Ecological Sanitation
Closing the Loop

One of the most potent forces in the world today is urbanisation. Some of the seemingly disconnected problems associated with urbanisation - water scarcity, food insecurity and pollution - are really the manifestation of several underlying assumptions and actions. One assumption is that there are no limits to resources such as water and land. Another is that the environment can assimilate the wastes that we produce from using these resources. These assumptions lead to linear flows of resources and wastes that are not reconnected. The technological developments to serve these linear flows have become part of the problem, not the solution.

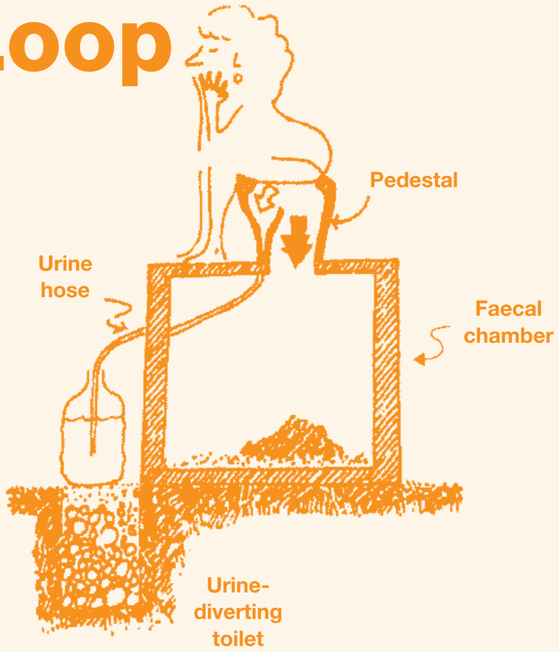

Figure 2: Urine-diverting toilets facilitate treatment and re-use.

Today, nearly half of humanity has no access to any type of sanitation (WHO and UNICEF 2000). The rest of humanity relies on conventional approaches to sanitation, which fall into one of two categories: water-borne systems and pit latrines. Both 'flush and discharge' and 'drop and store' technologies were built on the premise that the nutrients we excrete have little value, and that waste is suitable only for disposal. Consequently, the environment is polluted, nutrients are lost, and a wide array of health problems result (Esrey 2000).

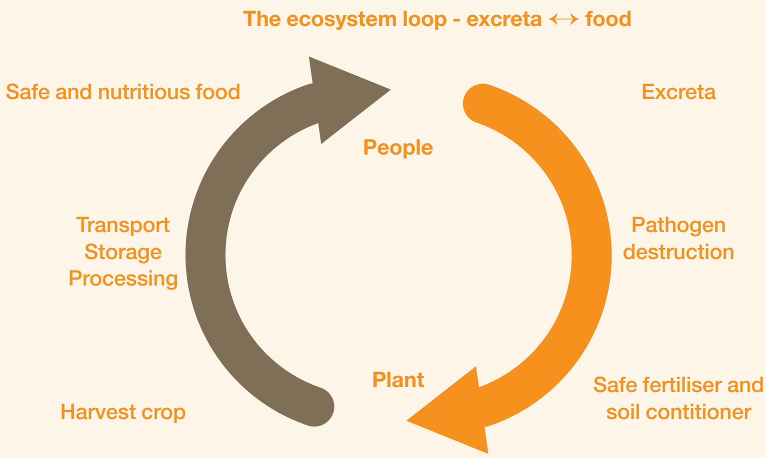

Figure 1: Ecological sanitation is safe, green and valuable

Ecological sanitation (Esrey 1998) represents a shift in the way people think about and act upon human excreta. It is an ecosystem approach (Figure 1) that recognises the need and benefit of promoting human health and well-being, while at the same time recovering and recycling nutrients, and conserving and protecting water sources. It represents a closed-loop approach, and is an attempt to move away from linear solutions of waste disposal towards a circular flow of nutrients.

Steven A. Esrey
UNICEF, New York, USA
sesrey@unicef.org
Ingvar Andersson
UNDP, New York, USA
ingvar.andersson@undp.org

DESIGN FEATURES

Conventional sanitation solutions assume that the environment can handle the waste, or they shift the burden to downstream communities. Ecological sanitation, on the other hand, minimises the reliance on external inputs, while simultaneously reducing the output of wastes from the system.

There are two basic design features of ecological sanitation. One is urine-diversion, in which urine and faeces are never mixed (see figure 2). The pedestal has a dividing wall, in which the urine exits from the front of the toilet, and faeces drop below the toilet from the back of the bowl. Another design combines urine and faeces, at which point urine and faeces can be processed together or seperated. In either case, it is possible to manage urine, faeces or excreta with little or no water, and it is also possible to keep the end-product out of ground and surface waters.

Pathogens are treated close to the point of excretion. Nearly all pathogens in excreta are found in faeces, while urine is sterile with few exceptions (e.g. *Schistosoma haemotobium* - a trematode worm which causes Bilharzia or Schistosomiasis). If faeces are kept separate from urine, the pathogens in faeces are much more easily treated in an ecological toilet without the use of harmful chemicals or complex processes and treatment plants. Microbiological testing on urine diversion toilets is being done in a number of countries. Evidence to date (Stenström 1999) indicates that the addition of lime or ash helps to desiccate faeces and raise the pH, which can effectively kill off pathogens within several months. Faeces, once desiccated, may be returned to soil or composted with organic household refuse if there is some concern that pathogens still exist. If it is suspected that pathogens survive the desiccation/pH phase, they can be killed within days at temperatures above 50°C or within a relatively short time during thermophilic composting (Feachem et al. 1983). Of course, over time pathogens will die if kept out of water and left undisturbed by weather or animals. This period may be up to two years if *Ascaris* ova are present.

If urine and faeces are combined, as is usual in conventional systems, it is harder to render excreta safe, though not impossible. More time, thermophilic composting and sometimes chemicals, such as chlorine, are necessary then to kill bacteria. In general, conventional sanitation solutions fail to treat excreta on- or off-site. Over 90% of sewage in developing countries is discharged without any treatment, into receiving bodies of water, and the figure for Latin America, which has the highest rates of water-borne systems, is 98% (Briscoe & Steer 1997).

Ecological sanitation also contributes toward the protection of human health by providing a healthy environment. Human excreta contain very low levels of heavy metals. For example, in Sweden urine contained less than 3.2 mg cadmium per kg of phosphorus (P), compared to 26 mg Cd/kg P in commercial fertilisers and 55 mg Cd/kg P in sludge (Jönsson et al. 1997). In addition, there has been some concern about the excretion of pharmaceuticals (Raloff, 1998). Many of these products may be partially or fully reconstituted when deposited into water, but when excreta are returned to soil, they appear to be broken down rapidly by soil microorganisms (Stockholm Vatten et al. 2000). The uptake by plants should be negligible.

Returning nutrients to soils may restore soil fertility more than reliance on commercial fertilisers. Ecological sanitation is a household or community-managed operation. Recycling nutrients for home gardening is often the domain of women, who may get additional food or income. Treated excreta can also be packaged into plastic bags and sold as fertiliser to provide income (Morgan 1999). It is also well known that when women have control over resources, they are more likely to use those resources for food and health care of family members than will men.

Resource value of human excreta

Human excreta are comprised of two basic components, urine and faeces. Each has very different properties, they are produced in different quantities, and they require different care in processing. Published figures indicate that more than 1 litre of urine and less than 200 g of faeces, including moisture, is produced daily (Del Porto & Steinfeld 1997), depending on the type of diet, location, age, activity and health status. Urine contains nearly 80% of the total nitrogen found in excreta and about two-thirds of the excreted phosphorus and potassium. The majority of the carbon excreted, up to 70%, is found in faeces. The quantities shown above may suggest that excreta contain few nutrients. Each person urinates annually about 4 kg of nitrogen, 0.4 kg of phosphorus, and nearly 1 kg of potassium. Total excretion is 4.5 kg of nitrogen, more than half a kg of phosphorus, and 1.2 kg of potassium. This is the amount needed to grow a year's supply of grain for every person (Wolgart, 1993). In an urban setting of one million people, this equates to 4.5 million kg of nitrogen, nearly 600,000 kg of phosphorus, and more than 1.2 million kg of potassium. Although using only urine is valuable, both urine and faeces should be recovered and recycled to avoid long-term depletion of soils.

EXAMPLES FROM AROUND THE WORLD

Achieving ecological sanitation solutions requires a change in how people think about and act according to human excreta. In some societies, human excreta are considered a valuable resource, and the handling of excreta poses no problem. In fact, urine has been used as a resource in many parts of the world for centuries. It was used in Europe for household cleaning, softening wool, hardening steel, tanning leather and dying clothes. The Greeks and Romans used it to colour their hair, and African farmers use it for fermenting plants to produce dyes. The Chinese pharmaceutical industry uses it to make blood coagulants. In other societies, excreta, and particularly faeces, have been considered dirty for centuries. Experience shows, however, that urine diversion is acceptable, and the handling of urine poses far fewer taboos than that of faeces. Many people do not know that faeces can be processed and converted into humus, with all the typical characteristics: pleasant-smelling, easy to handle as soil, and innocuous. Furthermore, experience shows that after people have become familiar with these systems, no flies or smells occur, and people install these toilets inside their homes.

Wallgarden

Ecological sanitation has been gaining momentum during the past decade

Ecological sanitation has been gaining momentum during the past decade. In most places where it is being tried, health issues have been at the forefront. Microbiological testing of excreta has occurred. However, methods have varied, and sample sizes are small due to the costs involved. In general, excreta can be safely processed, but failure to pay attention to maintenance, and insufficient or infrequent use of lime or ash, may fail to adequately destroy all pathogens. Anecdotal evidence from several locations indicate that people prefer vegetables grown with urine fertilisation, and in China people are willing to pay more for vegetables grown in urine (Mi Hua, personal communication, 2000).

In Mexico City, experimentation with fermented urine to grow food has shown that leafy vegetables do very well (Arroyo, personal communication, 2000). This includes lettuce, cilantro (coriander), parsley, celery, fennel, scented herbs, prickly pear, and chile piquin. Good results were obtained for cauliflower, broccoli, cabbage and root produce (turnips, carrots, beets and onions). Fruiting plants, such as tomatoes, squash, cucumber, peppers and aubergines have not done as well with fermented urine as with other fertilisers. This may be due in part to the continued use of nitrogen, in the form of fermented urine, during the fruiting process. When the subsoil is enriched with worm compost, the results for fruiting plants improve dramatically. In the case of tomatoes, produce is increased from 3 to 5 kg per plant when the compost is

Bitter Gourd next to toilet in Kerala, India

Conclusions so far indicate that the health risk is negligible

Rooftop gardening in China using human urine (source Uno Winblad)

enriched with the phosphorus and potassium compounds from worm composting. Others (Guadarrama 2000) in Cuernavaca, Mexico have been experimenting with human urine as a source of nitrogen in organic vegetable production. The experiments compared human urine versus a control on the production of chard, celery and beets. For each vegetable yields were higher when urine was applied compared to the control. The central root, length of step and area of foliage was greater in urine fertilised vegetables, and no diseases or pests were found.

In Guangxi province, China, urine-diversion toilets (double-vault dehydration) are gaining momentum. Rooftop gardening (see foto) uses only urine to grow vegetables, such as tomatoes, cabbages, beans and pumpkins. Faeces are carted to the fields. Urine and faeces are used in fields to grow corn, rice and bamboo. In China, farmers have commonly used night soil, often untreated, to grow food. It has been recognised for centuries as a valuable fertiliser. A pilot project of 70 urine-diverting toilets has grown to over 30,000 toilets in both densely populated rural and urban areas. This effort has been supported at the top political level.

In a pilot project in Kerala, India, urine from toilets is diverted into a growing area attached to the back of the toilet. Bitter gourds are grown, which are sliced, fried and eaten. This first stage has met with success, and there is demand to have more toilets built. Island communities in the Pacific also have wash-water gardens, largely driven by the need to not pollute and destroy their livelihood - fishing. Some of the Island communities, such as Fiji, have wash-water gardens in schools as well.

In Zimbabwe, there has been much experimentation in the past few years with ecological sanitation. It is now spreading to periurban areas of Harare and to neighbouring countries, with various toilets designed for different purposes being tried. In addition to urine-diverting toilets, other ecologically sound toilet systems are also being used. The 'arbourloo' is a system in which both urine and faeces are deposited in a shallow pit. When it is nearly full, it is topped off with soil and allowed to digest and decompose for several months. At that time, trees are planted in the topsoil. A wide variety of fruit-bearing trees grow very well in this type of system. Guava, banana, mulberry and paw paw respond very well and grow very fast. Avocado, mango and citrus grow slower initially. All these fruit trees supply valuable micronutrients, improving the nutrient status of consumers.

In the mid 1990's, a number of ecological housing estates were built in Stockholm, Sweden. One of the main features built into the design was the development and testing of an ecosystem-based sanitation system with urine-diverting toilets. Urine was collected, stored and applied to the fields. Faeces were treated in the conventional manner. The Stockholm Water Company was the lead agency, and research is still being conducted on health, environment and social acceptance of the system. Conclusions so far indicate that the health risk is negligible, and the emission of nitrogen and phosphorus is reduced by 50-60% compared to conventional sewage. Urine has also been found to be a valid substitute for mineral fertilisers to grow cereals, with no negative impact on the crop or the environment. And, as reported above, urine contains less heavy metals than does conventional sewage or fertilisers.

Other countries throughout the world are experimenting with ecological sanitation. Not all are promoting the re-use and recycling of nutrients. Many of these initiatives have come about because of local problems, such as pollution or water scarcity. Today, support for ecological sanitation comes from many quarters: international agencies such as UNDP, UNICEF and donors such as Austria, Germany and Sweden as well as international NGOs such as CARE and Wateraid, and local and national NGOs.

REFERENCES
- Briscoe J & Steer A. 1993. New approaches to structural learning. Ambio 22 (77): 456 and WHO, Environmental Health Newsletter 27 (Supplement, 1997).
- Esrey SA, Gough J, Rapaport D, et al. 1998. Ecological Sanitation. Stockholm: SIDA.
- Esrey SA. 2000. Rethinking Sanitation: Panacea or Pandora's Box. In: Chorus I, Ringelband U, Schlag G & Schmoll O (eds), Water, Sanitation and Health, International Water Association, London.
- Del Porto D & Steinfeld C. 1997. The Composting Toilet System Book. Concord, Mass.: Center for Ecological Pollution Prevention.
- Jönsson, H. 1997. Assessment of sanitation systems and re-use of urine. In: Drangert J-O, Bew J, and Winblad W, Ecological Alternatives in Sanitation, Proceedings from SIDA Sanitation Workshop, Balingsholm, Sweden.
- Feachem RG, Bradley DJ, Garelick H et al. 1983. Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. New York: John Wiley & Sons.
- Guadarrama RO, 2000. Human urine used as a source of nitrogen in the production of organic crops, in Cuernavaca, Morelos, México: a case study.
- Jönsson H, Stenström T-A & Sundin A. 1997. Source separated urine, nutrient and heavy metal content, water saving and faecal contamination. Wat. Sci. Tech. 35(9): 145-152.
- Morgan P. 1999. Ecological sanitation in Zimbabwe – an overview. Paper presented at the International Workshop, Ecological Sanitation – Closing the Loop to Food Security, 17-21 October 1999, Cuernavaca Mexico.
- Raloff J. 1998. Drugged waters: does it matter that pharmaceuticals are turning up in water supplies? Science News 153: 187-189.
- Stenström T-A. 1999. Health security in the re-use of human excreta from on-site sanitation. Paper presented at the International Workshop, Ecological Sanitation – Closing the Loop to Food Security, 17-21 October, 1999, Cuernavaca Mexico.
- Stockholm Vatten et al. 2000. Urinsortering – en del av kretsloppet. Stockholm: Byggforskningrådet.
- Wolgast M. 1993. Rena vatten - om tankar I kretslopp. Uppsala, Sweden: Creanom HB.
- World Health Organization and United Nations Children's Fund. 2000. Global water supply and sanitation assessment 2000 Report. Geneva: WHO & UNICEF.