Fighting the urine blindness to provide more sanitation options

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Abstract

South Africa is trying hard to improve sanitation in the country and presently a White Paper is being prepared to outline the sanitation policy. A brief look around the globe shows that most countries are facing sanitary problems, especially in the expanding cities in the Southern Hemisphere. There is a need to know what is being done in other countries in order to extend the policy options. This article provides such information and focuses on excreta disposal systems which use little or no water, and various ways to use the end-products of faeces and urine. We have to do away with our urine blindness to discover new possibilities.

Introduction

The possibility to "sewer the world" is rapidly fading away in the light of global population increase, difficulties to treat waste water due to the explosive increase in the use of chemicals by man, water shortages, and the growing awareness of the limited supply of phosphorus on the globe to support biomass production.

In a water-scarce country like South Africa sanitation options are needed which minimise the demand on water resources (Schutte and Pretorius, 1997). The search for options should include both households with high water consumption, which are mostly connected to sewerage systems, as well as unserved communities.

The available options of environmental sanitation are many, but the number could be increased if urine blindness is overcome i.e. our tendency to think about mixed excreta instead of urine *per se*. This shows that sanitation is not just a technical fix but an intriguing interplay of norms and attitudes among professionals as well as users. The reasons for installing an improved collection of excreta may vary, and often include status/pride, convenience, hygiene and improved health. Rarely is improved nutrition mentioned, however, since recirculation of nutrients is hardly practised or contemplated.

Three different principles to handle human excreta

Until recently two principles have been used in disposal of human excreta. The most prestigeous system applies the "flush-and-discharge" principle which relies on a water-borne sewerage system, while its poor cousin the "drop-and-store" principle is represented by latrine pits. Both principles allow for many variations.

The drop-and-store principle ranges from cat hole defaecation to VIP toilets, usually without water unless anal cleansing is practised. Such solutions are feasible to get rid of excreta but impair recirculation and the faecal content will degrade the groundwater if the pit reaches the saturated zone. The flush-and-discharge principle is often seen as the ultimate solution, at least since the days of the great sanitarians in Britain. The range of

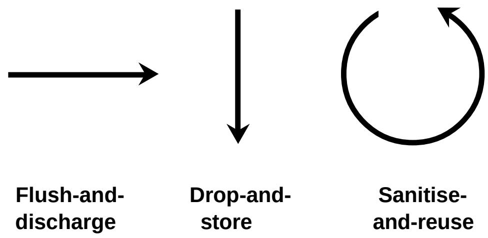

Figure 1
Three different principles to dispose of human excreta (Winblad, 1997)

seweraged alternatives relates to the amount of water used for flushing and the degree of treatment of the effluents. Usually the sewage is mixed with other waste water along the route in the pipe which makes it more difficult to treat before discharging it into rivers and lakes. The content of heavy metals in the sludge from treatment plants is normally too high to make it fit-for-use on agricultural fields. The World Bank (1992) has recently estimated that only some 5% of the sewage from cities in the Southern Hemisphere is treated in any way. Therefore, it would be more appropriate to name this principle "flush-and-forget".

An alternative to the above principles is to "sanitise-and-reuse" the human excreta. This principle builds on recirculation of nutrients rather than water. Urine and composted faecal matter are returned to the land. It is viewed as a sustainable, environmentally-friendly principle for the reuse of nutrients after these have passed through the human body. This principle has nothing in particular to do with either affluent or poor areas.

The professional ownership of the three principles varies; the drop-and-store is managed by the users and extension workers, while the flush-and-discharge/forget principle concerns water engineers and chemists, and the sanitise-and-reuse is the responsibility of ecologists, agriculturalists and users.

In this article we will look more closely into the potential and constraints with applications of this third principle of sanitise-and-reuse.

Freed from the urine blindness

The history of human excreta is one where urine and faeces seldom have been kept separated, neither practically nor mentally. The idea of sanitised reuse of nutrients is simple but has

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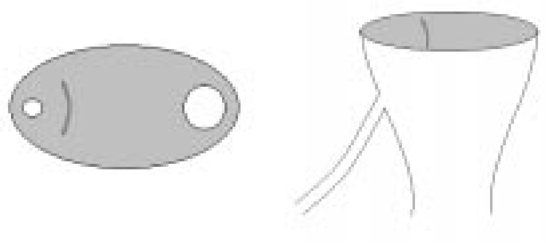


Figure 2
The principle of the no-mix toilet

been obscured by the "success" of sewerage systems. Professionals like engineers and chemists have tended to use advanced technology to prevent an unhealthy situation in towns within the framework of the sewerage system. When, for example, the water chemist sets out to solve problems of heavy metals in the sludge, he or she is likely to look for a chemical solution, rather than a nutrient-oriented approach. Therefore, involving more professional groups in water and sanitation problems will provide more options.

The urine blindness also applies to the ordinary users. Excreta is not the most common topic for discussion, or for research for that matter. This urine blindness has delayed innovative improvements and left a number of "dry" options undeveloped.

By mixing urine and faeces we create a compound which smells and is less tempting to reuse in any way. If, however, urine and faeces are kept separated, as supplied by the body, the smell from faeces is negligible. The reason is that the smell is caused by bacteria in the faeces which release ammonia from the urea. The smell from urine itself is much less pronounced.

It is not until recently that trials have been conducted which keep faeces and urine separated, sometimes called urine diversion. This is easily done in a closet with two bowls as shown in Fig. 2; one in front for urine and one at the rear for faeces. The urine bowl is connected to a pipe and the faeces and cleansing material drop into a container.

The urine diversion system not only allows a range of sophistication as shown in Fig. 3, but it also provides for step-wise upgrading. The selected combination among all these alternatives is guided by ecological and affordability considerations among the users. Firstly, one or both bowls may be connected to flush water. The urine pipe may lead to the soil/garbage heap where the urine partly evaporates, or enter a shallow infiltration pit, or lead to a storage tank, from there to be reused as a fertiliser. The faecal material may be flushed or not, and can then be dehydrated and composted before it is incinerated or burnt or used as a soil conditioner. The bowl for the faeces may even be connected to a sewerage system if available.

Variations of the principle of sanitise-and-reuse are extensively used in China, Central America and Sweden. Some examples of no-mix toilets are shown in Fig. 3.

There are a number of reasons why the no-mix principle is gaining ground. It will:

- use less or no water for flushing
- be more affordable than sewerage systems
- allow households to manage it and thus put less pressure on municipal resources
- release less (or no) smell than drop-and-store alternatives
- dispose of the bulky urine *in situ* and a small volume of faecal compost remains
- make accessible urine which contains most of the nutrients in the excreta
- turn waste into a useful resource i.e. fertiliser
- simplify the treatment of the remaining waste water at the treatment plant.

There are many aspects pertaining to dry systems which must be looked into, like hygiene and efficiency of sanitising procedures and people's acceptance.

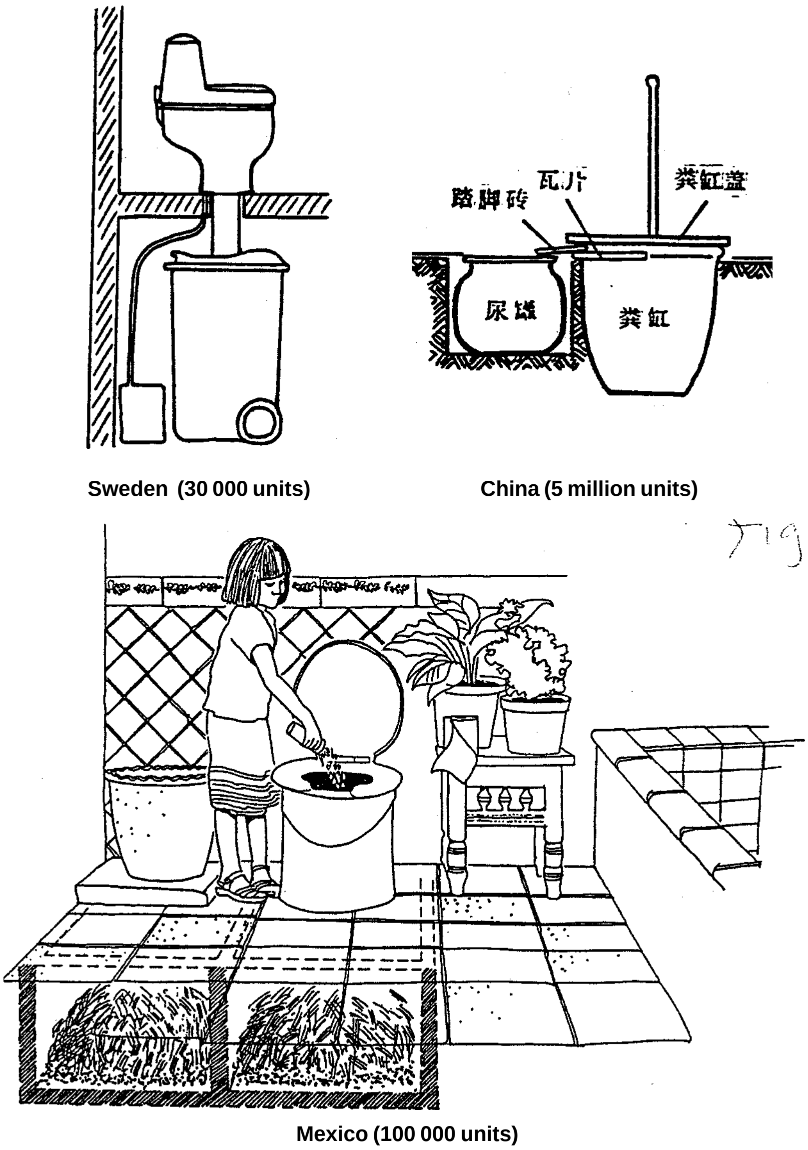


Figure 3
No-mix toilet units being used in various countries

Sanitising urine and faeces

Most pathogenic micro-organisms are found in the feaces. Fortunately, their survival times are not very long in composts since the high temperature (50 to 70°C) and low moisture rate are detrimental to survival. In China the compost is kept for some 20 d in the summer and 60 d in the winter before it is applied to the field. To be on the safe side it is often recommended to keep the compost for six months to ascertain that pathogens and ova are killed.

The urine contains few pathogenic micro-organisms but may contain *Ascaris* ova and *Schistosoma* eggs. If the excretor has used antibiotics there may be end-products in the urine which may be harmful to the micro-organisms in the soil. Experiences from China and Japan indicate that urine may be used as a fertiliser straightaway if the above three components are not present in the urine. Household members usually know whether this is the case or not.

However, faecal material may accidentally enter the urine bowl and mix with the urine. Therefore, a good practice is to store also the urine for six months before applying it on the home garden. By that time pathogens have perished due to high pH (around 9), lack of food, being consumed, or natural death. Some ova may persist, and according to a study (Wang Junqi et al., 1997) about 95% die off within two months. It is then advisable not to put the urine fertiliser onto the part of vegetables that is to be eaten.

People's perceptions of urine and faeces

Attitudes and perceptions about health hazards and revulsion to faeces and urine vary between cultures and often people's ideas about urine differ from those about faeces. Tanner (1995) writes that every social group has a social policy for excreting; some codes of conduct which will vary with age, marital status, gender, education, class, religion, locality, employment and physical capacity. The human dimension was found by Cross (1985) to be a severely neglected concern in environmental health and yet one that is of central importance to a full understanding of the potential reuse of nutrients in human waste. For example, a process of social conditioning is involved in the identification of those smells which may be categorised as offensive in particular cultures. However, as noted by Loudon (1977), it is a matter of common observation that among individuals accustomed to the smells of putrefaction, such as those involved in specialised occupations, conditioning modifies or suppresses a response which may well have a biochemical basis, even though reinforced by socio-psychological factors.

People's perceptions of urine have hardly been studied. Hansen (1928) reported that urine was stored and used as a detergent for washing clothes and dyeing in the Danish countryside in the 19th century. A century earlier, European artisans collected urine and canine excrement for industrial purposes (Reid, 1991). Urine is considered as a spiritual pollutant by Koranic edict, and demands that Muslims minimise contact with human excreta (Hanafi, 1985). In Sweden urine has been used to smear wounds, and to some extent to drink as therapy (Frode-Kristensen, 1966). Oral information confirms the same uses in South Africa. Recently urine has been shown to have a disinfective property.

Faeces are perceived quite differently, and they are regarded as offensive and unpleasant to handle (Fortes, 1945 on the Tallensi; Malinowski, 1929 on the Trobriand; Hamlin, 1990 on the British; Reid, 1991 on the French). An exception seems to be people's perception of cleansing a child's bottom, which fits Loudon's comment above on conditioning. Furthermore, one may find differences in male and female perceptions due to varying exposure to adult excreta when caring for elderly and incapacitated persons.

Professionals and (lay)men foster strong opinions that adult faeces are hazardous to health because the stool may contain a variety of pathogens, like *Giardia* and *Entamoeba* parasites, *Shigella* and *Campylobacter* bacteria and Rota virus. More generally, Douglas (1978) argues that it is difficult to think of dirt except in the context of pathogenicity within contemporary European ideas, and that makes it, according to her, more important to understand dirt-avoidance before the perception was transformed by bacteriology.

Faeces may carry definite cultural meaning, for example that one's faeces can be a medium for revenge and therefore must not be seen by others, or that faeces of certain kin must not be mixed (Tanner and Wijsen, 1993). Such perceptions are difficult to maintain in crowded urban areas and they may gradually disappear, as expected by Loudon. A study in peri-urban Eldoret in Kenya indicates such a change. Only 10% of the informants thought it unsafe to throw children's faeces into the latrine due to reasons like e.g. child stool should not be mixed with those of adults, child stool has to be hidden due to the danger of a witch picking on the stool of a particular child, and faeces left on shallow latrines can be picked by people with ill will (Akongá, 1996).

Cow dung seems, from its practical usage, to be viewed as less offensive than human faeces. A century ago it became popular in rural Sweden to attach the latrine house (with no pit) to the stable so that human faeces and dung from the stall-fed animals were mixed to make them less revulsive when applied to the fields. Fortes reported a similar practice among Tallensi farmers to use a mixture of human faeces and animal manure as fertiliser. Another common way to get rid of faeces, also today, is to let pigs and dogs scavenge, i.e. eat the human faeces and produce their own faeces which are not regarded as equally revulsive.

Another way of approaching people's attitudes to excreta is how sewermen and excreta collectors are viewed. Read (1991) writes about the professional pride shown by Parisian sewermen. Another example from South Africa tells that the ethnic group Bhaca are eagerly saught after in the whole of the Republic as attendants at sewage treatment works (Mbambisa and Selkirk, 1990). A possibly contrasting example is given by Tanner (1995) who notes about the social position of lavatory cleaners that "In Hinduism it is done by out-casts but much the same status applies to cleaners in western societies." In ancient Rome the cleaning of the Cloaca Maxima was performed by prisoners of war (Hösel, 1987). We may infer from this information that the general perception of human waste was one of disgust. At the same time, however, the organisation of the disposal of human waste was highly regarded and led by one of the most prestigious officials in the Roman Empire.

Keeping in mind that all these examples from various periods and parts of the world exclusively deal with mixed excreta, my impression is that both professionals and laymen may still consider plain urine harmless and inoffensive. A reason for this may be the fact that urine is indistinguishable from water on the ground, and stepping into it is quite different from stepping into human faeces. To what extent would this relaxed view on urine make people prepared to use it for their own benefit?

Alternative dry systems in Sweden

An indirect way to acquire information about people's views on excreta is the fact that some hundred ”ecological villages” have been founded in Sweden by people interested in leading an environmentally friendly life. They have organised themselves and built or bought houses and installed a variety of devices for reuse and circulation of water and nutrients and for saving energy. Most villages are at a distance from towns but an increasing number of projects take shape in urban settings. The residents often have a middle-class background with good education and ability to get bank loans for their projects just like when building conventional houses.

At present, also municipal councils and some of the major contractors are sensing that the future may hold in store more of ecological approaches and therefore they invest in test houses. All these developments show clearly that assumed norms and attitudes of urine and faeces may change rather quickly if viable alternatives appear.

Dry systems have been on the market since the early 1970s. Initially, these systems were for use in summer cottages rather than in apartments. More than 50 000 units have been sold so far. Agenda 21 resolutions in 1992 has promoted serious activities in Sweden concerning alternative options for disposal of excreta. An earlier interest among ecologically-minded people has now broadened into a public concern, also among authorities. The Swedish Environmental Protection Authority (SEPA) has approved a number of disposal systems and the regulation makes the users responsible for the maintenance.

In a market overview done by the Swedish Consumer Protection Board, 42 different ”dry” systems involving 22 manufacturers are presented. Most of them are small companies, but recently two of the well-established white-ware manufacturers offer no-mixing toilets i.e. those which keep faeces and urine separated. 21 systems keep faeces and urine separated, another five have this as optional and four systems first mix and then separate faeces and urine. Twelve systems mix excreta and compost it or have it removed in buckets/plastic bags.

The majority of the units for permanent buildings are made of porcelain with two bowls, while most units for summer houses are made of plastic. Only one of the marketed toilets has a lid, which covers the faeces when the chair is unoccupied.

The cost of the units excluding installation runs between 120 to 4 000 US$ (1997), and for instance the cost of a porcelain pedestal is only slightly more expensive than a conventional one. From the user's point of view, the household saves the fee for connecting to a communal water and sewerage system which runs at 6 000 to 12 000 US$.

Commercial presentation of dry systems

All 22 manufacturers argue in their promotion material in favour of protecting the environment, mainly by saving water and/or lessen the discharge to rivers and lakes. Most manufacturers emphasise reuse/recirculation of the nutrients in faeces, while few mention the possibility to use urine in the garden. The advertisements in the press claim that the units are easy to install, are hygienic and free from odour, and use no chemicals.

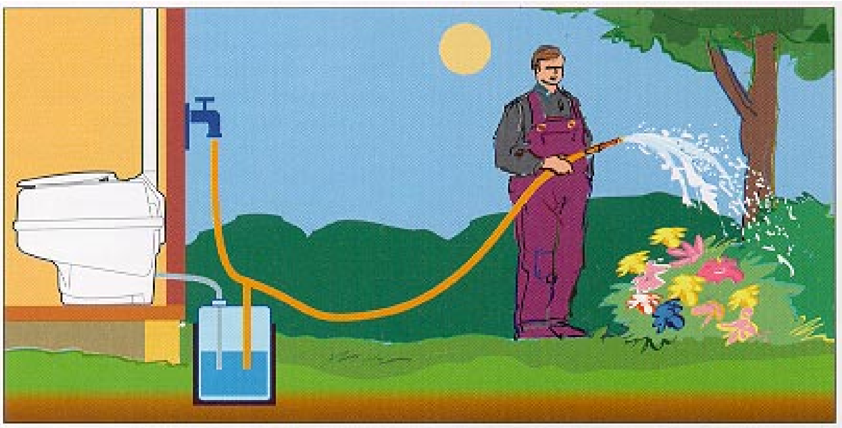
The modern composting latrine is described in rather idyllic terms, as opposed to the smelly bucket latrine of the past. One advertisement puts it as follows:

> ”Forget everything that reminds you of stinking dry (bucket) toilets and malfunctioning compost toilets. The Septum ecotoilet combines the simpleness of the dry toilet with the convenience of the flush toilet, however, with no need for electricity or water.”

Rarely is the word faeces mentioned in the information material, but instead the end-product compost is being used. It seems that information about drying the faeces is an acceptable way of conveying a message to the potential consumers. This may be due to the fact that not only are Swedes late urban dwellers (flush toilets were introduced on a large scale around the First World War and many of the flats in Stockholm still had dry toilets on the ground outside the building at the end of the Second World War) but also a sizeable proportion of the families have summer cottages with a compost latrine or a bucket latrine which is emptied by the family and collected by communal staff.

The manufacturers have switched over from approaching only ecologically-minded customers to reaching the general public. Currently, there is an interesting change of emphasis from composting of faeces to using the collected urine. Some company leaflets have changed their texts only this year. One company now offers a urine tank which is airtight so that the ammonium is not released. Also the urine tank is connected to the plastic pipe to water the garden so that the underpressure sucks the tank and mixes the urine and the water in the pipe (see sketch below).

If the advertisements and leaflets indicate how consumers are assumed to perceive urine and faeces, we may conlude that it is possible to communicate the message that faeces can be composted (together with other biological waste from the household) and used safely in the garden. Yet the use of urine is mentioned rarely, not because of cultural resistance, but because it was not an option until very recently.



Sketch of diversion of urine from the toilet to watering the lawn

Experiences and perceptions among some Swedish users of dry systems

There are a number of studies of users' experiences from several experiments. For example, Schmidtbauer (1996) interviewed 14 farmers, 5 property managers and 28 households in Ale in southern Sweden. The farmers expressed positive attitudes to use human urine on their fields, tenants believed in recirculation of nutrients, while the property managers preferred to wait for initiatives from tenants.

The Eco-house in Norrköping town is a three-storey house with 18 flats, built in the 1960s and converted into an eco-house last year. The aim of the conversion was to reduce energy consumption and to handle waste water and garbage locally. Potable water is still taken from the municipal system. The new toilets are water-driven and urine and faeces are kept separate. The urine is flushed with 0.2 ℓ of water and drains into a urine tank. After some six month storage to allow antibiotics to disintegrate, the content is collected and used by a farmer. Faeces are flushed with 4 ℓ of water to a separator in the basement which separates the liquid. The dehydrated faeces are composted together with household garbage for some eight months before it is used as soil conditioner in the residents' small gardens near the house. The separated flush water is radiated with UV light to kill the germs and led, together with bath, dish and laundry water to a three-chamber tank for sludge separation. This treated water is then spread out in a root-filtering system in an ecology park situated in a beautifully formed marsh close to the house. Also the rainwater is taken care of locally.

Botta et al. (1997) made an initial study of this eco-house which included residents' perceptions. They found, among other things that the no-mixing chairs were appreciated by both women and men (men need to sit when urinating). The firm responsible for the treatment plant had to solve numerous operational problems. The residents accepted the inconveniences of smell from the initially malfunctioning composting system, since they were well-informed about the pilot character of the new system.

A critical evaluation of the eco-village of Toarp in southern Sweden was reported by Fittschen and Niemczynowicz (1997). The village was established in 1992 comprising 37 houses with water from a well, dry sanitation, and a common treatment facility for the grey water. Three different kinds of composting (mixing) toilets were installed. All three had some kind of shortcomings, and one brand of toilet received many complaints about flies, smell inside, wet composting material, and difficulty to clean the chair. Reasons for the bad results were, among other things, that the composting process was not supplied with sufficient oxygen, and the residents were not informed about how much carbon-rich material was needed in order to improve the C:N ratio. 11 out of 12 respondents were ”very” or ”quite” satisfied with the Norwegian system with four rotating chambers, while 11 out of 16 Ekoloo users were ”quite” or ”very” dissatisfied. In 1995 the housing corporation let the households decide if they wanted to switch to flush toilets. All but four households did so.

User experiences of no-mixing toilets are generally positive, while some of the mixing toilets face dissatisfaction. The compost material is often being used as fertiliser in the home garden. Reuse of urine is less developed and several projects rely on farmers who collect the urine and spread it on their farms.

The quantity of excreta and its content disclosing a “urine blindness”

A person excretes less than 500 ℓ of urine and 50 to 180 kg (wet weight) of faeces in a year depending on water and food intake, while a dairy cow produces between 30 to 40 ℓ of urine per day and several kilograms of dung per day (Polprasert, 1995).

Human faeces contain a large proportion of water (70 to 85%), and the rest is mainly organic material including micro-organisms. One gram of faeces may contain, for example, about 100 million bacteria some of which are pathogenic.

Urine contains mostly water, 93 to 96%, and dry solids of some 50 to 70 g per person per day (Polprasert, 1995). The urea derives from ammonium and carbon dioxide (NH_3 and CO_2) and easily dissolves in water and becomes accessible to plants. Unfortunately bacteria present in the faeces (*Micrococcus urea*) can, through an enzyme, decompose the urea into ammonia gas, which dissipates into the atmosphere. However, the smell of ammonium can be reduced by keeping faeces and urine apart.

It has been shown that the nutrient content of human waste collected in a year is approximately equal to what has been eaten during the year. If a person eats some 250 kg of cereals, his excreta contain the amount of various nutrients required for the corresponding cereal or biomass production. Table 1 gives details of three important nutrients in human (Swedish) excreta and the amounts of nutrients required for cereal production.

The figures for phosphorus and potassium in urine are higher than in other studies reported by Cross (1985). The nitrogen content in urine (but not faeces) seems to vary with the intake of protein (Jacks, 1997). The figure of 4 kg is for a Swede eating 70 to 80 g of protein per day, and it exceeds nitrate values for

TABLE 1
NEED FOR FERTILISERS (NITROGEN, POTASSIUM AND PHOSPHORUS) TO PRODUCE 250 KG OF CEREALS AND THE CONTENT IN (SWEDISH) FAECES AND URINE

Important nutrients	Urine 500 ℓ/yr	Faeces 50 ℓ/yr	Total	Nutrient need for 250 kg cereals
Nitrogen (N)	4.0 kg, 88%	0.5 kg, 12%	4.5 kg, 100%	5.6 kg
Phosphorus (P)	0.4 kg, 67%	0.2 kg, 33%	0.6 kg, 100%	0.7 kg
Potassium (K)	0.9 kg, 71%	0.3 kg, 29%	1.2 kg, 100%	1.2 kg
Total amount of N+P+K	5.3 kg	1.0 kg	6.3 kg	7.5 kg

Sources: SEPA, 1995 and Wolgast, 1993

Nigerians two to three times as reported in studies by Egun and Atinmo (1993) and Atinmo et al. (1988), where protein intakes were some 45 g/d and 25 g/d respectively. Irrespective of differences in exact figures it is clear that human urine provides the bulk of nutrients, contrary to what is generally believed. This may partly explain why there is a *urine blindness* when it comes to using excreta in plant production.

The fact that urine mixed with water is a good fertiliser and that a person urinates almost half a cubic metre annually, gives a reason to look at human excreta from a new perspective. Instead of exclusively regarding excreta as a health hazard and community problem (which it evidently is) we can view at least urine as a resource for agricultural production.

Capacity of vegetation to utilise urine and faeces

UNDP (1996) has recently estimated that some 15% of food production in the world comes from urban agriculture (farming, horticulture, animal husbandry, fish ponds, etc.). Cities like Lusaka and Dar es Salaam reach figures as high as 50%. Given that half of the world's population will soon live in urban areas, it is to be expected that recirculation of nutrients in urban areas will feature high in the near future.

The land area needed to produce people's average annual intake of, say, 250 kg of cereals would be 2 500 m^2 since the average global output is about 1 t/ha·yr. It varies substantially between different agricultural zones, however, and whether irrigation or dryland farming is contemplated; from less than 500 m^2 in irrigation agriculture to perhaps as much as 5 000 m^2 in dryland farming on marginal land.

It is assumed that many rural people have had more or less explicit ideas about how much excreta the vegetation can consume. In general terms one may state that if half of the food consumed in Lusaka is produced within the city boundary, a first approximation would be that half of the accumulated excreta could become input into the urban agriculture. An early, closer scientific look was taken by Pettenkofer's disciple Max Rubner. He estimated that excreta from 80 persons could be used to fertilise a hectare (Schadewaldt 1983). In other words, one person could fertilise some 125 m^2. FAO has reported application rates of nightsoil in China of 20 to 30 t/ha, which corresponds to disposing of the annual human waste from one adult on 250 to 300 m^2 if only one crop per year is anticipated. As expected, these figures differ partly because they represent different geographical areas, different diets of the population and varying intensity of plant production. It reminds us of the importance that local data are needed on e.g. agriculture, efficiency and nutrient intake in order to find out what area can be fertilised with a person's accumulated excreta. Moreover, losses of ammonia (nitrogen) to the atmosphere have to be considered. Such losses may be considerable from faeces. The loss from urine was very low, however, if it was immediately mixed into the soil by harrowing (Jönsson, 1997).

Vegetation on some 100 m^2 may be enough to consume the nutrients from the urine nutrients of one person if intensive horticulture is practised with, say, three crops per year. We may formulate the above information in an equation which reads:

The urine equation

An (1) adult eats 250 kg of cereals per year, which has been grown on less than 250 m^2 and fertilised to perhaps 50% by the person's urine mixed with her used waste water.
Drangert, 1996

Daily household water use varies and peri-urban residents with no piped water may use as little as 10 to 20 ℓ. The resulting quantity of waste water can be mixed with the excreted 1.5 ℓ of urine in order to make a perfect fertiliser. Some 20 ℓ of fluid can be disposed of daily on a few square metres and easily infiltrated into the soil. Waste water infiltration rates into soils of different types have been estimated and found to vary considerably; from as much as 50 ℓ/m^2·d in gravel, coarse and medium sand to 8 ℓ/m^2·d in silty clay loam and clay loom (Franceys et al., 1992). Too much waste water may, however, pollute the groundwater with nitrogen and phosphorus (Lagerstedt et al., 1994). The authors recommend for instance, planting of deep-rooted trees close to latrine pits as counter-measures. The Swedish Environment Protection Agency estimates that waste water from households requires an infiltration area of 5 to 20 m^2 per person (with a daily use of some 200 ℓ of water) while a conventional treatment plant requires only 0.1 m^2 per person (SEPA, 1992).

Available space and use of urine in urban agriculture

It is obvious that open space available in densely populated urban areas does not allow *in situ* recirculation of all nutrients in human excreta, even if all open space were allotted to agriculture. A balance has to be achieved between utilising excreta in the neighbourhood and transporting it to distant sites through sewers or on trucks and bicycles.

China has a long record of farmers collecting mixed excreta and applying it onto their farms. Japan imported this tradition in the 12th century, and farmers bought urine and faeces from towndwellers. When cheap chemical fertilisers became available the Japanese farmers switched over to them and the town councils had to solve the arising sanitation problem partly with sewers (Matsui, 1997). Up to this day 50% of the excreta in Japan is collected by the municipality and returned to agricultural land.

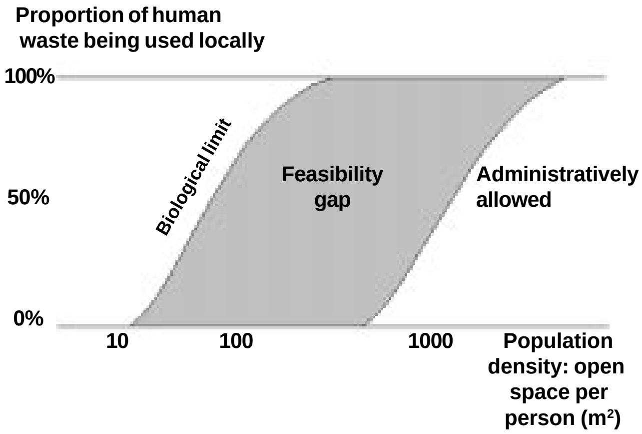
Poor settlements on urban fringes may look very different depending on the age of the settlement, economic and cultural conflict patterns, etc. Settlement patterns around every single city also vary a lot. Keeping such differences in mind, we can still try to discuss recirculation of nutrients in urban agriculture. Any recommendations on how to dispose excreta must, however, be sensitive to people's perceptions and local physical conditions. Residents' skills and knowledge of urban agriculture are important - in addition to their perceptions of use of human excreta.

The relationship between outdoor space and plant uptake of nutrients is summarised in Table 2. There is a biological limit to what is possible to achieve. Another limit is set by what activities are administratively allowed. In-between these limits there is a "feasibility gap" that is being explored.

If the population density is low, say, each person having on average more than 500 m^2 of open space like in peri-urban Trivandrum in India, household members may take care of the spread of urine and faeces in the garden and fields close by. They may urinate directly on the fields or collect urine in a bucket or container in the latrine house, mix it with waste water and spread it on the farm in the evening to reduce losses of ammonia. Faeces may be dropped in a shallow latrine or in a cat-hole and covered with soil. A fairly intensive use of excreta in agriculture would recirculate most nutrients in such areas of living.

This way of dealing with excreta is an individual affair which is similar to what is being practised in rural areas. Such a decentralised system does not require much effort by the authorities or the local power structure. Healthwise it is a rather safe

TABLE 2
PROPORTION OF HUMAN WASTE TO BE RECIRCULATED AND USED IN URBAN AGRICULTURE IN RELATION TO POPULATION DENSITY (LOG SCALE)



method, except for hookworms which can survive in the soil for several months (a protective measure is to wear shoes).

The other extreme, when a person has less than, say, 20 m^2 of open space like in parts of Khayelitsa in Cape Town, there is little room for urban agriculture. However, various NGOs try to promote horticulture in the peri-urban areas. Health precaution requires strict care in handling of the faeces, if they are not dried or incinerated or buried in a pit. The large volume of waste water-urine mix will almost serve as irrigation water and requires an intensive horticultural activity to consume the nutrients. In the town of Cuernavaca in Mexico, households with no-mix toilets in crowded areas place buckets and tyres filled with soil and compost on their roofs and water the vegetables with the urine mix (Clark, 1997). Only a keen and skilful horticulturist is expected to manage such a task. Alternatively, removal of excreta from the area, on the other hand, would require a well-organised collection and transport system.

Interesting combinations of recirculation locally may be found in the "feasibility gap", in the spectrum of about 20 to 500 m^2 of open space per person. Small home gardens would be able to absorb the prepared urine. Excess urine may soak into the ground without medium-term harm to the groundwater. In compounds where cows are kept there may, however, occur raised levels of nitrate and phosphorus in the groundwater. A raised nitrate level will affect the water quality in nearby wells for a long period of time. If the available space is above, say 200 to 300 m^2, a more casual way of agriculture would be to utilise all nutrients in urine.

The odour-free faeces can be disposed of in any preferred way. In areas with deep groundwater levels, pit latrines may be convenient, while areas with shallow groundwater levels should aspire for other solutions. Dry-box inclusion, incineration and physical removal of the faeces are some of the alternatives.

Women usually take care of the cleaning of the toilets and latrines in the home, they handle most of the grey water, they often do the gardening, and are responsible for feeding the family. Therefore, the potential use of urine mixed with grey water in watering and fertilising the garden - be it a lawn, trees or a vegetable garden - does not require a change of responsibilities between men and women in the household.

The question of putting more pressure on overloaded women should be addressed since it may become an obstacle for this application of human-derived nutrients into food production. Only the individual woman will in the end decide whether it is a worthwhile effort. However, women who are already involved in gardening may find it easier to use grey water and urine than fetching water from a well to watering their garden.

Summary

There are at least three reasons to overcome our *urine blindness* and to use urine; urine is bulkier than faeces and more expensive to transport, urine contains more nutrients than faeces, and people have a more relaxed view on urine than on faeces. If peri-urban residents are interested, they can easily use urine in plant/food production and increase their food intake, thus reducing malnutrition. The remaining dry faeces may easily be disposed of in any culturally accepted and hygienic way.

Limited capacity of town councils causes large numbers of peri-urban dwellers to lack piped water and/or water-borne sewerage, and they are left to explore their own solutions. The low cultural revulsion from urine may increase people's willingness to keep urine and faeces separated, and use both dried faeces and urine nutrients in urban agriculture. Poor peri-urban dwellers may appreciate the possibility to use the urine in intensive gardening and earn part of their living from it (in the way some wealthy people do, and as was done in war-time Europe). This is probably more tempting than following the advice to improve health by building a latrine and using it regularly.

By introducing the common measure of "per square metre" we have been able to establish crude relationships like the urine equation between the soil capacity to absorb urine, plant production and plant requirement of nutrients, land area required for a person's food intake, amount of nutrients in human excreta, and the density of population in peri-urban areas. The conclusion is that the environmental capacity to use urine in urban agriculture varies with the population density, but appears to be enough in most circumstances. However, in very densely populated areas with, say, 10 m^2 of open space per person, it would require strong efforts by skilful and keen horticulturists.

Well-intended interventions may fail due to neglect of individual values or societal norms, or they may succeed thanks to other, seemingly unrelated values which were not contemplated by the intervention. The discussion in this paper presents a plural view on the reuse of nutrients in excreta while paying attention to perceptions and possibilities. There is not a single best solution, but there is a need to softening the resistance to alternative excreta disposal as evidenced by many local regulations.

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