Chapter 2

Important aspects of ecological sanitation

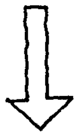
2.1. ECOLOGICAL SANITATION - A GLOBAL OVERVIEW

Uno Winblad, Architect/Planner, WKAB, Pataholm 5503, S-384 92 ÅLEM, Sweden (uno.win@wkab.se)

Introduction

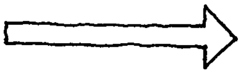
There are basically three ways in which we can manage human excreta at the household level: 'drop-&-store', 'flush-&-discharge', and 'sanitize-&-reuse'.

Drop-&-store is based on safe storage of the material containing pathogenic organisms. The device in this system is a pit toilet.



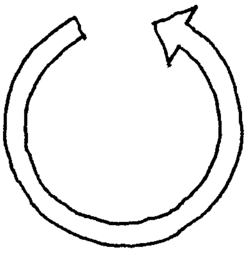
The system is simple, easy to understand and to use, and accepts any kind of anal cleansing material. But it cannot be used everywhere: it is unsuitable where we cannot dig a deep pit (because of rocky soil, soft sand, high groundwater table or lack of space) and in areas where there is periodic flooding. The pit toilet is malodorous, breeds flies, and may harbour mosquitoes. Valuable nutrients are lost and the groundwater may be contaminated. Basically it is a bottom-of-the-garden system, unsuitable for in-house application, high-standard housing and crowded conditions.

Flush-&-discharge is based on dilution and removal of the human excreta. The device is a WC connected to a sewage system.



Those who can afford it and have access to water for flushing often regard flush-and-discharge as the ideal system. It can be installed indoors, on any floor and at any population density. It has a high status, is generally regarded as the ideal solution and is promoted in cities and towns around the world, even in poor countries where people cannot afford it and in arid areas where there is hardly enough water for drinking. (The drawbacks of flush-&-discharge systems are outlined on pp 3-5 of the paper 'Towards an ecological approach to sanitation' distributed to the workshop participants.)

Sanitize-&-reuse systems are based on accelerated pathogen destruction through dehydration and/or composting. The device is either a dehydrating toilet or a composting toilet.



We may also call sanitize-&-reuse systems 'ecological sanitation' because they are based on fundamental ecological principles: zero pollution, water conservation and recycling. Ecological sanitation systems are relatively unknown outside East Asia and many attempts to introduce them in other parts of the world have failed because of lack of knowledge of the principles involved and the design and management options available.

Global overview

The purpose of this talk is to present a number of ecological sanitation systems in use around the world. I have divided these into two categories, dehydration and decomposition, and into two subgroups, urine diversion and no urine diversion.

Dehydration means that the humidity of the contents of the vault is brought down to below 20%. For effective decomposition humidity must be kept above 60%. In a dehydrating system pathogens are destroyed by depriving them of water and by increasing the pH above tolerable levels. Users help the process by adding dry materials and lime (or ash) as part of routine management. The humidity interval of 20-60% should be avoided, because it results in incomplete dehydration, slow and malodorous decomposition and fly breeding. Instead, it provides the perfect conditions for reproducing harmful organisms that produce unpleasant odours.

Dehydration vs decomposition

20%<----------------------------	----------------------------	---------------------------->60%
(dehydration)	(microorganisms and odours flourish)	(decomposition)

Examples of ecological sanitation systems:

	Urine diversion	*No urine diversion*
Dehydration	long-drop (Yemen) 'WM Ekologen' (Sweden) twin chamber (Vietnam) twin chamber (Mexico) solar heated (El Salvador)	earth toilet, Ladakh (India)
Composting	no-cost toilet (China) solar heated (Mexico) multi-unit (Sweden)	'Clivus Multrum' (Sweden) solar heated (Ecuador) CCD (South Pacific)

Conclusions

Within the overall concept of ecological sanitation there is a range of options: for rich as well as poor communities, for urban as well as rural locations, for humid as well as dry climates and for a variety of cultures.

There is ample proof that the concept of sanitize-and-reuse does work, and that ecological sanitation systems, when properly managed, do function very well.

The three main prerequisites for the successful introduction and adoption of ecological sanitation are:

- those who plan, design, build and operate fully understand the basic principles involved;
- the system must be adapted to local conditions;
- the users must be fully involved in implementation and operation.

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2.2

ECOLOGICAL SANITATION IN SWEDEN - EVALUATION

Per-Arne Malmqvist, Assoc. Professor, SWECO and VBB Viak, Box 2203, S-403 14 Göteborg, Sweden (pmt@vbb.se) and Luleå University of Technology, Division of Sanitary Engineering, S-97187 Luleå, Sweden

Background

In Sweden a number of 'eco-villages' were constructed during the 1990s using urine-separating wastewater systems. Recently some larger domestic houses have also been equipped with urine-separating toilets. The reasons for the interest in separating systems are mainly that:

- farmers or the agricultural industry do not accept sewage sludge on their farmland owing to the (verified or suspected) content of heavy metals and harmful organic substances;
- the sludge from the treatment plants utilises the contents of nitrogen and potassium to only a minor degree, even if the sludge is used for fertilising.

Reactions from municipal water and wastewater works have mostly been negative, and a considerable number of arguments have been raised against urine separation. A common attitude is that the system may work and be useful in sparsely built-up areas, but it is not suitable for the densely populated city.

Thus, the evaluations referred to below emphasize the densely populated city, where the problems and the potential are anticipated to be much greater.

Evaluation

Among the quantitative evaluation methods dealt with in this paper are:

- *Pragmatic methods such as 'analysis of direction' and others.* In several studies of alternative wastewater systems in Sweden during the last few years simple models have been used. These have in common that alternative systems are compared with each other, and with a set of criteria developed at the start of the analysis. Often these have been divided into main criteria (health requirements, flows of phosphorus and nitrogen, use and recovery of energy, discharges to receiving waters, investment and annual costs) and secondary criteria (various).
- *Life cycle assessment.* Life cycle assessment (LCA) is a method for analysis and assessment of the environmental impact of a material, product or services throughout its entire life cycle. A life cycle includes raw material extraction, processing, transportation, manufacturing, distribution, use, reuse, maintenance, recycling and waste treatment. LCAs are often comparative studies, e.g. comparisons of different products performing the same function, different process alternatives or different waste handling alternatives.
- *Environmental impact assessment (EIA)* EIA aims to serve as a decision support on different levels. The two most common applications are proposed projects (e.g. construction or changes in wastewater systems) and municipal planning. There is also a close connection between EIA and legislation.

Other evaluation methods, such as mass balances, ORWARE, exergy analysis and others, will not be dealt with here.

All quantitative evaluation methods have considerable elements of subjective values integrated in the method. Also, the limits of the systems studied are crucial to the results of the study. If only the municipal wastewater system is studied, one result may be obtained, but a totally different result may be obtained if an enlarged system is studied, including the provision of drinking water and food. Further, the limits for the associated energy system studied are very important.

Case study: the Eco-Guide project

The aim of the Eco-Guide project has been to develop and apply planning and evaluation tools for wastewater systems. In the project two different urban areas were studied: Bergsjön, a suburb of 13,000 inhabitants in Göteborg, and Hamburgsund, a small coastal village of 1100 inhabitants. In each area three different wastewater systems were studied: the existing system with conventional piping and treatment, a local alternative with sand filter beds and wetlands, and a system where wastewater is separated into urine, faeces and grey water. The different wastewater systems have been compared and evaluated using different approaches: analysis of direction, environmental impact assessment and life cycle assessment. Conclusions were drawn concerning the environmental effects of the chosen system and the application of different evaluation methods.

Concerning the environmental effects the separating wastewater system turned out to be the best choice both in Bergsjön and in Hamburgsund. Discharges of nutrients and polluting substances to air, water and land were minimised and the nutrients were recycled. From an energy point of view the existing system in Bergsjön was favourable owing to the recovery of heat and the production of biogas. In Hamburgsund there were no economical or technical prerequisites for energy recovery. The investment costs per capita were lower in the existing system in Bergsjön than in the alternative systems. The costs of operation were, on the contrary, lower in the alternative systems. In Hamburgsund the costs for both investment and operation were lowest in the local wastewater alternative.

The results are to a great extent dependent on the choice of area to be studied and the chosen technical solutions. However, some general conclusions were drawn.

* Importance of the scale. Large wastewater systems (like Bergsjön) use less energy per capita than small systems (like Hamburgsund). Investment and operation costs are also lower in a large-scale system.

* Importance of use of energy. Recovery of energy is an important factor for environmental considerations. Heat pumps, for example, use the large amounts of heat in wastewater. Energy consumption during the operational phase is larger than that for the manufacturing of components in the wastewater system (investment phase). The energy use for investments is, however, not negligible when studying systems with many components.

Within the project three evaluation methods have been compared. An LCA is applicable especially when studying energy use and environmental impact on a global level. An EIA is useful when describing environmental impact on a local level. The results from the simplified analysis of direction produced similar results to the more comprehensive evaluation methods.

Case study: Hammarby Sjöstad

Hammarby Sea Town is now being planned as a living area for about 15,000 people. The environmental requirements have been set at a high level. The environmental goal for the area is to be 'twice as good' as the ambitious environmental plan for Stockholm in general. In order to achieve this goal, alternative systems have been studied for the handling of wastewater and the solid waste from households.

The selected wastewater systems have been evaluated using one set of main criteria and one set of supplementary criteria. The main criteria used were:

- Hygiene
- Energy consumption during the operational phase
- Investment and operations cost
- Discharges and utilisation of phosphorus
- Discharges and utilisation of nitrogen.

The criterion 'hygiene' is assessed as a restriction: none of the studied systems must create any hygienic risk to human beings.

The energy criterion has been assessed from an exergy point of view, that is, fossil fuels, electricity and heat have been studied separately. The energy consumption during the investment phase has been considered negligible compared to the operations phase.

Among the supplementary criteria were the following:

- Social aspects. How will the inhabitants accept and use different installations in the household? What impact will alternative, 'ecological' systems have on the behaviour of the inhabitants to make them more environmentally conscious?
- Organisation. Who will own and operate different parts of the system? What complications does a split responsibility create?
- Operation and robustness. What kind of operational difficulties may arise? Are the decentralised, alternative systems more or less robust than centralised, conventional ones?
- Discharge of harmful substances such as heavy metals and organic substances to water bodies and soil.
- Acceptance by farmers. Will separated wastewater fractions or composted household organic wastes be more or less accepted by farmers and their cooperative companies?

Further criteria may be raised, such as impact from traffic (noise and air pollution), the development of new products for use in Sweden or for export, etc.

In the study four scenarios were investigated:

Scenario 0 The wastewater is conveyed to the central treatment plant in a conventional manner. The effluent from the treatment plant passes large heat pumps, which extract heat for the district heating system. The sludge is digested, producing biogas. The organic waste from the households is brought to the central incineration plant, producing heat for the district heating system.

Scenario 1 Separating toilets are installed in the households. Faeces and grey water are transported to the central treatment plant. The urine is pumped to a storage tank on the outskirts of the area, for subsequent transport to farmland. Transport distances are assumed to be 30 or 100 km (two cases) The organic solid waste is treated locally by composting, one reactor in each block (about 300 persons), for subsequent transport to farmland.
Scenario 2 Separating toilets and household waste disposers are installed. Organic waste and faeces are pumped directly to the digester at the central treatment plant. The grey water is brought to the inlet of the treatment plant. Urine is dealt with as in Scenario 1.

Scenario 3 Separating toilets and a vacuum system for the organic solid waste are installed. Organic waste and faeces are brought to a local digester or an aerobic stabilisation tank. The grey water is treated in a local treatment plant. Urine is dealt with as in Scenario 1. All fractions, except sludge from the grey water treatment, are transported to farmland.

In summary, the scenarios have been assessed according to a ranking system, where 1 is the most favourable and 4 the least favourable.

Criteria	**Rank**			
	Scenario 0	*Scenario 1*	*Scenario 2*	*Scenario 3*
Main criteria:				
Hygiene	1	2	2	2
Energy consumption	1	2	3	4
Cost	1	2	3	4
Use of phosphorus	2	1	1	3
Use of nitrogen	3	2	2	1
Supplementary criteria				
Social aspects	3	1	2	2
Organisation	1	2	2	2
Operation & robustness	1	2	3	4
Discharges of harmful substances	1	1	1	1
Acceptance by farmers	3	2	2	1

The values in the table should be summarised in order to achieve a 'total best' system. The final decision on the choice of system is a matter of evaluation, and should be done by the inhabitants-to-be, by politicians and by other groups, besides the person who made the evaluation. Most but not all of the detailed environmental goals for Hammarby Sjöstad are reached in Scenarios 0, 1 and 2.

Conclusions

- Each wastewater system must be selected and designed on the basis of the local conditions. A solution that may be suitable in one place may not be so in another place.
- The choice of evaluation method may influence the result of the evaluation. However, more important is the selection of limits for the system studied.
- The final decision on the choice of wastewater system involves more players than the evaluator, and certainly comprises considerable elements of evaluation

2.3

ASSESSMENT OF SANITATION SYSTEMS AND REUSE OF URINE

Håkan Jönsson, Senior Lecturer, Department of Agricultural Engineering, Swedish University of Agricultural Sciences (hakan.jonsson@lt.slu.se)

Introduction

One of the most pressing issues during the next century is the development of sustainable systems for the handling and treatment of toilet wastes. The price paid for the present lack of such systems is high in terms of disease and death, effects on the environment and in wasted resources.

Currently, nearly 3,000 million people, i.e. approximately half of the world's population lack even the most basic sanitation (WHO, 1996). This is one of the main reasons that every year 1,500 million people are infected with intestinal worms, and that more than 3 million people die of diarrhoea (WHO, 1995).

The usual approach to the problem of lacking sanitation is the introduction of conventional flush-type sewage systems. Sewage contains large amounts of pathogens, organic substances and plant nutrients. Discharges of sewage cause major effects on many receiving waters: contamination by pathogens, floating impurities, primary oxygen depletion caused by large emissions of organic substances, and secondary oxygen depletion caused by the biological degradation of algae which has grown due to large emissions of phosphorus and/or nitrogen. These emissions can be drastically reduced, but not eliminated, by sophisticated and costly sewage treatment. Thus, the conventional sewage system can be described as a flush-and-discharge system. It uses large quantities of clean water (in many places a scarce resource) to dilute and transport small amounts of toilet wastes.

The reuse of plant nutrients (nitrogen, phosphorus, potassium etc.) in our human excreta is necessary for sustainable food production. These nutrients are provided by the soil to the plants which serve as our food. If they are removed from the soil without new nutrients being supplied, then the soil will eventually be depleted.

Humans produce urine and faeces, not sewage. The chemical, physical and hygienic characteristics of urine and faeces differ drastically and the two products need different types of treatment before they can be safely applied to arable land. Therefore, it is often easier to design a sustainable sanitation system if the urine and faeces are treated separately than if they are mixed.

Definition

This paper concerns separating systems. Urine and faeces leave the body separated. In source separating (urine separating) systems they are kept and handled separately. Such systems require source separating toilets.

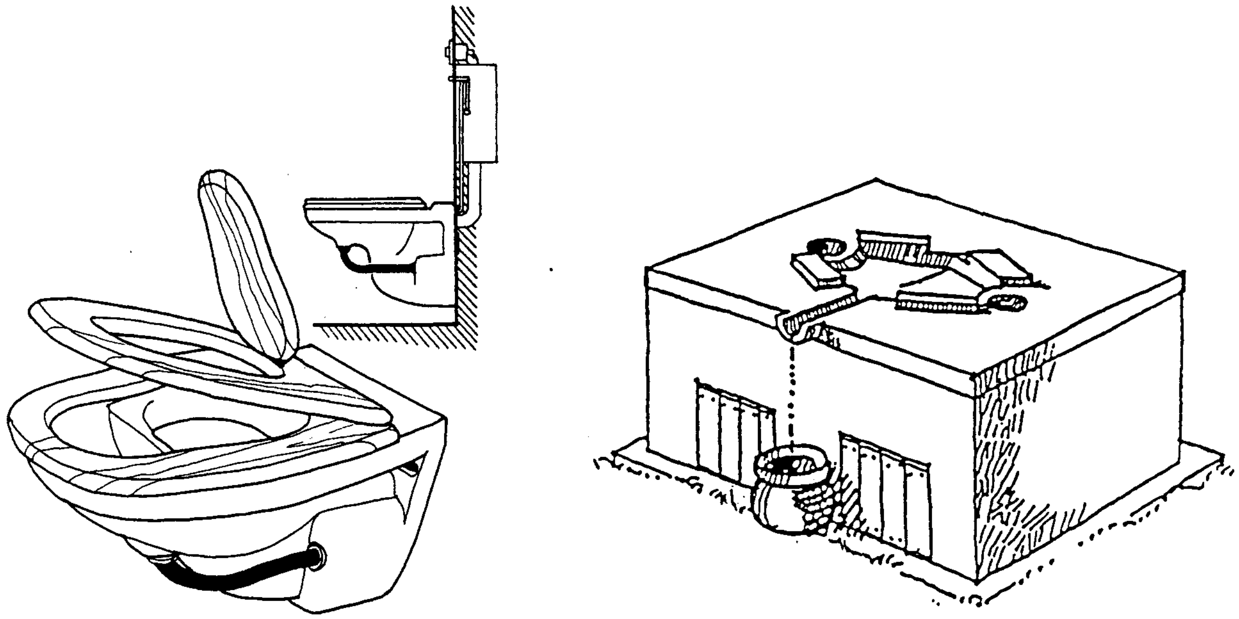

Fig. 1. A source-separating double-flush toilet is shown to the left. With this toilet both urine and faeces are flushed away with water, the urine requiring just a small amount of water (0.1-0.3 l/flush) and a storage tank, whereas the faeces are flushed away with the normal amount of water (in Sweden 4-8 l/flush). Usually the faeces are later mixed with grey water and treated in a sewage plant. An unflushed source separating toilet, a Vietnamese double vault dehydrating toilet, is shown to the right. The toilet is shown without superstructure. (From Winblad, 1997)

Urine and faeces

For most persons average weight gain is small during their lifetime. Therefore, we excrete essentially the same amount of plant nutrients as we eat. This depends on diet and thus differs between different persons as well as between different societies. The quantities given in this paper are based on the average Swedish diet and Swedish circumstances.

Table 1. Estimated Swedish averages for weight of and plant nutrient content in urine and faeces (SEPA, 1995a) as well as the distribution of these variables between urine and faeces

Parameter	Urine		Faeces		Total toilet waste	
	g/pers.day	%	g/pers.day	%	g/pers.day	%
Wet weight	900-1200	90	70-140	10	1000-1400	100
Dry substance	60[a]	63	35	37	95	100
Nitrogen	11.0	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

[a] A large proportion of this dry substance is rapidly biodegradable. Much of it already degrades in the sewage pipes.

Between 65 and 90% of the excreted nitrogen, phosphorus and potassium is estimated to be excreted in the urine (Table 1). Furthermore, the plant nutrients excreted in urine are found in chemical compounds which are easily accessible for plants. Initially 80-90% of the nitrogen is found as urea (Orten & Neuhaus, 1982; Geigy Scientific Tables, 1981). This rapidly degrades to ammonium and carbon dioxide (Eqn. 1). In a measurement on a source separated sewage system in Stockholm, Sweden, Jönsson et al. (1997) found that 97.5% of the urine nitrogen was already in the form of ammonia when the urine entered the collection tank after an average pipe transport of just one or two hundred metres. This shows that urea degrades very rapidly, not only in conventional but also in source separating systems.

$$CO(NH_2)_2 + 3\,H_2O \rightarrow CO_2 + 2\,NH_4^+ + 2\,OH^- \qquad \text{Eqn. 1}$$

The urea degradation increases the pH value of the urine, from its normal slightly acid reaction (often pH around 6) when excreted (Kirchmann & Pettersson, 1995; Jönsson et al., 1996) to a value normally around 9 (Olsson, 1995; Kirchmann & Pettersson, 1995; Jönsson et al.., 1997). The phosphorus in urine is in the form of phosphate and the potassium is in the form of ions (Kirchmann & Pettersson, 1995; Jönsson et al., 1996).

Many chemical fertilisers contain, or dissolve to, nitrogen in the form of ammonium, phosphorus in the form of phosphate 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.

Naturally source separated urine is liquid, but a small amount of sediment rapidly forms. Therefore, the handling equipment has to be tolerant of small amounts of fast-settling suspended solids.

Faeces contain undigested fractions of food which contain plant nutrients. However, organically bound plant nutrients are not plant available: the undigested food residuals have to be degraded before their plant nutrients become available, and so the plant availability of the nutrients in the faeces is expected to be slower than that of the nutrients in the urine.

The low water content in faeces means that source separated faeces should be handled with equipment for solid handling. It also means that the risk of a leaching liquid appearing is small, and that only a small amount of water, 65 g/person and day according to Table 1, has to be evaporated to completely dehydrate the faeces.

System assessment

Which requirements should be put upon a sustainable sanitation system? These can be classified into four groups: hygiene, environmental impact, resource usage and socioeconomic parameters (SEPA, 1995b). Health protection is the main reason for developing good sanitation systems. This is also the main reason for the development and widespread use of the conventional flush-and-discharge sewage system.

Sewage contains large amounts of pathogens, organic substances, plant nutrients and different chemical substances, giving it large potential for environmental impact. Sometimes this can lead to an indirect threat to the health of the population (spoilt drinking water supply, destroyed fishing etc.).

Both directly and indirectly, a sewage system uses scarce resources. A conventional flush-and-discharge system, for example, directly uses water, energy, and often also treatment chemicals. To construct it building materials are needed, which have used scarce resources in production.

The socioeconomic parameters are often critical when assessing whether a sewage system can be realised or not. If it is too expensive, too unreliable or is socially unacceptable, then that system is not a realistic possibility, regardless of how good it is in other respects.

Preliminary assessment of three different sanitation systems

In this section a first preliminary assessment and comparison is made between three different sanitation systems.

System 1. An unflushed source separating system. The urine is accumulated in a collection tank. Then, for hygienic reasons, it is stored separately in a storage tank, with no new urine being added, before it is used as a fertiliser on arable land. The faeces are collected in a container, where they also receive a primary treatment: dehydration or uncontrolled composting. To ensure safety the faeces are given a secondary treatment. This is assumed to be controlled composting, but it could be controlled thermal sanitation (solar energy, or in connection with anaerobic digestion) or incineration.

System 2. A conventional water-based flush-and-discharge system. Urine and faeces are mixed and flushed away with water. This black water is mixed with grey water. The sewage is assumed either to be emitted completely untreated (which is the case for 95% of the sewage in the third world; World Resource Institute, 1992) or to be treated in an advanced sewage treatment plant.

System 3. A conventional drop-and-store pit toilet. Urine and faeces are dropped collectively in a pit where they are stored, for hygienic reasons. When the pit is full it is abandoned for a new one.

Hygiene

As hygiene is treated in depth in another paper only a few general remarks will be made. Faeces are heavily contaminated with pathogens. Most, if not all, intestinal pathogens use faeces as a main pathway for spreading.

Although not sterile the pathogen content of fresh urine is generally low, even though some pathogens are spread via urine. However, in many situations the main hygienic risk with source separated urine is the risk of faecal contamination, often stemming from persons with diarrhoea, i.e. sick persons. Thus, source separated urine should be treated as if heavily contaminated.

In system 1, the unflushed source separating system, all human excreta are collected and treated. The hygiene risk is local, since it emanates from the handling and reuse of the urine and faeces. With a properly functioning system and adequate secondary treatment no pathogens should be spread to the environment. The hygienic risk depends on the pathogen content of the source separated products when they are handled.

The survival in stored source separated urine of eight different pathogen and indicator organisms has been tested in the laboratory (Jönsson et al, 1996; Olsson, 1995). Most of the tested organisms died off rapidly, within a week, in stored urine with pH around 9; one organism died off slowly and two organisms, *Salmonella* phage 28B and *Clostridium perfringens*, were not affected at all during the experiment (approximately 70 days). The experiment also showed that the further away from neutral the pH, the higher the temperature and the less diluted the urine was, the more rapid was the die-off. Based on this experiment in Sweden, six months of separate storage is currently considered a sufficient secondary treatment and sanitation of source separated urine for its safe reuse as a fertiliser. The length of the separate storage period needed in other countries, with other pathogenic loads and other storage temperatures, has not yet been investigated.

One major advantage provided by the source separation in system 1 is that the really heavy pathogenic load is limited to the faeces, the weight and volume of which is limited to around 100 g/person and day. The special precautions needed, owing to the high pathogenic load, are simplified by the small weight and volume of the faeces. It is advantageous if the faeces have been given a primary treatment and thus a primary sanitation, before they are first handled, i.e. before they are removed from the toilet. Dehydration and uncontrolled composting are two possible primary treatments. To achieve a high hygienic quality the faeces should also be given a secondary treatment, for example controlled composting or incineration.

In system 2, the conventional water-based flush-and-discharge system, the faeces and the urine are mixed with flush water and possibly also grey water and industrial wastewater. This increases the volume with high hygienic risk from 1.1 l/person (urine plus faeces) and day to between approximately 40 and 400 l/person and day. With this system the hygienic risk in the dwellings is low, as the sewage is flushed away. The risk emanates from leaking and overflowing sewage, from pathogens spread into the recipient water by the sewage emission and, when the sewage is treated in a sewage plant, from the handling and possible reuse of the sludge.

In system 3, the conventional drop-and-store pit toilet, the faeces and urine are mixed and stored in the pit. The hygienic protection is based on storing, or rather depositing, the excreta well away from humans, food and water. Thus, it is important that no pathogens should escape from the pit. However, lately it has been shown that pathogens might be spread by the infiltration of urine, which has seeped through faeces in the pit (Stenström, 1996).

Environmental effects

A sanitation system can pollute the surrounding environment via air and water. In system 1, the unflushed source separating system, all excreta are collected. The risk of any liquid leaching from the faeces should normally be small, as they are collected source separated. If the secondary treatment is controlled composting, leaching liquids might also arise at this step. If this occurs they should be collected and added to the process again, as a lot of water evaporates during composting.

Water emissions might also arise from the fertilised fields. However, if recycled toilet products were not used the fields would presumably be fertilised with some other agent. There is at present no reason to believe that water pollution from the fields will be greater when fertilised by adequately sanitised recycled toilet products than when fertilised in another way.

Water is evaporated in both the primary and the secondary treatment of the faeces. The faeces contain nitrogen, and part of this will be emitted as ammonia simultaneously with the evaporation of water. Ammonia is a serious air emission, since it is both eutrophicating (fertilising) and acidifying. Based on the ratio between carbon and nitrogen in faeces, the ammonia emission when composting faeces can be estimated at around 50% (Kirchmann, 1985; Hargelius et al., 1997). Assuming that 10% of the urine is wrongly separated and ends up together with the faeces, the ammonia emission from the treatment and handling of the faeces can be roughly estimated at around 1.3 g/person and day.

Ammonia is also emitted from the urine collection and handling. The urea of the source separated urine is quickly degraded to ammonia and carbon dioxide (Eqn. 1). Simultaneously the pH increases to around 9 (Jönsson et al., 1997; Kirchmann & Pettersson, 1995; Olsson, 1995). When the pH is high, the potential for a large ammonia emission is high. This implies that source separated urine should be handled in closed systems (i.e. tanks, containers etc. with only minimum ventilation), and that the urine should be spread and rapidly mixed into the soil. If it is not possible to mix the urine into the soil, then the soil should be such that the urine rapidly infiltrates into it, since the pH and the potential ammonia emission both decrease as the urine comes into good contact with the soil.

The first measurements of ammonia emission after spreading source separated urine are being made in Sweden this summer, and no results are so far available. However, in experiments with pig urine (Rodhe & Johansson, 1996) the ammonia loss was very low when the urine was spread and immediately mixed into the soil by harrowing. The loss was several times higher when the urine was spread in 10 cm high growing barley. It was 5% when urine was spread in bands between the rows of growing barley and 10% when the urine was broadcast over the barley. In the same experiment the ammonia loss when cattle urine was spread on pastures was very high, between 20 and 86%. This means that source separated urine should normally not be spread on pastures. If these measures are taken, it is estimated that the ammonia emission from the handling and spreading of source separated urine, at least under Swedish conditions, should be below 10% of nitrogen content or around 1 g/person and day (Hargelius et al., 1997).

Air pollution is also caused when fuels are used, for example to transport the toilet products to the fields. The quantity of these air emissions depend on the weight of the products transported and the distance. Since the toilet is unflushed the weight transported can be estimated at approximately 1100 g/person and day or 400 kg/person and day, 90% of which is urine. If the location for secondary treatment, separate storage for the urine and controlled composting for the faeces, is located either close to the fields to be fertilised or to the toilets, the transport distance can be kept to a minimum. The technology used by the system functions well also on a small scale. This helps to keep the transport distance at a minimum.

The emissions from the different systems are summarised in Table 2.

Table 2. Estimated water and air emissions from the three proposed sanitation systems

Variable	System 1	System 2[a]	System 3[b]
	g/person & day	g/person & day	g/person & day
Water emissions			
BOD_7	0	1-20	Often negligible
Nitrogen	0	6-13	6[b]
Phosphorus	0	0.08-1.5	Often negligible
Air emissions			
Ammonia	2.3	0.6-0	6[b]
Methane[c]	Negligible	Low - very high	Low - medium
Combustion Emissions (CO_2, NOx, SOx)	From transporting and handling 1.1 kg toilet products per person and day	From fertiliser production From handling 0 - 1[d] kg sewage sludge per person and day From generating electricity to the sewage plant	From fertiliser production

[a] The first figures give emissions when the sewage is treated, achieving 95% reduction of BOD (biological oxygen demand), 50% nitrogen reduction and 95% phosphorus reduction, and assuming that the dewatered (25% dry substance) anaerobically digested sewage sludge is recycled as fertiliser. The last figures assume no treatment or reduction at all.

[b] The total nitrogen emissions are probably approximately 12 g/person and day. In the table 50% are assumed to be emitted to air and 50% to water.

[c] The emission of methane is very difficult to estimate. The estimations are preliminary and studies of methane emission should be carried out.

[d] The amount of sludge produced varies greatly depending on the process: 1 kg sludge (3-4% dry substance) has been calculated as being due to black water alone at large Swedish sewage plants. 1 kg raw sludge reduces to 0.1 kg or less if it is anaerobically digested and dewatered to 25% dry substance.

The water emissions from system 2, the conventional flush-and-discharge system, are great. If the sewage, like 95% of that in the third world (World Resource Institute, 1992), is emitted completely untreated, the water emissions for nitrogen can be estimated at 12.5, for phosphorus to 1.5 and for BOD at 20 g/person and day. In many environments emissions of this size will have large and unacceptable negative effects. The water emissions will be large even if the sewage is treated by an advanced and well functioning sewage treatment plant. Such a plant might reduce the nitrogen emissions by 50%, the phosphorus emissions by 95% (chemical precipitation is assumed) and BOD emissions by 95%. Even so, for nitrogen the water emissions would be 6, for phosphorus 0.08 and for BOD 1 g/person and day. If the population density is high and the recipient is small, these emissions will also have large negative environmental effects.

If the sewage is emitted untreated the environmental effects of the air emissions from the sewage system *per se* are probably normally negligible; however, the water recipient might emit methane, a potent greenhouse gas, owing to serious oxygen deficiency caused by the sewage emission. If the sewage is treated in an advanced treatment plant the risk of oxygen deficiency in the recipient is drastically reduced. Instead, methane emissions are generated by the handling of the sewage sludge. These emissions will be high or very high if the sludge is deposited on a landfill or somewhere else where it becomes anaerobic. They will be small if the sludge is recycled and used as a fertiliser, since agricultural soils are aerobic. On the other hand, if the sludge is used as a fertiliser, ammonia will be emitted. Under Swedish conditions this ammonia emission has been estimated at 0.6 g/person and day when recycling digested and dewatered sludge from the treatment of just black water. When the sludge is used as a fertiliser it has to be transported to the fields, and the fuel used for this transport generates air emissions. The mass of the generated sludge varies widely. Around 1 kg or more of raw sludge might be generated per person and day just from the black water. The mass to be handled can be reduced to below 0.1 kg/person and day if the sludge is digested and dewatered to 25% dry substance.

A properly functioning sewage plant uses energy, usually electrical. The production of this electricity generates air emissions, the quantity and quality of which depend on the power plant used. Such emissions are significant and it is important that they are included when evaluating the total environmental effect of a sewage system.

Water and air emissions from system 3, the conventional pit toilet, are hard to estimate as they depend on how much of the urine infiltrates into the soil and how much evaporates. However, only a minor fraction - perhaps 0.5 g/person and day - of the nitrogen will accumulate in the pit, since almost all organic material is eventually degraded and mineralised nitrogen is easily emitted to water and air. The other 12 g/person and day are emitted to air or water. The phosphorus and BOD content of the liquid leaching from the pit ought under most conditions to be negligible, if measured when the leaching liquid has passed through a few metres of soil.

In system 1 the recycled toilet products are used to fertilise crops. Neither system 2 nor system 3 normally delivers any fertilising products to sustain the arable soil. Thus, to equalise the systems and to maintain the productivity of the arable land, chemical fertilisers having the same effects as the toilet products recycled by system 1 have to be used when systems 2 and 3 are used. For the same fertilising effect approximately 10 g of nitrogen, 1.5 g of phosphorus and 3.5 g of potassium per person and day are needed as chemical fertilisers. The emissions from producing, distributing and spreading these chemical fertilisers should be added to the other emissions from systems 2 and 3.

Usage of scarce resources

Once established, system 1 uses few scarce resources. The main one is energy, which is used for transporting the recycled toilet products back to the fields, for spreading, and for turning and tending the compost used as secondary treatment of the faeces.

Nutrients are removed from the fields with the harvested crops. In sustainable agriculture the same amount of nutrients removed from a field should be returned to it. In Table 3 the nutrient content of the toilet products recycled by system 1 is compared to that of wheat and maize. It should be remembered that nutrients are also lost from the fields in ways other than with the harvested crop.

The fertilising effect of source separated urine, which contains the majority of the nutrients, seems from the few finished experiments to be almost as good as that of the corresponding amount of chemical fertilisers, provided that the ammonia emissions are kept low. So far only one pot experiment and one field experiment with cereals comparing the fertilising effect of human urine with that of chemical fertilisers have been completed. In addition, one field experiment with pig urine has been completed. In the pot experiment (Kirchmann & Pettersson, 1995) the uptake of urine nitrogen by barley harvested at the flowering stage was 42 and 22% at two application rates, and the uptake of ammonium nitrate nitrogen at the same application rates was 53 and 28% respectively. Kirchmann and Pettersson (1995) explained the lower uptake of urine nitrogen by higher gaseous losses of nitrogen (i.e. ammonia), 7 and 6%, from the urine pots than from the ammonium nitrate pots, which had losses of 0 and 2%, respectively. The utilisation of urine phosphorus was found to be 28% better than that of chemical fertiliser. The barley fertilised with urine derived 12.2% of the phosphorus from the fertiliser, whereas that fertilised with dipotassium hydrogen phosphate derived 9.1% from the fertiliser. In the field experiment by Johansson et al. (1997) the nitrogen effect of stored human urine on oats was compared to that of ammonium nitrate fertiliser at three different application rates. The human urine, which was surface spread and immediately harrowed into the ground, gave approximately the same yield as the corresponding amount of chemical fertiliser. Rodhe & Johansson (1996) compared the nitrogen effect on barley of pig urine with that of chemical fertiliser. Also in this field experiment the fertilising effect of urine was the same as that of the corresponding amount of chemical fertiliser.

Table 3. Content of nitrogen and phosphorus in the recycled toilet products from system 1 compared to the content in 162 kg of wheat and 153 kg of maize

Products	Nitrogen in kg	Phosphorus in kg
Recycled toilet products from system 1 per person and year	3.65	0.55
Wheat[a], 162 kg	3.36	0.55
Maize[a], 153 kg	2.44	0.55

[a] Chemical analysis according to Eriksson et al. (1972)

Using the recycled toilet products as fertilisers saves chemical fertilisers containing almost the same amount of nutrients, and hence also the resources needed to produce, distribute and spread them. This requires that each system should deliver the equal amount of fertiliser to arable land. Systems 2 and 3 fulfil this requirement by using chemical fertilisers. The production of the required amounts of fertiliser is considered a necessary function of systems 2 and 3, and its resource usage is therefore included.

The soil cannot sustainably produce healthy, high-quality food if it accumulates heavy metals. The heavy metal content of the recycled toilet products is very small. Source separated urine contains less than 3.6 mg of cadmium per kilogram of phosphorus (Jönsson et al., 1997; Olsson, 1995) and the corresponding figure for source separated faeces is estimated to be 20 mg (SEPA, 1995a). Sweden has long had restrictions and fees in order to decrease the cadmium level in chemical fertilisers, but it is still much higher than in source separated urine. The average cadmium level in Swedish fertilisers in 1994/95 was about 26 mg/kg phosphorus (Eksvärd, pers. comm.), whereas a few years earlier it was 40-50 mg/kg phosphorus. Many fertilisers on the international market contain higher levels of cadmium.

To establish system 1, the unflushed source separating system, source separating toilets with collection containers, a secondary treatment facility and equipment for transport and spreading are needed. These need to be capable of dealing with 1-1.5 l urine and 0.1 kg faeces per person and day.

Table 4. Usage of some scarce resources. (The figures apply to Swedish conditions)

Resource	*System 1*	*System 2*	*System 3*
Energy	For secondary treating, transporting and spreading 1.1 kg/person and day	For production of fertiliser (0.4 MJ/person and day) For pumping sewage (40-400 l/person and day), running sewage plant, and for handling sewage sludge (0-1 kg/person and day)	-
Water	-	For flushing toilet (50 l/person and day)	-
Fossil phosphorus	-	1.5 g/person and day (if no sewage sludge is recycled)	1.5 g/person and day
Fossil potassium	-	3.5 g/person and day	3.5 g/person and day
Infrastructure	Source separating toilets, secondary treatment facility and transporting and spreading equipment for 1.1 kg/person and day	Toilets, piping system for water and sewage, sewage plant, sludge treatment and reuse/disposal facility and equipment	Pit toilets

System 2, the conventional flush-and-discharge system, uses energy for pumping the sewage and, if equipped with a sewage plant, for running this. The energy usage varies depending on the construction and size of the plant.

System 2 uses water to flush the toilets. The Swedish Environmental Protectioncy Agency (SEPA, 1995a) estimates flush water usage at 50 l/person and day. Swedish toilets use 4 (new) to 8 (old) litres per flush. To transport the sewage a piping system is needed; often also a piping system is needed to supply the water. To preserve the environment a sewage plant and sludge treatment facility are also needed. An additional function of system 2, compared to systems 1 and 3, is that grey water and industrial wastewater can often be piped and treated together with the toilet waste. However, this is often also the reason for the high or very high heavy metal concentration in sewage sludge, which makes it unfit for use as an agricultural fertiliser.

If no sewage sludge is recycled, chemical fertilisers containing 10 g of nitrogen, 1.5 g of phosphorus and 3.5 g of potassium need to be produced per person and day when comparing system 2 with system 1. Besides using fossil resources of phosphorus and potassium, the production uses energy, more than 0.4 MJ/person and day (37 MJ/kg nitrogen, 19 MJ/kg phosphorus and 7.5 MJ/kg potassium; Jönsson et al., 1995).

In system 3 no plant nutrients are recycled from the toilet waste. Thus the same amount of chemical fertiliser has to be added when using system 3 as when using system 2 without any sludge recycling.

Socioeconomic parameters

The relevant socioeconomic parameters vary considerably with the situation. Therefore, except for two remarks, these are left to others to investigate based on specific situations.

System 1 provides local control not only over the sanitation system, but also over part of the system supplying the agricultural fertiliser urgently needed for sustainable food production. The technologies used by systems 1 and 3 are simple and easy to maintain.

Conclusion

Different sanitation systems should be evaluated concerning hygiene, the impact on the environment, usage of resources and socioeconomic parameters.

A very preliminary evaluation of hygiene indicates that one advantage of an unflushed source separating system is that the volume of the most pathogen-contaminated fraction is kept small, since it is limited to the faeces. Furthermore, since the faeces fraction is dry, the risk of leaching liquid should be small. This is important since leaching liquids, besides being a direct health hazard to those handling the faeces, might also contaminate surface and/or groundwater. The low water content also improves the possibilities of good sanitation results in primary and secondary treatments.

Since the unflushed source separating system collects, treats and recycles the excreta, the environmental impact is limited to the gaseous losses from the system, estimated at 2-3 g of ammonia per person and day, and to the impact of collecting, transporting, secondary treating and spreading approximately 1.1 kg of toilet fertiliser products per day. With a conventional pit toilet the emissions of nitrogen to air and/or water can be great. If the sewage from a conventional flush-and-discharge system is emitted untreated, heavy environmental effects can be caused by the emitted organic matter, phosphorus and nitrogen. These emissions can be significantly decreased if the system contains an advanced sewage treatment plant.

Methane is generated when organic matter is degraded anaerobically. This is a very potent greenhouse gas. When a conventional flush-and-discharge system is used methane can be generated both in the recipient water, if its oxygen storage is completely depleted, and from the treatment and disposal of the sewage sludge. Methane is probably also emitted from pit toilets, but the quantity is uncertain. Methane emissions from different sanitation systems need to be studied.

A conventional flush-and-discharge system uses a good deal of water. Energy is needed for pumping the sewage, and for treating the sewage if this is done. Also an extensive piping system is needed. Since normally no plant nutrients are recycled, this system implies the use of chemical fertilisers, and the resources needed for their production should be added to the other resources used by the system. The pit toilet system also implies the use of chemical fertilisers to sustain agriculture. Apart from this, resource usage by the pit toilet system is low.

A sanitation system should be evaluated based on the specific situation where it will be used. Socioeconomic variables must be thoroughly considered, along with hygiene, environmental impact and resource usage.

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2.4

DISEASE CONTROL

Thor Axel Stenström, Swedish Institute for Infectious Disease Control, S-105 21 Stockholm Sweden. (Thor-Axel.Stenstrom@smi.ki.se)

Introduction

At all times and in most cultures humans have known that faecal material and wastewater may transmit diseases but at the same time have a valid potential for fertilization. The difference today, however, is that with our rapidly growing knowledge we can, in theory, make more sound risk assessments while at the same time taking advantage of the nutrient potential of the material.

In ancient Egypt different filtration methods, through sand, clay or charcoal, were already in use for drinking water. The Persian kings used to boil their water and store it in silver vessels. Filtration through volcanic stones has been used in many cultures, and in parts of Africa (e.g. Sudan) local tradition is to add certain clays to drinking-water pots, to act as adsorbents for microorganisms.

Similarly, reducing direct contact with faecal material and its secondary transmission to water was traditionally included in many religions. According to the Old Testament in the Bible, defecation should be performed outside the camp: one should carry a stick to dig a hole in a secluded place, defecate in the hole and cover the dropping afterwards with the stick. Similar rules exist in old Hinduism in relation to how Brahmins should answer the call of nature: they should not defecate at the edge of a river, dam or well, but in a hole, where they also pour the water for anal cleansing. According to an Islamic Hadith one should be aware of "three cursed things: to leave faecal material close to water sources, on the road or in the shadow". These rules of life were all preventions against direct and secondary disease transmission to others.

Nowadays we tend to focus our discussions on one transmission route for pathogens at a time, excluding or diminishing the importance of others. This approach often leads to failure to take remedial and preventive action against disease spread, if the route of spread is not clearly established, as in confined epidemics. The large urban and periurban areas of today are a good example of this problem.

Urban and periurban centres as a focus of disease transmission

Three main things apply to the prevention of disease transmission today, as well as in the future:

- the role of perception and medical anthropology in understanding habits, transmission routes and the potential for prevention by adequate treatment of waste and waste products, especially where these are used for crop fertilization; also the inadequate treatment of faecal material in society, and secondary transmission through vector animals;
- the multitude of transmission routes in existence, and factors such as location, potential pollution sources and fertilization of untreated waste, inadequate waste treatment and seasonality;
- the prevalence of disease within the society in question, and the local habits.

When we consider a poor urban area several factors surface as being essential for disease transmission both within and from the area. Some of these are:

- poor housing and limited indoor space per individual;
- the density of people within an area and limited outdoor space, giving numerous opportunities for pathogen transmission between individuals;
- private or family domains compared to common or public domains, where many areas can be considered no-one's responsibility;
- a high influx and outflux of people, favouring the import and export of disease;
- low per capita income, a high unemployment rate and a break-up of social structure, leading to a careless mentality in relation to personal hygienic practices;
- possibly a higher proportion of vulnerable individuals, including young children, old and sick or immunocompromised and malnourished persons;
- on an individual family basis, a deterioration in food handling and storage practices.

These features coincide with:

- the breakdown or non-existence of safe water sources and sanitary facilities, favouring indirect spread of pathogens through contact with fresh faecal material;
- non-existent rubbish collection facilities and often the occurrence of standing water or stormwater heavily polluted with faecal material and organic waste, favouring the coexistence of relatively large populations of rodents as well as other animals acting as secondary transmitters of disease to humans. These areas are also breeding sites for different insects acting as vectors, as well as sites for direct parasite transmission;
- sometimes the coexistence of a high proportion of domestic animals.

These factors combine the vulnerability of subgroups favouring the introduction of pathogens within the area with factors enhancing the possibilities of direct as well as environmental transmission within the population. It also favours a secondary "public" as well as a "family-based" secondary transmission.

The exposure to many of the pathogens may occur early in life in such settings, creating early immunological protection. Further exposure now and then will boost this protection effect for otherwise healthy adults, whereas vulnerable individuals will have been weeded out. This situation is sometimes taken as an excuse by politicians and some professionals for not acting. However, this neglects infections in small children, inactive immunological agents and the introduction of new agents, against which no protection exists in the community and for which the setting may serve as a focus for epidemics. These situations are by no means restricted to developing countries only, and the situation will exacerbate in the future.

These areas also pose a problem for further disease transmission, not just within the society itself but also as a continuous locus for the export (and import) of diseases to other areas. It is deleterious in preventive remedial measures to isolate one factor for action in such situations. The need for clean water and better sanitary conditions will increase. However, disease transmission will not be prevented simply by improving the water situation, but rather needs a multifactorial approach.

Disease transmission through contaminated water or inappropriate sanitary facilities - an international dilemma?

Waterborne disease outbreaks have had a tendency to be looked upon by many politicians as odd events occurring infrequently. They have also been considered by some as "the rich man's problem", in the sense that solutions are not on hand or affordable for poor communities. Sometimes they have been seen as mere statistics.

Human faecal products have similarly been looked upon as a 'deposition problem'. Most of us have a perception of faecal material as repulsive and not to be touched. The obvious solution is that if faecal material is not considered a waste product but merely an economic and agricultural resource, can be shown to be safe in relation to disease transmission and does not look like faecal material, it may be accepted in most cultures, thereby reducing the risk of accidental contact by uncontrolled spread in the environment.

As regards disease transmission, the persistences for different pathogens, variable infective doses, time of latency for some parasites in the environment and different susceptibilities between individuals are some of the factors that have created insecurity in the reuse of such products.

Newly recognised organisms with a high resistance against environmental factors have also created a feeling of insecurity. The role of such organisms is under investigation. The Milwaukee *Cryptosporidium* outbreak in the US has served as an national and international alarm-bell in water treatment. Realisation that the current treatment barriers and disinfection practices may not be enough to safeguard the water has raised demands for direct routine monitoring of different groups of pathogenic organisms. Secondly, it has also focused attention on the relatively large group of people that may be susceptible, owing to immune defects, age or other factors. Thirdly, it has brought forward a growing interest in zoonotic spread, i.e. organisms transmitted from animals to man. This interest in zoonotic transmission also exists in Sweden, partly due to the number of *Campylobacter* outbreaks transmitted through water. However, it also focus on the potential of human disease transmission through animal manure, which further questions the role of disease transmission from different type of waste products to man.

All these factors prevail to a large extent in developing countries and in poor urban situations, where the sick, the malnourished, the young and elderly may all be more likely to contract diseases through faecal contamination, as well as being more likely to transmit the diseases further secondarily. Prevention of disease transmission through sanitary interventions in such situations will never occur if, for example, young children are kept away from the sanitary facilities, and the sick and old are too weak to use them, and therefore defecate in the gutter just outside the house.

Several international epidemics or outbreaks have also been suspected of being caused by vegetables irrigated with wastewater and thereafter exported and consumed in other areas or countries. This type of international transmission will most likely occur at a higher frequency in the future.

Deposition of faecal material in pit latrines - risk of groundwater contamination

Over the last few decades national authorities in developing countries, as well as various donor agencies, have recommended and promoted the use of pit latrines to reduce the presence of human waste and thereby counteract the transmission of enteric diseases. These efforts have led to an improvement in sanitary conditions in many instances, but in others no apparent improvement has been observed and in some cases even a deterioration has occurred. The ever-increasing demands in the cities and periurban areas will further enhance the need for on-site sanitation and sources of drinking water. The use of pit latrines has also hampered the reuse of faecal material as a resource.

Poor siting of latrines or wells may create extensive groundwater pollution by microorganisms. A safety distance of 10-30 m between latrines and wells has been adhered to in many developing countries, but without considering factors that may affect the actual risk of pollution. To assess and exemplify this as a transmission route, we conducted a number of simple experiments where bacteriophages were introduced as biotracers into different latrines in two periurban African settings. It was shown that transmission occurred within days under the prevailing conditions, from the latrines to wells up to distances of between 50 and 100 metres. This shows that although parasites and bacteria may be held back effectively, some viruses were not. The old rules may therefore not be applicable.

This example also demonstrates a second possibility, namely the potential of assessing different transmission routes by means of bacteriophages. Different tracers can be applied simultaneously to study the impact of groundwater transmission, food handling practices or person-to-person transmission. Further studies need to be done to assess the relative impacts of different transmission routes in different communities.

Treatment and preventive alternatives for waste in deposition and reuse

A multitude of treatment options and approaches exist to reduce or diminish the number of pathogens in waste products. However, many of these have not been evaluated for reuse situations for land fertilisation.

Preventive measures can also be taken at different levels with an exposure barrier approach. These include deposition, treatment, waste product separation, reuse optimisation, ways of application, crop selection and human exposure control.

Urine separation is an example of waste product separation and reuse. The pathogens excreted in the urine are fewer than those in faecal material. Among them are *Leptospira, Salmonella typhi* and *paratyphi* and *Schistosoma haematobium.* According to our investigations the *Salmonella* group of bacteria seem to be highly susceptible to the environment in the collected urine, with a rapid die-off. *Schistosoma* will probably also die off rapidly. *Leptospira* has not been investigated. The main problem, however, is the faecal contamination that may and will occur. Owing to the low degree of dilution within a urine-separating system the concentration of pathogens may potentially be high. A number of bacterial pathogens have been tested, and most of these will have a rapid die-off. Some parasites, like *Cryptosporidium* and *Ascaris,* have also been investigated in preliminary trials and seem to be reduced within a couple of months. Viruses may be a problem but have so far not been investigated. However, most pathogens will be reduced within a couple of months. The present rule in Sweden is that the separated urine should be stored for six months before use. This time may be reduced in the future, or in relation to ways of application to arable lands.

The combined faecal waste has been investigated in a wet composting process in Sweden and in relation to temperature. In this thermophilic liquid composting system we applied a strategy to assess the sanitary effects in relation to time, treatment and temperature. By adding small `teabags' of *Ascaris* eggs to the material, and bacteriophages with an elevated temperature resistance, and doing some supplementary laboratory analysis with bacterial strains, we were able to give definite time/temperature relationships for an effective treatment.

Evaluation of dry composting systems

There is a need for simple comparable approaches to the evaluation of dry composting systems and other treatment alternatives applicable in developed as well as developing countries. Current assessments of faecal indicator bacteria are less valid, as these are more susceptible than many true pathogens. The direct assessment of different pathogens is also less valid, as these may vary to a very high degree between situations and experimental evaluations. They also vary in susceptibility depending on the treatments applied.

By selecting organisms with a high resistance to a certain treatment it may be possible to accrue baseline information on the die-off and hygiene and form a sustainable base for comparable risk assessment in different situations.

For dry composting systems the addition of *Ascaris* eggs under controlled conditions, combined with evaluations of added innocuous bacteriophages, may be the best and cheapest approach to evaluate storage time, temperature effects and pH effects (e.g. by lime treatment). This will also make it possible to compare and quantify the treatment effects of different systems.

In conclusion I believe:

- that the approaches taken within this workshop, for the reuse of waste with separation of the liquid and dry phases, are the best for the future from a hygienic point of view;
- that this approach may diminish the accidental presence of faecal material and the risk of accidental spread within vulnerable societies;
- that caution must be raised not to create new routes of transmission through food products and animal vectors
- that evaluation of the treatment alternatives at hand should be standardized, so as to promote the systems and clarify the questions relating to pathogens.

The increasing need for alternative treatment systems for wastewater handling also raise a demand for simple assessment schemes to be applied. The potential routine monitoring applied in some developed countries is not applicable in many developing areas. A promising approach to both waste and wastewater handling is source separation of the material. This is also essential for their reuse in agriculture. Also, in these situations biotracers may give a good indication of the treatment potential and times needed. The choice of organisms may vary from time to time and between systems.

2.5

PERCEPTIONS, URINE BLINDNESS AND URBAN AGRICULTURE

Jan-Olof Drangert, Dept of Water and Environmental Studies, Linköping University, 581 83 Linköping, Sweden (jandr@tema.liu.se)

Introduction

The problems and inconveniences caused by human excreta are aggravated in towns. The Romans built their Cloaca Maxima to rid the city of human waste before Christ was born; today all over the world cities are trying hard to get rid of faeces and urine in one way or another.

Given that any arrangement relies on the perceptions people have, we need to know more about these. So far, however, no comprehensive history of excreta has been written, but we have some good compilations on the development of technologies over the millennia (e.g. Hösel, 1987).

The legacy of the water closet

Water-closet technology has been promoted successfully all over the world. This ingenious system does the work of the former cleaners in Rome and London. However, not enough attention has been paid to the circumstances under which it functions properly. Europeans, as well as engineers in the south, have been trapped by a climatic and agricultural bias. For instance, in Rome, where long aqueducts carried water from distant rivers to the town, the constant water flushed all debris and household waste through Cloaca Maxima back to the river Tiber, which empties into the Mediterranean Sea. The one million citizens of Rome imported much of their food from neighbouring countries and did not have to worry about the reuse of nutrients in the effluent. Likewise, the unique natural conditions in London made it possible to flush out all black water into the sea; the enormous quantity of water in the River Thames, flowing the year around, and the regular ebb and flow of the tide carried the contaminated water into the North Sea. With cheap, imported fertilizers the British were not concerned about a decline in soil fertility.

A sustainable society presupposes the recirculation of nutrients or the import of food from other places. However, the legacy of the water closet seems to impede creative thinking in most countries. In a world with limited nutrients and an increasing number of inhabitants we can hardly hope for a constant flow of fertilizers, but should, whenever possible, reclaim the nutrients from human waste. This has been done in many places in varying ways over time. Chinese farmers collecting buckets of nightsoil for their agriculture is a major example. However, the history of human excreta is one where urine and faeces have seldom been separated, either practically or mentally. This `urine blindness' has left a number of dry options undeveloped.

Perceptions of urine and faeces

Attitudes and perceptions about health hazards and people's revulsion against faeces and urine vary between cultures, and often people´s attitudes towards urine differ from those towards faeces. Tanner (1995) writes that every social group has a social policy for excreting: some norms of conduct will vary with age, marital status, sex, education, class, religion, locality, employment and physical capacity. The human dimension was found by Cross (1985:I-1) to be a seriously neglected in environmental health, and yet it is of central importance to a full understanding of the potential reuse of human waste. For example, a process of social conditioning is involved in the identification of those smells which may be categorized as disgusting in particular cultures. However, as noted by Loudon (1977:168), it is a common observation that among individuals accustomed to the smells of putrefaction, such as those involved in specialized occupations, conditioning modifies or suppresses a response which may well have a biochemical basis, even though reinforced by sociopsychological factors. People´s perceptions of urine have hardly been studied. A Koranic edict considers urine to be a spiritual pollutant, and Islamic custom demands that Muslims minimize contact with human excreta (Hanafi 1985). In Sweden urine has commonly been used to smear wounds, and to some extent to drink as therapy (Frode-Kristensen 1966:18). Recently urine has been shown to have a disinfectant property. Hansen (1928:88) reported that in the Danish countryside in the 19th century urine was stored and used as a detergent for washing clothes and dyeing. A century earlier, European artisans collected urine and canine excrement for industrial purposes (Reid 1991:10).

Faeces are perceived quite differently, and are regarded as offensive and unpleasant to handle (Fortes 1945:8 on the Tallensi; Malinowski 1929:378 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 on conditioning. Furthermore, one may find differences in male and female perceptions, owing to varying exposures to adult excreta, as is expected in the care of the elderly and incapacitated.

Both professionals and laymen foster strong opinions that adult faeces are hazardous to health because the stool may contain a variety of pathogens, such as *Giardia* and *Entamoeba* parasites, *Shigella* and *Campylobacter* bacteria and rotavirus. More generally, Mary Douglas (1978:34) argues that it is difficult to think of dirt except in the context of pathogenicity within contemporary European thinking, and this makes it more important to understand dirt avoidance before perception was transformed by bacteriology.

Faeces may carry a 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 the 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. A study in periurban Eldoret in Kenya indicates this by stating that only 10% of the informants thought it unsafe to throw children´s faeces into the latrine, for example because children's stools should not be mixed with those of adults; children's stools should be hidden because of the danger of a witch picking on the stool of a particular child; and faeces left in shallow latrines can be picked up by people with ill will (Akongá 1996:42).

From its practical uses cow dung seems to be seen 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 repulsive when applied to the fields. Fortes reported a similar practice among Tallensi farmers, using a mixture of human faeces and animal manure as fertilizer. Another common way tó get rid of faeces is to let pigs and dogs scavenge, i.e. eat the human faeces and produce their own faeces, which are not regarded as equally repulsive.

Another way of approaching people´s attitudes to excreta is how sewage workers and excrement collectors are viewed. The emerging picture is a fairly homogeneous one. Noble (1991) writes about the professional pride shown by Parisian sewermen. Another example from South Africa tells that the ethnic group Bhaca are eagerly sought after as attendants at sewage treatment works (Mbambisa and Selkirk, 1990). On the other hand, according to the same source, highly qualified Transkeians are reluctant to work in the sewage treatment field. A possibly contrasting example given by Tanner (1995:90) mentions the social position of lavatory cleaners: "In Hinduism it is done by outcastes, 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 1987:22). We may infer from this that the general perception of human waste was one of disgust. However, the organization of waste disposal was highly regarded and led by one of the most prestigious officials in the Roman Empire.

Bearing in mind that all these examples from various times and parts of the world deal exclusively with mixed excreta, my impression is that both professionals and laymen 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 faeces. To what extent would this relaxed view of urine make people prepared to use it for their own benefit?

Alternative dry systems in Sweden

Dry systems have been on the market since the early 1970s. Initially, these were intended for use in summer cottages rather than in apartments. More than fifty thousand units have been sold so far. The Agenda 21 resolutions of 1992 promoted serious activity in Sweden concerning alternative options for the disposal of excreta. An earlier interest among ecologically minded people has now broadened into a public concern. The Swedish Environmental Authority (SEPA) has approved a number of disposal systems and the present regulations make the user responsible for maintaining the system.

Some one hundred ecological 'villages' have been founded in Sweden by people interested in leading an environmentally friendly life. They have organized themselves and built or bought houses and installed a variety of devices for the reuse and recirculation of water and nutrients and the saving of 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 a good education and an ability to get bank loans for their projects, just as when building a conventional house.

Municipal councils and some of the major contractors are also beginning to sense that the future may have more ecological approaches in store, and therefore they invest in test houses. All these developments clearly show that assumed norms and attitudes may change rather quickly if viable alternatives appear.

A market survery carried out by the Swedish Consumer Protection Board presents 42 different 'dry' systems involving 22 manufacturers. Most of these are small companies, but two of the well-established whiteware manufacturers offer no-mixing toilets, i.e. keeping faeces and urine separated; 21 systems keep faeces and urine separated, another five have this as an option and four systems first mix and then separate faeces and urine. Twelve systems mix excreta and compost it or remove it in buckets/plastic bags.

The majority of the units for permanent buildings are made of porcelain with two bowls, whereas most units for summer houses are made of plastic. Only one of the marketed toilets has a lid inside the bowl to cover the faeces.

The cost of the units, excluding installation, is between 1,000 and 30,000 SEK, and the cost of a porcelain unit is only slightly higher than a conventional toilet. From a user´s point of view, the household saves the fee for connection to a communal water and sewerage system, which runs at 50,000-100,000 SEK.

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 reducing the discharge to rivers and lakes. Most manufacturers emphasize the reuse/recirculation of the faeces, but fewer mention the possibility of reusing urine in the garden. The adverts in daily papers 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 advert puts it as follows:

> ”Forget everything that reminds you of stinking dry (bucket) toilets and malfunctioning compost toilets. The Septum ecotoilet combines the simplicity of the dry toilet with the convenience of the WC, without the need for electricity or water.”

Rarely is the word faeces mentioned in the information material, but instead the word for the end-product, compost, is used. It seems that drying the faeces is an acceptable way of conveying a message to potential customers. This may be because 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 at the end of the Second World War), but also a sizeable proportion of families have summer cottages with a compost latrine or a bucket latrine, which is emptied by the family and collected by municipal staff.

The manufacturers have switched from approaching only ecologically minded customers to reaching the general public. There is currently 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 ammonia is not released. Also the tank is connected to a plastic pipe to water the garden, so that the underpressure drains the tank and mixes the urine and the water in the pipe.

If the adverts 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. The use of urine is mentioned only rarely, not because of cultural resistance, but because it has only very recently become an option.

Experiences and perceptions among users of dry systems

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

The Eco-house in Norrköping town is a three-storey building with 18 flats, built in the 1960s and converted into an eco-house last year. The aim was to reduce energy consumption and to handle wastewater and garbage locally. Potable water is 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 litres of water and drains into a urine tank. After some six months' storage to allow antibiotics to disintegrate, the contents are collected by a farmer. Faeces are flushed with 4 litres of water to a separator in the basement which separates the liquid from the solids. The dehydrated faeces are composted together with household garbage for some eight months before being used as fertilizer in the residents´ small gardens near the house. The separated flush water is irradiated with UV light to kill the germs and piped, together with bath, dish and laundry water, to a three-chamber tank for sludge separation. The treated water is then used in a root-filtering system in the ecology park situated in a beautifully formed marsh. Rainwater is also taken care of locally.

Botta (1997) made an initial study of this eco-house, which included residents´ perceptions. Among other things, she found that the no-mixing toilets were appreciated by both women and men (men need to sit when urinating). The firm responsible for the treatment plant faced numerous operational problems. The residents accepted the inconvenience of smells from the initially malfunctioning composting system, since they were well-informed about the pilot nature 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 and comprisedng 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 received many complaints about flies, smells, wet composting material, and difficulty in cleaning. The reasons for the poor 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. Eleven out of 12 respondents were 'very' or 'quite' satisfied with the Norwegian system with four rotating chambers, whereas 11 out of 16 Ekoloo users were 'quite' or 'very' dissatisfied. In 1995 the housing corporation let the households decide if they wanted to keep the dry latrine or switch to water closets. All but four chose a WC.

User experiences of no-mixing toilets are fairly positive, but some of the mixing toilets face user dissatisfaction. The composted material is often used as fertilizer in the home garden. The reuse of urine is less developed, and several projects rely on farmers to collect the urine and spread it on their farms.

Capacity of the vegetation to utilize urine and faeces

UNDP (1996) has recently estimated that some 15% of world food production 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 the recirculation of nutrients will feature highly in the near future, as was the case a century ago in Europe.

The land area needed to produce people´s average annual intake of, say, 250 kg of cereals, would be 2500 m^2, since the average global output is about one tonne per hectare. This varies substantially between different agricultural zones and whether irrigation or dry-land farming is contemplated: from some 500 m^2 in irrigation agriculture to perhaps as much as 5000 m^2 in dry land farming on marginal land.

It is assumed that many people have had more or less explicit ideas about how much excreta vegetation can consume. For instance, if half of the food consumed in Lusaka is consumed within the city boundary, a first approximation would be that half of the accumulated excreta could be input into the urban agriculture. An early, closer scientific look was taken by Pettenkofer´s disciple Max Rubner, who took on the chair of Robert Koch as professor in Berlin. He estimated that excreta from 80 persons is enough to fertilize a hectare (Schadewaldt 1983), or in other words one person could fertilize some 125 m^2. FAO (1977) reported application rates of nightsoil in China of 20-30 tonnes per hectare, which corresponds to disposing of the annual human waste from one adult on 250-300 m^2, with only one crop per year. As expected, these figures differ partly because they represent different geographical areas, different diets and varying intensities of crop production. It reminds us of the importance of local data on, for example, agriculture, efficiency and nutrient intake, in order to find out what area can be fertilized with a person´s accumulated excreta.

Losses to the atmosphere of ammonia and to the soil of phosphorus by fixation may be considerable from faeces, whereas the loss from urine was very low if it was immediately mixed into the soil by harrowing (Jönsson, 1997). Vegetation on some 50-100 m^2 may be enough to consume the nutrients from the urine of one person if intensive horticulture is practized with, say, three crops a year. We may formulate the information in an equation as follows:

The urine equation

An (1) adult eats 250 kg of cereals per year, which has been grown on less than 500 m^2 and fertilized to perhaps 50% by the person´s urine mixed with her used wastewater.

Drangert, 1996

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

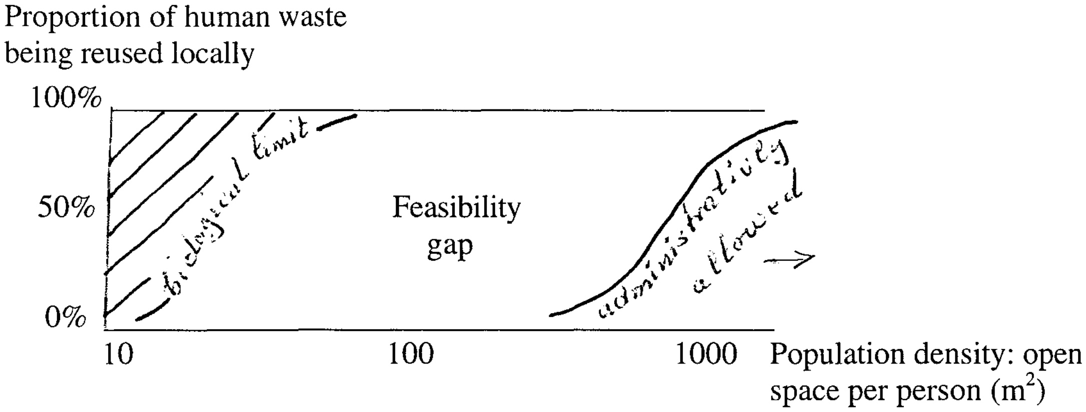
Reuse in urban agriculture

It is obvious that the open space available in densely populated urban areas does not allow *in situ* recirculation of all 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.

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 city also vary considerably. Keeping such differences in mind, we can still try to discuss recirculation of urine and faeces 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 the reuse of human excreta.

The relationship between outdoor space and plant uptake of nutrients is summarized in Figure 1. There is a biological limit to what it is possible to achieve, and another limit to what is administratively allowed. In between these limits there is a 'feasibility gap' that is being explored.

Figure 1. Proportion of human waste to be recirculated and reused in urban agriculture in relation to population density (log scale)



If the population density is low, each person having on average more than, say, 500 m^2 of open space, as in periurban 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 wastewater and spread it on the fields in the evening. 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.

This way of dealing with excreta is an individual affair similar to what is already practised in rural areas. Such a system does not require much effort by the authorities or the local power structure. Healthwise it is fairly safe, 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, as in parts of Khayelitsa in Cape Town, there is little room for reuse of urine and faeces. The large volume of wastewater-urine mix will almost serve as irrigation water and requires a thick vegetation cover to consume the nutrients. Only a keen and skilful horticulturist can be expected to manage such a task. Health precautions require strict handling of the faeces, if they are not dried or incinerated or buried in a pit. Alternatively, removal of excreta from the area would require a well-organized collection and transport system.

Interesting combinations of recirculation locally may be found in the 'feasibility gap', in the spectrum of about 20-500 m^2 of open space per person. Small home gardens would be able to absorb the prepared urine. The soil´s capacity to digest urine varies, and the hydrological regime, type of vegetation, pH etc. determine what happens to the nutrients. Excess urine may soak into the ground without medium-term harm to the groundwater. In compounds where cows are kept, however, raised levels of nitrate and phosphorus may occur in the groundwater. A raised nitrate level will affect the water quality in nearby wells for a long time. If the available space is above, say 200-300 m^2, a more casual way of agriculture would suffice to utilize all urine.

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

Summary

There are at least three reasons to overcome our 'urine blindness' and to reuse urine: urine is bulkier than faeces and more expensive to transport; it contains more nutrients than faeces; and people have a more relaxed view on urine than on faeces. If periurban residents are interested, they can easily reuse urine in agriculture and increase their food production, thereby reducing malnutrition. The remaining dry faeces may easily be disposed of in any culturally accepted and hygienic way.

The limited capacity of town councils causes large numbers of periurban dwellers to lack piped water and/or sewerage, and they are left to explore their own solutions. The lesser cultural revulsion against urine may increase people´s willingness to keep urine and faeces separate, and use both in urban agriculture. Poor periurban dwellers may appreciate the possibility of using urine in intensive gardening and earning part of their living from it (in the way some wealthy people do, or as was done in wartime 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 such as the *urine equation* between the soil's capacity to absorb urine, plant production and plant nutrient requirements, the land area required for a person´s food intake, the amount of nutrients in human excreta, and the density of population in periurban 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.

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 fertilizing the garden - be it a lawn or vegetable garden - does not require a change of responsibilities between men and women in the household. The woman can be in control of all the aspects of urine-based agriculture. However, the question of putting even more pressure on already overworked women should be addressed, as it could become an obstacle. Only the individual woman will in the end decide whether the effort is worthwhile. However, women who are already involved in gardening may find it easier to reuse grey water and urine than fetching water from a well to water their garden.

Well-intended interventions may fail owing to neglect of individual values or societal norms, or they may succeed thanks to other, seemingly unrelated, values that were not contemplated by the intervention. The discussion in this paper presents a plural view on the reuse of excreta while paying attention to perceptions and possibilities. There is no single best solution, but there is a need to soften the resistance to alternative excreta disposal, as evidenced by many local regulations.

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2.6

INSTITUTIONAL AND FINANCIAL CONSEQUENCES OF ECOLOGICAL SANITATION

Jorge Vargas Cullell, P.O. Box 348-2050, Costa Rica (jvcaam@sol.rasca.co.cr)

Introduction

In many developing countries water is an increasingly scarce and expensive resource. It is a documented fact that the poor bear the brunt of this well known problem (Garn and Briscoe, 1994; World Bank, 1993). However, governments and international institutions continue to advocate sewerage as the normal or ideal system to manage human excreta and wastewater in urban centres. Yet if water is an economic good, and in many urban centres it is a particularly expensive and scarce one, a *non sequitur* emerges between the diagnosis "water scarcity" and the recommendation urban sanitation based on sewerage. Consequently, the "sewerage for all" ideal may be callled into task.

Any debate over this issue faces a seemingly insurmountable obstacle. An ingrained perception of low-cost alternatives as substandard and temporary solutions for the urban poor still holds sway in many sanitation policies. Its underlying assumption is that economic modernization will bring about increased institutional and financial capabilities which, in turn, will make it possible in the future to supply the ideal service to everyone.

For vast urban populations, however, temporary solutions are anything but temporary. In spite of new news on financing water supply and sewerage services, policies based on "sewerage for all" as an ideal face harsh realities. Sewerage remains by far the most expensive technology, and in developing countries the costs of providing sewerage continue to rise. It also demands increasing water consumption levels, which may prove infeasible in many urban areas.

In addition, given the absence of adequate treatment facilities, sewerage heavily pollutes coastal areas and river basins. In Latin America, less than 2 % of all urban sewerage is treated. In Costa Rica, a country with otherwise high sanitation achievements, treatment of effluents remains an exception, and almost all decentralised treament plants are out of service (Reynolds, 1997)

The acute and growing problems affecting developing countries´ urban centres certainly beg for new approaches to urban sanitation. These do not necessarily presuppose doing away with sewerage, but imply combinations of different technical solutions. However, the difficulties in conceptualizing and implementing new sanitation approaches on a city/regional scale must not be underestimated, as they stretch far beyond financial, technical or managerial predicaments. A fundamental change in urban sanitation policies´ conceptual and practical frameworks may be required, for which a few settlements and institutions are fully prepared. Nonetheless, some things may provisionally be said.

This paper discusses some of the long-term daunting institutional and financial choices faced by urban sanitation policies based on the "sewerage for all" ideal. The discussion will be approached through a fictional situation, considering an imagined "City X". The paper aims at depicting fundamental policy dilemmas faced by fast-growing cities, even when sound financial policies are followed. Its purpose is not to prove the feasibility of any alternative low-cost sanitation policy, or to lump together all sewerage as one possible solution. Rather, it intends to dissipate the illusion that low-cost sanitation represents a temporary solution for poor urban households, and to argue that the time has come to consider new approaches to urban sanitation as something more than substandard solutions.

Sewerage for all revisited

"City X" is a busy city of roughly two million inhabitants in the developing world with a rapid growth rate (3.5% annually). City dwellers may be classified into two social groups, poor and non-poor. The former, who represent around 50% of the city's population. grow faster (4.5%) than non-poor households. Although poor households have very low estimated average annual income, say USD 300, there is a hidden informal economy which provides additional income, an extra USD 300 on average per poor household.

Sanitation goals

Public authorities in "City X" currently discuss the 20-year water supply and sanitation strategic coverage goals. Their current situation and target is depicted in Table 1.

Table 1. "City X" 20-year goals for urban sanitation

Population	*Current (1997)*	*Targeted (2017)*
Population	2,000,000	4,000,000
No. of households (average of 5 persons per hh)	400,000	800,000
In-house water supply	80% (Tegucigalpa 79%)	100%
Public standpost	20%	0%
Sewerage (public system)	50% (Tegucigalpa 58%)	100%
Any kind of latrine (pit, VIP,.)	30%	0%
No sanitary facility	20%	0%
Sewage treated	4% (Costa Rica urban 2%)	100%

Source: City council report 1997

These goals demand large new water and financial resources, as well as substantially enhanced institutional capabilities. However, as table 2 suggests, "City X" faces somewhat stringent restrictions on each of these fronts.

Table 2. Requirements to reach full coverage of water and sanitation by 2017

Resource	*Source*	*Restrictions*	*Additional requirements*
Water	groundwater	pollution by infiltration, urban growth affects regeneration	$130*10^6$ m^3 at 140 lt/person/day
Finance	domestic	international household purchasing power, credit availability, economic risk	water: USD 49 million (capital cost USD 150 per household) sewerage: USD 367 million (USD 600 per household)
Institutional capability		lack of trained staff and fiscal policies	new technicians, funds for O&M, improved control and capabilities

In addition, "City X" officials strongly feel that policies should be consistent with targeted goals and existing restrictions. Hence, they favour (rather optimistic) policies based on the following.

- Households and communities should contribute to the construction of new facilities and their operation and maintenance. Flexible arrangements will be set up to allow communal management according to local resources. Local participation is expected to cut construction costs by, say 20%, and O&M costs by, say 30%. In short, decentralised policies based on flexible public and private partnerships will be followed.
- Users of water supply services must be charged the "financial costs of abstracting, transporting, storing, treating and distributing the water and the economic costs of water as an input" (Briscoe and Garn, 1994:19). Sewerage requires more complex financial arrangements, Following Briscoe and Garn, costs "should be assigned to different levels according to the benefits accruing at different levels" (ibid 20). City officials estimate that 75% of construction and O&M costs should be assigned to "City X" households, and the rest should be charged to other stakeholders (industries etc.).
- Increased institutional input will enable capital costs and operation and maintenance costs to be cut by 20%.
- No subsidies will be granted, yet officials think it is both socially and politically infeasible to charge poor households more than 18% of their estimated incomes (average plus hidden) for water and sewerage. This figure exceeds what poor households currently pay to informal water vendors for a much more limited water supply in some cities such as Tegucigalpa, Honduras.

Unpleasant hints

For strategic planning purposes officials need some idea about the "big picture". Can sewerage for all be realistically envisaged as "City X"'s sanitation policy goal for the year 2017? In other words, should all efforts be directed toward the universalization of sewerage?

Table 3 suggests that "sewerage for all" as a policy goal seems to run into difficulties, even if the city assists in applying sound principles. In spite of full cost recovery policies, and of cost reduction through local participation and increased institutional efficiency, the City expects poor households to face payment difficulties. Even if poor households were willing to pay up to 18% of their monthly incomes for water and sanitation, unless the economy substantially improves, the City does not expect them to provide additional monies.

Table 3. Financial consequences of sewerage for all in "City X"

Item	*1997*	*2017 (full coverage)*	*Difference*
No. of households	400,000	800,000	400,000
poor	200,000	482,000	282,000
non-poor	200,000	318,000	118,000
Water consumption (m^3)			
used by the poor	35,000,000	123,000,000	88,000,000
used by non-poor	35,000,000	81,000,000	46,000,000
Total	70,000,000	204,000,000	134,000,000
Investments (USD) in			
water		49,000,000 (12%)	
sanitation		367,000,000 (88%)	
Total		416,000,000 (100%)	
O&M costs	37,200,000	96,000,000	59,000,000
Financial surplus/deficit*		./.28,000,000	./.6,500,000
water		0	0
sanitation		./.28,000,000	6,500,000

* Figures refer to cumulative deficit during the period 1997-2017. Non-poor willing to pay 2.5% of income for water and sanitation respectively, and poor willing to pay 9% respectively.

Given that costs top payments from poor households which comprise the majority of the new demand in the year 2017 the water and sanitation system will confront an increasing financial deficit (USD 27.9 million in that year). All of this deficit comes from sewerage. Unless ”City X” receives permanent and increasing external transfers (external funds or national funds via central government) the financial situation cannot expect to improve. There is no reason, however, to expect flow of external resources to offset the deficit.

Finally, City officials expect a rapidly increasing water demand. If consumption patterns remain unchanged, by the year 2017 water demand may reach a level three times higher than 1997, prompting rising costs and scarcities.

Policy dilemmas

”City X” officials know that even if they choose a ”sewerage for all” policy goal (and pray for the water and money to come), many poor households will continue using other sanitation alternatives for a long time. Even if open defecation is eliminated - a short term goal - sewerage should not be expected to follow shortly.

If ”temporary” encompasses a rather long period the notion of low-cost sanitation as a substandard technology must also be called into question. However, the low-cost technologies at hand (pit, VIP latrines) seem improper for dense urban settlements. New and substantially improved sanitation alternatives must be developed.

”City X” officials urgently need affordable sanitation options. At issue are not just the principles of sound financial and management policies of urban sanitation: the fundamental problem seems to be that sewerage for all as a policy goal seems out of reach, even if sound financial policies are applied. Who is going to pay for a ”sewerage for all”goal? Running up an astronomical bill seems not to be a realistic response. In an era of fiscal austerity and economic transformation, shopping around for hundreds of millions of dollars seems futile.

Finally, extended sanitation coverage to all of the sprawling population poses a nearly impossible task for City X´s inefficient sanitation institutions. If they perform ill at the existing coverage levels, what can be expected other than managerial chaos if coverage expands? Also, some functional order must be created in a city where sanitation authorities traditionally have allowed a confusing gamut of strategies in the management of human waste. For example, when dealing with substandard solutions ”City X” officials actively or passively nurture de facto decentralization. This occurs when no specific institution deals with the problems of vast urban areas, and communities have to manage human waste disposal at their own expense or with the help of private organisations.

Issues in the large-scale application of new sanitation policies

In terms of strategic thinking, ”City X” needs new sanitation approaches upon which financial, institutional, organisational and technical policies must be consistently implemented. Whatever the specifics, the approaches seem to rest on a few unavoidable principles:

- water must be considered an economic good
- ”City X” must have affordable sanitation
- high-quality sanitation must play a major role in sanitation policies
- sanitation alternatives must be environmentally sound, and
- new decentralised institutional arrangements must be developed

These seemingly simple principles, known as "eco-sanitation" (Winblad et al., 1997) launch "City X" into unchartered territory and experimental programmes should be carried out before large-scale applications are considered.

The policy goal for experimental urban eco-sanitation programmes is to set up safe, affordable and effective urban sanitation systems in densely populated areas. Such a goal faces two critical issues: on the one hand, making scores of sanitation devices work properly (performance of devices) and, on the other implementing the safe handling, transportation and reuse of the output of these devices (handling of output).

From an institutional perspective, City officials should initiate sweeping reforms to enable the implementation of new sanitation policies, even at an experimental stage. Reforms go beyond improving the efficiency of existing public institutions. These were set up to manage centralised flush systems that involve complex technical tasks and substantial financial resources, and little if any local training, education and participation.

New sanitation policies aimed at tackling extensive urban sanitation problems call for decentralised institutional arrangements based on extensive community participation in the design, construction, operation and maintenance of such systems. Community participation should be coupled with a strong and enforceable regulatory framework and stable cooperation between stakeholders such as households, local organisations, non-governmental organisations municipalities, private firms and public institutions.

New sanitation policies imply a functional partnership between stakeholders. Institutions monitor and evaluate the participation of many actors, including households and communities, in the safe handling, transportation, storage and disposal of output of toilets.

In short, in a new regulatory framework institutions perfom key policy functions:

- defining standards for the handling, transportation, storage and reuse of urine and desiccated or composted material
- establishing monitoring and evaluation procedures
- implementing systems of incentives and sanctions, and
- mobilizing and allocating resources to fund the construction of sanitation systems

To control and monitor local eco-san systems one may consider a number of options involving varying degrees of decentralization. For example. in cities where technically able private firms exist, they could undertake these functions. In such cases community organisations could have the right to select the enterprise in charge of monitoring their community sanitation from a pool of authorized firms. However, in cities with more stringent technical and institutional capabilities, policy makers may rely on simpler arrangements. Traditional systems may be adapted to perform basic control and monitoring over sanitation devices, for example, the donkey system in the old city of Harar in Ethiopia. Finally, public officials may explore the desirability of making different sanitation systems coexist.

Conclusion

In the sprawling cirties of the developing world "sewerage for all" will probably have low economic and institutional feasibility and cold prompt acute water scarcities. In spite of its egalitarian ethos, "sewerage for all" as an ideal may actually deepen current inequalities in water supply and sanitation. It will also provide further environmental problems. Given stringent financial and institutional capabilities a probable outcome is "sewerage for some, substandard sanitation for the poor, and pollution for all".

The time is ripe to implement alternative urban sanitation policies. However, these require a preliminary experimental stage before going up to scale. Experimental projects have manyfold goals: to adapt sanitation practices and beliefs; to test technologies; to set up standards; to test the effectiveness, affordability and safety of handling: transportation and treatment systems; to develop a fit regulatory framework: to train stakeholders; and to build up organisational and institutional capabilities.

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