SANITATION, PUBLIC HEALTH AND THE ENVIRONMENT:

LOOKING BEYOND CURRENT TECHNOLOGIES

L M Austin Pr Eng and S J van Vuuren Pr Eng

CURRICULUM VITAE OF AUTHORS

Aussie Austin graduated with a B.Sc Eng in civil engineering at the University of Pretoria in 1973. He spent the first twenty years of his career with consulting engineers, where he was involved in a diverse range of projects in the fields of roads, water supply, sewerage, stormwater management, railways and airports. He subsequently spent one year with the Department of Transport before joining CSIR Building and Construction Technology in 1994. He has since completed an M.Eng (Water Resources Engineering) at the University of Pretoria and his main field of interest is the research, development and implementation of alternative sanitation technologies.

Professor Fanie van Vuuren heads the Hydraulic Division in Civil Engineering at the University of Pretoria, South Africa. He has been active in the South African Institution of Civil Engineering and served as chairman of the Water Division, chaired the Education Sub-committee and was a member of the Executive Board. He has presented various courses, published extensively and lectured in Kentucky, USA. His main interest lies in pipeline engineering and economics and he has developed a number of utility programs. He is currently leading research on the de-aeration of large diameter pipelines as well as the application of genetic algorithms in water systems.

SYNOPSIS

Where there are poor or non-existent sanitation facilities, human excreta are spread throughout the environment and people, soils and bodies of water are negatively affected. With rapid population growth, especially in urban areas, the situation cannot improve unless there is a significant change in the manner in which sanitation systems are chosen, designed and implemented.

While waterborne sanitation systems have been widely successful in controlling the transmission of excreta-related diseases in most cities of industrialised countries, they have also created severe damage to ecosystems and natural water resources where the wastewater is inadequately treated. VIP toilets may also not be suited to densely populated urban areas, due to the increased risk of environmental pollution. Other systems should rather be employed, and they should preferably operate well without piped water.

The paper describes urine diversion sanitation systems, which have been used successfully in many developing countries, including South Africa. This sanitation technology is suggested as an additional means of combating the health and environmental problems caused by inadequate sanitation in many areas of the country.

INTRODUCTION

In most developing countries of the world – and South Africa is no exception – the most commonly used sanitation technologies are waterborne sewerage at one end of the scale and pit toilets at the other. There are some intermediate technologies, such as septic tanks, but it is a fact that everybody aspires to the top-of-the-range article. This is so despite implications such as high water usage, high operation and maintenance costs, and the advanced technology and institutional capacity required for removal, treatment and disposal of the excreta. VIP toilets have unfortunately also acquired the stigma of being a “poor man’s solution” to the sanitation problem, which has tarnished the image of this basically sound technology.

Both waterborne and VIP systems have, however, often been the cause of faecal and other pollution in ecosystems (Simpson-Hébert 1997; DWAF 1999; WRC 1993). This paper seeks to address the issue by proposing an alternative, environmentally sustainable approach to the sanitation challenge.

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Vast amounts of faecally contaminated material contaminate the living environment of people, soils and bodies of water worldwide. Existing systems and available resources are often inadequate to deal with the associated social and behavioural factors. This has contributed much to the escalation in ecological problems. With rapid population growth, especially in urban areas, the situation will not improve unless there is a significant change in the manner in which sanitation systems are chosen, designed and implemented (Simpson-Hébert 1997).

Environmental problems in turn undermine the process of development, which is further hampered by rapid population growth. In all developing countries, especially in sub-Saharan Africa, the growth of the population in the urban areas alone is outstripping the capacity of these regions to provide for basic needs such as shelter, water and sanitation (Kaseva 1999).

Water quality is deteriorating all over the world due to pollution. Some cities in developing countries treat only about 10 % of their sewage (Björklund 1997). Even in South Africa, recent reports have indicated that an alarming proportion of sewage waste in many towns and cities across the country does not reach treatment plants, but flows untreated into the rivers. This is regarded as one of the most pressing water quality problems in the country. In many cases, even when sewage waste reaches the treatment plant, poor operation or a malfunctioning system means that partially treated sewage effluent is discharged into rivers (DWAF 1999).

In many urban centres, the poorest groups face the most serious environmental hazards and have the least possibility of avoiding them or receiving treatment to limit their impact on health (Wall 1997). Early this century, it is predicted, more than half of the world's population will be living in urban areas. By the year 2025 this urban population could rise to 60 %, comprising some five billion people. The rapid urban population growth is putting severe strains on the water supply and sanitation services in most major conurbations, especially those in developing countries (Mara 1996). In Africa today, over half the population is without access to safe drinking water and two-thirds lacks a sanitary means of excreta disposal. Lack of access to these most basic services to maintain health lies at the root of many of Africa's current health, environmental, social, economic and political problems. Hundreds of thousands of African children die annually from water- and sanitation-related diseases. Despite significant improvements during the International Drinking Water Supply and Sanitation Decade (1981-1990), progress has now stagnated. More people are without adequate services in Africa today than in 1990, and at the current rate of progress full coverage will never be achieved (WSSCC 1998).

THE SOUTH AFRICAN EXPERIENCE

Inadequately maintained sewer-reticulation systems in urban areas have caused adverse environmental impacts, most often as a result of leaking or blocked sewers, but sometimes also as a result of overloaded or inadequately operated or maintained treatment works and failed pumping stations. In poor areas, especially, most of the operational difficulties are concentrated at the user end of the systems, where personal cleaning materials other than proper toilet tissue paper are used, and also due to a lack of education on the proper use of cistern flush toilets (WRC 1993).

Many community sanitation schemes have been successfully implemented utilising VIP toilets. In the authors' experience, however, others have been problematic, often due to poor design and construction practices or to social factors such as a lack of community buy-in, or a combination of these. Sufficient attention is not always given to factors such as environmental impact, social issues, water-supply levels, reliability or institutional capacity.

The sanitation policy of the South African government stresses that sanitation is not simply a matter of providing toilets, but rather an integrated approach which encompasses institutional and organizational frameworks as well as financial, technical, environmental, social and educational considerations (DWAF 1996). It is recognised that the country cannot afford to provide waterborne sanitation for all its citizens – nor, for that matter, should it necessarily aspire to do so. It is also acknowledged that, at all levels, the sanitation problem is related to socio-cultural, educational and institutional issues, with the lack of appropriate facilities and inadequate guidelines being a contributory factor.

THE WAY FORWARD

With the continuous growth of urban populations and the high incidence of low-income people living in informal areas, there is no possibility of providing conventional waterborne sewerage to all people who are currently without adequate sanitation facilities. Other systems have to be employed. Ideally, they should provide the same health benefits as waterborne sewerage, while remaining affordable to poor people. They should operate well without piped water and provide as great a convenience for users as possible. They should also be simple and reliable to operate and maintain (Cotton et al 1995).

Sanitation approaches based on flush toilets, sewers and central treatment plants cannot solve the sanitation problem. Nor can the problem in high-density urban areas be solved by systems based on various kinds of pit toilets. There exists an erroneous assumption that the basic problem is one of “sewage disposal”, while in fact the problem is the disposal of human faeces and urine, not sewage. This is because the human body does not produce “sewage”. Sewage is the product of a particular technology. To handle faeces and urine separately is not a great problem, as each human produces only about 500 litres of urine and 50 litres of faeces per year. Fifty litres of faeces should not be difficult to manage. The problem only arises when these two substances are mixed together and flushed into a pipe with water to form sewage. This means that, instead of only fifty litres of problem material, it becomes necessary to deal with 550 litres of polluted, dangerous and unpleasant sewage (Winblad 1996a & 1996b). In a conventional waterborne system, this may use as much as 15 000 litres of pure water (and sometimes more).

Methods of providing good sanitation without the concomitant use of large volumes of water should rather be sought. Based on recent trends in water use and population growth, the availability and utilisation of water have been projected to the year 2030. The results show that South Africa will reach the limits of its economically usable, land-based fresh water resources during the first half of this century. A greater emphasis should therefore be placed on water conservation coupled to the most beneficial use of this scarce resource. This should be combined with a comprehensive programme to instil in the public an appreciation of the true value of water and the importance of a changed approach to water utilisation countrywide (DWAF 1997). Alternative sanitation technologies that support this approach are an important component of the overall strategy.

While “conventional” sanitation options may be suited to certain situations, in other circumstances, where both water and space are scarce, there is a clear need for permanent, emptiable toilets which do not require water (Dudley 1996). It is acknowledged that a well-engineered VIP toilet, correctly used and well maintained, is an asset in the struggle to break the cycle of disease transmission and environmental degradation caused by inadequate sanitation facilities, but these systems are not without their problems. Geotechnical conditions, such as hard or rocky ground, for instance, may require additional, expensive, resources for excavation of pits, or the structure may need to be raised in order to minimise the volume of excavation. In other cases, non-cohesive soils will require a pit to be lined in order to prevent collapse of the structure. Pits should preferably also be avoided in areas with shallow water tables (less than 0,5 m below the base of the pit), especially in aquifers with high hydraulic conductivity. These toilets are also unsuited to densely populated urban or peri-urban environments, due to the increased risk of environmental pollution.

Full pits are a further problem. In many cases the owners will not be in a financial position to empty them, even if the toilets have been constructed with this in mind (e.g. removable cover slabs). While there may be plenty of available space in rural areas to dig further pits, this will seldom be the case in densely populated urban areas. The cost of digging a new pit and moving or rebuilding the superstructure has not even been taken into account here, so for all practical purposes the initial investment is lost when the pit fills up. Some other solution should be sought in these cases. If a dry toilet is designed and constructed in such a way that the faeces receptacle can be quickly, easily and safely emptied, then one of the biggest operation and maintenance problems associated with these toilets will be obviated. If the excreta can also be productively and safely used for agricultural purposes (if the community is so inclined) the technology will become even more attractive.

Whatever technology is implemented, however, it is important to keep a cardinal principle in mind – namely, that it is better to protect the environment from faecal pollution than to undertake expensive measures to reduce pollution that has already taken place. According to Simpson-Hébert (1997), the approach to the sanitation challenge should be ecologically sustainable, i.e. concerned with the protection of the environment. This means that sanitation systems should neither pollute ecosystems nor deplete scarce resources. It further implies that sanitation systems should not lead to degrading water or land and should, where possible, ameliorate existing problems caused by pollution. It is also maintained (Simpson-Hébert 1996) that the sanitation sector should continue to innovate low-cost facilities for people with different needs, from different climates, and with different customs. More research and better designs are still needed. Furthermore, there is a need in some societies to recycle human excreta as fertiliser. Human excreta can be rendered harmless, and toilet designs that do this in harmony with agricultural and social customs hold promise for the future.

Sanitation programmes fulfilling the above principles simultaneously have a greater likelihood of long-term sustainability (Simpson-Hébert 1997). The following recommendations are consequently made for implementing sanitation programmes:

(a) Impetus should be provided for research and development for a range of systems applicable to differing cultural and environmental conditions; and

(b) a demand should be created for systems that move increasingly toward reuse and recycling of human excreta.

ECOLOGICAL SANITATION TECHNOLOGY

Problems with conventional sanitation approaches have been shown to include inadequate institutional capacity to deal with the sanitation process, a fixation with providing either a full waterborne system or a VIP toilet, the social acceptability of different systems, and the perception that dry, on-site sanitation systems are inherently inferior. The basic purpose of any sanitation system is to contain human excreta (chiefly faeces) and prevent the spread of infectious diseases, while avoiding damage to the environment. If an alternative sanitation technology can perform these functions with fewer operational and maintenance problems than those associated with conventional VIP toilets, and also produce a free, easily accessible and valuable agricultural resource for those who wish to use it, then the implementation of such a technology should be actively encouraged.

The technology of ecological sanitation, or "dry box" toilets, has been used successfully for decades in many developing countries, e.g. Vietnam, China, Mexico, El Salvador, Ecuador, Guatemala, Ethiopia and Zimbabwe, and recently also in South Africa. Even in a highly developed country such as Sweden there is a great deal of interest in the technology (Esrey et al 1998; Hanaeus et al 1997; Höglund et al 1998; Jönsson 1997; Wolgast 1993). The most important characteristic of this technology is the low moisture content in the faeces receptacle. The urine is diverted at source by a specially designed pedestal and is not mixed with the faeces. A schematic representation is given in Figure 1. A pit is not necessary, as the entire structure may be constructed above ground, or may even be inside the dwelling. The faeces compartment is solar-heated by means of a black-painted metallic or UV-stabilised PVC cover flap. Ash, dry soil or sawdust is sprinkled over the faeces after each defecation. This serves to absorb the moisture and control odours and flies. The generally dry conditions in the faeces receptacle facilitate the desiccation of the contents, which can thus become safe for handling within a relatively short time. The desiccated faecal matter makes a good soil conditioner, while the urine, when diluted with water, is an excellent fertiliser, being rich in nitrogen, phosphorus and potassium.

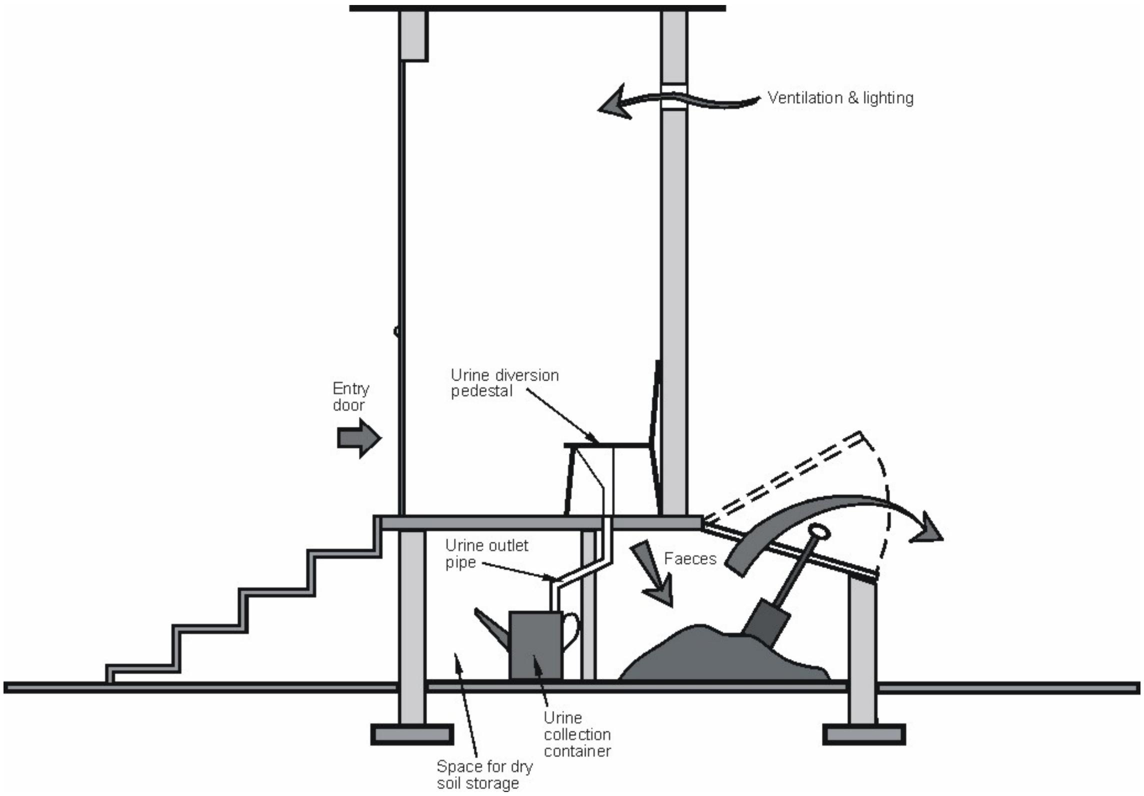

Figure 1: Schematic representation of a urine diversion ("dry-box") toilet

Biology of human excreta

For adult persons who maintain approximately the same mass during their lifetimes, the excreted amounts of plant nutrients are about the same as the amount eaten. The excreted amounts of plant nutrients depend on the diet and thus differ between individuals as well as between societies (Jönsson 1997). A great deal of research on the subject has been carried out in Sweden and Table 1 is based on the average Swedish diet and circumstances. Although the comparative figures for other countries can be expected to be somewhat different, the overall picture will be essentially the same.

Table 1: Estimated Swedish averages for mass and distribution of plant nutrient content in urine and faeces, expressed as percentages of total mass excreted
(based on Jönsson 1997)

Parameter	Urine		Faeces		Total toilet waste	
	g/p/d	%	g/p/d	%	g/p/d	%
Wet mass	900-1200	90	70-140	10	970-1340	100
Dry substance	60	63	35	37	95	100
Nitrogen	11	88	1,5	12	12,5	100
Phosphorus	1,0	67	0,5	33	1,5	100
Potassium	2,5	71	1,0	29	3,5	100

Roughly 65 to 90 % of the excreted nitrogen, phosphorus and potassium are found in the urine. Furthermore, plant nutrients excreted in urine are found in chemical compounds that are easily accessible for plants. Initially 80-90 % of the nitrogen is found as urea, which rapidly degrades to ammonium and carbon dioxide, while the phosphorus and potassium are in the form of phosphates and ions respectively. Many chemical fertilisers contain, or dissolve to, nitrogen in the form of ammonium, phosphorus in the form of phosphates, and potassium in the form of ions. Thus, the fertilising effect of urine ought to be comparable to the application of the same amount of plant nutrients in the form of chemical fertilisers (Jönsson 1997).

Potential for reuse of human excreta

Key features of ecological sanitation are prevention of pollution and disease caused by human excreta, treatment of human excreta as a resource rather than waste, and recovery and recycling of the nutrients. In nature, excreta from humans and animals play an essential role in building healthy soils and providing valuable nutrients for plants. Products of living things are used as raw materials by others. Conventional approaches to sanitation misplace these nutrients, dispose of them and break this cycle (Esrey et al 1998).

The fertilisers excreted by humans are sufficient to grow 230 kg of cereal each year, as illustrated in Table 2. The table is based on an average human production of 500 litres of urine and 50 litres of faeces per year.

Table 2: Annual excretion of fertiliser by humans compared with fertiliser requirement of cereal (Wolgast 1993)

Fertiliser	500 ℓ urine	50 ℓ faeces	Total	Fertiliser need for 230 kg cereal
Nitrogen	5,6 kg	0,09 kg	5,7 kg	5,6 kg
Phosphorus	0,4 kg	0,19 kg	0,6 kg	0,7 kg
Potassium	1,0 kg	0,17 kg	1,2 kg	1,2 kg
Total N+P+K	**7,0 kg (94 %)**	**0,45 kg (6 %)**	**7,5 kg (100 %)**	**7,5 kg**

Human urine is seen to be the largest contributor of nutrients to household wastewater. If no phosphate detergents are used, at least 60 % of the phosphorus and 80 % of the nitrogen in household wastewater comes from urine. The total quantities of nutrients in human urine are significant when compared with the quantities of nutrients in the mineral fertilisers used in agriculture. For example, it is estimated that in Sweden the total yearly production of human urine contains nitrogen, phosphorus and potassium equivalent to 15-20 % of the amounts of these nutrients used as mineral fertilisers in 1993. Thus, by source-separating human urine, the amounts of nutrients recycled to arable land can be significantly increased while at the same time the nutrient load of wastewater can be significantly reduced. Furthermore, the use of recycled toilet products as fertilisers will save the use of chemical fertilisers containing the same amounts of nutrients, as well as the resources needed to produce and distribute them (Jönsson 1997).

A further advantage of using human urine instead of chemical fertilisers or sewage sludge is the very low concentrations of heavy metals found in urine (Jönsson 1997). This viewpoint is supported by Hanaeus et al (1997), who state that the quality of sewage sludge is not fully trusted by agriculturalists due to the risk of hazardous compounds being present. Cadmium, for example, bio-accumulates in the food chain. According to Höglund et al (1998), human urine in Sweden contains less than 3,6 mg Cd/kg P, while commercial chemical fertilisers contain approximately 26 mg Cd/kg P. Furthermore, the sludge from the 25 largest sewage plants in Sweden was found in 1993 to contain an average of 55 mg Cd/kg P.

Although faeces contain fewer nutrients than urine, they are a valuable soil conditioner. After pathogen destruction through dehydration and/or decomposition, the resulting inoffensive material may be applied to the soil to increase the organic matter content, improve water-holding capacity and increase the availability of nutrients. Humus from the decomposition process also helps to maintain a healthy population of beneficial soil organisms that actually protect plants from soil-borne diseases (Esrey et al 1998).

System hardware and operational aspects

The basic requirement of a urine diversion sanitation system is a toilet pedestal that prevents urine and faeces from being mixed together, as shown in Figure 1. The urine can be collected in any suitable sealed container if its reuse for agricultural fertiliser is desired. Alternatively, it can be led into a soakpit. The superstructure requirements are similar to an ordinary VIP toilet, and can be made from any suitable materials. No pit is needed, so the toilet may be installed inside the dwelling if desired. This has decided advantages – users are protected from the elements, have more privacy and do not need to fear molestation, particularly at night. The faeces-collection chamber is on the outside of the building; this serves two purposes – namely, easy accessibility and absorption of solar energy for dehydration. Faecal pathogens are vastly reduced, or even destroyed, through the combined effects of heat, lack of moisture and time. The desiccated faeces may be easily gathered and reused in the garden, or arrangements may be made for bagging, collection and disposal.

An example of an actual pedestal designed by CSIR Boutek and installed in a project in the Eastern Cape is illustrated in Figure 2. A typical completed unit for the same project is shown in Figure 3.

Urine diversion pedestals may be fabricated from various materials – for example, plastic, fibreglass, and even concrete. The latter are finished off very smoothly and may then be painted, after which they look quite attractive. They are also fitted with standard seats and lids, obtained commercially. In Sweden, pedestals are made of porcelain, similar to conventional toilets, and are of excellent quality and appearance. Figure 4 portrays a porcelain pedestal inside a building in Stockholm.

Figure 2: A urine diversion pedestal made from rotationally moulded plastic, installed in the village of Sinyondweni near Umtata, Eastern Cape. Urine is collected in the front compartment and led away by a pipe. Faeces drop through the rear opening and are collected in a receptacle beneath.

Figure 3: Completed urine diversion toilet unit at Sinyondweni

Figure 4: A porcelain urine diversion toilet pedestal in Stockholm, Sweden

Health aspects

According to Golueke (1976), environmental factors of importance in the die-off rate of pathogens are high temperatures, low moisture contents and time. A high temperature, especially, is the most important consideration, as all living organisms, from the simplest to the most complex, can survive at temperatures only up to a certain level. Above that level, they perish. Regarding moisture content, all biological activity comes to a halt at moisture contents of 12 % or less, although the process would be disastrously slowed long before that level was reached. Generally, moisture content begins to be a severely limiting factor when it drops below 35 to 40 %. Also, time *per se* does not kill the microorganisms; rather, it is the *continued exposure to an unfavourable condition* that does the job.

Desiccation of faeces maximises the destruction of enteric microorganisms. This greatly increases their value and manageability as an agricultural resource, both as a fertiliser and soil conditioner, as well as reducing pollutant burdens on the aquatic environment and health hazards associated with handling. Experimental data has confirmed that dry storage of faeces for a minimum period of one year usually results in a product of substantially improved microbiological quality (Wheeler and Carroll 1989).

Urine is generally sterile. There is a possibility, however, that faecal contamination can still enter the urine bowl of the pedestal. This usually happens where users are suffering from stomach disorders, when the faeces are watery and tend to spray on emission. Experiments in Sweden have established that six months of storage time for source-diverted urine is usually sufficient for the destruction of pathogenic organisms. However, this is also dependent on the temperature and dilution of the mixture – lower temperatures and higher dilutions tend to increase the survival time of the pathogens (Olsson 1996; Höglund et al 1998).

CONCLUSION

The task of improving the quality of life everywhere, ridding the country of widespread disease caused by poor or non-existent sanitation facilities, eliminating malnourishment and improving food production in soils which are often of poor quality, all without detrimental effects on the environment, is an enormous challenge. To do all this without using more water requires engineers and policy makers to be bold and innovative.

The philosophy of ecological sanitation is based on the concept of human excreta as a valuable resource, not simply as an unpleasant waste product to be disposed of. The implications of the dry-box approach for urban ecology and municipal economy are less environmental pollution, reduced water consumption, no need for sewers or sewage treatment plants, and the production of a valuable resource (Winblad 1996a). The question is not whether urine diversion toilets are a good or bad idea, but rather how authorities, engineers and the public can be assisted to develop confidence in them.

BIBLIOGRAPHY

Abbreviations:

DWAF	Department of Water Affairs and Forestry, South Africa
Sida	Swedish International Development Cooperation Agency, Sweden
WEDC	Water, Engineering and Development Centre, Loughborough University, UK
WRC	Water Research Commission, South Africa
WSSCC	Water Supply and Sanitation Collaborative Council Working Group on Promotion of Sanitation (World Health Organisation, Geneva)

Björklund, G (1997). *Comprehensive assessment of the freshwater resources of the world*. News Flow, Global Water Partnership, no 1/97. Stockholm.

Cotton, A, Franceys, R, Pickford, J and Saywell, D (1995). *On-plot sanitation in low-income urban communities: A review of literature*. WEDC, Loughborough, UK.

Dudley, E (1996). *Technological options for dry latrines. Dry sanitation: an eco-sustainable alternative*. Workshop, San Salvador, El Salvador.

DWAF (1996). *Draft White Paper: National Sanitation Policy*. Pretoria.

DWAF (1997). *Overview of water resources availability and utilisation in South Africa*. Pretoria.

DWAF (1999). Water Affairs develops strategy to manage pollution from poorly serviced areas. *Imiesa*. Vol 24 no 3. March, Johannesburg.

Esrey, S, Gough, J, Rapaport, D, Sawyer, R, Simpson-Hébert, M, Vargas, J and Winblad, U (ed) (1998). *Ecological sanitation*. Sida, Stockholm.

Golueke, C G (1976). Composting: A review of rationale, principles and public health. *Compost Science*, summer edition.

Hanaeus, J, Hellström, D and Johansson, E (1997). A study of a urine separation system in an ecological village in northern Sweden. *Wat. Sci. Tech.* Vol 35 no 9, Elsevier Science Ltd, UK.

Höglund, C, Stenström, T A, Jönsson, H and Sundin, A (1998). Evaluation of faecal contamination and microbial die-off in urine separating sewage systems. *Wat. Sci. Tech*. Vol 38, no 6. Elsevier Science Ltd, UK.

Jönsson, H (1997). *Assessment of sanitation systems and reuse urine*. Sida Sanitation Workshop, Balingsholm, Sweden.

Kaseva, M E (1999). The African city in sustainable human settlement development – a case of urban waste management in Dar es Salaam, Tanzania. *SAICE Journal*, 1st quarter 1999, 41(1). Johannesburg.

Mara, D D, Ed (1996). *Low cost sewerage*. John Wiley and Sons, UK.

Simpson-Hébert, M (1996). Sanitation and the seven Ps - Problems, Promise, Principles, People, Politics, Professionalism - and Potties. *Waterlines*. Vol 14, no 3.

Simpson-Hébert, M (1997). *Responding to the sanitation challenge of the 21st century*. WSSCC, Geneva.

Wall, K (1997). A résumé of WASH, UNDP and World Bank water and sanitation experience. *Water SA.* Vol 23 no 3. WRC, Pretoria.

Wheeler, D and Carroll, R F (1989). *The minimisation of microbial hazards associated with latrine wastes*. Wat. Sci. Tech. vol 21 no 3. Elsevier Science Ltd, UK.

Winblad, U (1996a). *Rethinking sanitation. Dry sanitation: an eco-sustainable alternative*. Workshop, San Salvador.

Winblad, U (1996b). *Towards an ecological approach to sanitation*. International Toilet Symposium, Toyama, Japan.

Wolgast, M (1993). *Recycling system*. Brochure produced by WM-Ekologen ab, Stockholm, Sweden.

WRC (1993). *Urban sanitation evaluation*. WRC report no 385/1/93, Pretoria.

WSSCC (1998). Urgent action needed by leaders in Africa. *Source Bulletin*. No 2, December. World Health Organisation, Geneva.