wastes in municipal landfills, and hence the variety of organisms present. Analysis of samples is accordingly problematic.

Pahren (1987, quoted in Engelbrecht, 1993) found that the numbers of total coliforms in municipal waste ($7{,}7 \times 10^8\ g^{-1}$), were much the same as the numbers found in undigested sewage sludge ($2{,}8 \times 10^9\ g^{-1}$) and in hospital waste ($9{,}0 \times 10^8\ g^{-1}$). Pahren observed that environmental conditions within landfills reduce the survival rates of microorganisms, with relatively low counts often found in leachate. Engelbrecht and Amirhor (1975, quoted in Engelbrecht, 1993) in an examination of various reports in the literature, noted that the densities (per gram of dry municipal waste) of faecal streptococci and faecal coliforms were some $2{,}8 \times 10^3$ and $5{,}0 \times 10^3$ organisms respectively. It was also found that the numbers of total coliform, faecal coliform, faecal streptococci and total plate count bacteria varied considerably with the age of the leachate. The rate of inactivation of viruses is partly a function of the age of the landfill. Besides Streptococcus spp., other microorganisms identified in municipal landfills include E. coli; Klebsiella spp., Enterobacter spp., Staphylococcus spp., Salmonella spp. and Proteus spp. (Engelbrecht, 1993).

The Department of Water Affairs and Forestry has stipulated that a water quality monitoring plan must be prepared for groundwater, surface water and leachates - in order to prevent or at least to contain leachate migration and the subsequent contamination of surface and groundwaters (Anonymous, 1994: Document No. 1). The water quality plan involves pre-disposal background monitoring (discussed earlier); operation monitoring (detection and investigative monitoring), and post closure monitoring. The plan accordingly, is an integral component of the permitting requirements. An appeal against compliance with the minimum monitoring requirements may be considered by the Department in certain very defined circumstances.

Both groundwater and surface water must be monitored above and below the landfill site. It follows that the number and locality of sampling points must be carefully chosen in the landfill investigation phase, where the size of the landfill as well as the types of waste to be received, are important sampling design parameters. A comparison of upgradient (ambient) data and downgradient data will indicate the extent of contamination caused by the landfill. Leachate monitoring is required at all B^+ and H sites, or where <u>otherwise</u> deemed necessary by the Department (for example at B^- landfill sites with sporadic leachate generation problems).

The Department of Water Affairs and Forestry has specified the water quality determinands (parameters) which should be examined in both groundwater and surface water. The Responsible Person must however, also test for other determinands as necessary or as specified in the permit, for instance, at H sites. Groundwater levels in the monitoring boreholes must likewise be recorded. Detection monitoring comprises routine monitoring which is undertaken every six months. Indicator determinands only, are assessed to test for any contamination. Routine determinands are as follows: P alkalinity*, chemical oxygen demand, chloride, nitrate (as N), pH, potassium and total dissolved solids. Several additional determinands must be examined on an annual basis, namely, calcium, electrical conductivity, fluoride, magnesium, sodium and sulphate. Further (investigative) monitoring will be required by the Department of Water Affairs and Forestry if detection monitoring indicates possible contamination (increasing determinand concentrations). Investigative monitoring is usually undertaken on a monthly basis, or as

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* P alkalinity is determined by titration to the phenolphthalein end point of pH 8,4. M alkalinity by contrast, can be determined by using the methyl-orange end point, which is approximately pH 4,5 (depending on the initial condition of the water).

specified by the Department. Determinands which must be examined in any detailed analysis of water quality include the following: P alkalinity, boron, cadmium, calcium, chemical oxygen demand, chloride, hexavalent chromium, total chromium, cyanide, electrical conductivity, free and saline ammonia (as N), lead, magnesium, mercury, nitrate (as N), pH, phenolic compounds, potassium, sodium, sulphate and total dissolved solids. These determinands must also be examined as part of the background analysis during the new landfill investigation phase, or for the first time monitoring at an existing landfill site (Anonymous, 1994: Document No. 1). Leachate must be sampled at suitable points in the leachate collection system, at the same frequency and using the same determinands (as per groundwater and surface water), unless otherwise stipulated by the Department. The Department will advise the Responsible Person at B^- landfills of leachate determinands to be examined in the event of troublesome sporadic leachate generation.

The Responsible Person must maintain records of all analyses undertaken at the site. The results must be submitted to the Department every six months or as specified in the permit. Post closure monitoring (see Section 17.21) must be undertaken in the same way as operation monitoring, with special emphasis on groundwater testing. Regular reports must be submitted to the Department in the post closure phase. Further particulars on water quality monitoring can be found in Anonymous (1994: Document No. 3)*. While a number of waste managers have already installed monitoring systems, much remains to be done especially at unpermitted and concept permitted landfills, and at other waste storage or leachate generation sites. Overall estimates of the extent to which monitoring procedures have been instituted at waste sites in South Africa, are provided in Table Q14.

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* See Anonymous, 1994. Minimum requirements for monitoring at waste management facilities, Document No. 3, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 49 p. (The publication contains important information inter alia on the types of aquifers in South Africa; some risk assessment procedures for aquifers; analytical parameters and South African Bureau of Standards methods of analysis; recommended sampling points and sampling frequencies, and water quality data interpretation). Groundwater quality assessment is also discussed in: Weaver, J.M.C., 1992. Groundwater sampling: a comprehensive guide for sampling methods, WRC Report No. TT 54/92, Water Research Commission, Pretoria, various pages, as well as in Weaver, J.M.C., 1992. Groundwater sampling: an abbreviated field guide for sampling methods, WRC Report No. TT 56/92, Water Research Commission, Pretoria, various pages. According to Anonymous (1994: Document No. 3), indicator determinands of particular interest include the following: nitrate and agrichemicals for agricultural waste; sodium and sulphate at power generation plants; pH, electrical conductivity, manganese and sulphate at mines; chemical oxygen demand, chloride and nitrate at general waste disposal sites; hexavalent chromium, trihalomethanes and total organic carbon at hazardous waste sites, and finally sewage parameters such as chemical oxygen demand, ammonium and phosphate (as PO_4).

Table Q14: **Estimates of the number of waste sites in South Africa adequately equipped with monitoring facilities, 1994.**

Type of site	Sites properly equipped (percentage)	Sites routinely monitored (percentage)
Coal fired power stations	90	90
Mines (reactive environments)	5	3
Mines (inert environments)	0,5	<0,1
General waste	0,5	0,3
Hazardous waste	50	50
Radioactive waste	100	100
Agriculture (feedlots)	1	<0,1
Agriculture (diffuse sources)	3	<0,1
Waste irrigation	5	3
Sewage works (unlined maturation ponds and sludge)	<0,1	<0,1
Septic tanks and pit latrines	1	<0,1
Urban development (including stormwater drains)	1	<0,1

Source: After Anonymous, 1994. Minimum requirements for monitoring at waste management facilities, Document No. 3, Waste Management Series, Department of Water Affairs and Forestry, Pretoria, 49 p.

Note:

(i) Statistics for coal fired power stations refer specifically to coal stockpiles, the wet and dry disposal of ash, dirty water systems and discharged water.

(ii) Data for reactive environments at mines refer to slimes (slurry), ore discards, rock discards and impounded as well as discharged mine water. Inert environments at mines comprise slimes (slurry), ore and rock discards and discharged mine water.

South African aquifers are very vulnerable to pollution, since virtually all usable groundwater occurs within 60 m of the soil surface. Other pollution predisposing factors include aquifer recharge mechanisms, the dominant type of aquifer found in this country (secondary or fracture flow aquifers), and the preferential flow-paths of contaminants usually into rivers. (Flow-paths in turn, are dependent on water table gradient, fractures and geology). It follows that there is a fairly rapid rate of transport of contaminants in secondary aquifers, whereas leachate migration is slower and more localized in primary or porous flow aquifers (Anonymous, 1994: Document No. 3; Hodgson, 1995)*. Kok (1990, quoted in Anonymous, 1991 - see Table Q15)**, observed that aquifers of the coastal plain of Natal/KwaZulu are at a considerable risk in terms of formal landfills and other dump sites, due to the generally shallow groundwater. Kok (1990) assigned a pollution risk factor ranging from 0 to 10 to various geological formations in Natal/KwaZulu: with 0 indicating no risk to aquifers, and 10 indicating the greatest risk of contamination (Table Q15).

The importance of accurate geological data for the design and operation of landfills and other waste sites was emphasized by Meyer, Duvenhage, Coetsee and Weaver (1994)***. Meyer et al (1994) examined the geology and groundwater quality at five different sites in South Africa. These were: a municipal solid waste landfill; a Class 1 (H) hazardous waste landfill; an industrial site where chloride-rich effluent is disposed of in unlined evaporation ponds; a gold mining site with slimes dams and evaporation ponds, and a series of artificial recharge basins for a coastal aquifer (involving the infiltration of stormwater and industrial effluents). Meyer et al found that geophysical investigations undertaken at the various sites revealed the presence of a number of significant geological features, which had a direct bearing on the geohydrology of the area surrounding each site. Meyer et al concluded that a detailed knowledge of the geological structure as well as geohydrological information is of great importance in understanding and predicting the future migration of leachate at waste disposal sites. Geophysical techniques therefore, are a valuable tool in the assessment of groundwater contamination at waste sites.

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* Hodgson, F.D., 1995. Personal communication, Institute for Groundwater Studies, University of the Orange Free State, Bloemfontein.

** See Kok, T.S., 1990. The utilization and pollution risk of ground water in the Natal region, Technical Report No. Gh 3716, Directorate of Geohydrology, Department of Water Affairs, Pretoria, 18 p. + app.

*** See Meyer, R., Duvenhage, A.W.A., Coetsee, V. d A. and Weaver, J.M.C., 1994. The evaluation and development of geophysical techniques for characterizing the extent and degree of ground water pollution, WRC Report No. 267/1/94, Water Research Commission, Pretoria, 115 p. + app.

Table Q15: The pollution risk of aquifers in Natal/KwaZulu.

Geological formation	Nature of aquifer	Pollution risk factor
Karoo Supergroup		
Tillites	Contact zones with dolerite	2
Shales	Contact zones with dolerite	4
Mudstones	Contact zones with dolerite	4
Basalt	Basins of decomposition	1
Natal Group sandstone	Joints, faults and bedding planes	8
Granite	Faults and fractures	6
Quaternary and Tertiary sediments	Pervious sand and gravel	10

Source: After Kok (1990, quoted in) Anonymous, 1991. Zululand Joint Services Board: potable water resources and distribution Phase 1 Report, December 1991, Report No. 1558/10, Watermeyer Legge Piesold and Uhlmann, Pietermaritzburg, 55 p. + app.

See also: Campbell, E.E., Parker-Nance, T. and Bate, G.C., 1992. A compilation of information on the magnitude, nature and importance of coastal aquifers in southern Africa, WRC Report No. 370/1/92, Water Research Commission, Pretoria, 192 p.

Note: Campbell, Parker-Nance and Bate (1992) made the important point that local authorities in general along the coastal belt of South Africa, are largely uninformed on groundwater management. Obvious dangers in terms of aquifer contamination due to poorly located waste sites are apparent.

Parsons and Jolly (1994)* observed that no standard method has been used in South Africa to-date, to assess the probable or actual impacts of landfills and other waste sites on aquifers. The lack of a uniform system has resulted in inconsistent conclusions being reached in geohydrological studies undertaken at certain waste sites. Accordingly, a computer program known as the Waste-Aquifer Separation Principle (WASP) was devised for South African conditions. The purpose of WASP is to assist in the geohydrological

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* See Parsons, R. and Jolly, J., 1994. The development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria, WRC Report No. 485/1/94, Water Research Commission, Pretoria, 79 p. + app. See also, Parsons, R. and Jolly, J., 1994. WASP manual, WRC Report No. TT 67/94, Water Research Commission, Pretoria, 20 p. + app. and floppy diskette.

selection of suitable (new) solid waste sites. WASP can also be used to identify additional data required for the landfill selection process. The method can likewise be used to examine the suitability of already existing solid waste sites. The WASP method in essence, involves an assessment of the potential risk of aquifer contamination.

The WASP procedure is based on 29 similar methods used elsewhere in the world. A central theme of WASP is the necessity for the separation of landfill sites and aquifers. Three factors were identified as significant for the assessment of site suitability, namely, the threat factor, the barrier factor, and the resource factor. The threat factor refers to the threat posed by the volume and quality of the leachate. The barrier factor defines the ability of the unsaturated (barrier) zone to separate the waste body from an aquifer. The resource factor attempts to quantify the strategic value of the aquifer as a resource in terms of the user or potential user, for example, a farmer or a town. A WASP index is calculated once scores for all three factors have been determined. The index is correlated against a generalized interpretation, with sites being defined as highly unsuitable, unsuitable, marginal, suitable or highly suitable. The WASP procedure incorporates a data reliability rating where all input data are rated with regard to detail and reliability. Parsons and Jolly (1994) stressed that further validation of WASP will be necessary, once more field data become available for a wide range of waste site and geohydrological conditions. There is a possibility that WASP will in future form part of the landfill permitting (application) process. Other risk assessment methods are described in Parsons and Jolly (1994).

Parsons (1994)* raised a number of important issues regarding groundwater recharge and leachate generation which have direct relevance to the minimum requirements of the Department of Water Affairs and Forestry. Parsons inter alia questioned the use of the simplified climatic water balance equation to determine whether a site should be classified as a water surplus or a water deficit area, or more specifically, whether significant or sporadic leachate generation could be anticipated. Different minimum requirements, as discussed in this chapter, apply depending on whether the site is regarded as a B^- or B^+ site and accordingly, whether an advanced leachate collection and management system is required or not. Parsons likewise maintained that the validity of the Hydrologic

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* See Parsons, R., 1994. A review of approaches and methodologies for determining leachate generation at waste disposal sites and groundwater recharge, WRC Report No. 564/1/94, Water Research Commission, Pretoria, 69 p. + app.

Evaluation of Landfill Performance (HELP) Model has not been established in South Africa. Parsons stressed that proper testing is necessary under local conditions (arid and semi-arid areas in particular), before the model can be generally applied. Parsons argued that should the basis of the water balance calculations prove to be invalid, then less stringent requirements are being set and maintained in the drier parts of South Africa, with possible implications for the environment as well as human, animal and plant life. A further difficulty is that the climatic water balance method is only fully applicable if the landfill is properly designed and operated according to modern practices - with effective management to reduce the rate of leachate generation (Parsons, 1994).

Leachate generation and the contamination of aquifers is the subject of much scientific investigation and debate both in South Africa and overseas. It is apparent that more research is necessary which will inevitably result in changes in perceptions as well as design, operation and monitoring procedures. The interested reader should maintain close contact with leading authorities in the field in order to stay up-to-date. Insofar as South Africa is concerned, the Department of Water Affairs and Forestry has adopted a differentiated protection approach to groundwater in this country. Differentiated protection refers to the prevention of pollution in high quality and high yielding aquifers. Less stringent controls are applied in other cases in order to accommodate the industrial, urban and agricultural sectors; and in view of the scarce financial and manpower resources. Aquifers are accordingly categorized on the basis of geological features, depth and vulnerability to pollution, as well as population needs. The differentiated protection policy acknowledges that not all aquifers are equally vulnerable to contamination, are of usable quality, or are equally valuable. The (water quality) precautionary principle is nevertheless strictly applied to the siting of waste disposal sites. Caution is essential to prevent pollution wherever possible - in view of the limited contaminant assimilation capacity of groundwater - and hence to avoid very costly and virtually impossible remedial action.

Other groundwater policies include the limited degradation approach which aims to maintain groundwater quality at the highest possible level, while allowing pollution up to specified protection levels (standards). The most restrictive policy is that of non-degradation where groundwater is fully protected and maintained in a natural state. Very few countries have adopted the latter approach, and it is recognized that some contamination is unavoidable in a modern economy (Anonymous, 1994: Document No. 3).

The need for definitive guidelines for groundwater protection in South Africa, has been given considerable impetus by the requirements of the Reconstruction and Development Programme (RDP), and specifically the Community Water Supply and Sanitation (CWSS) Programme formulated by the Department of Water Affairs and Forestry. One important objective of the RDP is to provide adequate potable water to rural households (discussed in the chapter on water supply planning). A three-tier approach has been proposed to protect groundwater resources in South Africa from contamination (Xu and Reynders, 1995)*. The first tier or first line of defence concentrates on the establishment of guidelines for aquifer protection for development projects (rural schemes, agricultural/industrial expansion and waste disposal sites), which could or will pollute groundwater. It is regarded as essential that first tier guidelines for protection purposes be rapidly implemented country-wide, with special reference to peri-urban and rural boreholes/wells/springs and on site sanitation systems, as well as livestock concentration areas. The main thrust of first tier protection involving minimum, although basic standards, is to reduce the impact of smaller (pollution) point sources on groundwater. Short term measures will be applied to ensure that potential or actual sources of contamination, such as unsanitary borehole installation/operation and inappropriate sanitation systems, are accorded a high priority. Attention will also be paid to a safe separation distance between on site sanitation facilities and boreholes, wells and important *springs - particularly for new rural water and sanitation projects (discussed further in the* chapter on sanitation). It has been suggested that the Department of Water Affairs and Forestry should be responsible for implementing first tier protection.

The second tier refers to the catchment or regional scale protection of aquifers via regulation of major point and diffuse sources of contamination. Such a medium term planning programme should be undertaken at central and provincial level. Second tier

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* See Xu, Y. and Reynders, A.G., 1995. A three-tier approach to protect groundwater resources in *South Africa*, Water SA, VOL 21(3), p. 177 - 186. See also, Xu, Y. and Braune, E., 1995. A guideline for groundwater protection for the Community Water Supply and Sanitation Programme, Department of Water Affairs and Forestry, Pretoria, 49 p.

policies involve the mapping and risk classification of the vulnerability of selected aquifers, using the differentiated protection approach*.

The third tier of protection involves the designation of special protection zones around a specific groundwater source (such as boreholes, wells and important springs), or a probable future source. Zoning will be applied in certain priority areas as defined by the differentiated protection principle (Braune, 1994, quoted in Xu and Reynders, 1995). Third tier policies should ideally be applied primarily by local authorities, who are familiar with conditions in their own areas of jurisdiction. Third tier policies constitute an advanced stage of groundwater protection and are therefore longer term objectives. A detailed knowledge of South African groundwater conditions is required for zoning purposes, where given strategies based on careful national research, are readily available to prevent or contain (attenuate) groundwater pollution. It follows that site specific information is vital for zoning needs. Both regulatory (legal) and non-regulatory mechanisms will be used as part of the third tier approach. The former includes land use zoning restrictions and the minimum requirements as described in this chapter. An important legal method is the

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* An aquifer system management classification procedure (as well as associated decision support tools), was recently developed for South African conditions. The classification system is a useful planning tool which will help to define the level of protection required for a variety of aquifers. The classification represents a point of departure for the national and regional categorization of South African aquifers. The classification system will be amended in the light of practical experience. Briefly, aquifers are classified as follows: **sole source aquifer systems** which supply 50% or more of the domestic water in any area where there are no reasonably available alternative sources. Aquifer yields and water quality are immaterial. The second category concerns **major aquifer systems** with highly permeable formations (usually with a known or probable presence of significant fracturing). These aquifers can provide large volumes of good quality water (<150 mS m^{-1}). The third category comprises **minor aquifer systems** consisting of fractured/potentially fractured rocks which lack a high primary permeability, or other formations which have a variable permeability. Water quality may likewise be variable. These aquifers (although not high yielding), are important for localized supplies and for river base flow purposes. **Non-aquifer systems** (the fourth type) are systems with a very limited permeability, and which seldom contain groundwater in exploitable quantities. Water quality may be poor. Nevertheless, protection from permanent or persistent contamination sources may be required. The fifth type of aquifer is a **special aquifer system** (for specific cases), which will be designated by the Minister of Water Affairs and Forestry. An example of the latter is a subterranean water control area. Other factors such as the vulnerability of the aquifer to contamination must also be considered for management (decision-making) purposes. A simple weighting and rating approach has therefore been recommended. Each category or class of aquifer, for example, a sole source aquifer system has been given a numerical value. A second variable consisting of three generic classes (high/medium/low) has been assigned based on a number of parameters. These user-defined parameters could for instance, include population density and drought risk. The two ratings must be multiplied to obtain a groundwater management decision-support index. The numerical index is interpreted by means of management action criteria. The criteria specify the most appropriate management strategy, namely: limited protection; low level protection; medium level protection; high level protection, and strictly no degradation. One version of the procedure uses national aquifer vulnerability classes as the second variable, in order to obtain a Groundwater Quality Management classification. The numerical values and the levels of protection needed, are the same as before. See: Parsons, R., 1995. A South African aquifer system management classification, WRC Report No. KV 77/95, Water Research Commission, Pretoria, 20 p. + app.

outright prohibition of any storage or activity associated with certain chemicals or industrial processes. Non-regulatory methods could include training programmes as well as self regulation and public education. In essence, the proposed three-tier approach will facilitate the protection of groundwater resources on a national (small point source impact minimization); regional (vulnerability classification preceding differentiated protection), and local (protection zoning) level - in the short, medium and long term (Xu and Reynders, 1995).

17.21 <u>The rehabilitation, closure and end use of landfills</u>

The final stage of the life cycle of a landfill involves the rehabilitation and closure of the site. It is an important requirement that the Department of Water Affairs and Forestry must be given one year's notice of the impending closure of an operating site. Permits are necessary for all unpermitted operating landfills before they can be considered closed. In such cases, permitting refers to the rehabilitation, closure and end use of the site. Landfills closed after August 1990 also need a permit before they can be regarded as <u>officially</u> closed.

A revision of the closure and end use requirements is necessary at permitted operating sites, including sites developed as per the minimum requirements. A closure design must be compiled along the lines of the original landfill design (discussed earlier in the chapter). The closure design at unpermitted operating and closed sites (in most cases), will be the first landfill design ever submitted. Aspects which require attention in the closure design include any problems specific to the site; the final landfill capping and landscaping; permanent stormwater drainage systems and leachate plus gas management structures; as well as anti-erosion measures, and any other infrastructure needed in terms of the end use plan. Special care is necessary at all sites not designed or operated in accordance with the minimum requirements.

A closure report must also be compiled. The report compares the existing conditions at the site with the desired closure and end use requirements. The report must describe all rehabilitation measures necessary (prior to final closure), in order to ensure that the site is environmentally acceptable both in the short and long term. Considerable remedial work must be undertaken at all sites not designed/operated in terms of the minimum requirements; and also where progressive rehabilitation of redundant parts of the site was not carried out. The closure design and report must be submitted to the Department of Water Affairs and Forestry for approval. Following an on site inspection and acceptance of the proposal, the Responsible Person can then proceed with actual site rehabilitation and closure. A final site inspection undertaken inter alia by staff of the Department of Environment Affairs, the Department of National Health and Population Development, and the Department of Water Affairs and Forestry is required before the site is declared closed. The provisions of the end use plan can then be applied*. Permission for closure will not be granted unless all rehabilitation and other procedures as specified in the closure design/report - plus any further measures deemed necessary by the Department of Water Affairs and Forestry - have been attended to.

Regular inspections of the site in the future must be undertaken by the Permit Holder to ensure that the final cover has not been damaged (due to erosion, uneven subsidence or fire); and to check that all water drainage and leachate systems are fully functional. No nuisances should be evident. The Permit Holder must repair any damage at his own expense**. The Department of Water Affairs and Forestry will determine the period (up to 30 years), during which inspections for maintenance purposes must be undertaken in order to contain health, safety, nuisance and environmental impacts. The Department will also specify the water quality monitoring period (up to 30 years in the case of some B^- sites, most B^+ sites and all H sites). Frequent reports with particular reference to groundwater quality at these sites must be submitted to the Department in the post closure phase.

17.22 Conclusion

The (occasionally utopian) minimum requirements for landfill sites have been discussed at some length in this chapter***. Landfills are the final means of disposal for much of the solid waste generated in industrialized countries. An understanding of certain aspects

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* The most common end use for Class G sites is public open space (for sport and recreational purposes). No public access to Class H sites can ever be allowed. The appropriate end use for existing and recently closed (unpermitted) sites will need to be determined as part of the permitting process. Discussions must be held inter alia with the Interested and Affected Parties.

** The Department of Water Affairs and Forestry will attempt to trace the previous owner or operator (where remedial action is required), for sites closed before August 1990.

*** Readers are reminded that the minimum requirements are presently being revised. The relevant documents will be released in due course.

of the operation and control of landfill sites may provide the reader with additional environmental information. The data may be useful inter alia for an assessment of catchment water quality issues and related implications. These implications include the real costs of surface and groundwater contamination in a semi-arid country, and the costs of treating resultant diseases. While landfills and other waste sites are an essential component of modern civilization, it is also true that much can be done to reduce waste generation in the first instance, and to recycle or reuse suitable materials. Society-at-large must decide whether prolific consumption is worth the environmental and medical risks, now and in the future.

17.23 Pesticides, herbicides and fungicides (agrichemicals)*

17.23.1 The classification of agrichemicals

Considerable concern has been expressed in recent years about the number of agricultural chemicals (especially pesticides) used in South Africa. Besides pesticides, herbicides and fungicides, other chemicals of interest include fumigants; algicides (algal poisons); molluscicides (snail poisons); nematicides (nematode poisons); acaricides (mite poisons); avicides (bird poisons), and rodenticides (rodent poisons) - collectively known as agrichemicals (agrochemicals) - or sometimes simply as "pesticides" or biocides. Also defined as agrichemicals are plant growth regulants, defoliants and desiccants. Pesticides per se are generally used in the largest quantities and may have the most severe effects on human health and the environment, if used in an irresponsible manner. In 1975, the World Health Organization (WHO) developed a classification of agrichemical toxicity, based on the amount of the chemical required to kill 50% of a random sample of experimental animals (mainly rats, but also rabbits). The procedure is known as the LD_{50} value, namely, the lethal dose expressed in mg of agrichemical per kg of animal body mass**.

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* Discussion partly based on London, L., 1992. Agrichemical hazards in the South African farming sector, South African Medical Journal, VOL 81(11), p. 560 - 564. (The section on agrichemicals was reviewed by J.B. Vermeulen, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria. The author (P.G. Alcock) is however, responsible for any errors in the text).

** Whereas older LD_{50} tests examined the active ingredient/s only, the latest procedure concerns the overall hazard of the product per se including toxic interactions between all chemicals - even those present in trace amounts - constituting the product. Animal studies therefore, provide data on the total toxic effects of the product. Where no experimental data are available however, estimates of toxicity are based on the active ingredient/s (technical grade only), for liquid formulations. A calculation is used for dry formulations, as per the WHO.

Agrichemical toxicity is classified by the WHO in terms of three hazard categories, namely, Classes Ia, Ib, II and III (Table Q16). Class Ia agrichemicals are extremely hazardous, while Class III substances are the least dangerous.

The classification system includes the exposure route and the type as well as the formulation (for example, granular versus liquid) of the agrichemical in question. It must be emphasized that the WHO classification system as well as the RSA classification system (Table Q16), serve as guidelines which should not be rigorously applied in the absence of sound professional judgement, further scientific evidence, and experience. In 1985, the Food and Agriculture Organization (FAO) re-affirmed the validity of the WHO classification system, and recommended the use of colour coding on product labels to visually indicate the hazard of the various types and formulations of agrichemicals (Vermeulen, 1995) (see Table Q16). Numerous site factors however, can influence the actual degree of hazard (London, 1992). These factors include incorrect storage or chemical interactions during storage; careless handling or mixing during preparation for use, and weather conditions at the time of application. Also of major importance is the presence of other substances or agrichemicals applied at the same time (which can interact with each other); the frequency of exposure; the time interval between application and exposure; the detoxification (decomposition) rate (itself dependent on many parameters); the availability of washing facilities, and the vegetation density (where relevant) in the target area. Of primary significance is the risk or the actual occurrence of acute or subacute (non-fatal) human morbidity (illness) - as opposed to animal model data - and chronic health effects such as cancer, due to low grade, although long term exposure*. Fears have been expressed regarding the future effects of agrichemicals on the environment in general (not fully reflected in the LD_{50} test or any subsequent agrichemical classification).

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* Readers are reminded that the term "acute" refers to a disease of rapid onset, severe symptoms and brief duration. The term "chronic" refers to a disease of long duration, involving very slow changes and often with a gradual onset. "Subacute" describes a disease that progresses more rapidly than a chronic condition, but which does not become acute.

Table Q16: The World Health Organization agrichemical toxicity categories, as per the LD_{50} test, 1975.

WHO classification class	Oral intake (mg kg^{-1} experimental animal body mass)		Dermal intake (mg kg^{-1} experimental animal body mass)	
	solids	liquids	solids	liquids
Class Ia (extremely hazardous)	≤5	≤20	≤10	≤40
Class Ib (highly hazardous)	5 - 50	20 - 200	10 - 100	40 - 400
Class II (moderately hazardous)	50 - 500	200 - 2 000	100 - 1 000	400 - 4 000
Class III (slightly hazardous)	>500	>2 000	>1 000	>4 000

Source: (i) After London, L., 1992. Agrichemical hazards in the South African farming sector, South African Medical Journal, VOL 81(11), p. 560 - 564.

(ii) After Vermeulen, J.B., 1995. Personal communication, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria.

Note: (i) The higher the concentration of active ingredient, the greater is the hazard. Very low LD_{50} values indicate extreme hazard.

(ii) As a general rule, an agrichemical formulated as a solution or as an emulsifiable concentrate, is more hazardous than when formulated as a dust, granules or as a wettable powder.

(iii) Intake routes include the eyes and the lungs. Inhalation however, is not considered in the above classification system, since oral and especially dermal intake is far more relevant in outdoor agricultural situations. The WHO system classifies liquid preparations as four times more hazardous than the corresponding solid preparations, given that dermal intake occurs in most cases of accidental poisoning, and that dermal effects may be rapid. Tolerance limits accordingly, are broader for liquids per category, reflecting the greater hazard.

(iv) The new (hazard) classification system used in South Africa is directly based on the international system, with certain differences. In terms of the RSA Classification Code of Agricultural and Stock Remedies, one important change involves the WHO Class III category

(Anonymous, 1991)*. All WHO Class III compounds with LD_{50} oral intake values of >2 000 and >3 000 mg kg^{-1} body mass for solids and liquids respectively, become Group IV compounds in the RSA system. (Note the change from class to group). Hazard refers to the acute risk to human health due to accidents following the correct use, storage or transport of agrichemicals - as specified by the manufacturers and competent international organizations**. Hazard in terms of the South African system is indicated on the label (attached to the container), as follows:

WHO classification class	RSA classification group	Hazard statement and symbol
Ia	Ia	Very toxic; skull and crossbones on red background
Ib	Ib	Toxic; skull and crossbones on red background
II	II	Harmful; St Andrew's cross on yellow background
III	III	Caution; no symbol on blue background
III (compounds unlikely to present acute hazard in normal use - not recognized as a separate class by the WHO)	IV (a separate group in the RSA system)	Green colour only

Most classifications (in reality) are undertaken on the basis of the acute oral LD_{50} value. However, where considerable toxicity (LD_{50}) differences are apparent in terms of oral versus dermal effects, the particular compound will always be classified as part of the more restrictive group (for example, Group II instead of Group III). A substance may also be subsequently reclassified or withdrawn if the acute hazard to man (whether due to human toxicological evidence or other factors), differs from that indicated by the LD_{50} test only.

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* See Anonymous, 1991. Guidelines for the RSA Classification Code of Agricultural and Stock Remedies and associated labelling practices, Department of Agriculture and the Agricultural and Veterinary Chemicals Association of South Africa, Pretoria, various pages. A simplified guide to the storage of agrichemicals, the treatment and disposal of empty containers, first aid hints and the RSA Classification Code, as well as relevant labelling practices can be found in Anonymous, undated. Agricultural chemicals and stock remedies: responsible use, Agricultural and Veterinary Chemicals Association of South Africa, Halfway House, 33 p. (The Association is now known as the Crop Protection and Animal Health Association).

** It is essential to distinguish between a classification based purely on toxicity (used in the older literature) and which refers to the active ingredient/s only, and a classification based on hazard, where both the active ingredient <u>and</u> the formulation (reflecting the particular solvent - where applicable), are considered. As noted above, the toxicity of the active ingredient can be greatly altered by the formulation. The formulation *per se* can result in further hazards. For example, the product besides being toxic may also be very corrosive, highly flammable, an irritant or an oxidizing agent. Such properties have important health as well as storage and handling implications.

The LD_{50} test accordingly, is the most fundamental, but not the only criteria considered for classifying agrichemicals. All agricultural and stock remedies are classified in terms of the South African Bureau of Standards Code of Practice 0228-1990 (The identification and classification of dangerous substances and goods). A register of all these agrichemicals (and other substances and goods) is maintained by the Department of National Health and Population Development, as well as by the Department of Agriculture. The South African Bureau of Standards Code of Practice 0229-1990 (Packaging of dangerous goods for road and rail transportation in South Africa), and the International Maritime Dangerous Goods Code (IMDG-code) are applicable for bulk transport purposes (Anonymous, 1991 - above).

(v) Three core publications, firstly on pesticides and fungicides*; secondly, on herbicides, and thirdly on plant growth regulants, defoliants and desiccants are available for South African conditions. It is vitally important that the latest edition of the three publications be consulted by readers requiring specific details on the various products. The regular publication on pesticides and fungicides provides concise data on the required dosage and application method/s for pests and diseases of many standing crops as well as trees and lawns. Information is likewise provided for pests of veld and pasture grasses (for example, rabbits and termites), as well as for pests of stored produce plus hides, skins, wool, timber and furniture. Also included is information on water pests (blackfly larvae, mosquito larvae and marine borers). Other pests including those found in dwellings, general storage rooms and in animal shelters are also discussed. Chemicals for use in repelling bush buck, bush pig and duiker are described, along with fungicides. Much emphasis is placed on the safe use of pesticides and fungicides, and the publication includes a section on the handling of victims of poisoning. The names and addresses of local manufacturers and South African agents of the various pesticides and fungicides are listed, along with eight South African Bureau of Standards codes of practice relating to the safe transport, use, and disposal of surplus pesticides and associated hazardous waste. Other data contained in the publication include an index of common names of active ingredients with the equivalent trade names and related information. Finally, the maximum permissible pesticide residues in specified crops (at the time of harvesting or after post-harvest treatment) for human consumption are outlined. (Residues in foodstuffs are examined in more detail, later in the chapter).

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* See Nel, A., Krause, M., Hollings, N., Greyling, J. and Dreyer, M., 1993. A guide to the use of pesticides and fungicides in the Republic of South Africa, thirty-sixth revised edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 332 p. (It should be noted that data on the poison classification (group) of the active ingredient/s listed in the publication, as well as the LD_{50} criteria for acute oral and dermal toxicity with reference to rabbits and rats, were provided in previous editions of the publication).

(vi) The regular publication on herbicides* provides information (in the same format as per pesticides and fungicides), for numerous crops as well as for pastures and commercial forests. Guidelines are likewise provided for noxious plants including tree species such as Acacia dealbata (Silver Wattle) and Sesbania punicea (Red Sesbania) - both of which have invaded valuable riverine areas in Natal/KwaZulu. (See the chapter on soils and soil erosion). The publication also contains information on the treatment required in respect of bush encroachment, for firebreaks and for lawns and turf. The control of aquatic weeds** is also discussed, specifically, Eichhornia crassipes (water hyacinth); Lagarosiphon spp. (oxygen weed); Phragmites australis (common reed); P. mauritianus ("fluitjiesriet"); Pistia stratiotes (water lettuce); Potamogeton spp. (pondweed); Salvinia molesta (Kariba weed), and Typha capensis (common bulrush). A classification of herbicides into 23 chemical groups is outlined in the publication. An index of common names of active ingredients with the equivalent trade names and related information, as well as a listing of English and Afrikaans common names and botanical names for noxious plants is included. Data are likewise provided on the LD_{50} values for acute oral and dermal effects on rabbits and rats with reference to active ingredients. Maximum permissible residues in crops (at the time of harvest) for human consumption are specified. The names and addresses of local manufacturers and South African agents of the herbicides listed in the publication, are also presented.

(vii) Data on the correct use of plant growth regulants, defoliants and desiccants can be found in the fifth edition of the relevant publication***. The publication provides information for a variety of crops as well as for hedges, lawns and grasses. An index of common names of active ingredients with the equivalent trade names plus related information is included. Data on the LD_{50} values for acute oral and dermal effects on rabbits and rats in terms of active ingredients are tabulated. Maximum permissible residues in crops (at the time of harvest) for human consumption are outlined. The names and addresses of local manufacturers and South African agents of products listed in the publication, are likewise presented.

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* See Vermeulen, J.B., Dreyer, M. and Grobler, H., 1993. A guide to the use of herbicides, fourteenth edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 137 p. (Herbicides, with a few marked exceptions, are less hazardous than pesticides. Fungicides have a relatively low toxicity, while nematicides have a high toxicity).

** See also, Steÿn, D.J., Scott, W.E., Ashton, P.J. and Vivier, F.S., 1979. Guide to the use of herbicides on aquatic plants, Technical Report No. TR 95, Department of Water Affairs, Pretoria, 29 p.

*** See Vermeulen, J.B. and Greyling, J., 1990. A guide to the use of plant growth regulants, defoliants and desiccants, fifth edition, Plant Protection Research Institute, Department of Agricultural Development, Pretoria, 22 p. (A later edition is available: Vermeulen, J.B., Dreyer, M. and Grobler, H., 1995. A guide to the use of plant growth regulants, defoliants and desiccants, seventh edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 26 p.).

Agrichemicals can also be categorized in terms of chemical class or with regard to their use spectrum (International Programme on Chemical Safety, 1990, quoted in London, 1992). A combined (overview) classification system is presented in Table Q17. The health implications of agrichemicals (briefly discussed below) are varied, reflecting the number of products available. It is a statutory requirement that any agrichemical (legally defined as an agricultural or stock remedy) must be registered prior to general release on the South African market. Registration is undertaken by the Registrar: Act No. 36 of 1947, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Private Bag X343, Pretoria, 0001. The particular agrichemical can only be legally sold once the Department in association with other departments (National Health and Population Development; Environment Affairs; Manpower, and Water Affairs and Forestry) has examined the (experimental) product data - plus other relevant information - and is satisfied that all legal and other requirements have been met*. The controlling legislation is the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947 (as amended)**.

A total of 1 211 agrichemicals (albeit several with the same active ingredient) was registered for use in South Africa in 1989 (Fourie, 1989)***. Approximately 10 - 15 new products (with new active ingredients) are registered in South Africa each year. The Registrar is assisted by an inspectorate service whose duties involve checking on compliance with the Act. Only two inspectors based in Pietermaritzburg are available for the whole of Natal/KwaZulu. A number of organizations may be called upon to undertake agrichemical research and testing with regard to South African conditions.

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* Staff of the various departments (with two representatives from the Agricultural Research Council) constitute the Standing Interdepartmental Advisory Committee for the Protection of Man Against Poisonous Substances - known as INDAC. Final approval for the registration of an agricultural or stock remedy is given by INDAC. The Department of National Health and Population Development has a vital role in the initial registration process, where remedies must be assessed by the Department in terms of toxicological properties and human health as well as environmental risks. The registration of current agricultural and stock remedies must be renewed each year. An application must be submitted to the Registrar: Act No. 36 of 1947 for any amendment to an existing remedy.

** Further particulars relating to the registration of fertilizers, farm feeds, agricultural remedies and stock remedies; as well as import requirements, the registration of sterilizing plants, and the duties of pest control operators can be found in Government Regulation Notice GN R1449/83 and other notices listed therein.

*** See Fourie, H.O., 1989. An estimation of the health implications of chemical contaminants in food and water: a total diet ("market basket") study, WRC Report No. 173/1/89, Water Research Commission, Pretoria, 43 p. + app.

Table Q17: An overview classification of agrichemicals, with regard to chemical class and use.

Category	Class
Insecticides	Organophosphates (for example, parathion, malathion and dichlorvos)
	Carbamates (for example, carbaryl)
	Organochlorines (for example, DDT*, lindane, heptachlor*, aldrin*, dieldrin* and hexachlorobenzene*)
	Pyrethroids (for example, permethrin and cypermethrin)
	Insect growth regulants
	Miscellaneous substances (for example, organotin compounds)
Herbicides	Dinitrophenols and derivatives
	Phenoxyacetic herbicides (for example, 2,4-D and 2,4,5-T*)
	Bipiridyls (for example, paraquat and diquat)
	Substitute ureas
	Triazines (for example, atrazine)
	Amides
	Miscellaneous substances
Fungicides	Pthalimides (for example, captan)
	Dithiocarbamates
	Pentachlorophenol
	Hexachlorobenzene*
	Ergosterol biosynthesis inhibitors
	Miscellaneous substances
Rodenticides	Anticoagulants (for example, warfarin)
	Sodium fluroacetate*
	Miscellaneous substances (for example, red squill and strychnine)
Fumigants	Methyl bromide
	Dibromochloropropane* and ethylene dibromide
	Phosphine
Plant growth regulants	Various substances (for example, gibberelic acids, cyanamide and carbamates)
Miscellaneous	Arsenicals

Source: (i) After London, L., 1992. Agrichemical hazards in the South African farming sector, South African Medical Journal, VOL 81(11), p. 560 - 564.

(ii) After Vermeulen, J.B., 1995. Personal communication, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria.

Note: (i) Substances marked with an asterisk are no longer commercially available in South Africa. Some products have been replaced by more effective compounds, while others have been banned. Readers should bear in mind that the above table addresses a complex topic, and has been greatly simplified.

(ii) Agrichemicals may be referred to by their chemical name, trade name/s and their common name. Trade names may vary between manufacturing companies and from country to country. The common name can be the chemical name, trade name or some combination of the two.

(iii) Organochlorines (of all the types of agrichemicals), have aroused considerable anxiety in terms of the environment. Organochlorines (especially DDT) bioaccumulate, are photostable (not rapidly broken down by sunlight) and are generally resistant to degradation, both in biological systems and in the broader environment (Plapp, 1981, quoted in Barlin-Brinck, 1991)*. Widespread contamination of the world ecosystem has resulted, with relatively high concentrations found in most organisms at the top of the various food chains. Organochlorines can be divided into two types, namely, the cyclodienes and the chlorinated hydrocarbons. Organochlorines are soluble in fats and accumulate in the adipose (fat) tissues of man and animals. Organochlorines have chronic (long term) toxicological effects on higher animals and man, and interfere with reproduction in animals. Certain compounds are regarded as carcinogenic.

Organophosphates are the major group of agrichemicals currently in use. Many organophosphates are fast acting and are rapidly degraded, while others are more stable. Organophosphates are much less environmentally persistent by comparison with organochlorines. The organophosphates accordingly, are much more biodegradable, bioaccumulate less, and are usually not photostable. Organophosphates are highly toxic to man and higher animals. Carbamates share certain properties with organophosphates, most important of which, is their lack of environmental persistence.

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* Discussion in (iii) based on Plapp (1981, quoted in) Barlin-Brinck, M., 1991. Pesticides in southern Africa - an assessment of their use and environmental impact, Conservation Division, Wildlife Society of South Africa, Durban, 97 p.

Pyrethrum as a natural pesticide derived from the pyrethrum plant has been used for a very long time. Pyrethrum per se has a very low toxicity to man, although the chemical has extremely rapid effects on insects (often with a limited duration). Various synergistic compounds (mainly methylenedioxyphenyls) have been combined with pyrethrum to increase the overall toxicity of the formulation. The synthetic pyrethroids are much more metabolically stable and photostable than the natural compound, and are more toxic at low rather than high temperatures. (The synthetic pyrethroids are especially toxic to fish). Formamidines are a newer type of compound with a low persistence. It should be noted that the precise mode of action of the organochlorines, the synthetic pyrethroids, and the formamidines is unknown.

(iv) Various agrichemicals are withdrawn from commercial sale from time to time in the interests of public safety and for environmental reasons. A landmark decision in 1981 was the banning of the acquisition, disposal and sale of remedies containing a mixture of different isomers of BHC (excluding gamma-BHC with a purity grade of at least 99% - lindane); DDT, and dieldrin. In terms of the prohibition, aldrin (a possible carcinogen), could only be used under buildings for the control of wood termites*. Any agricultural remedy containing an inorganic arsenic compound cannot be used on vegetative matter - with the exception of material derived from citrus - which is intended for animal and human consumption. The use of any agricultural remedy containing a mercury compound was likewise prohibited on all vegetative matter intended for animal and human consumption. The use of unregistered agricultural and stock remedies (in terms of Act No. 36 of 1947) on any plant or animal intended for animal and human consumption was also prohibited.

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* It should be noted that while the acquisition, disposal and sale of the various substances was banned with effect from the 1st of May 1981, the use of these substances was banned as of the 1st of January 1982. The prohibition of the 1st of May 1981 (Government Regulation Notice GN R928/81) was subsequently repealed and amended by GN R384/83 of the 25th of February 1983 (where minor changes in legal terminology only, were effected). A further Government Regulation Notice, namely, GN R383/83 also of the 25th of February 1983, declared certain additional substances and remedies to be agricultural remedies in terms of Act No. 36 of 1947.

Such organizations include the following:

- Grain Crops Institute, Private Bag X1251, Potchefstroom, 2520.
- Infruitec, Private Bag X5013, Stellenbosch, 7599.
- Institute for Tropical and Subtropical Crops, Private Bag X11208, Nelspruit, 1200.
- Nietvoorbij Institute for Viticulture and Oenology, Private Bag X5026, Stellenbosch, 7599.
- Plant Protection Research Institute, Private Bag X134, Pretoria, 0001.
- Roodeplaat Vegetable and Ornamental Plant Institute, Private Bag X293, Pretoria, 0001.
- Small Grain Institute, Private Bag X29, Bethlehem, 9700.
- South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300.
- Tobacco and Cotton Research Institute, Private Bag X82075, Rustenburg, 0300. (All the organizations listed, with the exception of the Sugar Association Experiment Station, are part of the Agricultural Research Council. Experts from several universities in South Africa are likewise involved in testing agrichemicals).

17.23.2 Some human health implications of agrichemicals

The range of illnesses caused (or believed to be caused) by agrichemicals depends mainly on the active ingredient/s, as well as a host of other factors including the extent and duration of exposure. (The latter reflects inter alia weather conditions, substance concentration, and the agrichemical decomposition rate). Of major significance is the age, physical and nutritional state of the victim*. Both local and systemic effects may be evident. Local effects on the skin, conjunctiva and respiratory tract can include irritant and allergic dermatitis, conjunctivitis, coughing and bronchospasm (London, 1992 - above). Acute systemic effects of organophosphates and carbamates involve [acetyl]cholinesterase (an important neurological enzyme) inhibition - which results in dizziness, blurring of vision, increased secretions and finally, muscle paralysis and respiratory failure**. Delayed neuropathies (diseases of the peripheral nerves) resulting in numbness and weakness, are likewise caused by acute exposure to organophosphates. There is some evidence that subsequent neuropsychological impairment may follow organophosphate poisoning (Rosenstock, Daniell, Barnhart, Schwartz and Demers, 1990, quoted in London, 1992). Other acute effects of agrichemicals can include pulmonary oedema (accumulation of fluid in the lungs). Subacute systemic effects can involve stimulation of the Central Nervous System, chloracne (an acne-like skin disorder), and porphyria (disturbance of the metabolism of the breakdown products of haemoglobin). The latter results in inflammation of the nerves, severe blistering of the skin due to sunlight sensitivity, abdominal pain, and mental disturbances.

A characteristic of organochlorine compounds is their ability to accumulate in the body, and to reach undesirable levels through repeated exposure to small quantities. Organophosphates by contrast, can condition the body - via repeated contact or the intake of small quantities - to increasing susceptibility. Later exposure to an additional small dose can suddenly result in acute symptoms or death (due to acetylcholinesterase inhibition). A number of agrichemicals (especially the organochlorines) have been associated with (chronic) Central Nervous System damage long after exposure. Organochlorine pesticides administered to experimental animals have been implicated in liver and renal damage. Paraquat exposure has been implicated in the development of early-onset Parkinson's disease (Rajput and Uitti, 1987, quoted in London, 1992). Human immunological

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* A useful publication in this regard is the following: Fourie, H.O., 1984. Poisoning by Chemicals in Agriculture and Public Health: Trade Names, Chemical Classifications, Toxicology, Symptomatology and Treatment Procedures, ENG Enterprises, Pretoria, 340 p. (A revised and updated version of this publication can be obtained from the Agricultural and Veterinary Chemicals Association of South Africa, P O Box 1995, Halfway House, 1685).

** See Innes, D.F., Fuller, B.H. and Berger, G.M.B., 1990. Low serum cholinesterase levels in rural workers exposed to organophosphate pesticide sprays, South African Medical Journal, VOL 78(10), p. 581 - 583. See also, Fuller, B.H. and Berger, G.M.B., 1990. Automation of serum cholinesterase assay - paediatric and adult reference ranges, South African Medical Journal, VOL 78(10), p. 577 - 580.

impairment has also been linked to agrichemicals (London, 1992). Much debate surrounds the long term mutagenic (producing genetic changes), teratogenic (causing prenatal defects), and carcinogenic potential of agrichemicals in man. Numerous animal studies however, provide evidence of the dangers inherent in the use of agrichemicals. It should be borne in mind that the hazard associated with a given agrichemical may in part be due to the transformation of the agrichemical to a toxic metabolite (breakdown product), either in the environment or within the human or animal body itself.

Comprehensive data on poisoning in this country are difficult to derive, although agrichemical poisoning is a notifiable disease by virtue of the Health Act No. 63 of 1977. (Refer to the chapter on health). The relevant (official) statistics for South Africa in the period 1980 - 1987 were 842 cases of illness and 66 deaths (Van Pletsen, 1988)*. The notification rate in South Africa for 1992 was 0,37 cases of illness per 100 000 population (142 formally notified cases of illness) (Anonymous, 1994)**. London (1992) observed that the reporting of agrichemical-related diseases in South Africa (as in many other countries) is incomplete, with evidence of the considerable under-reporting of both morbidity and mortality. A study undertaken in the western Cape in the period March 1977 - February 1980 revealed that less than 5% of the 104 registered deaths due to agrichemical poisoning, had been officially notified (Coetzee, 1981, quoted in London, 1992)***.

Readers are reminded that morbidity and mortality statistics for agrichemical poisoning - as a notifiable disease - can be found in the official yearbooks and in the annual reports of the Department of National Health and Population Development, as well as in Epidemiological Comments (see the chapter on health). Central Statistical Service (CSS) reports on morbidity do not provide data specifically on agrichemical poisoning or poisoning

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* See Van Pletsen, D. (ed), 1988. Official Yearbook of the Republic of South Africa: South Africa 1988-89, fourteenth edition, Bureau for Information, Pretoria, 816 p.

** See Anonymous, 1994. Health trends in South Africa 1993, Department of National Health and Population Development, Pretoria, 96 p.

*** See Coetzee, G.J., 1981. The epidemiology of pesticide mortality in the western Cape, Department of Community Health, University of Cape Town, Rondebosch, 34 p. (Coetzee found that the mean annual mortality rate per 100 000 population (in terms of the study parameters), was 1,02. Higher mortality rates of 3,45 and 3,93 were evident in the Little Karoo and Langkloof regions respectively. A seasonal variation in mortality was apparent. The data include deaths by suicide).

in general*. However, CSS reports on mortality refer to the category: Accidental poisoning by agricultural and horticultural chemical and pharmaceutical preparations, other than plant foods and fertilizers (International Statistical Classification of Diseases, Injuries and Causes of Deaths (ICD) Code E863)**. Data on further causes of death due to poisons (for example, suicide and deliberate poisoning) are also provided in the relevant publications. Those readers requiring a more detailed overall analysis of deaths caused by poisoning, for instance as a result of the accidental ingestion of - or contact with - gases, petroleum products and solvents as well as corrosive and caustic chemicals, plus unspecified solid and liquid substances (all relevant to this chapter), should examine the following categories: Accidental poisoning by other solid and liquid substances, gases and vapours (ICD Code E860 - E869) and Injury undetermined whether accidentally or purposely inflicted (ICD Code E980 - E989). These categories may not include medical symptoms arising from poisoning, and which were treated in terms of the medical symptoms per se. The data are for one year (1990) only. Earlier (and later) Central Statistical Service reports on deaths are listed (report numbers only), in the chapter on health. The health and safety of employees is protected by the Occupational Health and Safety Act No. 85 of 1993, which replaced the (since repealed) Machinery and Occupational Safety Act No. 6 of 1983. The Chief Directorate: Occupational Safety, Department of Manpower, Private Bag X117, Pretoria, 0001, is the reporting authority for occupational diseases and injuries.

It is important to note that Group I substances are controlled by virtue of the Hazardous Substances Act No. 15 of 1973. The Act is administered by the Department of National Health and Population Development. In terms of the Act, Group I products (including specified agrichemicals), cannot be freely sold***. Restrictions also apply to the

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* See for example, Anonymous, 1993. Census of hospitals, community health care centres and other health service establishments, 1990, CSS Report No. 93-01-01 (1990), Central Statistical Service, Pretoria, 176 p.

** See for example, Anonymous, 1992. Deaths of blacks: 1990, Report No. 03-10-01 (1990), Central Statistical Service, Pretoria, 255 p., as well as Anonymous, 1992. Deaths: whites, Coloureds and Asians, 1990, Report No. 03-09-01 (1990), Central Statistical Service, Pretoria, 559 p.

*** Group I hazardous substances (with regard to this particular Act) are divided into A and B categories, where the latter concerns agrichemicals with an oral LD_{50} (active ingredient) value of less than 50 mg kg^{-1}. Category A refers to other hazardous chemicals. Category A and B substances are listed in Government Regulation Notice GN R452/77, as amended by GN R1381/94.

importation, manufacture, storage, transportation and disposal of such substances. Strict records must be kept of all sales*.

It is a contradiction that a prescription is required for many fairly harmless medicines, although a small child can enter a store and buy as many bottles of certain pesticides - including at least one Group Ib product - as needed for home use**. The careless (untrained) householder is then free to use the Group Ib product for example, with a cheerful and "moenie worrie nie" disregard for all in the immediate vicinity. The storage of agrichemicals vis-a-vis foodstuffs is also not satisfactory in some supermarkets. Bardin, Van Eeden and Joubert (1987)*** observed that pesticide poisoning is an important cause of admission to intensive care units at large South African hospitals. It follows that poison information centres (briefly discussed in the chapter on health), are vital sources of information for the medical profession as well as for the general public. The centre at

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* All suppliers and manufacturers are required, by virtue of GN R453/77, to maintain a poisons register for (Act No. 15) Group I substances. Inspectors of the Department of National Health and Population Development are responsible for checking the registers. Empty Category B Group I agrichemical containers (also in terms of GN R453/77), should be firmly closed and returned to the supplier (where returnable). Reuse of the containers is restricted to Category B Group I substances.

** An example is chlorpyrifos 480 g ℓ^{-1} emulsifiable concentrate (active ingredient: chlorpyrifos - an organophosphate) for use inter alia on ants, army worms, crickets and aphids in the garden. Group Ib in this context refers to the RSA Classification Code and not to Act No. 15 (as originally proclaimed). However, in terms of GN R1381/94, all Category B Group I substances (Act No. 15 of 1973) are now the equivalent of either a Group Ia or Ib substance (as per SABS 0228-1990 and hence the RSA Classification Code). Numerous other substances (over and above those listed in GN R452/77), are also classified as Group Ia and Ib chemicals - see SABS 0228-1990.

*** See Bardin, P.G., Van Eeden, S.F. and Joubert, J.R., 1987. Intensive care management of acute organophosphate poisoning: a 7-year experience in the western Cape, South African Medical Journal, VOL 72(9), p. 593 - 597. See also, London, L., Ehrlich, R.I., Rafudien, S., Krige, F. and Vurgarellis, P., 1994. Notification of pesticide poisoning in the western Cape, 1987 - 1991, South African Medical Journal, VOL 84(5), p. 269 - 272. (The authors found that organophosphates as well as carbamates (such as aldicarb) were the most important causes of officially notified acute agrichemical poisoning in the western Cape in the period 1987 - 1991). See in addition, Perold, J.G. and Bezuidenhout, D.J.J., 1980. Chronic organophosphate poisoning, South African Medical Journal, VOL 57(1), p. 7 - 9., as well as Hayes, M.M.M., Van der Westhuizen, N.G. and Gelfand, M., 1978. Organophosphate poisoning in Rhodesia: a study of the clinical features and management of 105 patients, South African Medical Journal, VOL 54(6), p. 230 - 234.

the Johannesburg General Hospital for instance, dealt with some 10 000 enquiries annually before being closed*.

Considerable concern has been expressed regarding the health of farm workers exposed to agrichemicals. Staff on many farms are potentially at risk in view of the marked use of agrichemicals in the agricultural sector, and the general ignorance of South Africans (especially those who should know better)! A useful case study was reported by London (1994)**. It would appear that most incidents of poisoning are experienced in the intensive crop growing areas such as the western Cape and the Vaalharts Irrigation Scheme (Cape/Transvaal border). Vector control programmes can also have health implications. The use of DDT for malaria control was first undertaken in South Africa in 1946. Some 210 t are still used annually for this purpose. Bouwman, Cooppan, Reinecke and Becker (1990, quoted in London, 1992 - above)***, found that significantly higher levels of DDT and its metabolites (by comparison with non-control areas), were evident in the breast milk of exposed mothers in northern KwaZulu, where DDT is used for the control of malaria. Higher levels of DDT in human serum have likewise been detected in the same area. It is a moot point whether malaria - especially dangerous for pregnant women/their unborn babies and very young children - is more of a threat than elevated DDT levels. Other effective pesticides should rather be used. The latter option is now being investigated.

London (1992) stressed the need for health studies in the agricultural sector with specific reference to chronic cases of illness. There is similarly, an urgent need for the training or

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* The Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort, 0110, is the primary poison information centre for domestic animals, livestock and wildlife. For a brief discussion see Nel, P.W., 1988. Chapter 13. Veterinary science and the study of disease transmission in southern Africa. The incidence of acute pesticide poisoning in domestic animals and wildlife: diagnoses made at the Veterinary Research Institute, Onderstepoort, since 1957, In: Macdonald, I.A.W. and Crawford, R.J.M. (eds), Long-term Data Series Relating to Southern Africa's Renewable Natural Resources, South African National Scientific Programmes Report No. 157, Foundation for Research Development, CSIR, Pretoria, p. 351 - 353.

** See London, L., 1994. Agrichemical safety practices on farms in the western Cape, South African Medical Journal, VOL 84(5), p. 273 - 278. (It follows that the misuse of agrichemicals by the informal and developing agricultural sectors is likewise of concern where illiterate and semi-literate people are involved).

*** See also, Bouwman, H., Reinecke, A.J., Cooppan, R.M. and Becker, P.J., 1990. Factors affecting levels of DDT and metabolites in human breast-milk from KwaZulu, Journal of Toxicology and Environmental Health, VOL 31(2), p. 93 - 115., as well as Bouwman, H., Cooppan, R.M., Becker, P.J. and Ngxongo, S., 1991. Malaria control and levels of DDT in serum of two populations in KwaZulu, Journal of Toxicology and Environmental Health, VOL 33(2), p. 141 - 155.

re-training of farmers and accordingly their staff in the proper storage and use of agrichemicals, as well as the safe disposal of empty containers*. It is important to note that very hazardous agrichemicals must be stored (at all times) in a locked cupboard, room or enclosure (in terms of the Hazardous Substances Act No. 15 of 1973). As indicated earlier, the Act also refers to the disposal of empty containers for Category B Group I substances.

Agrichemical containers disposed of locally by users should be punctured and flattened or broken, and then buried at a depth of at least 1 - 1,5 m. Aerosol containers must not be punctured or incinerated before burial. Combustible containers (paper and wood) must be burnt in the hole. The smoke must not be inhaled. The disposal point should be more than 100 m away and preferably downstream from any dam, borehole, well or spring. Burial in soils with a high water table, as well as in very sandy soils with a marked leaching potential should be avoided (Anonymous, undated)**. These precautions do not apply in urban areas where the municipal landfill is the disposal site.

Empty containers, especially drums, must not be used to store water. Under no circumstances should agrichemicals be transferred from their original container to a container usually storing cosmetics, food or drink (for example, lemonade bottles). No agrichemical container should ever be used to store cosmetics, food or drink. Agrichemicals in storage (or during transport) must always be kept separate from foodstuffs. Care should be taken to ensure that the containers will not be damaged and will not leak. All safety and other equipment should be checked prior to agrichemical application. The manufacturer's recommendations regarding the dosage rate and the

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* Formal training on agrichemicals for sales staff is undertaken by Technikon Pretoria, Private Bag X680, Pretoria, 0001 (using literature supplied by the Agricultural and Veterinary Chemicals Association of South Africa). The Technical College of South Africa, Private Bag X7, Pinegowrie, 2123, offers a correspondence course for pest control operators. The National Occupational Safety Association, P O Box 26434, Arcadia, 0007, has a training module on some safety aspects of agrichemicals. The module forms part of an occupational hygiene course. Various ad hoc training sessions are presented by agricultural co-operatives, agricultural training centres and chemical companies.

** See Anonymous, undated. Agricultural chemicals and stock remedies: responsible use, Agricultural and Veterinary Chemicals Association of South Africa, Halfway House, 33 p.

method of application should be followed at all times*. The careful disposal of equipment rinsing-water is necessary to avoid contamination of water sources. Compliance with these simple precautions will markedly reduce the hazards of agrichemicals, especially on the farm (Nel, Krause, Hollings, Greyling and Dreyer, 1993)**.

A national agrichemical retrieval scheme was announced in 1994, in order to safeguard human and animal health and to protect the environment. The first step is to determine the quantities of prohibited or redundant agrichemicals stored in depots, warehouses and on farms in South Africa. The next part of the programme will involve the retrieval and subsequent disposal of old stocks in a safe manner (mainly by incineration). The programme is being undertaken by the Department of Agriculture and the Agricultural and Veterinary Chemicals Association of South Africa.

An innovative procedure known as Integrated Pest Management (IPM), which is applied to some extent in South Africa, aims to reduce the health and environmental effects of agrichemicals***. IPM involves the use of pesticides <u>only if necessary</u> (when pest numbers exceed a certain threshold), with the reduction or elimination of routine or calendar spraying undertaken regardless of actual infestation levels. Another aspect of IPM is the use of indigenous (or imported) pest species which prey on troublesome crop pests; as well as the use of "selective" or soft pesticides targeted at specific problem species. Cultivars which are more pest-resistant are also being introduced. Further measures include the use of sticky materials to trap or exclude insects, and sex pheromones designed to interfere with mating. An important prerequisite for IPM is the careful monitoring of pest numbers, and an understanding of pesticide properties as well as pest biology - such as the effectiveness of natural enemies. Difficulties of IPM include the timing of spraying to combat one set of pests, which may interfere with the biological control of different pests on the same crop. Many farmers, in addition, lack the necessary

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* In terms of Government Regulation Notice GN R1716/91 of the 26th of July 1991, agrichemicals <u>must</u> be used in accordance with the specifications printed on the label. Failure to do so (in the event of damage to health and/or the environment) could result in a criminal charge being laid - and probably also a civil claim for damages.

** See Nel, A., Krause, M., Hollings, N., Greyling, J. and Dreyer, M., 1993. A guide to the use of pesticides and fungicides in the Republic of South Africa, thirty-sixth revised edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 332 p.

*** See Giliomee, J.H., 1989. Integrated pest management in apple orchards: where do we stand?, <u>South African Journal of Science</u>, VOL 85(6), p. 361 - 362.

expertise and information. These farmers are averse to the economic risks which could follow the incorrect monitoring of pest numbers and hence poor decision making (Giliomee and Glavovic, 1992)*. Relevant information however, is available inter alia from the Plant Protection Research Institute.

17.23.3 Agrichemical residues in crops

Minute quantities of agrichemicals are present in all edible foodstuffs (Nel et al, 1993), and are therefore also found in faeces and urine. The (latest) Recommended International Maximum Limits for Pesticide Residues - compiled by the Codex Alimentarius Commission (of the Food and Agriculture Organization and the World Health Organization) - stipulate internationally acceptable standards for agrichemical residues in exported and imported foodstuffs. Accordingly, Maximum Residue Levels (MRLs) have been defined for numerous agrichemicals and crops. In order to assess whether a particular MRL will not damage the health of consumers, it is first necessary to calculate the potential daily intake. The assumption is made that the total quantity of a consumed commodity contains the maximum amount of residue (the MRL) which is permitted. The figure so derived, may not exceed the Acceptable Daily Intake (ADI). The ADI is determined from the no-effect level, which in turn is derived from a two year feeding study mainly involving experimental animals. The no-effect level is then extrapolated to humans, usually allowing for a 100-fold safety factor. The figure thus obtained is the ADI, namely: the amount of a given agrichemical which, when ingested daily throughout life and based on the available data, will not be harmful to a "normal" person.

A withholding period is also applied as an important health measure. The withholding period is the time interval between the last application of the specific agrichemical and harvesting (sale) of the crop; or the period between post-harvest treatment and the sale of the crop. Farmers have a **solemn responsibility** to consumers to faithfully observe the withholding period, and to apply the agrichemical in the concentration prescribed by the manufacturer. It follows that agrichemical concentrations above those specified by the manufacturer will result in higher residues and accordingly a longer withholding period, or alternatively, risk to the consumer. Crops destined for export are routinely tested in terms

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* A useful discussion of legal and other aspects of agrichemicals is the following: Giliomee, J.H. and Glavovic, P.D., 1992. Chapter 20. Pesticides, In: Fuggle, R.F. and Rabie, M.A. (eds), Environmental Management in South Africa, Juta, Cape Town, p. 523 - 543.

of the Agricultural Product Standards Act No. 119 of 1990 (which replaced the since repealed Agricultural Produce Export Act No. 51 of 1971)*. Produce sold locally however, is seldom regularly examined on any scale especially in the smaller towns of South Africa.

Relevant MRL and associated data (where applicable) are provided by Nel et al (1993) for pesticides and fungicides; by Vermeulen, Dreyer and Grobler (1993) for herbicides, and by Vermeulen and Greyling (1990) for plant growth regulants, defoliants and desiccants - see Table Q16. The data refer to agrichemicals registered as per the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No. 36 of 1947. The permissible concentrations are specified in terms of the Foodstuffs, Cosmetics and Disinfectants Act No. 54 of 1972 and several Government Regulation Notices**. The latter Act is administered by the Department of National Health and Population Development, and by local authorities who have delegated powers.

A "market basket" analysis to determine typical residues in 142 South African foodstuffs was undertaken by Fourie (1989)***. The study excluded the rural black population (with different dietary practices). Fourie found that residues were well within acceptable levels, and compared very favourably with residues present in the diets of people living in developed countries. Fourie concluded that chronic exposure does not exist for those consuming a typical western diet in South Africa.

17.24 Agrichemicals and the environment****

Agrichemicals (especially pesticides) are temporarily present in relatively high concentrations at the application site, decreasing with time as a result of transfer and

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* The Directorate of Plant and Quality Control, Department of Agriculture, Private Bag X258, Pretoria, 0001, is the controlling authority in this regard.

** MRL and ADI data are likewise provided for meat, milk, milk products and eggs. Act No. 54 of 1972 also deals with other food contaminants such as microorganisms, various insect infestations, heavy metals, antibiotics and food additives.

*** See Fourie, H.O., 1989. An estimation of the health implications of chemical contaminants in food and water: a total diet ("market basket") study, WRC Report No. 173/1/89, Water Research Commission, Pretoria, 43 p. + app.

**** Discussion based on Barlin-Brinck, M., 1991. Pesticides in southern Africa - an assessment of their use and environmental impact, Conservation Division, Wildlife Society of South Africa, Durban, 97 p.

degradation. Transfer processes include movements between soil, water, air and living organisms. The three main environmental degradation pathways involve chemical, photochemical and biological processes (Baunok, 1980)*.

Agrichemicals sprayed on land/vegetation are retained by adsorption on soil particles, although most agrichemicals can be removed by surface runoff, reaching rivers and then dams. Agrichemicals are also leached into groundwater, ending up in rivers in due course. (Leaching is a very important transport mechanism). The reverse process occurs where contaminated water is applied by irrigation. Agrichemicals are also released into the air either in a gaseous form (by evaporation), or in a solid form through attachment to fine soil particles. The particles are then removed and are transported by strong winds before being deposited elsewhere as dustfall, or by rain and other types of precipitation. Certain agrichemicals can move through the upper layers of the soil profile as a vapour. Agrichemicals present in water are concentrated in the top layer and are either evaporated or are transported downstream, eventually reaching the ocean (the final sink). Agrichemicals accordingly, may enter the food chain at any given point (Baunok, 1980).

Agrichemicals (pesticides in particular) can reduce environmental quality and may influence essential ecosystem functioning (Pimentel and Edwards, 1982, quoted in Barlin-Brinck, 1991). Changes can include a reduction in species diversity; the modification of food chains; altered patterns of energy flow and nutrient cycling, and a deterioration in air, soil and water quality. The resilience and stability of ecosystems may therefore be at risk. While agrichemical use in South Africa (in terms of overall consumption) is low by European standards, it is possible that severe environmental effects may now be evident in some parts of the country. Detailed research however, is required to obtain an holistic assessment of environmental damage in South Africa. Barlin-Brinck (1991) provided a brief, first analysis of the relatively few case studies described in the South African literature**. Adverse effects are most often found in birds (including their eggs), and

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* See Baunok, I., 1980. Pesticides in the environment: their behaviour, distribution and analysis - a review report, CSIR Report No. APRG/80/4, Air Pollution Research Group, CSIR, Pretoria, 43 p.

** It is important to bear in mind that the discussion in this section (and the following sections) may be somewhat historical, since a number of compounds referred to in the various reports are currently no longer commercially available in South Africa. It would appear that no comprehensive overview publication on the present situation in South Africa in terms of the broader environment is available. It is accordingly not clear to what extent old stocks of banned substances are still being used, and more importantly, to what degree long term persistence of previously banned compounds is apparent in the environment.

especially in birds of prey (raptors) which are near or at the top of their food chain. Organochlorines which are persistent, and which have chronic (long term) toxicological effects have been implicated (amongst other chemicals), in the drastic decline of the Cape Vulture and the Blue/Crowned/Wattled Crane populations*. The Red-billed Oxpecker has also virtually disappeared in the stock farming areas of South Africa (Barlin-Brinck, 1991).

De Kock (1985, quoted in Barlin-Brinck)** reported on the levels of polychlorinated biphenyls (PCBs) as well as DDT and its metabolites inter alia along the south east Cape coast. Both PCBs and DDT metabolites (mainly DDE) in varying concentrations were found in coastal birds, in estuarine fish species, and in blubber and liver samples of the common dolphin. (The latter survey was undertaken off the coast of Natal/KwaZulu). Dolphins are near the top of their food chain and are mainly shallow water animals. Dolphins are accordingly subject to the effects of sediment and other substances such as agrichemicals which are washed down rivers, thereby entering the inshore zone. It has been suggested that one of the reasons for the decline in the dolphin population is the agrichemical content of inland and coastal waters. Organochlorines have been detected in the Cape fur seal in both Cape and Namibian waters (Henry, 1976, quoted in Barlin-Brinck, 1991); and in trace amounts in whales landed in Durban in 1974 (Henry and Best, 1983, quoted in Barlin-Brinck)***. Low levels of organochlorines have also been found in sediments in False Bay, and in the sewage effluent (offshore) pipeline at Green Point (Cape Town).

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* It is unclear to what extent DDT levels (and other chemicals such as polychlorinated biphenyls or PCBs) in South Africa, were/are due to local use within the country or are derived from elsewhere as a result of long range atmospheric transport. PCBs are used inter alia as an insulating fluid in electrical and heat transfer applications, and are not pesticides. However, PCBs are difficult to remove from water and are virtually non-degradable. Considerable concern has been expressed regarding their persistence in the environment. PCBs are closely related to organochlorine pesticides in terms of chemical character and human health effects. For a brief discussion of pesticides in the air, see Baunok, I., 1984. Analysis of airborne pesticides at selected sites in South Africa, South African Journal of Science, VOL 80(6), p. 277 - 279.

** See De Kock, A.C., 1985. Polychlorinated biphenyls and organochlorine compounds in marine and estuarine systems, M.Sc. Thesis, Faculty of Science, University of Port Elizabeth, Port Elizabeth, 150 p.

*** See Henry, J. and Best, P.B., 1983. Organochlorine residues in whales landed at Durban, South Africa, Marine Pollution Bulletin, VOL 14(6), p. 223 - 227.

Sibbald, Connell, Butler, Naidoo and Dunn (1986)* examined the levels of dieldrin (a possible human carcinogen) in mussels in the immediate vicinity of the Reunion canal mouth, as well as in mullet caught near the mouth of the Mhlatuzana canal in Durban Harbour. Dieldrin levels in mussels were low and compared favourably with concentrations in mussels from elsewhere in the world. Higher levels of dieldrin were found in the mullet. Molluscs however, generally accumulate dieldrin at a much lower rate than fish (Marlow, 1986, quoted in Sibbald et al, 1986). The data suggested that a similar low level of dieldrin contamination was apparent for both mullet and mussels. Importantly, dieldrin levels in mussels were found to be higher in an earlier study undertaken in the same area, possibly reflecting the prohibition on the acquisition, disposal and sale of dieldrin which came into effect on the 1st of May 1981 (see Table Q17).

Pick, De Beer and Van Dyk (1981, quoted in Barlin-Brinck, 1991)** found evidence of BHC, DDT, DDE, dieldrin and endosulfan in several species of birds and fish collected in or near rivers and dams in the Transvaal. Similarly, agrichemicals such as dieldrin and DDE as well as PCBs were found inter alia in fish-eating birds living near the Hartbeespoort Dam (Transvaal) and the Voëlvlei Dam (Cape) (Greichus, Greichus, Amman, Call, Hamman and Pott, 1977, quoted in Barlin-Brinck). A later study of sediment and fish in the Lower Vaal River showed that dieldrin, DDT and DDT metabolites (mainly DDE) were present in fish in very low concentrations. Generally higher levels of PCBs however, were evident in the fish (Bruwer, Van Vliet, Sartory and Kempster, 1985, quoted in Barlin-Brinck, 1991)***. An analysis of birds and fish from the Wilderness Lakes ecosystem in the Cape revealed that DDE in very low concentrations was present in all specimens (De Kock and Boshoff, 1987, quoted in Giliomee and Glavovic, 1992 - above)****. Sheep and cattle dip remedies have been implicated in damage to aquatic environments (Brooks and

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* See Sibbald, R.R., Connell, A.D., Butler, A.C., Naidoo, P. and Dunn, J.D., 1986. A limited collaborative investigation of the occurrence of dieldrin in selected biota in the Durban area, South African Journal of Science, VOL 82(6), p. 319 - 321.

** See Pick, F.E., De Beer, P.R. and Van Dyk, L.P., 1981. Organochlorine insecticide residues in birds and fish from the Transvaal, South Africa, Chemosphere, VOL 10(11), p. 1243 - 1251.

*** See Bruwer, C.A., Van Vliet, H.R., Sartory, D.P. and Kempster, P.L., 1985. An assessment of water related problems of the Vaal River between Barrage and Douglas weir, Technical Report No. TR 121, Department of Water Affairs, Pretoria, 185 p.

**** See De Kock, A.C. and Boshoff, A.F., 1987. PCBs and chlorinated hydrocarbon insecticide residues in birds and fish from the Wilderness Lakes system, South Africa, Marine Pollution Bulletin, VOL 18(7), p. 413 - 416.

Gardner, 1980)*; while the use of avicides has also resulted in the destruction of aquatic organisms (Palmer, 1994)**.

Crops have likewise been affected. Incidents of (probable) widespread hormone herbicide damage to vegetables in the Tala Valley near Camperdown, resulted in the withdrawal of 2,4-D (iso-octyl ester) formulations for use in Natal***. Severe problems were first apparent in 1986 (continuing until 1992), when vegetable farmers up to 100 km away from farms where hormone herbicides had been sprayed on maize, timber, sugar cane, pastures and turf (aerial spraying as well as ground application), found evidence of stunted, damaged and abnormal vegetable crops (Laing, 1995)****. Problems were particularly noticeable for lettuces, cabbage seedlings and tomatoes. An intensive research programme to investigate the situation was undertaken by the then Department of Agricultural Development. Also involved in the research was the Department of Horticulture as well as the Department of Microbiology and Plant Pathology (University of Natal, Pietermaritzburg), and affected parties. The investigation revealed that not all the damage was due to herbicide drift*****. The available data however, suggested

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* See Brooks, P.M. and Gardner, B.D., 1980. Effect of cattle dip containing toxaphene on the fauna of a South African river, Journal of the Limnological Society of Southern Africa, VOL 6(2), p. 113 - 118.

** See Palmer, R.W., 1994. Detrimental effects of fenthion (Queletox® UL), used to control Red-billed Quelea (*Quelea quelea*), on rheophilic benthic macroinvertebrates in the Orange River, Southern African Journal of Aquatic Sciences, VOL 20(1/2), p. 33 - 37.

*** The application of agricultural remedies containing 2,4-D (iso-octyl ester) in Natal was banned in terms of Government Regulation Notice GN R2370/91, dated the 27th of September 1991. The acquisition and use of agricultural remedies containing 2,4-D (dimethylamine salt); 2,4-DB (sodium salt); MCPA (dimethylamine salt); dicamba (dimethylamine salt), and any other salts or esters of 2,4-D (except APM salt) was likewise banned on all farms in the Camperdown Magisterial District (excluding farms in KwaZulu), as well as on certain farms in the Pietermaritzburg and Richmond magisterial districts. Also prohibited was the aerial spraying in Natal *per se* of remedies incorporating the substances listed above. The aerial spraying of agricultural remedies containing MCPA (potassium salt); MCPB (sodium salt); any salt or esters of triclopyr, and any salts of dicamba was similarly prohibited in Natal in terms of GN R2370/91. It is worth noting that farmers and suppliers in the western Cape voluntarily agreed to a ban on the use of 2,4-D (iso-octyl ester) products several years before the problems in the Tala Valley began (Cairns, A.L.P., 1995. Personal communication, Department of Agronomy, University of Natal, Pietermaritzburg).

**** Laing, M., 1995. Personal communication, Department of Microbiology and Plant Pathology, University of Natal, Pietermaritzburg.

***** For a discussion of some meteorological factors in relation to herbicide drift, see Preston-Whyte, R.A., 1991. Atmospheric conditions associated with crop damage in the Tala area, Natal, South African Journal of Science, VOL 87(8), p. 352 - 353. See also, Anonymous, 1991. Task group to decide on safe use of hormone herbicides/Clear picture emerges from Tala research, Agricultural News, No. 23, 10 June 1991, p. 1 - 2, 8.

that certain herbicides were the probable main cause of damage (Laing, 1995). Allegations were made in the Natal press of birth defects and respiratory illnesses amongst the farming community in the Tala Valley, although no conclusive proof was ever provided. Much bitterness was engendered, culminating in a Supreme Court application brought by vegetable farmers against the herbicide suppliers*. The matter did not proceed for legal reasons.

The events in Tala Valley served to focus public attention on the dangers (or potential dangers) of agrichemicals, and the problems of untrained (or insufficiently trained) operators. Sheer carelessness by users or crop spraying firms <u>may</u> well have caused some of the damage. Deficiencies in current scientific techniques and equipment, in terms of the ability to detect and identify agrichemical drift, also became apparent. Certain loopholes in South African environmental law were clearly identified with regard to claims for damages. Other effects included economic hardship, a reduction in land values in the Tala Valley, and a marked loss of morale amongst the farming community in the area. The Tala Valley was not the only affected locality. Probable hormone herbicide damage to vegetable crops was also suspected in the Richmond and Greytown districts (Laing, 1995).

17.25 <u>Agrichemicals and freshwater</u>

17.25.1 <u>Potable guidelines</u>**

Potable guidelines/criteria for only a few agrichemicals (pesticides in particular), have been recommended in terms of water quality parameters in South Africa. Other than remedies containing for example, arsenic and mercury, no definitive guidelines are found in the South African Bureau of Standards 1984 specifications (see the chapter on water quality). A similar situation is evident for the proposed criteria put forward by Pieterse

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* There was, and still is, some disagreement on the <u>extent</u> of hormone herbicide damage in the Tala Valley. Plant stress is caused by a number of factors including a lack of one or more nutrients, as well as a sudden and marked drop in air temperature. Rapid saturation of the soil by heavy rain (leading to a decrease in oxygen in the top soil) can also result in plant stress. Plant stress likewise, is caused by herbicides. It is sometimes difficult to isolate the specific cause/s of plant stress, especially when several factors are operating concurrently (Cairns, 1995 - personal communication).

** Unless otherwise specified in this section, the terms "drinking" or "potable" water refer to water ingested by humans.

(1989)*. Certain pesticide criteria were provided by Kempster, Hattingh and Van Vliet (1980)** with regard to livestock watering, river/dam water (the protection of aquatic life), and for irrigation requirements (see the chapter on water quality). Criteria for pesticides in potable water were likewise compiled by Kempster et al (1980) - data not presented in the chapter on water quality but listed in Table Q18. No limits for pesticides are available in the water quality guidelines for domestic, recreational (and industrial) use, as published by the Department of Water Affairs and Forestry. Values for livestock watering (agricultural use) are those provided by Kempster et al***. Lusher (1984)**** recommended several water quality criteria inter alia for organochlorines in marine biological ecosystems (including "estuaries"). The respective values vis-a-vis Table Q18 (in $\mu g\ \ell^{-1}$) are as follows: aldrin 1,3; chlordane 0,004; dieldrin 0,001; endrin 0,003; heptachlor 0,004; lindane 0,16; toxaphene 0,07; polychlorinated biphenyls 0,03; DDT and derivatives 0,001, and methoxychlor 0,03.

The lack of comprehensive pesticide criteria for drinking water in South Africa is somewhat surprizing. It should be borne in mind however, that water is only one route for human agrichemical intake. Liquid intake is defined by individual daily potable, cooking water and beverage consumption (see the chapter on water supply planning); and/or occasional body contact with polluted waters. Secondly, real difficulties are apparent in establishing limits given the wide range of active ingredients and metabolites, the often localized use of specific agrichemicals, and the low concentrations in water*****. Suitable limits nevertheless have been carefully defined in South Africa - albeit using overseas data - for numerous active ingredients and metabolites in foodstuffs (refer to Section 17.23.3).

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* See Pieterse, M.J., 1989. Drinking-water quality criteria with special reference to the South African experience, Water SA, VOL 15(3), p. 169 - 178.

** See Kempster, P.L., Hattingh, W.H.J. and Van Vliet, H.R., 1980. Summarized water quality criteria, Technical Report No. TR 108, Department of Water Affairs, Forestry and Environmental Conservation, Pretoria, 45 p.

*** See Anonymous, 1993. South African water quality guidelines, VOL 1, Domestic use, 216 p., VOL 2, Recreational use, 134 p., VOL 3, Industrial use, 222 p., and VOL 4, Agricultural use, 286 p., Department of Water Affairs and Forestry, Pretoria.

**** See Lusher, J.A. (ed), 1984. Water quality criteria for the South African coastal zone, South African National Scientific Programmes Report No. 94, Foundation for Research Development, CSIR, Pretoria, 25 p. + app.

***** For a brief discussion of these issues, see Stander, G.J., 1980. Micro-organic compounds in the water environment and their impact on the quality of potable water supplies, Water SA, VOL 6(1), p. 1 - 14.

Table Q18: **Water quality criteria for human drinking water, in terms of pesticides.**

Determinand	Unit	Minimum	Median	Maximum
High toxicity				
Pesticide, aldrin	$\mu g\ \ell^{-1}$	1	1	17
Pesticide, chlordane	$\mu g\ \ell^{-1}$	3	3	3
Pesticide, dieldrin	$\mu g\ \ell^{-1}$	1	1	17
Pesticide, endrin	$\mu g\ \ell^{-1}$	0,2	0,5	1
Pesticide, heptachlor	$\mu g\ \ell^{-1}$	0,1	0,1	50
Pesticide, lindane (γ-BHC)	$\mu g\ \ell^{-1}$	4	5	56
Pesticide, parathion	$\mu g\ \ell^{-1}$	3	35	100
Pesticide, toxaphene	$\mu g\ \ell^{-1}$	5	5	5
Pesticide, 2,4,5-TP	$\mu g\ \ell^{-1}$	10	10	30
Polychlorobiphenyls	$\mu g\ \ell^{-1}$	-	1	-
Moderate toxicity				
Pesticide, DDT	$\mu g\ \ell^{-1}$	42	50	100
Pesticide, malathion	$\mu g\ \ell^{-1}$	50	100	100
Pesticide, methoxychlor	$\mu g\ \ell^{-1}$	10	100	1 000
Pesticide, 2,4-D	$\mu g\ \ell^{-1}$	20	100	1 000
Pesticide, 2,4,5-T	$\mu g\ \ell^{-1}$	2	100	100

Source: After Kempster, P.L., Hattingh, W.H.J. and Van Vliet, H.R., 1980. Summarized water quality criteria, Technical Report No. TR 108, Department of Water Affairs, Forestry and Environmental Conservation, Pretoria, 45 p.

Note:

(i) A number of agrichemicals listed in the table are no longer commercially available in South Africa, although due to persistence or the use of old stocks may well be present in the environment.

(ii) A revision of the above data is probably necessary in view of the current knowledge of agrichemicals and their implications.

(iii) Polychlorobiphenyls (PCBs), also referred to in the literature as polychlorinated biphenyls, are included in the table although these compounds (as briefly discussed earlier in this chapter), are not pesticides.

(iv) In Canada, (human) potable water pesticide values are applied in the case of livestock watering, due to possible pesticide accumulation in livestock and accordingly, secondary impacts on people (Anonymous, 1993. South African water quality guidelines, VOL 4, Agricultural use, Department of Water Affairs and Forestry, Pretoria, 286 p.).

17.25.2 Surveys of agrichemical concentrations in water

(a) Surface waters

Very few detailed studies of agrichemical concentrations in freshwater have been undertaken in South Africa. The results of an important study on surface waters in the Orange Free State were discussed by Hassett, Viljoen and Liebenberg (1987)*. The survey examined the concentration of 14 organochlorine substances for the period 1984 - 1985, at 15 sites located in intensive crop farming (maize and wheat) areas in the north, north western, central and south eastern O.F.S. The sites consisted of 12 rivers, one wetland and two dams. The primary contaminant found in surface waters was the herbicide atrazine which is widely used on maize lands to control weeds. Atrazine is believed to be toxic to algae at very low concentrations (Brockway, Smith and Stancil, 1984, quoted in Hassett et al, 1987). In terms of human health, atrazine has possible mutagenic and teratogenic properties (Hallenbeck and Cunningham-Burns, 1985, quoted in Hassett et al). The highest concentrations of atrazine were found in northern and north western O.F.S. and in the Welbedacht Dam in the south east. Maximum concentrations were evident in January and February, with an overall peak concentration of 82,3 $\mu g\ \ell^{-1}$ noted in the survey. Atrazine was detected in surface waters in the months October to April.

The second most frequently detected agrichemical was *p,p'*-DDT with a maximum concentration of 0,8 $\mu g\ \ell^{-1}$ (in the Welbedacht Dam). In general *p,p'*-DDT levels were less than 0,5 $\mu g\ \ell^{-1}$ with a median value of 0,2 $\mu g\ \ell^{-1}$. The agrichemical was only found during the period September to March (the rainy season). Endrin (a suspected carcinogen)** was found on three occasions in single samples taken from three sampling sites (including the Welbedacht Dam), at concentrations between 2,1 - 4,2 $\mu g\ \ell^{-1}$. Contamination by other agrichemicals was infrequent and occurred at

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* See Hassett, A.J., Viljoen, P.T. and Liebenberg, J.J.E., 1987. An assessment of chlorinated pesticides in the major surface water resources of the Orange Free State during the period September 1984 to September 1985, Water SA, VOL 13(3), p. 133 - 136. See also, Grobler, D.F., 1994. A note on PCBs and chlorinated hydrocarbon pesticide residues in water, fish and sediment from the Olifants River, eastern Transvaal, South Africa, Water SA, VOL 20(3), p. 187 - 194., as well as Van Steenderen, R.A., Theron, S.J. and Hassett, A.J., 1987. The occurrence of organic micro-pollutants in the Vaal River between Grootdraai Dam and Parys, Water SA, VOL 13(4), p. 209 - 214.

** Endrin was withdrawn from the market several years ago, and is no longer commercially available in South Africa.

very low concentrations. An examination of the surface water agrichemical and monthly rainfall data suggested that leaching and surface runoff plays an important role in the transport of contaminants to surface waters in the O.F.S. Such a pattern has been found elsewhere in the world. The presence of *p,p'*-DDT in surface waters in the study area confirmed the persistence of the banned substance (or possibly the use of old stocks).

Atrazine was also detected in a study of the Vaalharts Irrigation Scheme in the period 1987 - 1989. The survey was undertaken by the then Hydrological Research Institute (now the Institute for Water Quality Studies) of the then Department of Water Affairs. Further details are given below.

(b) Groundwater

Two important groundwater surveys in South Africa in terms of agrichemicals were described by Weaver (1993)*. The Hex River Valley in the winter rainfall region of the Cape, is an intensive fruit and grape cultivation area where agrichemicals are in regular use. Irrigation is applied in the summer months. For the purposes of the survey, 14 substances (11 agrichemicals and three metabolites) were examined at 12 sampling sites in the Valley (eight shallow wells and four tile-drains). Sampling was undertaken three times during the survey, namely: in July (winter rainfall and maximum water table conditions); in October/November (after maximum agrichemical use), and in February (following the maximum application of irrigation water with a near-minimum water table). Weaver found that none of the test substances was present in any water samples at concentrations above a detection limit of 5,0 $\mu g\ \ell^{-1}$ for 13 compounds, and 25,0 $\mu g\ \ell^{-1}$ for the highly toxic nematicide aldicarb - trade name Temik. Weaver observed however, that the soil and groundwater characteristics of the area are such that agrichemicals can reach the water table. Important characteristics include a shallow water table and an unconfined aquifer; as well as coarse soils with a low clay content, a low pH and a high hydraulic conductivity. The presence of nitrate and potassium in varying concentrations in the groundwater (derived from surface-applied fertilizers), clearly indicated that leaching of chemicals into the groundwater was taking place. A further (limited) survey undertaken

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* See Weaver, J.M.C., 1993. A preliminary survey of pesticide levels in groundwater from a selected area of intensive agriculture in the western Cape, WRC Report No. 268/1/93, Water Research Commission, Pretoria, various pages. (Published studies on agrichemicals in groundwater in South Africa are rare. The data are therefore examined in some detail).

in the study area, and using a detection limit of 0,2 $\mu g\ \ell^{-1}$ in respect of the herbicide simazine (one of the original chemicals tested for), revealed that no simazine could be found in the groundwater.

The second groundwater survey with particular reference to atrazine, was undertaken at the Vaalharts Irrigation Scheme. The study involved a follow-up of previous research begun by the then Department of Water Affairs. The Vaalharts Irrigation Scheme is the largest irrigation scheme in South Africa, with 32 000 ha under irrigation (mainly flood irrigation). The most important crops are maize, lucerne, groundnuts and cotton. Crop rotation is standard practice in the area. Soils comprise clayey sands and sands of alluvial origin. Seven agrichemicals at 11 surface water sampling sites were examined as part of the survey undertaken by the then Hydrological Research Institute. Of the seven substances, only atrazine was regularly detected throughout the year (at varying concentrations) at all sampling sites. Four agrichemicals were not detected at all, while two were only found at low concentrations in certain samples. The detection limit for atrazine was 0,03 $\mu g\ \ell^{-1}$. Of the 135 surface water samples (in terms of atrazine), 27% were below the detection limit, while 59% varied between 0,03 - 0,5 $\mu g\ \ell^{-1}$. The balance of samples exceeded 0,5 $\mu g\ \ell^{-1}$. The highest concentration found was 1 001,61 $\mu g\ \ell^{-1}$.

Of particular interest was the water quality in the incoming and outgoing canal system. In the incoming irrigation canal (surface water), the concentration of atrazine ranged from 0,12 - 1 001,59 $\mu g\ \ell^{-1}$ with a median value of 0,42 $\mu g\ \ell^{-1}$. Atrazine levels in the outgoing canal varied between <0,03 - 0,73 $\mu g\ \ell^{-1}$ with a median of 0,06 $\mu g\ \ell^{-1}$. Atrazine was not detected in 32% of samples derived from the drainage canal carrying surface and seepage water away from the scheme to the Harts River. This was in contrast to the incoming canal water where atrazine was detected in all samples. Nitrate (+ nitrite) concentrations in both canals were also examined. Considerably higher levels of nitrate were evident in the outgoing drainage canal water. Nitrate was also present in groundwater tested in three boreholes (12 samples), although there was no evidence of atrazine or other agrichemicals in the groundwater.

Weaver (1993) observed that the method of flood irrigation used at the Vaalharts Irrigation Scheme resulted in a 7-fold reduction of atrazine (following percolation through the unsaturated zone). There was a 35-fold increase in nitrate concentrations as a result of the localized application of fertilizer. Weaver concluded that the incoming irrigation water had a low nitrate content, with the atrazine carried in surface runoff from upstream maize lands. No atrazine is used at the irrigation scheme per se due to relative persistence in soils with a higher clay content. The danger of atrazine damaging the next crop, especially cotton, is thereby avoided.

In order to further examine atrazine concentrations, 12 soil samples were obtained from four fields at the Vaalharts Agricultural Research Station. Atrazine (one treatment only) had been applied to the four fields during the previous 3 - 63 months. All soil samples consisted of silt/fine sand (Hutton Form soils - see the chapter on soils and soil erosion). Atrazine was not found in any of the soil samples, nor in two (other) boreholes at the Research Station. Atrazine was only detected in one open drain at a very low concentration.

Weaver suggested that atrazine breakdown under typical South African conditions of warm weather and a low soil pH could result in a (reduced) half-life of some two weeks - with no evidence of the substance after approximately 90 days*. Based on data from the two groundwater studies (the Hex River Valley and the Vaalharts Irrigation Scheme), Weaver concluded that the atrazine had most probably been rapidly degraded, and hence was not present in groundwater (with the exception of certain drainage water at Vaalharts). An alternative hypothesis was that atrazine had been flushed out of the system and could therefore not be detected, or could only be periodically detected in low concentrations. Evidence for the degradation scenario was provided by nitrate concentrations. Nitrate is a relatively mobile molecule by comparison with the survey agrichemicals. Assuming that the alternative hypothesis was true, nitrate would be flushed out faster than the agrichemicals and would not be found in groundwater. The presence of elevated nitrate levels in groundwater provided proof that leaching of surface-applied chemicals to the groundwater was taking place.

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* A useful background discussion is the following: Smit, N.S.H. and Nel, P.C., 1980. Chapter 18. Factors influencing availability of atrazine in South African soils, In: Neser, S. and Cairns, A.L.P. (eds), Proceedings of the Third National Weeds Conference of South Africa, A.A. Balkema, Cape Town, p. 151 - 158.

17.26 Summary

Weaver (1993) emphasized that the reported studies do not imply that agrichemicals are absent from South African groundwaters. The data only refer to the specific agrichemicals tested, and the areas surveyed. The studies accordingly, are first approximations only. Weaver recommended that overseas scientific experience and techniques should be carefully examined for application in this country. A most important procedure is the use of simulation models to evaluate the potential for the agrichemical contamination of vulnerable aquifers. Research is also required to identify agrichemicals with a long half-life, or with other properties which preclude their use on land overlying vital aquifers*. Weaver has warned, for example, of possible problems developing in groundwaters of the Hex River Valley due to the widespread use of aldicarb. It follows that the routine testing for selected agrichemicals should be part of any national groundwater quality sampling and assessment programme in South Africa. (See the chapter on water quality).

The actual impacts of agrichemicals on the environment (including water systems) have not received detailed attention in South Africa. While the limited data suggest that agrichemical concentrations in freshwater are well below the few water quality criteria thus far enumerated in this country, it is also apparent that complacency could result in difficulties at a later stage. Water, moreover, is only one means of agrichemical transmission. Reference has been made to the considerable under-reporting of agrichemical morbidity and mortality statistics, and it is clear that a more determined approach is required for all aspects of agrichemical use and disposal in South Africa. It must be borne in mind however, that agrichemicals form one component of a much larger spectrum, namely, hazardous or potentially hazardous substances. As discussed earlier in the chapter, much needs to be done to establish functional monitoring and control mechanisms for wastes in general. An important current initiative is the investigation of a Designated National Authority (DNA) to co-ordinate country-wide regulatory activities, for example, for the transport and disposal of chemicals and waste. It is possible that the Department of Environment Affairs will be appointed as the DNA for South Africa. The lack of integrated regulatory procedures is problematic in several countries, and is not

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* These recommendations presuppose the availability of South African expertise. Local expertise should likewise be available to assist other countries in southern Africa.

unique to South Africa (Vermeulen, 1995)*. It has been recognized internationally that the efficient co-ordination of policies and practices on chemicals and waste is essential**. An encouraging trend is the number of agreements which have recently been signed inter alia by South Africa. Access to international research and expertise is once again available to this country.

17.27 Some primary publications on solid waste management in South Africa***

17.27.1 General issues

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- Anonymous, 1988. Towards guidelines for services and amenities in developing communities, Department of Development Aid, Pretoria, various pages. (The publication is commonly referred to as the "Green book", and contains a short section on solid waste management for black urban areas).

- Anonymous, 1991. First report on the situation of waste management and pollution control in South Africa, January 1991: report to the Department of Environment Affairs by the CSIR Programme for the Environment, Report No. CPE 1/91, CSIR, Pretoria, 359 p. + app.

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* Vermeulen, J.B., 1995. Personal communication, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria.

** A case-in-point is the (Montreal) Protocol on Substances That Deplete the Ozone Layer. In this regard it should be noted that methyl bromide, a fumigant used in many parts of the world, has been identified as an important agent responsible for damaging the ozone layer.

*** Regular conferences are organized by the Institute of Waste Management (Southern Africa). The conference papers - not all of which are published in the formal journals - are an important source of current information on waste management in general. Also of interest are papers presented at anaerobic digestion symposia. Further particulars of the latter can be obtained from the International Centre for Waste Technology (Africa), c/o the Department of Microbiology and Plant Pathology, University of Natal, Pietermaritzburg. (See addresses at the end of the chapter).

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- Anonymous, 1994. Guidelines for the provision of engineering services and amenities in residential township development, Department of National Housing and the National Housing Board, Pretoria, various pages. (The publication is commonly referred to as the "Red book", and contains a short section on solid waste management for black urban areas. The document is a revised version of Anonymous (1988 - above), and an earlier set of guidelines).

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- Vermeulen, J.B., Dreyer, M. and Grobler, H., 1993. A guide to the use of herbicides, fourteenth edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 137 p. (Refer to the latest edition).

- Vermeulen, J.B. and Greyling, J., 1990. A guide to the use of plant growth regulants, defoliants and desiccants, fifth edition, Plant Protection Research Institute, Department of Agricultural Development, Pretoria, 22 p. (A later edition is available: Vermeulen, J.B., Dreyer, M. and Grobler, H., 1995. A guide to the use of plant growth regulants, defoliants and desiccants, seventh edition, Directorate of Livestock Improvement and Agricultural Production Resources, Department of Agriculture, Pretoria, 26 p.).

- Weaver, J.M.C., 1993. A preliminary survey of pesticide levels in groundwater from a selected area of intensive agriculture in the western Cape, WRC Report No. 268/1/93, Water Research Commission, Pretoria, various pages.

- Worthing, C.R. (ed), 1991. <u>The Pesticide Manual: a World Compendium</u>, ninth edition, British Crop Protection Council, Farnham, Surrey, 1141 p. (The book is available at the Life Sciences Library, University of Natal, Pietermaritzburg).

<u>**For further information contact**</u>:

- African Raptor Information Centre, P O Box 4035, Halfway House, 1685.

- African Seabird Group, P O Box 341113, Rhodes Gift, 7707.

- Agricultural and Veterinary Chemicals Association of South Africa, P O Box 1995, Halfway House, 1685. (The Association is now known as the Crop Protection and Animal Health Association).

- Agricultural, Mining and Industrial Chemical Manufacturer's Association, P O Box 781811, Sandton, 2146.

- Aluminium Can Recycling Association, P O Box 14976, Wadeville, 1422.

- Association of Societies for Occupational Safety and Health, P O Box 35764, Menlo Park, 0102.

- Centre for Dolphin Studies, Port Elizabeth Museum, P O Box 13147, Humewood, 6013.

- Centre for Water and Wastewater Research, Department of Biotechnology, Technikon Natal, P O Box 953, Durban, 4000.

- Chemical and Allied Industries' Association/Chemical Industry Environmental Forum, Private Bag 34, Auckland Park, 2006.

- Chief Directorate: Occupational Safety, Department of Manpower/Advisory Council for Occupational Safety, Private Bag X117, Pretoria, 0001.

- Chief Directorate: Sea Fisheries, Department of Environment Affairs, Private Bag X2, Rogge Bay, 8012.

- Chief Directorate: Shipping, Department of Transport, Private Bag X193, Pretoria, 0001.

- Collect-a-Can, P O Box 43304, Industria, 2042.

- Council for the Environment/Department of Environment Affairs, Private Bag X447, Pretoria, 0001.

- CSIR Environmental Services/Division of Water Technology, CSIR, P O Box 395, Pretoria, 0001.

- Department of Accounting, University of Pretoria, Pretoria, 0002. (The Department publishes an annual review of the environmental reporting data supplied by a variety of South African companies).

- Department of Landscape Architecture, University of Pretoria, Pretoria, 0002. (The Department undertakes site surveys involving ecological planning and is a source of relevant expertise).

- Department of Mineral and Energy Affairs, Private Bag X59, Pretoria, 0001.

- Department of National Health and Population Development, Private Bag X828, Pretoria, 0001.

- Department of Zoology, Potchefstroom University for Christian Higher Education, Private Bag X6001, Potchefstroom, 2520. (Staff of the Department have expertise on the impacts of agrichemicals on human health and the environment).

- Directorate of Plant and Quality Control, Department of Agriculture, Private Bag X258, Pretoria, 0001.

- Division of Earth, Marine and Atmospheric Science and Technology, CSIR, P O Box 320, Stellenbosch, 7599.

- Dolphin Action and Protection Group, P O Box 22227, Fish Hoek, 7974.

- Durban Port Captain, Portnet, P O Box 1027, Durban, 4000.

- Earthlife Africa (Pietermaritzburg Branch), P O Box 100468, Scottsville, 3209.

- Endangered Wildlife Trust, Private Bag X11, Parkview, 2122.

- Environmental Justice Networking Forum, P O Box 100029, Scottsville, 3209.

- Environmental Management Services, Chamber of Mines of South Africa, Private Bag X2, Regents Park, 2126.

- EPPIC (Environmental Planning Professions Interdisciplinary Committee), P O Box 90142, Bertsham, 2013.

- Geological Survey, Department of Mineral and Energy Affairs, P O Box 900, Pietermaritzburg, 3200/Private Bag X112, Pretoria, 0001.

- Glass Recycling Association, P O Box 562, Germiston, 1400.

- Grain Crops Institute, Private Bag X1251, Potchefstroom, 2520.

- Industrial Environmental Forum of Southern Africa, P O Box 1091, Johannesburg, 2000. (The Forum produces an annual report which contains useful information on environmental issues).

- Infruitec, Private Bag X5013, Stellenbosch, 7599.

- Institute for Groundwater Studies, University of the Orange Free State, P O Box 339, Bloemfontein, 9300.

- Institute for Soil, Climate and Water, Private Bag X79, Pretoria, 0001.

- *Institute for Tropical and Subtropical Crops, Private Bag X11208, Nelspruit, 1200.*

- Institute for Water Quality Studies, Department of Water Affairs and Forestry, Private Bag X313, Pretoria, 0001.

- Institute of Environmental Law/Institute of Maritime Law, University of Natal, Private Bag X10, Dalbridge, 4014.

- Institute of Marine Law, University of Cape Town, Private Bag, Rondebosch, 7701. (The Institute publishes a journal Sea Changes, which contains valuable summary information on amendments to South African marine legislation and coastal zone regulations, as well as pollution and conservation legislation).

- Institute of Packaging (South Africa), P O Box 56145, Pinegowrie, 2123.

- Institute of Waste Management (Southern Africa), P O Box 1378, Pinegowrie, 2123.

- International Centre for Waste Technology (Africa), c/o the Department of Microbiology and Plant Pathology, University of Natal, Private Bag X01, Scottsville, 3209. (The African Land Remediation Centre was recently established in the Department. The Remediation Centre undertakes research on the bioremediation of chemically contaminated soil).

- Keep South Africa Beautiful Association (and related organizations), P O Box 1514, Randburg, 2125.

- Kimberly-Clark of SA Ltd, P O Box 555, Umhlanga Rocks, 4320.

- KwaZulu-Natal Recycling Forum, c/o the Wildlife Society of Southern Africa, P O Box 2985, Durban, 4000.

- KwaZulu-Natal Waste Contractors Association, 160 Lewis Drive, Amanzimtoti, 4126.

- Maritime Law Association/Environmental Law Association, c/o Shepstone and Wylie, P O Box 205, Durban, 4000.

- Mondi Recycling, P O Box 29074, Maydon Wharf, 4057.

- Nampak Paper Recycling, P O Box 20527, Durban North, 4016.

- National Centre for Occupational Health, P O Box 4788, Johannesburg, 2000.

- National Occupational Safety Association, P O Box 26434, Arcadia, 0007.

- National Recycling Forum, P O Box 1378, Pinegowrie, 2123.

- Nietvoorbij Institute for Viticulture and Oenology, Private Bag X5026, Stellenbosch, 7599.

- Occupational Hygiene Association of South Africa, P O Box 1722, Johannesburg, 2000.

- Oceanographic Research Institute, P O Box 10712, Marine Parade, 4056.

- Onderstepoort Veterinary Institute, Private Bag X05, Onderstepoort, 0110.

- Percy FitzPatrick Institute of African Ornithology, University of Cape Town, Private Bag, Rondebosch, 7701.

- Plant Protection Research Institute, Private Bag X134, Pretoria, 0001.

- Plastics Federation of South Africa, Private Bag X68, Halfway House, 1685.

- Poison Working Group (of the Endangered Wildlife Trust), P O Box 72334, Parkview, 2122. (The Group is mainly concerned with the effects of agrichemicals on wild birds, and is involved in a number of programmes including the education of farmers, and the reporting of agrichemical abuses to the relevant authorities. The Group maintains a database of poisoning incidents involving wildlife and publishes a regular newsletter, namely, Antidote. Various in-house reports are available from the Group).

- Pollution Research Group, Department of Chemical Engineering, University of Natal, Private Bag X10, Dalbridge, 4014.

- Registrar: Act No. 36 of 1947, Directorate of Livestock Improvement and Agricultural Production Resources, Private Bag X343, Pretoria, 0001. (The two inspectors for Natal/KwaZulu can be contacted via the Department of Agriculture, P O Box 345, Pietermaritzburg, 3200).

- Research Institute for Reclamation Ecology, Potchefstroom University for Christian Higher Education, Private Bag X6001, Potchefstroom, 2520. (The Institute is involved inter alia with the rehabilitation of areas disturbed by construction or mining activities).

- Richards Bay Port Captain, Portnet, P O Box 181, Richards Bay, 3900.

- Road Freight Association (Hazardous Chemicals Committee), P O Box 4660, Randburg, 2125.

- Roodeplaat Vegetable and Ornamental Plant Institute, Private Bag X293, Pretoria, 0001.

- Rose Foundation, Suite A9, Waverley Court, Kotze Street, Mowbray, 7700. (The Foundation is a non-profit company which co-ordinates the collection of used engine/machinery oil for refining purposes. The Foundation is also involved in public awareness campaigns to prevent the dumping of used oil and hence environmental damage).

- Sappi War on Waste, P O Box 41040, Rossburgh, 4072.

- Small Grain Institute, Private Bag X29, Bethlehem, 9700.

- South African Bureau of Standards, Private Bag X191, Pretoria, 0001.

- South African Chemical Institute, P O Box 93480, Yeoville, 2143.

- South African Drum Reconditioners Association, P O Box 12822, Jacobs, 4026. (The Association promotes the responsible reconditioning and sale of used plastic and metal drums, thereby protecting health and the environment).

- South African Institute of Engineering Geologists, P O Box 2812, Pretoria, 0001.

- South African Institute of Mining and Metallurgy, P O Box 61127, Marshalltown, 2107.

- South African Institution of Chemical Engineers, P O Box 27706, Yeoville, 2143.

- South African Institution of Civil Engineers, P O Box 93495, Yeoville, 2143.

- South African National Foundation for the Conservation of Coastal Birds, P O Box 11-116, Bloubergrant, 7443.

- South African Pest Control Association, P O Box 457, Westville, 3630.

- South African Radiation Protection Society, c/o S. Van der Woude, Council for Nuclear Safety, P O Box 7106, Centurion, 0046.

- South African Society of Occupational Medicine, P O Box 783854, Sandton, 2146.

- South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300.

- Southern African Crane Foundation, P O Box 905, Mooi River, 3300. (The Foundation has some data on the agrichemical poisoning of the three species of cranes found in the Natal Midlands).

- Southern African Ornithological Society, P O Box 84394, Greenside, 2034. (The Society is now known as BirdLife South Africa).

- Tobacco and Cotton Research Institute, Private Bag X82075, Rustenburg, 0300.

- Whale and Dolphin Foundation, P O Box 1233, Plettenberg Bay, 6600. (The Foundation is concerned inter alia with the effects of agrichemicals on whales and dolphins).

- Wildlife Society of Southern Africa, P O Box 394, Howick, 3290.

- World Wide Fund for Nature South Africa/The Green Trust, P O Box 456, Stellenbosch, 7599.

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