Ch 2. Sanitation management today and in future

Women washing clothes in a way which optimises water use (R. Shrestha)

Aeration lagoons in a city sewage treatment plant (J-O Drangert)

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Sanitation management is done at all levels from households to national legislature. Lawmakers formulate sanitation acts which regulate the administrative set up, define permissible levels of contamination, decide how to set tariffs and provide subsidies etc. Households and communities are guided by this framework, but they also have a fair amount of freedom to arrange for their own management.

David Satterthwaite (2007) summarises the development of sanitation management over the last two centuries in Europe and the present-day situation in the developing world:

> "Few large cities had their initial urban expansion guided by a rational plan and, for those few, plans were applied only to parts of the expansion, or the planning guidelines, rules and norms were only partially applied. The many factors influencing the location and initial development of cities include the availability of water, good location on transport routes (where river or sea transport may be important), the location of government (with government agencies and employees as potential sources of demand for goods and services), a healthy climate, rich agricultural lands and, especially in the past, defence. But the main driver of growth for most rapidly growing cities over the last two decades has been private enterprises choosing to concentrate there. Most cities initially developed and expanded with little government attention given to planning in the expanding urban periphery, for instance to protect watersheds or agricultural land or ensure sufficient land for housing, or to ensuring the provision of infrastructure there.
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> Over time, many cities have acquired structures of governance that address these issues and, as the competence, capacity and accountability of urban governments developed (usually backed by national reforms and more democratic systems of government), so urban expansion became less chaotic and provision of urban infrastructure and services greatly improved. In cities in high-income nations, it is taken for granted that there are planning controls on urban expansion and on new developments, which all new buildings will meet official building standards and that there are piped water, sewer and

> drainage networks to which new developments can connect. It is also accepted that the staff or urban governments are answerable to elected representatives. Yet it is only in the last 100 years or so that the governance structures to achieve this began to be accepted and developed. Only around a century ago, most cities in Europe still had infant and child mortalities that were higher than those of most cities in low-income nations today.
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> Most cities and smaller urban centres around the world still do not have governance structures that fulfil many of the key roles noted above. This is especially so in low-income nations and most middle-income nations. Most cities may be centres of wealth and opportunity but they are also centres of extreme poverty and usually of very large and often growing inequality – in terms of income levels, housing conditions and access to services.
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> Around a billion urban dwellers, a fifth of the planet's population are homeless or live in crowded tenements, boarding houses or houses or shacks in informal/squatter settlements (often three or more a room). Many are denied the vote, even in democracies, because they lack legal address required for voter registration. They are often exploited by landlords, politicians, police and criminals. Many city governments are unrepresentative, so any agreement negotiated between them and an enterprise (or other government agency) will not be recognized as legitimate by most local people. There are often problems with corruption (although this is often driven as much by the behaviour of external agencies as by local practices). Where city governments are elected, it is common for local politicians to use patron-client relationships with their constituents, which undermine democracy and accountability."

The author makes no attempt to analyse why the current conditions have evolved (See Module 1.4), but seems to suggest that more democratic regimes are capable of improving sanitary conditions. Also, the above account puts forward the conventional view, common among professionals, that the municipality or utility should provide services through all-embracing infrastructure. It also paints a rosy picture of conditions in high-income countries today and no information such as the city of London today discharges untreated sewage from overflowing WWTPs some 60 times per year into river Thames. Or that Brussels with the EU headquarters built its wastewater treatment plant only ten years ago.

In this chapter we deal mainly with sanitation arrangements that would enable individuals and communities to develop and install sanitation systems without becoming dependent on a complex network and administration governed to a degree by self-interest.

2.1 Sanitation arrangements

at household and community levels

Is there one sanitation system that suits all situations, or do we have to choose?

Learning objectives: to match management with technology and local conditions

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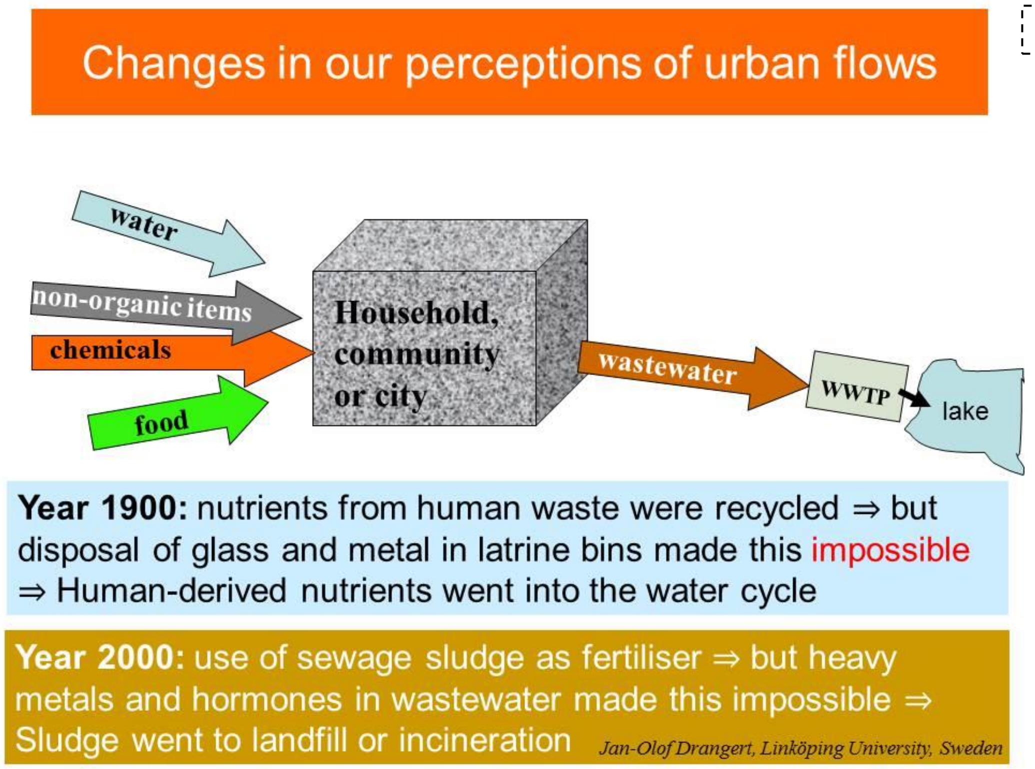
In this Module we treat the various levels of management as all being equally important. This means that we give latrine pits and wells the same respect as flush toilets and water conveyance over long distances. The reason is that simple technical systems are not easier to handle in their social context than sophisticated ones. Had that not been the case, there would be no need for this sourcebook, and the sanitation problems would have been solved. Management is about combining technology in ways which are adapted to all kinds of local conditions including socio-cultural factors, the economy, the available resources, etc.

A few examples are given to illustrate how all these aspects are intertwined. If the collection of rubbish is irregular, residents tend to drop their trash into drains, hoping that the next rain will flush it away. If large numbers of people do this, the drainage will collapse. If a small community sewage treatment system faces a high rate of non-payment, or if too little money is set aside for repairs, the system is likely to fail. Similarly, if some households use exorbitant volumes of water, the treatment plant may be over-stretched and the quality of sewage treatment will become unsatisfactory. If the supply of water to public toilets is erratic, vandalism is a likely response. If some families are too poor, or if they are for some other reason unwilling to put up the investment capital needed for a small community facility, then the selected, technical system may be inefficient or even ineffective.

Such examples show that a long-term sustainable solution is possible only if the technical arrangement matches the management capacity and all relevant local conditions. In Module 2.5 we introduce an algorithm to assist in selecting sustainable sanitation solutions. In the present Module we describe five authentic cases of alternative sanitation arrangements.

2.1 - 3



Module 1.3 describes how new household products that enter the urban flow have caused great harm to existing treatment arrangements – often to the extent that they had to be abandoned or totally revised at great cost. The picture shows two examples when changes in consumption patterns impact the whole sanitation system. Such changes to the composition and volume of consumer goods were not anticipated, and could not have been envisaged by professionals or by lawmakers when the infrastructure was designed. The same applies today – we do not know what the future holds. Maybe we stand a better chance today of keeping an eye on unfriendly products entering the market, but taking action will require hard choices by lawmakers.

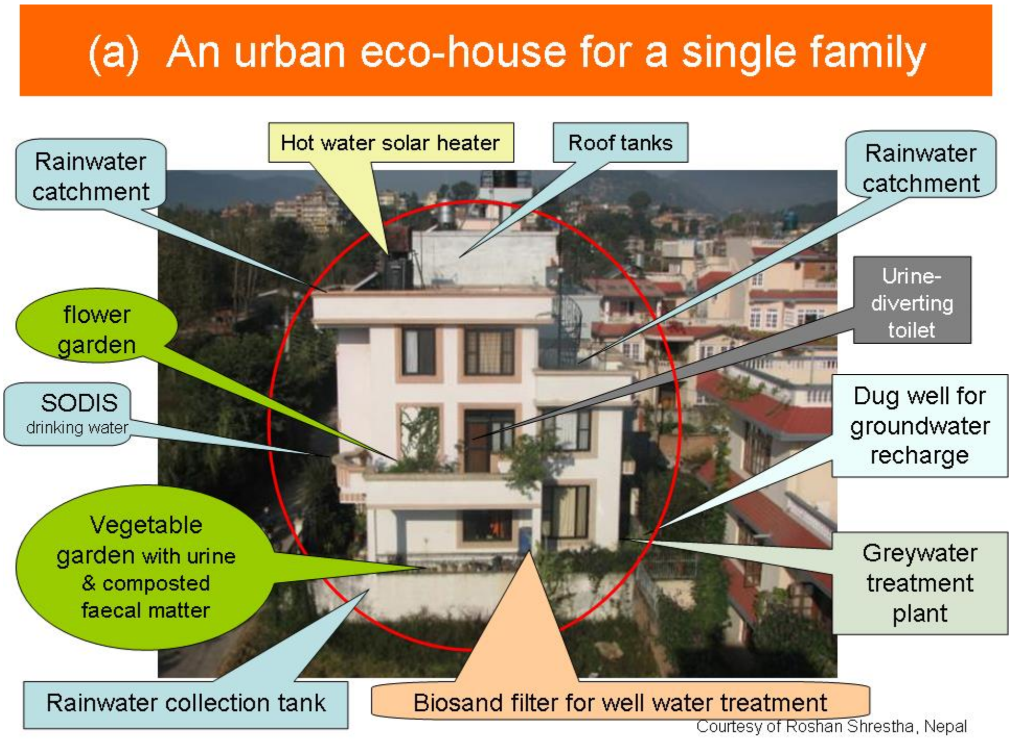
Householders dispose of many used items in sewers and drains. The contaminated water reaches utilities and they try to develop treatments that can destroy or remove the alien items. In the period 1870–1900 new manufactured consumer goods replaced those made of wood and other biodegradables. Households started to dispose of broken glass, tins, and other used products in the latrine buckets. The collection and composting system for excreta became impossible to maintain since farmers did not want to apply broken glass on their fields, and pigs could not survive the new diet. It was also too costly for utilities to separate alien products, and councils failed to persuade households not to dispose of such items in latrine bins. Thus, a fairly sustainable sanitation system had to be replaced by a less sustainable one: the flush toilet became the norm with sewers emptying everything without treatment in rivers and lakes.

During the period 1950–2000 many biodegradable goods were replaced by new chemical products that were not biodegradable. Soap from vegetable oil was replaced by chemical detergents and washing powder, etc. By the end of the century 30,000 chemical compounds were being used regularly by households. Antibiotics, endocrine disrupters and heavy metals such as cadmium were added to the wastewater, and wastewater treatment plants (WWTPs) were overwhelmed by these new compounds. Many of these new chemical compounds were not properly treated before being discharged to water bodies. Also, sewage sludge contained ALL the alien compounds and, therefore, wastewater treatment plants could no longer deliver usable sludge to farmers and so the nutrient-rich sludge went to landfills or it was incinerated. The whole system has to be revised drastically to find a new balance between pollution containment and our chemical society.

Large sanitation systems have the drawback of making treatment processes and effluent quality invisible to residents. Therefore, they are not readily aware of the impact of their waste. Residents have not been partners in addressing the sanitation challenges, because there is no organisation that takes a holistic view of the material flow system. For instance, management in utilities restrict themselves to using their clout to extract more funding from councils to try to "solve" all treatment problems at the plant they run. But this is not possible given the complex chemicals in the waste they receive.

Today's sanitation conditions vary and there are a number of new experiments going on to find more sustainable arrangements. Some of these will most certainly become widely used in the near future. Perhaps the most promising designs are those which are flexible enough to adapt to future changes in material flows and social norms. In the following slides we present five arrangements ranging from individual households to housing complexes and suburbs. They are of particular interest because they provide better sanitation and water services, make residents more engaged and knowledgeable, and save money on bills, and protect the water environment.

2.1 - 4



In the water-scarce capital of Nepal, Kathmandu, the population is growing quickly and the authorities cannot cope with planning or provision of services. They hope to construct a large-scale conveyance of water from a distant river to solve the water-shortage problem. Such supply thinking reduces the task to one of finding enough investment capital. Some innovative citizens are trying other options, however.

In 2002 Dr. Roshan Shrestha decided to build his own house in the city. In a conventional house he would have received tap water from the water utility for less than one hour once a week. To mitigate against low pressure in their water pipes residents install electric pumps to lift the water to a storage tank on an upper floor. As an environmental engineer, Dr. Shrestha knew that the wastewater was disposed of untreated into rivers, together with untreated stormwater. He designed his house to address such shortcomings.

Dr. Shrestha built two underground water tanks before the house was erected, a bigger one of 8 m^3 to collect rainwater for household use and a smaller one of 2 m^3 to store treated greywater. All roofs are flat in order to collect rainwater and he took the precaution of diverting the first flows of water from each shower of rain (to prevent debris from the roof entering the storage tank). The collected rainwater goes to the big underground tank or, when the tank is full, it passes on to a dug well to recharge the groundwater. Water from the dug well goes through a bio-sandfilter before being transferred to the underground tank. From here it is pumped up for household use. Rainwater is treated by the solar water disinfection (SODIS) method, exposed to the sun in plastic bottles for two days, and cooled before drinking.

The greywater is treated in a small vertical-flow reed bed filter (4.5 m^3) and collected in the small underground tank, and used for irrigation of the garden and to wash a car. The fairly dry faeces and paper from the urine-diverting toilet is put on a compost heap to be sanitised while the urine is used straight away in the gardens (WHO, 2006). The compost is later used as a soil conditioner.

Since all the arrangements were planned before the building started, the extra costs were calculated to be only about 3% above those of a conventional house. This extra investment was recovered in some 6 years since there are no water or wastewater bills. Thus, the arrangement earns money for the owner. However, he spends some hours per month to operate and monitor the system. These tasks are minimal because the family does not use products that would defile the greywater too much, since they want to facilitate the sand filtering and obtain a fair-quality effluent. He also has a small vegetable plot and lawn and flowers in the garden. In fact, the household is self-contained and does not burden the environment and nor does it add to the pressure to build a new water intake for the city at very high investment and running costs. And there is no stormwater leaving the compound, to the benefit of the whole community. See article in the Financial Times (UK, October 15, 2005).

It is useful to compare the costs incurred in this system with those of a conventional water supply and sewerage arrangement. If we assume that the total cost for a conventional house is 100 units of money, Dr. Shrestha paid 103 for his. We know that, despite a subsidised water tariff, he saved 3 money units in six years by not having to pay such a bill (the annual water fee is 0.5 money units). The cost of the whole house (100) would therefore be repaid within two centuries if we assume that interest rates and raised fees change at the same rate. The magnitude of return indicates indirectly the often high costs for conventional systems (paid by fees and/or subsidies). This would be a very attractive investment for any household and, at the same time, a neighbourhood with such houses would provide secure supply of water, controlled stormwater and local food production for those who choose to have vegetable gardens.

This is one of the few arrangements that can earn the owner an income over the years. The reason is that large water supply and sewerage systems are likely to be costly.

2.1 - 5

Courtesy of Roshan Shrestha, Nepal

The annual rainfall in Kathmandu is about 2,500 mm, most of it between April and September. The roof area is around 90 m^2, and if all rainwater could be collected, the total would be some 225 m^3. However, some water is lost in the screening of the first rain and if rain is plentiful the tank cannot store all the water, so actual collection is estimated to be 180 m^3. Some 80% of the household water requirement is covered by rainwater, and the rest comes from groundwater that is pumped from the dug well and treated before use. Family members are careful not to waste water and the monthly demand is only 8.4 m^3 or about 60 litres per person and day. This is less than half of what the same-sized family uses on average in Kathmandu. Part of the explanation is that no water is used for flushing the toilet, there is no water leakage in this eco-house, and treated wastewater is used for the garden (38% of total use).

The flat roofs (top-left) have a smooth surface to make them easy to clean and to promote rainwater flow. The pipe for rainwater enters the black sedimentation container (bottom-left) and the water proceeds to the 8 m^3 underground storage tank. The water quality in the tank has been tested and found to be good enough for all purposes, including drinking. During the rainy season excess water is diverted to the dug well to recharge the groundwater. The well itself has a storage capacity of 10 m^3. This serves two purposes: making use of all water during the rainy season and securing the groundwater level when pumping water. Another benefit in this particular case is that it improves well water quality. The groundwater has high nitrate levels that are diluted by the addition of pure rainwater. Top-right is the simple bio-sand filter for treating the water from the dug well before it is used or transferred to the underground water tank.

The arrangement also ensures that almost no stormwater leaves the plot. This compares favourably with septic tanks and untreated wastewater from the rest of the city.

(a 2) Waterless and odourless urine-diverting toilet

2.1 - 6

Courtesy of Roshan Shrestha, Nepal

Urine and faeces are kept separate in the porcelain toilet, and no water is used for flushing the drop hole or urine bowl. The urine is collected in a container (black drum on top of the blue drum) with a tap and is used to fertilise the small garden. The WHO guidelines say this is acceptable and recommend applying the urine directly on soil, not on leaves, and preferably not closer to harvesting time than one month (more in Ch. 3). The application and efficiency of urine as a fertiliser is dealt with in Ch. 4.

Faecal matter and tissue paper drops through the chute into the green wheelie bin. Since only two persons in the family use the dry toilet, the bin fills up slowly in four to five months. When full it is swapped for an empty one and moved outside to dehydrate for some months (right). The pathogen die-off depends on the efficiency of storage, but after 1–2 years it is safe to apply in the garden (WHO Guidelines 2006 and Ch. 3 in the sourcebook). Some of the stored faecal matter is also mixed with composted kitchen waste, and this co-composted material is used as a soil conditioner.

The pictures of this system were taken some years after the house was finished. A lot of technical and design development has taken place since then, but the principles remain the same. The main breakthrough is that the toilet is situated inside the house in a modern toilet room next to the master bedroom where you would expect to find a flush toilet. There is no smell and no flies.

There are many different designs of urine-diverting toilets as well as of the collection systems and recirculation to farmland (Module 5.5). Some examples are shown in the following.

2.1 - 7

(a 3) Gardening with greywater, urine and composted faecal matter

Reed bed for treating greywater that is recycled on the terrace

Lawn and flowers on terrace garden

SODIS treatment of drinking water

Courtesy of Roshan Shrestha, Nepal

The building occupies 90 m^2 of the total plot of 135 m^2, and the small garden provides vegetables and also pleasure and a safe place for the children to play (top right).

The open ground is covered with a lawn, a kitchen garden and bushes and flowers (top right). The family has also established a terrace garden. They grow tomatoes, radish, beans, salad greens, carrots, pumpkins, and fruit trees including guava and citrus. Urine and treated faecal matter are regularly applied as fertiliser and the householders also water and fertilise with treated greywater and other nutrients from the household.

Household greywater is treated in a small wetland with reeds (left) and used for all outdoor activities such as irrigation, watering the lawn and flowers, and washing the car.

The SODIS treatment of rainwater comprises keeping half-full pet bottles in the sunshine for a day or two (bottom right). The exposure to UV-radiation kills off bacteria and possibly most viruses. For this to happen, the rainwater must be clear with no visible solid particles that could prevent the radiation from exposing all living organisms. The high temperature of the water is part of the treatment since, for instance, all microorganisms will perish within three days if the water temperature is above 45^{o}C (Feachem, 1983). Some case studies about SODIS are available on the Eawag/Sandec website http://www.sodis.ch/Text2002/T-Projects.htm. Latin American experiences (mostly in Spanish) are available from the SODIS Foundation: http://www.fundacionsodis.org/.

(b) Self-contained neighbourhood with six houses in a small town in Australia

2.1 - 8

Courtesy of Garry Scott, Compost Toilet Systems, Mullumbimby, Australia

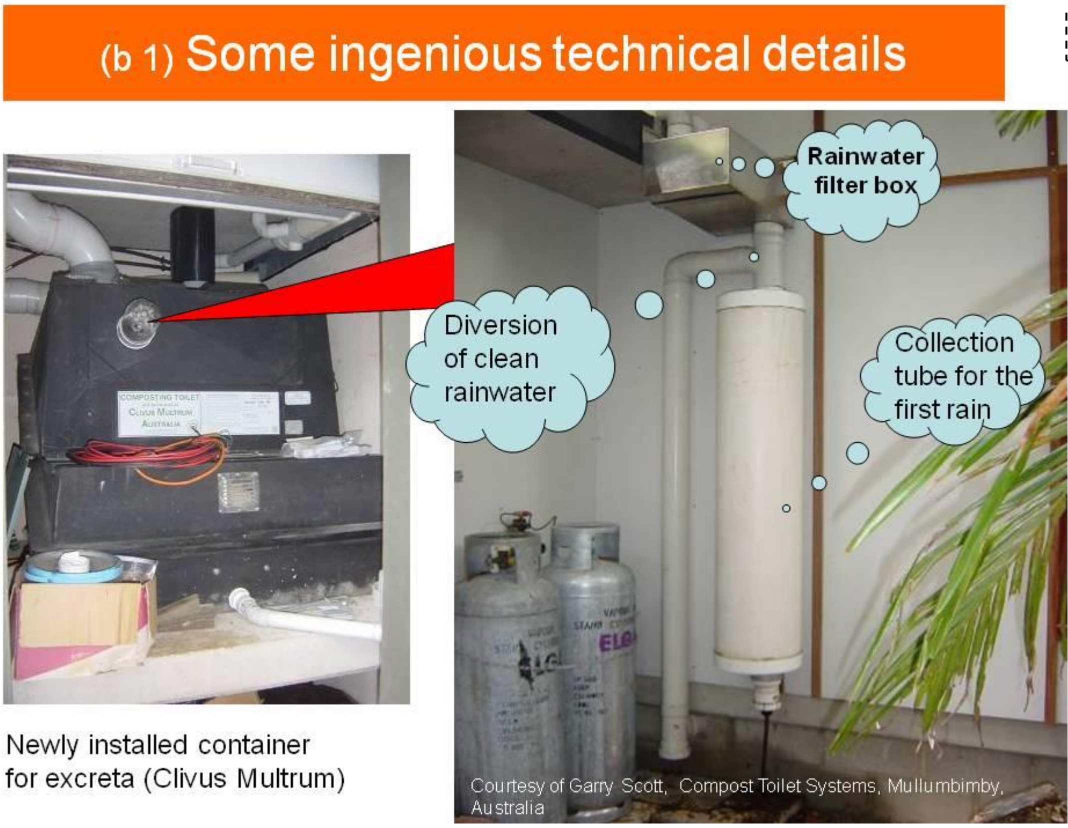
Six families purchased a piece of land to build six new exclusive homes in a small town (Byron Bay) in Australia north of Sydney. They were a group of professionals with an interest in sustainable living and with lots of green ideas. Municipal water and sewer pipes were next to the plots, but the families did not want to connect. They applied for permission to use rainwater as their water supply and to treat their wastewater and use it in their gardens. The council took two years to – reluctantly – accept the proposal on the condition that it was an experiment, so that no one else could refer to it as a precedent to justify building similar houses.

The roofs were enlarged (see picture) to send more of the annual rainfall of 2,000 mm into a 30 m^3 storage tank under each house. A simple device (next page) diverts the first water of a rainfall to avoid debris going into the tank. The collected rainwater is enough for the whole year since residents do not waste water. They know their supply is limited, and they practise conservation “automatically”. Water for drinking is extra treated in a small treatment unit under the sink in the kitchen which is run on electricity.

They installed waterless toilets (a kind of Clivus Multrum) so wastewater does not contain urine or faeces and is easy to treat. The greywater is treated in a horizontal-flow wetland (20 m^2) with papyrus and other water-demanding plants (in front of house). This unit services all six households. The effluent quality is good with BOD concentration of 5 mg/l and P of 0.1 mg/l, which is better than for water from the town wastewater treatment plant. They store the effluent in two 22 m^3 tanks for irrigation in the dry season.

The fancy porcelain toilet allows excreta and toilet paper to fall down into a big plastic container in the basement (bottom right). The container has a slanting interior floor which makes the pile move forward so that it is easy to empty. Also, if for some reason there is excess fluid in the container, this flows through the white pipe to a treatment unit. Each family is responsible for managing the dehydrated material and uses it in the garden as a soil conditioner. Needless to say, the toilets are odourless.

The arrangement requires little maintenance since it is monitored with an electronic control panel (bottom right). The cost for the arrangement was no more than for an ordinary house and this can be achieved when building from scratch. The payback time for the water and sanitation installations is 7–8 years, since the residents do not pay any fees for water and wastewater.

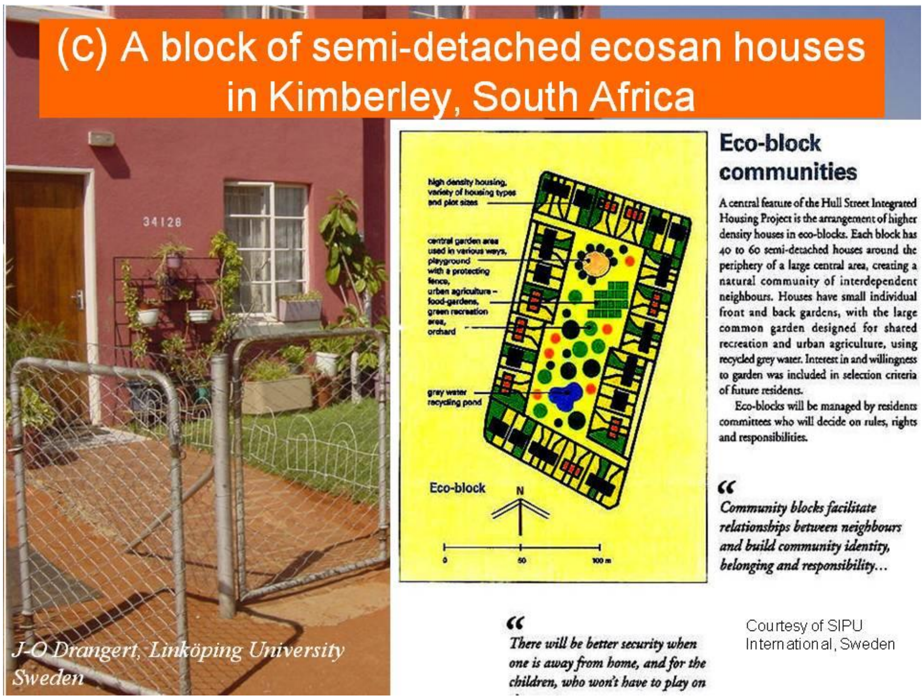


2.1 - 9

A worldwide experience is that the traditional fly screen on a toilet ventilation pipe is corroded by emitted gases. After a year there is no screen and the flies can fly in and out as they like. Often, there is no replacement available. A simple and easy alternative to monitor and get rid of flies is shown in the left-hand picture. A transparent plastic bottle cut in two has been inserted in the chamber wall. The upper part of the bottle is fixed in the wall from the inside, and the bottom of the bottle is attached from the outside. The flies in the chamber are attracted by the light and enter through the top of the bottle, only to be stopped by the bottom part. They cannot easily find their way back to the chamber and starve to death. They are easily removed by shaking the bottom part of the bottle. This fly catcher helps to monitor the chamber, since large numbers of flies is an indication that the material is too humid and/or that the ventilation is not working properly.

The first rain washes away whatever has been deposited on the roof, be it bird droppings or debris. None of these contaminants should enter the rainwater storage tank, and have to be removed. The device is a simple one. The rainwater flows to a filter box where debris is trapped, but not the small impurities (see picture). The first rainwater is collected in a 2 m vertical tube (right). A plastic ball floats on the water inside the tube and when water rises the ball will block the entrance of the tube, preventing more rainwater from entering. All subsequent rainwater is therefore forced into the smaller pipe to the left, which leads down to the storage tank under the house. The water in the tube slowly empties through the tiny black pipe at the bottom, so that by the time the next rain comes, the tube is empty and the process repeats itself. This is a self-managing device that has to be cleaned once or twice a year, and the filter box more frequently.

These houses are cheaper to run than conventional houses, and instead the owner has to carry out some tasks him- or herself. In this case a well-functioning utility loses customers, and this is one reason for municipal reluctance to give permission for the arrangement. Utilities in rapidly expanding cities may, on the other hand, not be able to supply good services and residents have to cater for their own sanitation needs anyway.



2.1 - 10

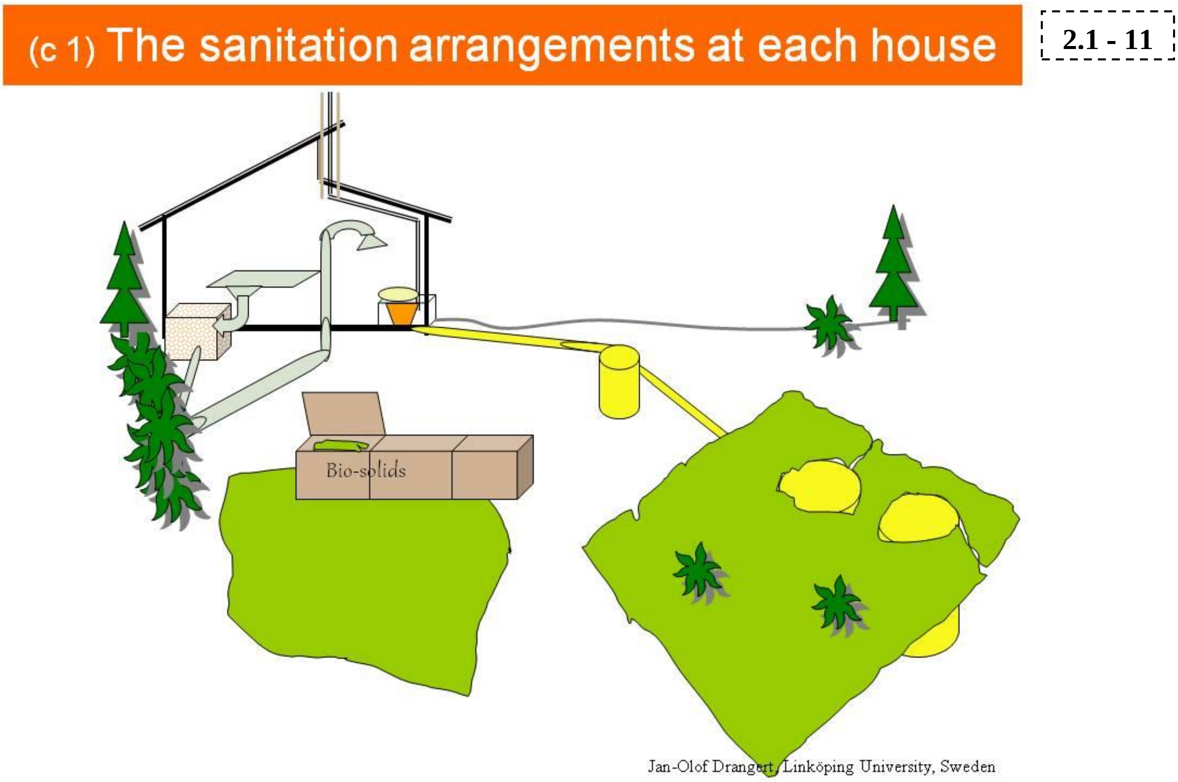
The Hull Street Integrated Housing Project is an entirely new town district in the centre of Kimberley in South Africa. The area, which used to belong to the diamond industry, is now owned by the municipality, and 2,500 houses are planned for the Project. Hefty government subsidies make it possible for families with low and medium incomes to move in. The objective is to build houses with sustainable sanitation and low water use, and to create a new urban settlement that promotes a sense of community and supports a more integrated society.

The one- and two-storey houses are supplied with communal water since there is no safe groundwater available (due to this being an old mining site) and the annual rainfall is only 400 mm (evapotranspiration is 2,100 mm) and is not enough to be the sole source of household water. Municipal water is pumped from the Vaal River 15 km away and at 30 m lower altitude.

Each household in South Africa is entitled to 6,000 litres of free potable water per month and they are only charged for the amount they use in excess of this. The daily water use in the affluent city of Kimberley is 190 litres per person, of which 115 litres end up in the sewage treatment plant, while much of the rest is used for watering private gardens. The water use in Hull St is much less – only some 50 litres per day because the residents do not want to pay for water and because they have waterless toilets and only small gardens.

Increasing demand for fresh water is not considered a constraint for expansion of the city, but the need to dispose of wastewater is. The two wastewater treatment plants are overstretched, and the effluent is discharged in Kamfersdam, which is a sanctuary for flamingos. Most of the dam water evaporates and there is great concern that pollutants will accumulate in the dam. The Hull Street project was encouraged to look for water-saving arrangements. The chosen solution in 2001 was urine-diverting indoor toilets and the productive use of treated greywater.

The council remained reluctant to make the necessary investment to expand and improve the plants due to the high costs involved. But, when the Ministry of Water (DWAF) imposed a moratorium on new sewer connections in 2009 the decision was taken to set aside 120 million Rand for this purpose. If the plants are upgraded, the promotion of dry sanitation will become more difficult. An alternative could have been to give all Kimberley households an expensive urine-diverting toilet (next slide), thereby reducing the contamination of the wastewater and removing the need to expand the treatment plant! At the same time, the demand for water would go down 30–40 %, and the saved water could be allocated to farmers or future town-dwellers.



Kimberley is situated in the highlands, some 1 200 m above sea level, and has an average of 9.4 hours of sunshine per day throughout the year. This is perfect for solar energy. But this also contributes to sharp temperature differences between day and night which creates problems for the natural ventilation of bathrooms (slide 2.7-6). In the Hull Street Project the vent pipe is indoors (picture) to maintain warmth in the night, and the section above the roof is insulated (brown colour) for the same reason. Thus, the warm air flows upwards since it is lighter than the air above the pipe, and the speed increases if the wind blows (creating an under-pressure that sucks out the air from the pipe). The air flows in the pipe, sucking air from the chamber and, eventually, air is sucked from the bathroom through the toilet chair drop-hole. However, if a section of the vent pipe is exposed to cold air, this section of heavier air may block the pipe.

Ideally, a vent pipe has no bends, since they slow down the velocity of the flowing air. In Hull St a reasonable balance between ensuring high air velocity and minimising the risk of rainwater leakage where the pipe penetrates the roof has been achieved by permitting two bends each of 45 degrees – not 90 degrees. However, had the toilet chair been placed along another wall in the bathroom, which also faces the garden, they could have avoided all bends! More details on ventilation in Module 2.7.

The original aim for Hull Street was to close the flows of water and of nutrients. The volume of greywater is modest; mostly less than 200 litres per day from each house, and is treated in an infiltration bed along the hedge fence. The kitchen water is pre-treated in a grease trap (light brown box) where the warm water will cool down and grease/oil/fat floats up. Also, crude organic matter is screened and removed, while microorganisms will start to decompose smaller particles. The greywater flows to irrigate the hedge (subsurface), but the soil has low infiltration capacity, so most treated greywater probably evapo-transpires through the leaves of the hedge.

The urine from each dry urine-diverting toilet and urinal flows by gravity to an underground plastic storage container (yellow) from where it is drawn or pumped to be applied as fertiliser. It is also possible to connect the urine tank to a water hose in order to avoid touching the urine. The running water in the hose creates an under-pressure in the urine pipe that sucks up the urine. Plants are watered with the water-urine mix. If the hose is kept close to the soil surface, this method prevents the waste of the nitrogen content of the urine.

Households not interested in gardening just let the urine flow over to two underground tanks in the common area (see map), from where it can be collected by anyone. If no resident is interested in using urine as fertiliser, it is collected by a council vacuum truck and applied on sports fields and city gardens.

Faecal matter is brought to a nearby composting station (200 m away) either by the householder or, if they prefer, by a small-scale entrepreneur for a small fee. Again, if a householder wants to engage in gardening he or she can use the composted faecal matter as a soil conditioner. But, and this is important, they can from one day to the next stop using the compost and/or urine without causing any harm or expense. They can also start using the compost material or urine any minute with no costs incurred! This flexibility allows residents to stay on if they get sick or, if they want to leave, can sell the house also to someone who is not garden-minded (Drangert et al., 2006).

The next picture shows the installations and how the residents use the system after some ten years.

2.1 -12

The urine-diverting toilet stands on the bathroom floor, and the bucket inside is pulled out from outside the house (previous slide and slide 2.7-7). This design was developed by the community in collaboration with a manufacturer, and it is called “the odourless Kimberley model”. An entrepreneur has access to the bucket even if the householder is not at home. The bucket is removed weekly to avoid smell, to ensure fly eggs do not have time to hatch, and so that the bucket is still light enough to be lifted easily. The residents are satisfied with the toilet. The slightly dehydrated faecal matter is brought to a composting unit where it is mixed with horse manure and straw (slide 2.6-8). When matured, the composted matter is taken back to the gardens. Gardens are lush despite the originally poor soil with very thin topsoil.

Unfortunately, the urine from the toilets and urinals cannot be collected easily due to installation errors, and most of it goes out together with the greywater to water a hedge.

The greywater arrangement in Hull Street does not provide an opportunity to use greywater in the garden, only for the hedge. However, households with washing machines and those washing outdoors let the used water out directly onto the garden (picture).

The variation in monthly household water use between households is extreme, ranging from 1 to 60 m^3. The housing company staff does not know whether the households are being billed or not, since billing is done by another department. One interpretation could be that the housing company actually appreciates overuse since an overflowing yard constitutes a persuasive argument to install a centralised sewerage which the company management would prefer. The fact is that big users are not billed and could continue to overburden the small greywater treatment/infiltration units. The result is damp ground and even backflow into their bathrooms. The big water users certainly know this consequence and the very few who overburden the system claim that the greywater infiltration pit is too small, and that they want a sewerage system installed. They hope that being connected to a sewerage system would increase the value of their property, enabling them to sell the originally heavily subsidised house at a nice profit.

(d) Eco-blocks in water-scarce Erdos, China

2.1 - 13

Source: Zhu Quiang 2008

Erdos Eco-town is a large-scale housing project which initially comprised 800 flats in multi-storey buildings erected in 2004–05. The driving need in Dongsheng District where Erdos is situated was to find a water-saving arrangement in this dry area with only 300–400 mm rainfall and a falling groundwater level. Water is supplied from surface water and groundwater (currently from 30 m deep wells). The demand for water in Erdos town already exceeds the supply by 20%, and water is rationed and available for an hour or so three times per day. The shift from public pit latrines to private flush toilets has provided one-third of the population with flush toilets, but has caused water sources to dwindle. Water scarcity is the stick that made the council to go for a dry toilet system which could cut water use by one-third. Note that this is a bold step in a country where a city can only acquire the status of Sanitary City if more than 80% of the inhabitants have access to a flush toilet.

The new eco-town has its own sanitation system with collection, composting and use of faecal and organic matter, storage and use of urine on nearby farms, treatment of greywater and use in gardens, and sorting, collection and use of other solid wastes. By 2008 the eco-town comprised 42 buildings with 832 apartment houses and a population of about 2,900.

The Government is responsible for building roads leading to the project site, for a surrounding road, for lighting and for the construction of a public transportation system. It also contributed with low charges and fees, such as fees for the sale of land and planning support for the EIA approval fees. The Government is also responsible for maintaining the ecosystem, while the construction company is only responsible for normal property management. The residents sign an agreement about the sustainable arrangements and proper use – of dry toilets in particular. They will also receive further training.

2.1 - 14

All sanitation arrangements are indoors and pipes go deep into the ground, since the winter lasts for six months and only one-third of the year is frost free.

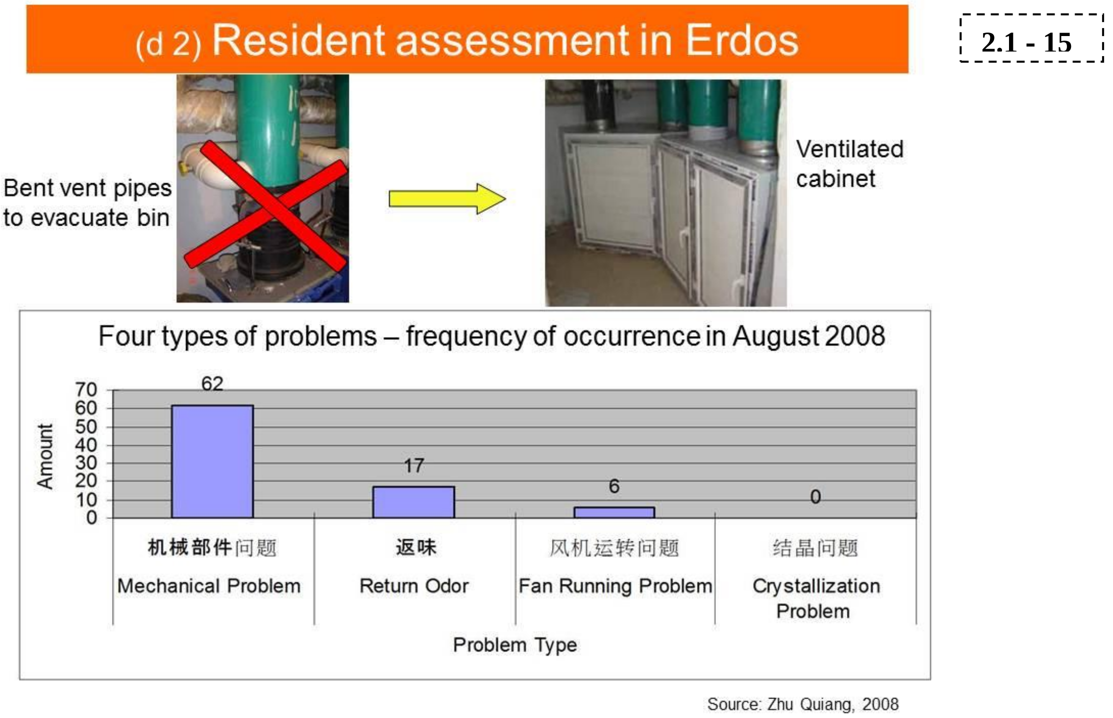
All the flats have a waterless urine-diverting toilet of porcelain (see pictures). They have been developed by the project and are manufactured locally. The "water" cistern has sawdust in it, which is sprinkled on the faecal matter before it drops through the shaft into the receiving blue wheelie bin in the basement. The bin is collected regularly by municipal staff and brought to a compost station nearby. Here, the contents are hygienised at a temperature of about 50 ^{o}C. The treated faecal matter contains no pathogens and is used as a soil conditioner.

The urine is collected in a temporary underground tank, before being taken by neighbouring farmers who fertilise their fields with urine instead of chemical fertilisers.

The large volume of greywater from kitchen, shower and washbasins is piped to a treatment plant. The pipes are laid 1.5–2 m deep to avoid freezing. The effluent is stored in a pond together with stormwater, all of which is used to water the green areas.

The residents own the flats and are expected to take care of their share of the faecal matter handling. A company is engaged to collect the urine, faeces and greywater from the houses and bring them to the sites set aside for treating them. The company also manages the various treatment units, while farmers are expected to come and collect the composted material and urine. The experience so far from this innovative project is that water is saved as planned.

The first residents were offered the flats at a subsidised rate in order to promote water saving and recirculation of nutrients (Flores, 2010). The highly educated residents entertain a positive perception of excreta recycling and local food production using treated urine and faecal matter (Gao, 2011). However, soon the residents found themselves surrounded by the expanding city connected to water supply and conventional sewerage. At the same time, they experienced technological shortcomings of their own water and sanitation installations. These changed circumstances lead to a switch to conventional flush toilets in 2010 (Rosemarin et al., 2012).



A survey conducted in August 2008 showed the kinds of problems residents faced during the first few years (Zhu, 2008: see graph): 62 % had mechanical problems with the toilet ‘flushed’ with saw dust, only 17% had sensed bad odours from the toilet, 6% had fans not working all the time (break down or energy cut), while no one had experienced crystallization in the urine pipe.

The construction company and some consultants formed a task force to identify the causes of the problems and to find solutions. Two major technical challenges have been tackled. The first relates to getting an airtight connection between the chute and the wheelie-bin to prevent bad odours in the storage room and potentially in the flats. After some trials with a spring, and later with a heavy locking mechanism, they finally decided to install a fire-proof cupboard or cabinet. The chute is permanently fixed to the cupboard, and the cupboard door is opened to remove the wheelie-bin from inside (upper right). It proved to be easier to make the door airtight rather than sealing the connection between the chute and the wheelie bin.

The second design challenge concerns ventilation (slide 2.7 - 6). Ventilation turns out to be a difficult problem in all places where air is to be removed – not just in situations involving sanitation. The aim when designing ventilation systems should always be to use natural ventilation as much as possible. If this is done, we get a design that will work partially even if there are energy cuts to the forced ventilation. There are some basic rules of thumb for natural ventilation: avoid 90-degree bends and horizontal piping. The double 90-degree bends shown in the left picture reduce the air-flow by almost half. The vent pipe with a diameter of 160 mm has the least friction for the air, and it should extend 1.5 m above the highest point of the roof. Be sure to insulate the vent pipes in cold climates and areas where there is great variation between day and night temperatures. Otherwise, the chilled heavier air in the pipe will block the passage of lighter warm air. Do not connect vent pipes from several cupboards or faecal storage vaults because this may cause unintended back-flow of air and smell. Such a connected system gives rise to different drafts in the pipes. Another problem relates to the position of the electric fan. Remember that it can suck paper out of the bin, and plastic bags thrown in the chute may block the vent pipe completely.

(e) High-rise housing complex in the water-scarce city of Bangalore, India

2.1 - 16

J-O Drangert, Linköping University, Sweden

The rapidly growing Bangalore City in India has almost 6.3 million residents (2005) and faces the challenge of water scarcity. The water intake at Cauvery River is 100 km away and its altitude is 500 m below the Bangalore's, which means that much energy is required to pump the water to the city. The water has very high energy content. Residents face erratic water-rationing with supply for only some hours per day. Many private house owners have drilled a well on their plots to secure water, and already the many thousands of wells cause over-abstraction of groundwater. But the city continues to grow and new resource-saving ideas are to being implemented (Drangert & Sharatchandra, 2012).

New housing blocks springing up on the city periphery contain hundreds or thousands of flats (see picture). The well-to-do residents pay more than US$100,000 for a flat and they expect to have a regular supply of water. However, the authorities cannot provide that service, and since 2006 builders have had to prove that they can save on water. If not, they do not receive a building permit. The only untapped permanent water resources are rainwater and treated used water. Despite this, some people still hope to tap more water from distant rivers. The rainfall is some 900 mm per year, and rainwater collection can make a useful contribution for high-rise buildings. However, the focus here is on the interesting treatment and use of used water.

The flats in new housing complexes have water-saving dual-flush toilets as standard. Hotels are requested to install waterless urinals, but so far there is no regulation about installing waterless toilets in flats. The new housing complexes have a mini-version of a conventional wastewater treatment plant in the basement which receives all the wastewater and, after treatment; some of the effluent is pumped back to the apartments in a separate pipe to be used for toilet flushing. A portion is also used for watering the gardens. The energy saving is huge, since the flush water is already on site and does not have to be pumped 100 km plus 0.5 km uphill. All water for flushing has to be pumped 30–40 meters up to the top floor. Residents appreciate not having to worry about a lack of flush water for the toilet.

The challenge for the operator of each building's wastewater treatment plant is to keep effluent quality high (colourless and odourless). The carrot and stick becomes very real in a decentralised system like this. The operator of the plant knows all too well that he cannot deliver smelly water for toilet flushing on any occasion, since the complaining residents will line up at the office immediately. This is very different from big treatment plants where operators will hardly ever meet affected people – and nature has no voice. The complicated operation and maintenance (O&M) of such mini-WWTPs (wastewater treatment plants) cannot be left to the residents, and money is allocated for the O&M contract to an accredited firm. The operator's main worry is to ensure odourless and colourless effluent.

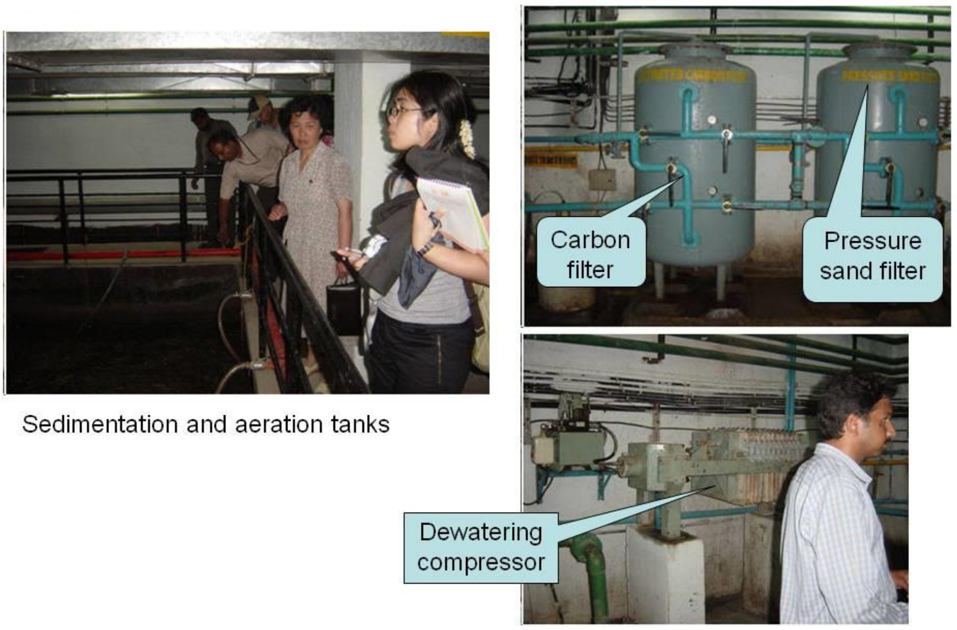
Since there are already 60 such mini-plants in housing complexes in the city (2008), there is a growing demand for trained operators. The State Pollution Control Board is preparing to train operators to be employed in upcoming complexes. There are also older housing complexes with no mini-treatment plant, facing the problem of resident complaints about water rationing and having no water for flushing. They now want to build mini-WWTPs as retrofits.

The average water volume supplied to the complex on the picture is 135 lpcd (design value) and 50 lpcd is recycled for flushing. Thus, the water saving is about 35 per cent without any changes in resident behaviour, only technical interventions. However, changes in behaviour such as choice of detergents etc. will become an issue if wastewater is to be treated to drinking water standard. The city water supply is complemented by another 25 litres during the monsoon season and coming from three drilled wells. At this stage some of the treated water is sent back through the sewer to the city wastewater treatment plant, while waiting for using this water in communal gardens. The next possible development is indicated in slide 2.1-19.

The benefits to the Bangalore Water Supply and Sewage Board are that it is relieved of supplying 40% of tap water and it only receives a small volume of already treated wastewater. Also, the over-abstraction of groundwater is not compounded. The residents benefit from a more reliable water supply, and it comes at a cheaper rate.

(e 1) Mini-wastewater treatment plant in the cellar

2.1 - 17



J-O Drangert, Linköping University, Sweden

The mini-WWTP occupies some 200 m^2 in the basement (alternative use of this space is to extend the garage) and comprises sedimentation and aeration tanks, sand, carbon and UV-filters, a chlorination unit before reuse, and also a compressor to dewater the sludge.

The wastewater enters by gravity from all flats, and daily some 220 m^3 is received. The sedimentation tank has a volume of 73 m^3, and the retention time in the mini-WWTP is 8 hrs. Initially, a flocculent is added to improve sedimentation of particles, and the water then flows to the aeration tank (130 m^3) where some 400 m^3/h of oxygen is needed to break down an estimated organic load of 77 kg per day. The sludge is collected in the subsequent secondary clarifier and pumped to sludge-drying beds with an area of 30 m^2. The next process step for the effluent is a pressurized sand filter which removes particles over a certain size. The filter is back-washed automatically every two hours. Thereafter, a carbon filter removes some e.g., metals. The chlorination is done as a precaution to prevent later re-growth of algae in the toilet cisterns. The quality of the effluent water is quite good for the measured parameters (next slide) and the residual chlorine level is less than 2 ppm.

The amount of wet sludge is small, about 40 kg per day which is reduced to 10 kg after dewatering. The sludge quality is rated to be good, mainly because no industrial wastewater is involved. It is applied as soil conditioner in the garden.

The investment cost for the whole technical system, including the mini-WWTP and dual pipes, is 45 million rupees or US$1 million. This amounts to R 100,000 per household which is about 2% of the purchase price of a Rs 4.5 million flat. The households pay some Rs 60,000 per month for the services to treat all its wastewater and another R 70,000 for energy to run the mini-WWTP, which corresponds to an average of Rs 300 per month per household. This amount is about equal to the heavily subsidised communal water and treatment, which costs about Rs 250 for some 20 m^3 per month.

The administrative and legal process is innovative and corruption proof. The builder has to set aside the equivalent of the building cost for the mini-WWTP at the bank account of the State Pollution Control Board before getting a building permit. This amount is paid back only after the final inspection of the plant is done. The builder has no reason to bribe the inspector since the builder will get the money back if the inspector is satisfied with the unit.

(e 2) Experiences and future trends

2.1 - 18

Item	Unit	Mini-wwtp	WWTP in the city Incoming	WWTP in the city outgoing
Colour	-	none	na	
Odour	-	none	na	
pH	-	7.4	6.9	7.85
TSS	mg/l	24	292	6.0
TDS	mg/l	844	Na	
FOG	mg/l	nil	Na	
COD	mg/l	25	540	32
BOD	mg/l	4	310	6
DO	mg/l	n/a	-	4.3

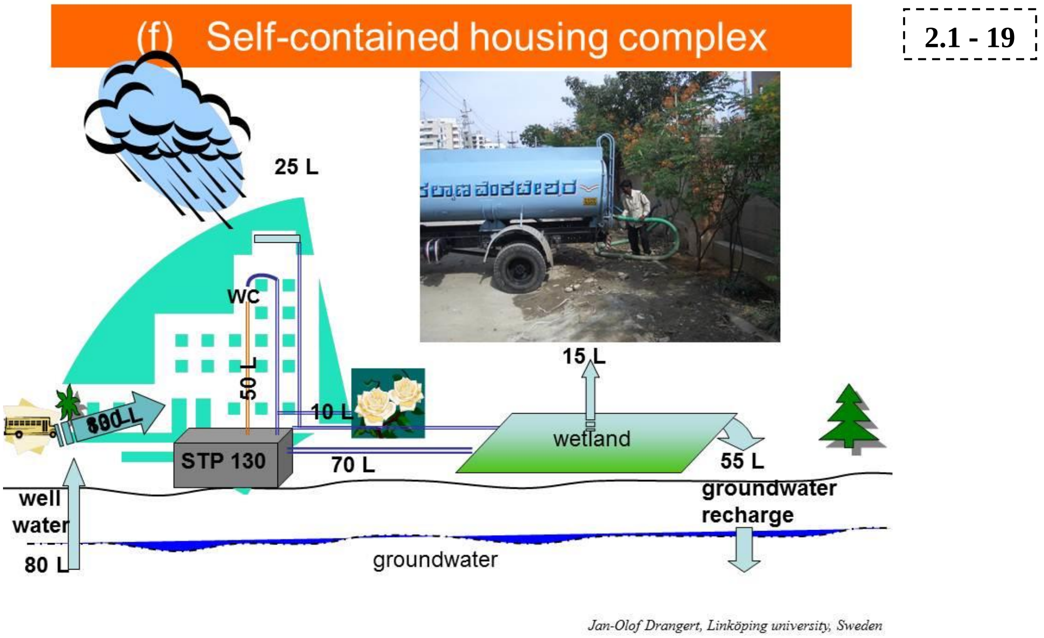
Ganesh Consultancy & Analytical Services, Bangalore (Mini-WWTP)

Government regulations require every wastewater treatment plant to self-monitor its performance, and to regularly forward a report to the State Pollution Control Board. The Board can also take its own samples as part of its responsibility to oversee the WWTP performance. If inconsistencies are found in a WWTP reports, the plant will be monitored more closely, and if the effluent quality does not meet the standards, the management can be fined and in serious cases the unit can be closed down. This has occurred on one occasion for a city WWTP.

A test protocol (picture) from the housing complex shows effluent that is colourless and odourless and contains no fats or grease (FOG). COD and BOD values are within the required standards and are lower than at the city WWTP. The amount of total suspended solids (TSS) is higher than from the city WWTP which is surprising. The given reason was that the carbon filter had not been changed. The efficiency of the mini-plant is comparatively good, although only few parameters were measured. A more stringent comparison should be made in order to be able to make general statements (see Module 4.5). The quality of the effluent allows it to be used to flush toilets as well as for landscaping, irrigation and groundwater recharge.

However, we need to understand the long-term effects of reusing 80% of wastewater for toilet flushing and gardening. In principle this practice is no different from ordinary river water which contains diluted effluent from upstream cities. However, in the case of mini-WWTPs the frequency of the reuse is greater. There is a risk of some accumulation of heavy metals and other compounds, but it is less in a decentralised unit as will be discussed in the greywater modules 4.5 and 4.7. The precautionary principle suggests that we should not go for drinking water quality unless the treatment is improved, and in the meantime use bottled or well water for drinking.

As always, the most important measure to secure good-quality effluent is to be careful with what is added to the water while using it. If households use only biodegradable detergents and washing powders, this will prevent lots of chemicals from being introduced into the system. The residents' contributions are still untapped and the above results have been achieved only through a technical arrangement. This will become an issue when you want to treat the water to achieve a higher level of purity. In the next phase the residents will be informed about the effects of various products that they use and dispose of in the water.



There is no water shortage in urban areas. The planning approach to make water demand and supply match each other needs to include the use of recycled, recently used water, groundwater, and rainwater. These are all locally available water resources which require little energy to tap into. Rainwater collection will also contribute to improved stormwater management.

The picture shows a proposed initiative aimed at helping the Bangalore housing complex to become economically, ecologically and socially sustainable. The proposal builds on the principles developed in Nepal (slide 2.1- 4). The wastewater is already treated in a mini-WWTP to make a high quality effluent with no odour or colour. It is pumped for toilet flushing (50 L per capita per day) while, say, 10 L pcd would be used for irrigation.

An improvement would be to let the remaining 70 L go to a horizontal-flow vegetative wetland for polishing (picture). In the wetland, some evapotranspiration would occur, say 15 L, and the remaining 55 L would be diverted to groundwater recharge wells. Rainfall over the whole compound adds 25 L pcd to groundwater recharge. At some distance from the recharge wells 80 L pcd of groundwater would be pumped up to a modern water treatment unit (involving ozonation or reverse osmosis) which would provide the households with good quality water safe for all household uses. This system will also take care of the potential accumulation of pollutants from frequent reuse since it would have been polished and also filtered during the travel through the ground and finally hygienised in the water treatment unit.

Some rainwater could be collected from roof tops and fed directly into the water treatment unit or to washing machines, since this soft water requires little washing powder.

If the proposed system is installed there will be no need to import/buy tanker water, and nor would any wastewater or stormwater leave the compound.

The investment cost for this project would be less than 5% of the cost of the housing area and it would add to the operation and maintenance costs. The arrangement can easily be modified to suit local preferences. For instance if dry toilets were installed the amount of sludge from the mini-WWTP would go down and urine and composted faecal matter could be used in the gardens and/or for agriculture in the neighbourhood. Dry toilets would also reduce the water requirements by some 40% which would help lower the cost of operation. It would also reduce the size of the area needed for the wetland and the mini-WWTP. The local situation determines what combination of demand management (water metering), rainwater, and recycling would suit the local population and their physical and economic status.

2.1 - 20

The recycling of water and nutrients proposed in the previous slide could be extended to greening the apartments. As an antidote to the rural exodus to cities, some city dwellers try to bring back a green and productive city. This time as vertical gardens attached to multi-story buildings and roof-top gardens. Some driving forces to reintroduce plants for local food production is to combat emissions and reducing energy demand. In the European Union, buildings alone contribute 40% of the total carbon dioxide emissions. If part of the heating and cooling of houses could be done using vegetation there is reason to believe that ecological living could take on in popularity. For instance, an office block and shopping centre in Harare (Zimbabwe) was designed as a termite mound to maintain its temperature within a range of a few degrees, despite external fluctuations from 5C – 30C and using just 10-20 % of the energy that a similar block would use for air-conditioning (Pawlyn, 2011).

9 m tall oak trees growing on balconies (picture above) of 27-storey buildings in Milan (Italy) provide shade, cooling and dust reduction in the summer, and allow light in the winter when the leaves have fallen (Financial Times Weekend 8/9 October, 2011). Had the apartments been individual houses, it would require 5 ha of land and 1 ha of woodland. Another development is to grow food on roof tops in added soil as in New York and London (Goode´s Greenpoint Garden). The soil can be replaced by nutritious water (hydrophonic agri, see Module 4.8) that can increase the yields 5-10 times while using less than 5 per cent of the water of soiled-based farming (Sky Vegetables). "Growing walls" with plants pitted in the porous concrete walls are spreading from small houses to high-rise in Sao Paulo (Brazil), while this type of tapestry of plants fixed to an external wall has become a fashionable cladding for boutique hotels and shopping centres. For more information about potentials to greening cities, search for example the internet webpages: London vegetable garden; Sky vegetables; Skyscraper farms.

These examples may foreshadow a new era of amalgamating urban and rural features in an efficient way. This goes together with health and safety legislation and planning laws. In the UK, informed by low-carbon policies, city authorities are starting to consider measures to promote the development of roof gardens. In cities such as New York tax breaks are available for building owners who invest in green roofs while authorities are starting to revise floor area ration zoning laws that currently limit the development (FT Weekend, April 24/25, 2010). In addition to providing a lifestyle and food products, access to open green spaces and views can increase the value of the property.

2.1 - 21

The five sustainable projects outlined above show a variety of combinations of sanitation arrangements. Given that most environmental problems are caused by untreated waste and wastewater, the focus is on organising the arrangements so that treatment becomes easy. It is obvious that the fewer flows we mix, the easier it is to treat each one since we know quite well what to reduce or take away. And we also know the content of the resulting sludge!

If faeces are not mixed with anything else the most problematic pathogens will not enter the other flows, thus making them safer. According to the WHO Guidelines of 2006 there are several affordable and safe methods to handle and treat faecal matter (see Chapter 3). When it is kept separate from faeces, nutrient-rich urine can be collected and used in agriculture with few restrictions.

Toilet water (flush water containing faeces and urine) can be used to produce biogas.

Greywater, which is household wastewater that does not contain toilet water, has a lot of components from household items such as detergents, shampoo, wasted medicines, paint residues etc. but is still manageable as long as it is not mixed with industrial wastewater. Much of the industrial wastewater is already treated by industry in order to recover compounds that can be reused.

In most cases mixing stormwater and sewage is a bad idea since the volume increases, and treatment efficiency is reduced. Increases in volume can also cause treatment plants to overflow temporarily. Such events can lower the treatment results significantly (see Lake Dianchi, slide 1.3-16).

Organic waste often makes up more than half the volume of solid waste from households, and can be used productively either to make soil conditioner or energy.

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People have always been obliged to manage excreta, greywater, stormwater and solid waste with the resources available to them. They may have focussed on requirements such as ‘no smell’, making the waste less visible in the house, using organic matter for agriculture, being modern, and complying with bye-laws. Sophisticated technologies have emerged over the centuries, but the underlying principles have long been understood. The Prophet Mohammad made statements ‘forbidding urination in stagnant water’ and urging people to guard against three practices which he said invite curses: ‘evacuating one’s bowels near a water source, by the roadside or in the shade’. The underlying principles are: using the sun to dry the faecal matter and keeping faecal matter isolated so that others do not have direct contact with it, avoiding seepage of micro-organisms into drinking water sources, and preventing nutrients in urine from polluting water bodies (and avoiding bilharzias/shistosoma infection). These principles are all relevant today.

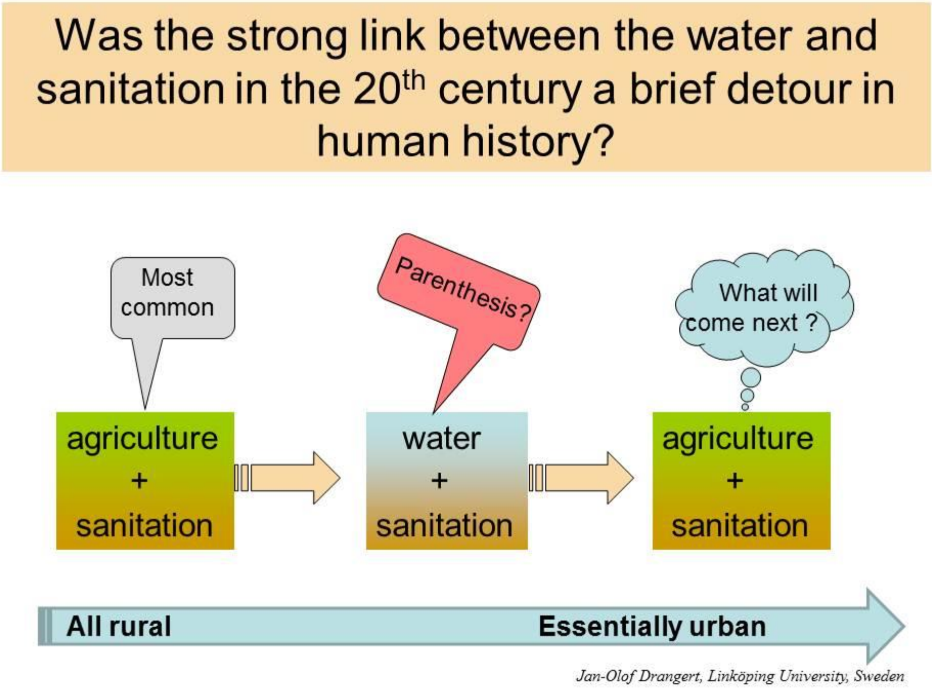
Archaeologists have excavated ancient toilets in many countries, for example 3,000–4,000 year-old squatting pans cut in stone in Sri Lanka (left picture) and the island of Crete. In multi-storey buildings in the densely populated ancient town Jana in Yemen, residents discharged urine down the adobe walls where it dried up before reaching the streets. Such walls could be called vertical drying beds.

Impressive water supplies have a long history in rain-scarce areas. The famous *kanats* in present-day Iran have supplied villages in dry areas with water from the mountains (Garbrecht, 1985). Kanats are underground tunnels collecting water from water-bearing layers of soil close to the mountains. These hand-dug tunnels are up to 10 km long and 30–40 m underground! People who spend their lives engaged in perilous excavation work to gain access to water would hardly use it to flush toilets. The principle is surely to return the used water and nutrients to agriculture.

Water from the River Tiber and smaller rivers was conveyed from the mountains to the city of Rome in aqueducts (see picture). They were built more than two thousand years ago, and served a city of one million inhabitants (Garbrecht, 1985). Most households had running water indoors and used an average of 500–600 litres per capita per day (including water for cleaning streets and sewers). The Romans knew that pumping water is more expensive than making use of gravity, so they constructed this huge system of canals on stilts. The aqueduct water could only be turned off at the intake, and would overflow if its flow was hindered somewhere else. Thus, the volume of wastewater that had to be disposed of was enormous. The Romans built huge sewer tunnels under the city, the famous Cloaca Maxima, emptying the untreated wastewater into the Tiber downstream of the city and into the Mediterranean Sea. The water system is an interesting and impressive technical achievement which served the Romans well. From a sustainability point of view, however, it failed to recirculate water and nutrients and contributed to eutrophication. According to Anil Aggarwal, a famous Indian environmentalist, the Cloaca Maxima is the most famous example of environmental destruction. What could have been done to avoid that?

Population pressure and what is manufactured in a society tend to guide the evolution of urban sanitation principles. We make the point that principles can be fulfilled through more than one technical option. We focus on urban arrangements, since rural people living in dispersed farmhouses typically try to recycle water and nutrients. There is no reason for farming communities to do otherwise, since they are dependent on the water and nutrient resources. In this Module we will look into major changes that have taken place in more recent times.

2.2 - 2

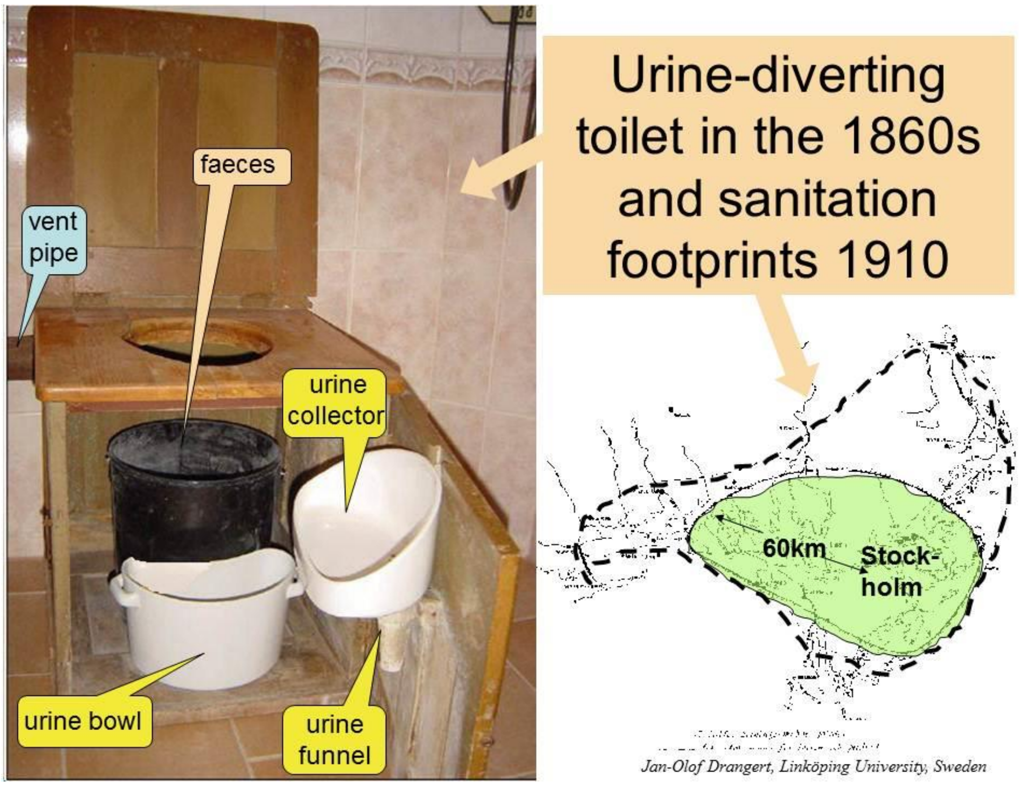


Agriculture and sanitation are closely linked in all agricultural societies, with the obvious exception of large mechanised farms of hundreds of hectares cultivated by a single family. Farmers use all the nutrients they can get hold of to replenish the soils – including animal manure, organic waste, and human excreta (left-hand box). An oft-cited example is the millennia-old Chinese practice of using human excreta from cities on farmland. Problems with such practices occur only when farmers and city-dwellers start using non-biodegradable chemical products.

Perceptions among urban residents about the link between agriculture and sanitation differ from those in rural societies. However, most cities, at least on the urban fringes, have maintained a rural connection and oftentimes also carry out urban food production on a large scale (UNDP, 1996). Cities today largely rely on food from the countryside in the country or abroad. An early example is ancient Rome where residents hardly bothered about returning nutrients to farmland. The main reason was probably that they conquered other fertile countries and made sure these supplied the food needed by Romans. Therefore, the Romans did not need to rely on their own food production, and they had very little use for human-derived nutrients.

As towns grew to cities (middle of picture), and in the second half of the 20th century when they grew into mega cities, the link between agriculture and sanitation tended to break down. Flush toilets emerged and toiletwater was not treated, but went as raw sewage to water bodies. Recirculation of nutrients disappeared (except for unlawful sewage irrigation) and chemical fertilisers provided the missing nutrients. Instead, a link with the water sector appeared in response to the huge need for flushing water. The simultaneous introduction of artificial fertilisers made the link between sanitation and agriculture even weaker (middle box).

However, the negative effects of indiscriminate dumping of wastewater into lakes and rivers soon became obvious. In the mid-twentieth century, wastewater treatment plants were built to recover some useful materials. The collected sludge was applied in agriculture, and the agricultural sector was linked again to sanitation. But the maintenance of this link has become problematic due to the presence of chemicals in the sludge (Drechsel et al., 2010). The accumulation of hazardous compounds that plants can take up constitutes a potential long-term threat to food quality. The expected future scarcity of phosphorus and potassium is likely to mean that nutrient flows of urine and faeces will be kept separated and directed straight to agricultural use. The looming depletion of phosphate rock, an essential ingredient in chemical fertilisers, is likely to become a driving force for reconnecting sanitation and agriculture. It may be that the strong link between the water and sanitation sectors in the 20th century was only a brief detour or parenthesis in human history.

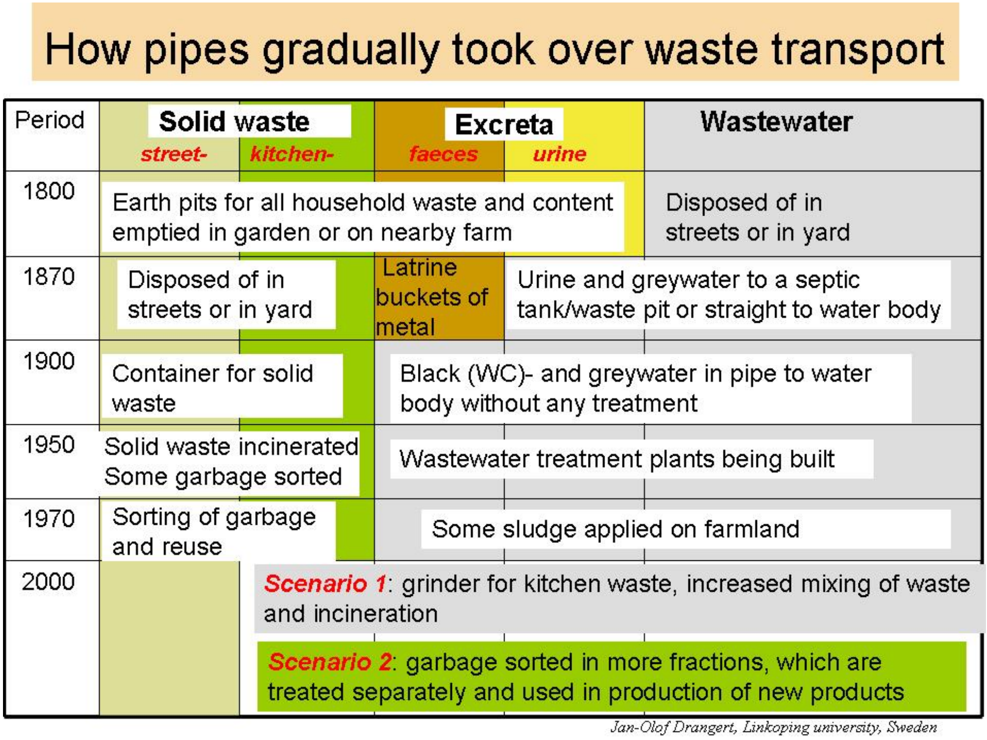


2.2 - 3

Let us go back 150 years when there were no chemical fertilisers. An indoor toilet in an urban flat in Sweden may have looked like the one in the picture. This toilet with a wooden chest and lid was introduced in the 1860s as a response to the introduction of multi-storey buildings in northern Europe. This was a time with no elevators. The flat owners did not want to descend, say, five floors to visit a bucket latrine in the yard, and then climb the stairs back home. The dimensions of the sewer pipes in the new houses were too small to allow faeces to pass through (no builder could foresee the coming of WCs). The indoor dry urine-diverting toilet was an invention with two important advantages. The first was to have an odourless toilet in the flat. Keeping faeces and urine apart reduces the bad smell and the remaining bad air was evacuated through a vent pipe (ending at the roof top). The second advantage was that the small volume of faeces and paper in the bucket had to be collected only once a month. Urine was funnelled to a porcelain bowl (the wooden door is open to show how it works) that was emptied in the kitchen sink several times per day. A step forward was to connect the urine funnel directly to the sewer pipe which meant that urine did not have to be taken to the kitchen for emptying. This system, however, had the disadvantage that the nutrient value in the urine was lost, and dumped P and N into the water bodies. At its peak the dry indoor toilet was used in one-third of the homes in Stockholm. (Drangert & Hallström, 2002).

The map shows the ecological footprint of the 350 000 inhabitants in the city of Stockholm in 1910. The smaller green "circle" depicts the area where farmers were using composted faecal matter and urine from Stockholm residents. This is the same area from where the Stockholm residents got most of their food. In those days the distance food was transported was relatively short. But, of course, the horses used for the transport contributed to CO_2 emissions. The dotted line depicts the farming area that used composted biodegradable solid waste from Stockholm to improve soil fertility. The farmers paid a small price for these fertilisers and they usually transported them when the snow made transport easy for horse-drawn sledges. Later, the municipal council built a separate railway from the city to a treatment plant for transporting the contents of the latrine bins to a excreta treatment 'factory' (Tingsten, 1911).

2.2 - 4

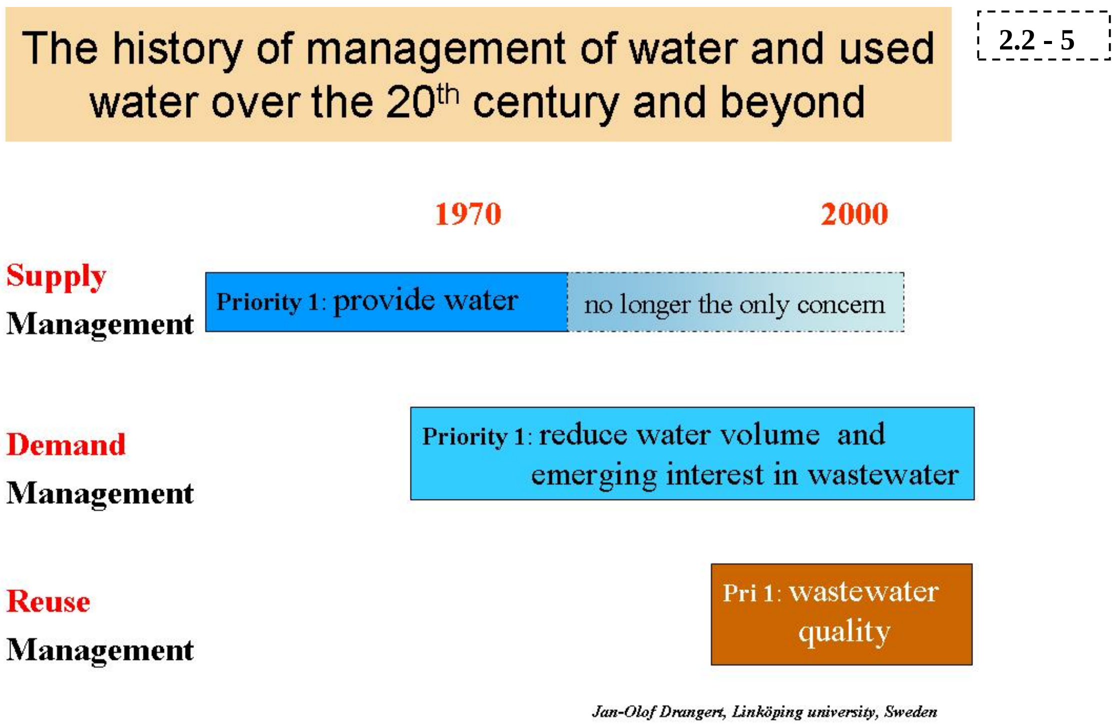


The evolution of urban sanitation seems to have been a constant move towards transporting everything in pipes (the grey-coloured part of the picture). It all started with a short pipe from the kitchen discharging greywater into the street or yard (up to the mid-19th century). By the turn of the century, 1900, and earlier in some countries, the pipe was extended to serve multi-storey buildings and in Stockholm urine was collected and added to the greywater and flowed to a sedimentation tank or straight to a water body. In other cities excreta was discharged untreated the same way.

The toilet water from the new WCs was piped but still not treated and it caused ever more problems and degradation of water bodies. It was only in the early 20th century that wastewater began to be crudely treated before being discharged in pipes reaching further and further away into lakes and seas. The small amount of sludge that was generated was not used but often landfilled. In the middle of the century, the water bodies had suffered a lot and eventually more efficient treatment was carried out. The vast amount of sludge that was now produced by sewage treatment plants was used as a fertiliser in many cases, but there are also several examples where the sludge was sent on barges to be dumped in the sea.

Today, the discussion is polarised between those who would like to grind all household organic matter and discharge it in wastewater which then goes to a WWTP, and those who oppose this practice. Proponents of this approach argue that the carbon in the organic matter is beneficial in the treatment of wastewater in the WWTP. The opponents maintain that continuing to sort all fractions of solid waste is preferable since we need these resources and residents are already accustomed to sorting waste. Excreta should instead be co-composted with other organic waste or added to a biodigester for biogas production or incinerated to produce heating.

The impression is that utilities lag behind industry when it comes to recirculation and reuse. For instance, some car makers have recently attempted to boost sales by claiming that they intend to reuse 95 percent of the material in the car when it is scrapped. In order to be able to do that, the car maker has to assemble a car in a way that makes it easy to disassemble, and use parts that are reusable. If a utility was to learn from this approach, it may look for other markets than just sludge for agriculture. They have to be proactive in demanding changes in the composition of the wastewater in order to be able to treat and use the water and constituents for productive purposes.



Let us now focus on the management of water and wastewater during the last 30–40 years (Drangert & Cronin, 2004).

Supply management has a long history and remained undisputed up to the 1970s (picture). The idea was that if anyone, community or industry, asked for more water the response should be to meet the request, if necessary by tapping more distant water sources. The user was supposed to pay the cost or less, since subsidies were rampant. Because the planning period for large water schemes may run for decades, supply management projects spilled over into the new millennium (Three Gorges Dam in China, the San Francisco River diversion in Brazil, the Lesotho Highland water project for South Africa, etc.). Rapid population growth in cities and mega-cities prompted more requests for water. In the 1970s, in the absence of more virgin water sources, rethinking of management strategies took place. Instead of just providing water, the authorities started to question how industries and households used the water they already had access to. This was a radical shift to initiate ***managing water demands***. The focus shifted to more efficient use of existing water through higher and progressive water tariffs, repair of leaks on mains, and the introduction of water-efficient household machines for washing clothes and dishes, as well as water-saving taps, shower heads and toilets. Huge amounts of saved water could now be offered to new users, and the pressure to find virgin water sources lessened. However, as towns grew even bigger, the supply was again strained and new solutions had to be looked for.

The obvious focus is now on what to do with the water that we have already used. The quality of wastewater comes to the fore, and so do ways to treat and use it again. If we do not pollute water too heavily while using it, the wastewater can be treated easily and at low cost. Industries were the first to recirculate water in a beneficial manner. If we are cautious, we have a nearby water resource that is never depleted! Such ***reuse management*** can connect water and agriculture and is likely to revolutionise the (waste)water sector in the near future.

In retrospect, it is interesting to see who the stakeholders were during the various management regimes. When **supply management** took precedence, it was essentially run by a small group of water engineers who managed to convince decision makers to make financial resources available for big projects. No doubt, these were impressive engineering feats. The users (industry and households) had to pay the full cost for these projects, if not through tariffs, then through taxes. **Demand management** on the other hand, engages many stakeholders from utilities, whitegoods manufacturers, designers, architects, construction firms, plumbers, etc. However, engineers whose sole preoccupation was the construction of networks of pipes to supply water were out. Now, as we move into the era of **reuse management** a number of other manufacturers are being engaged such as detergent companies, pharmaceutical industries, and the food industry. An important driver will be the household sector. Thus, the reuse system engages the whole society. Of course, a focus on reuse will require new institutions. But reuse management does not come easy due to resistance from vested interests (which make profits and are subsidised in the existing system), lobbying from utilities and competition on new product markets.

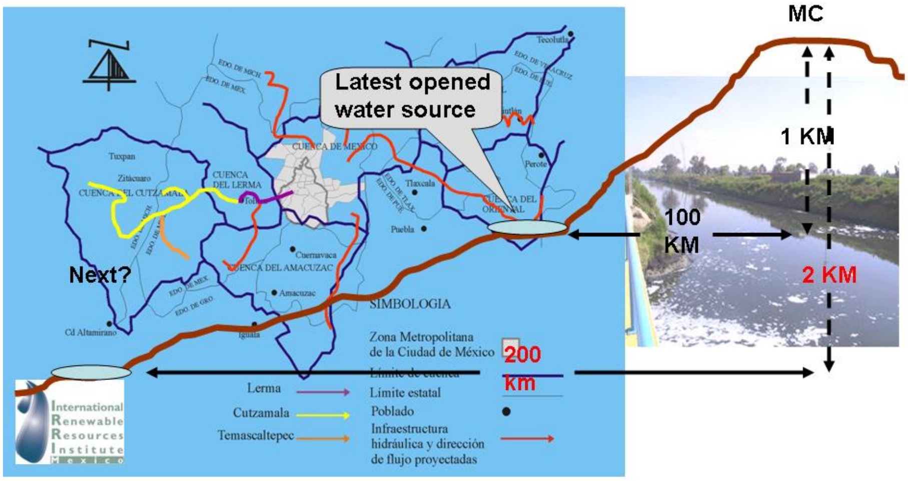
In practice, the three management approaches will go on in parallel. From a resource-point of view, a hierarchy would be preferred where reuse takes precedence, followed by demand management and lastly supply management (slide 1.3-8). This hierarchy requires novel thinking among not least professionals and decision-makers. Advanced cities such as Singapore and Sydney can represent the difficulties to stick to a hierarchy. Singapore has developed a reuse system where the wastewater from the whole city is treated in two plants to drinking-water standard. The treated water is today used by industry. In addition, half of the rainfall on the island is collected and stored in dammed river mouths and supplied to households. Another new supply-management measure is to desalinate sea water (PUB, 2012). Singapore has recently invested heavily in a desalination plant. However, with a visible progressive tariff the demand would decrease with, say, a quarter, and this saving would make the desalination plant redundant. The actual the city is only superficially applying the demand management tool of a progressive tariff with a first breakpoint at 40 m^3 per household and month. Few users will ever reach this level of some 350 liters per person per day, making the users economically insensitive to wasteful practices. Why is the hierarchy not adhered to?

The Singapore water utility is in charge of incoming and outgoing water which is highly desirable and a prerequisite for effective management. However, this total control of the water flows by one body seems to promote self-interest in the sense that engineering feats such as desalination take precedence over dull demand management activities such as changed tariffs and installation of water-saving devices in the households. Interestingly enough a similar development has occurred in Sydney where the previous engagement in demand-management was given up and a desalination plant was built (White, 2011).

A management hierarchy may be adhered to if there are balance and counterbalance built into the water and sanitation management system. This idea is put in practice in most countries´ political arena where government is managing the policies decided by parliament, and there is an independent monitoring body.

Mexico City now has 20+ million people

2.2 - 6



Courtesy of Ian Adler, International Renewable Resources Institute, Mexico

Jan-Olof Drangert, Linkoping university, Sweden

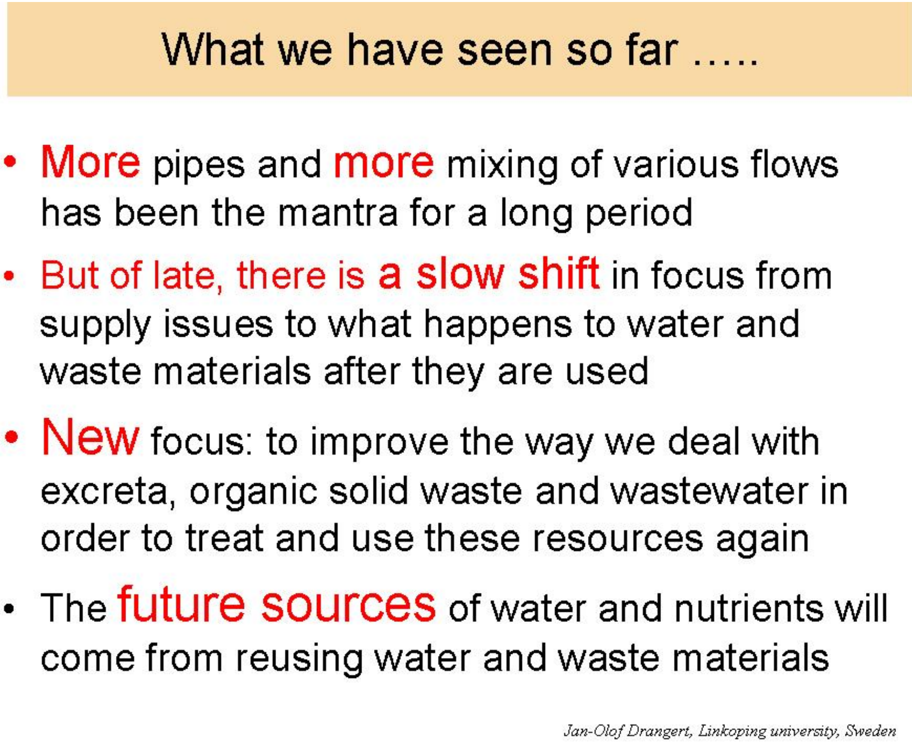
Mexico City may serve as an example of the changes that have taken place in water management. It is situated on a high plateau, 2,500 m above sea level, where the Aztecs established a religious and administrative centre on an island in the middle of a lake. The centre catered for 300,000 people and the Aztecs managed the area for hundreds of years. When the Spanish conquered the region, they retained the water and sewage system created by the Aztecs. The continuous growth of the city, however, has required water and food to be brought in from the surrounding areas, and today the area of the Aztec settlement is a 200 ha park, Parque Ecologico, in the borough of Xochimilco in the middle of the mega-city.

In 1980s a new water source was established about 100 km away and at an elevation 1,000 m below the city. This source was enough for a while, but as the population of the city passed 20 million inhabitants the authorities looked for other virgin sources to be tapped. The most promising one was 200 km away with an elevation 2 km below the city. This was after the oil crises of the 1970s, so there was some awareness of the costs involved in pumping water 2 km vertically, for the purpose to flush toilets. The assumption that humans can do anything, which had up until that time been the basis of approaches to planning, was now being questioned. Also, the proposed development met with strong opposition from neighbouring states (see map) which needed the virgin water for themselves. Forced to think differently due to increasing energy costs and opposition from these surrounding areas, the authorities started to adopt a demand management approach and use existing water more intelligently. However, 40% is still lost in leaking pipes due to earlier earthquakes. No rainwater is collected despite the fact that 25% of the land area is covered by roofs. If this continues, the residents will continue to be short of fresh water.

Today, the partly treated wastewater from the city flows in The Great Canal downhill and is being used for irrigation. Stormwater and wastewater is mixed and the city has invested in huge drainage pipes for stormwater at 40 m depths to withstand earth quakes, and this water has to be pumped over the crest of the catchment before it can begin its downhill journey. The question is when will the city council take reuse management on board?

It seems that our mindset is adapted to a world population of just some hundred millions, and we have not yet grasped the consequences of there being 6 billion humans on the globe – and that there will soon be 9 billion. Nor have we grasped that what we do as individuals has a cumulative impact on the Earth. Having said that, current discussions about climate change may enhance our understanding that the Earth is limited and is heavily affected by human activities.

2.2 - 7



Ministries of environment and other bodies try to keep up with changes in material flows through society and the environment. This is a mammoth task which involves battling with growing consumption, expanding populations and the many industrial and manufacturing activities going on everywhere. In addition, there is a rapid spread of substances between countries through trade, winds and rivers calling for international agreements.

The transport of liquid waste is done through pipes: initially greywater, then wastewater, stormwater and now, in some countries, organic waste after grinding and mixed with ordinary wastewater (slide 2.2-4). But the ensuing environmental problems in water bodies have turned the interest towards treatment before recharge. However, "upstream" activities to reduce waste creation are just beginning (Module 4.5) and are necessary since the waste flows are too complex to treat at the end of pipes.

It seems as if societies initially are more interested in satisfying the demand for goods and products than in preserving nature. Non-coordinated manufacturing and waste handling is emerging as a major problem. Here is one example which illustrates the situation: there are tenths of thousands professional chemists in Sweden working in industry and manufacturing. Many of them devote much of their time to developing new chemical products for the market. The primary goal, at least up to now, has been to make commercially viable products such as textiles and pharmaceuticals. These products are purchased and brought home to households. Sooner or later they end up in the wastewater stream and eventually at the wastewater treatment plant if there is one (or they go directly into the environment). For example, a few hundred chemists in Sweden's treatment plants are supposed to identify all these chemical compounds and develop methods for taking care of the stream of chemicals invented by many thousands industrial chemists. Due to the unequal numbers on the two sides, the battle is lost before it begins.

In order to reduce hazardous waste, laws are put in place to make industry responsible for devising treatments of the used products. For example, the EU has recently passed legislation banning certain chemicals i.e. the 2008 REACH program. The greywater module 4.5 deals with the potentials and constraints facing the regulators and utilities.

Car manufacturers are proactive and design the cars so that they are easy to dismantle when they are scrapped. The parts can then be recycled and become inputs in new products. In a similar manner, the houses could be built so that nutrients in the liquid waste stream could be collected separately and be recycled as fertiliser for food production. It would take separate flows of urine, faecal matter and blackwater from apartment buildings and private houses.

Previous huge investments in sewerage systems tend to prevent a swift change to new and more sustainable arrangements due to the fact that adding on to existing systems sometimes only incur marginal costs. This is sometimes called path dependency. The energy sector may provide inspiration for taking a new approach. A generation ago, advocates of alternative sources of energy such as wind, solar, wave, and geothermal energy were laughing stocks, while fusion and fission energy projects carried high status. Today, major energy companies are spearheading the use of alternative power sources and policy-makers are following their lead. We deal with such concerns in the next chapter.

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2.3 From Policy to Action

Learning objective: become aquainted with regulations and how to interpret them and translate them into local action

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A scan of what has been done in the sanitation sector worldwide over time shows a mix of trends and adaptations to local conditions. An enabling environment for improving sanitation covers the whole range from policy to action via good governance. A range of stakeholders is involved from individuals to utilities and from the private sector to central governments. The role of central government is threefold: to facilitate and arbitrate, to legislate, and to control/monitor – but NOT to be the operator of the system, because it then will be monitoring itself, which would cause conflicting loyalties.

For an extended period up to at least the 1980s, the supply of water dominated the public water sector, while wastewater treatment lagged behind even in urban areas. Sewage from the middle classes went untreated to water bodies, and it was up to each poor household to arrange its own sanitation. Laws and regulations often prescribed what technologies to use, with no or little consideration of local conditions. However, the ever-increasing investment costs of developing new water sources affected decisions both in the North and South (World Development Report, 1992). It was recognised that it may be more economical to manage the demand for water and provide various user groups with incentives to reduce their use of water, rather than to open new water sources.

Closer to the new millennium more proactive frameworks were introduced. A move towards principles rather than technology was advocated at the World Summit on Sustainable Development in Johannesburg in 2002. At the local level, utilities introduced progressive water tariffs, and in new districts, stormwater and sewage were kept separate. Industry manufactured water-saving devices like water-efficient showers and washing machines, and pour-flush toilets. In this way the heavy investment required to open a new water resource could be postponed or sometimes even made unnecessary.

Utilities had always been in the hands of the public sector and they were often rated as rather inefficient. In the 1980s and 1990s this monopoly was challenged by privatisation promoted by the World Bank, the IMF and other influential parties. International water companies expanded to fill the market offered to them. A number of metropolitan water utilities were taken over by international companies. Water and sewerage companies bought concessions in developed countries (often buying 100% of shares) and increasingly in developing countries (commonly owning around 50% of shares).

The heated political debate about the merits of privatisation gradually subsided (BPD, 2007). One reason was that the companies managed rather well in comparison with previous utilities, and they could not charge exorbitant tariffs. A few big companies also withdrew from some cities. Another reason was the emerging understanding that various parts of a utility could be *managed* by private companies without the company having to own the asset.

In the early 21st century, the discussion about privatisation had shifted to one of how to develop a private-public partnership. Such partnerships are typically based on a contract between a public authority and one or more private sector service provider. The public authority entrusts specific tasks to the private sector and stipulates precise objectives, while it retains regulatory control and ownership of all assets.

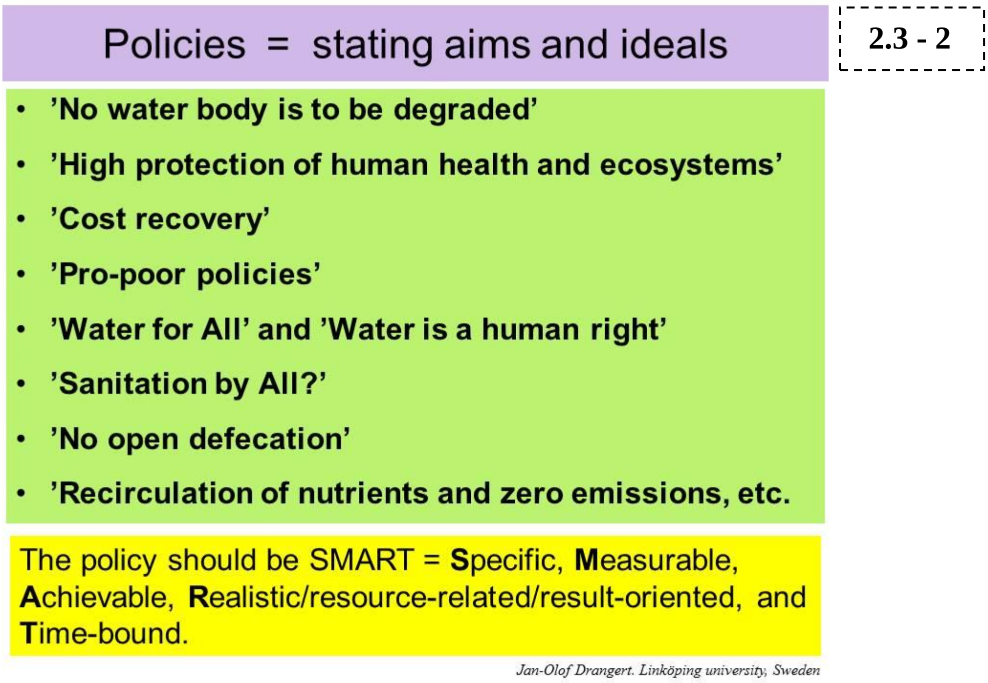
In 2001 the chairman of Suez Water Company in France wrote an open letter, “The Water Truce”, in which he hails evolving public-private partnerships in the sector. He suggests the basis is a common understanding that water itself is a public good and that the private sector provides the service of clean water continuously to users. The service is charged for but not the water. The public sector remains the owner of the facilities, and the company turns the right of access to water and sanitation into a reality for the poor as well as for the affluent. This indicates a change in the relationships between the companies, the public sector and inhabitants, and what the private sector can offer is to renew water infrastructure, to leverage new sources of finance and to apply more efficient management methods (Suez, 2001).

The involvement of the private sector was a leading theme of, for instance, the World Toilet Conference in Singapore in 2009. The Asian Bank and the World Water Supply and Sanitation Council (WWSSC) were actively propagating market-based solutions and cooperation between authorities, NGOs and business (WTO, 2009). The World Bank’s Water and Sanitation Programme has large programmes engaging the private sector in scaling-up sanitation in Asia. Still, households are often left out and have to accept whatever is offered to them.

As household products contain more and more chemical compounds they make wastewater treatment more complex and expensive (see Module 4.5). A number of compounds cannot be removed from the wastewater. The most important consequence of naming the facility a wastewater *treatment* plant maybe to make users blind to the fact that they themselves are the major contributor to the pollution problem. In a situation where the utility cannot treat the wastewater satisfactorily, it seems unavoidable that utilities will let households become a recognised partner of the management system (slide 2.4-9).

With rising public awareness of environmental issues, the engagement of households promises to be a positive development, since they are likely to protect water quality by refraining from discharging hazardous items in the sink or toilet. The awareness aspects were brought up on a broad scale at the Third World Water Forum in Japan in 2003, but not in connection to users’ impact on wastewater quality. The time is now ripe for this to happen. A special feature of the European Water Directive is its insistence that local populations should become involved to a greater extent in water protection (www.euwi.net/index.php).

In this module we deal with policies, strategies and management issues connected to sanitation development under different conditions.



Policies are typically adopted by governments and political parties to guide their course of action. Governments generally implement policies by enacting laws, creating implementing agencies, and expending public resources. Policies cover a number of aspects pertaining to sanitation. The examples in the picture are certainly not exhaustive and will change over time. New policies are added every year; some remain for a long time and some others are phased out quickly. A policy is likely to remain as long as the problem it is designed to deal with remains. An example is the EU framework directive that *'no water body is to be degraded'*. A similar directive can be found in a 500-year-old by-law for Stockholm city from 1557!

Policies are generally more elaborated and stringent for water than for sanitation. A pinnacle for water issues occurred during the 1980s which UN had declared the Water Decade. The new Millennium Development Goals (2000) resulted in a greater focus on sanitation and so did the Year of Sanitation 2008 – but the amount of attention given to sanitation remained far behind the amount given to water issues. Little research has gone into why this is the case. The reasons cannot be economic, since a cost-benefit analysis in 12 countries revealed that every US dollar invested in improving sanitation resulted in societal economic benefits of between US$5 and $23 depending on the country (ERM, 2005). These benefits are reaped by residents who have fewer sick days, etc.

South Africa is renowned for good policies documented as White Papers on various aspects of water and sanitation (see www.dwaf.gov.za). The European Union (EU) introduced a Water Framework in 2000 in order to harmonise and improve water and sanitation conditions for 500 million people in its 27 member states (http://www.euwfd.com/). China has developed an ambitious integrated river basin management policy to improve water use, water pollution control and sustainable conservation for its 1.3 billion people (NPC, 2002). Some brief comments concerning the policies mentioned in the picture are given below.

The protection of human health and ecosystems is a policy goal in most countries, and includes conservation of natural resources, upkeep of ecosystem services, and protection of public health.

Pro-poor policies are also almost universal (MDG 7). The earlier Water Decade slogan 'Water for All' is still valid, and 122 countries voted for a non-binding resolution in the UN calling on states and international organisations "to scale up efforts to provide safe, clean, accessible and affordable drinking water and sanitation for all" (UN, 2010). 41 countries abstained to vote. We need a new understanding of the concept of *human right to water* in order to make it a valuable policy tool. This notion evolved in rural situations where all people must have the right to access existing springs, rivers, and other 'natural' water sources. As people move to urban areas, the need for access to water remains but in cities, the water is conveyed from distant sources and access almost always entails energy for pumping. An unconditional right to free water would imply having enough energy for supplying the water. However, there is no human right to energy. This contradiction caused by the mixture of water and energy has to be resolved – possibly by charging a fee at least for the energy cost. This would be in line with the principle that water is an economic good with an economic value that does not have to equal the market price (WSP, 2010).

The issue of *no open defecation* is dramatized in crowded urban fringe areas. Actual implementation seems to be 'Sanitation *by* All' since poor residents cater for their own needs. This can be very effective from a human resource perspective (see Module 1.4), given that the municipal gives advisory support and by-laws are open to unconventional solutions. An interesting and apparently successful approach called the Community-Led Total Sanitation program has moved the focus from hardware to habit (Kar and Chambers, 2008). This revolutionary public health approach has reached many villages in Bangladesh (where it started), India, Sri Lanka etc. (Financial Times (UK), November 29/30, 2008). At a village level, promoters apply peer pressure by confronting communities where open defecation is practised. The villagers (transect)-walk in groups to popular squat sites to take in the sights and smells. They discuss how e.g. flies, chickens and human fingers spread the shit around, and that it can easily end up on the food they eat. The horror of realising one may be eating someone else's faeces forces the villagers to decide whether to improve the situation by building latrines to contain the spread – or not.

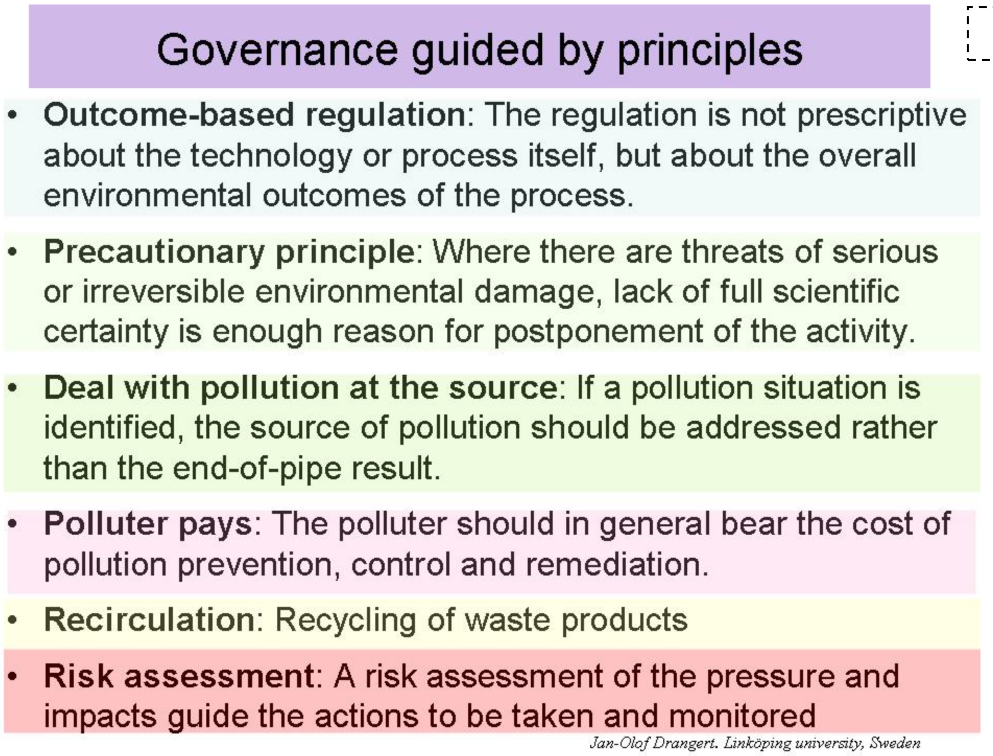
Recirculation of nutrients back to agriculture has not yet entered the sanitation policy in many countries, not even South Africa. However, WHO (2006) has done their part by issuing guidelines for the safe reuse of greywater and excreta.

A sectorial view of wastewater, excreta and greywater in this context would consider them to be costly by-products of the process of urbanisation, requiring substantial investments in treatment plants and disposal mechanisms. Yet such a view overlooks their value as a source of water and/or nutrients for plant production and fish cultivation (WHO, 2006).

Most policies advocate the right to 'good' things such as health, access to water, food security etc. The government usually becomes responsible for providing these benefits and they are prepared to do that in exchange for votes. These rights to goods are rarely balanced with responsibilities for the voters not to waste and not to pollute. Politicians may think that no votes will be gained from attempting 'to put the burden' of sanitation on the voters, so they remain silent on this issue. The policies rather concern industrial and agricultural polluters. The policy of 'no open defecation' is interesting from this point of view. It pinpoints the individuals, but in a face-saving manner.

When the government takes action, complex social forces may make the outcome of policy recommendations unpredictable (slide 2.3-12). Two examples can illustrate this point. Many slum dwellers make a housing career by using their own resources. Others are provided with piped water (and perhaps also sewers). They may sell the improved house, move to another slum further away and use the gained money for other purposes. They may request piped water once again, and the same process is repeated. Slum lords may also be active in such a process of relocation of residents. Similar challenges to government schemes may occur among rich residents in rich countries. All slum dwellers in Cape Town in South Africa are scheduled for upgrading. In order to jump the queue, scrupulous residents have deliberately set their slum on fire and been provided emergency attention. These examples show that good policies need good governance and implementation strategies.

2.3 - 3



The variety of arrangements on the ground is too diverse to be captured by detailed rules. Instead, functions and outcomes come to the fore. Over the last, say twenty years, there has been a move towards promoting change and improvements through guiding principles rather than detailed prescription of technologies and processes. This change in focus is global and is a challenge for local authorities with limited resources because they have to assess diverse proposals when deciding which ones should be given permits (slide 1.1-12).

1. A prominent example of the use of principles of an **outcome-based regulation** is the European Union Water Framework of 2000 which contains principles such as the ones in the picture above (see www.euwi.net/index.php). The framework deals with how to think and act.

2. The '**precautionary principle'** is necessary since new hazardous substances are emerging faster than authorities can study their effects. A large proportion of the discharges from chemical industries and from their products in household waste remain unregulated. But, with a precautionary principle, suspected hazardous products could be restricted or banned without full scientific proof. This would somewhat balance the industry's use of substantial resources to lobby for weak or less legislation that would interfere with their production (interview with the former EU Commissioner of the Environment, 2010).

3. **Pollution should be dealt with at the source** and not at the end of a pipe. When this approach is taken, there are more measures that can be used to reach the same goal of cleaner waste disposal. Moreover, trying to remove a pollutant once it has entered the environment is usually an expensive option. It is often cheaper to 'negotiate' with industries, households or salespeople at the point of sale to get them to change their practices in order to prevent the pollution of a river or marketplace (see Module 4.5). This may involve threatening the offender with fines or other measures. This may also lead to a more lasting solution.

4. The '**polluter pays**' principle was developed in the 1990s. The idea is to give a clear message to the polluter that he, not the taxpayers, must foot the bill. This principle has turned out to be quite difficult to put to work in practice. Public wastewater treatment plants are rarely sued for discharging less treated effluent, and the principle might only be used in cases of serious neglect. It is politically easier to sue private industries when they discharge polluted wastewater into a public sewer.

5. **Recycling of waste products** is being done in many industries because it is cheaper than making the same product from raw materials. This is particularly true for solid waste such as paper, aluminium tins, and glass, but also for wastewater itself. Faecal matter and urine alone are also possible to recycle in agriculture.

6. The new WHO Guidelines (2006) **assess risks** concerning reuse of greywater, faecal matter and urine. Handling recommendations complement the previous limits for sample values for bacteria count etc.

A paper commissioned by the Global Water Partnership reflected the prevailing wisdom of the water sector by identifying the following principles of effective water governance (Rogers and Hall, 2003):

Approaches should be:

- Open and transparent
- Inclusive and communicative
- Coherent and integrative, and
- Equitable and ethical

Performance and operation should be:

- Accountable
- Efficient, and
- Responsive and sustainable

This wish-list contrasts according to McGranahan and Satterthwaite (2006) with conventional government approaches in the 20th century to water and sanitation management. They characterise these as being

- Bureaucratic and labyrinthine, rather than open and transparent,
- Exclusive and expert-driven, rather than inclusive and communicative,
- Sectorial and segmented, rather than coherent and integrative,
- Biased in favour of those able to access the large water and sanitation networks, rather than equitable and ethical.

Assessing guiding principles and their adaptability to local conditions give rise to strategies for actual management.

2.3 – 4

The word “strategy” was developed for war situations, but is today a part of common management jargon. A strategy is an approach to moving or disposing staff and resources so as to implement the policy aims. The first requirement in a change process is to ‘*do the right thing*’ to achieve the goal. This may sound trivial but it is not. There may be more than one right thing to do and that requires a choice. Moreover, the policy goal itself may not be realistic, in which case any strategy will fail. For instance, donors decided as part of the Water Decade to drill a grid of boreholes from where water was to be pumped to surrounding villages in rural Tanzania. The system collapsed almost immediately due to pump breakdowns and a shortage of diesel to run the pumps. The goal to provide water by using a strategy of *piped* water was not realistic. The subsequent strategy was to provide water and this time by involving villagers in digging wells from which water was fetched in buckets. This strategy achieved some success. The lesson is that any strategy must have a realistic goal which is in keeping with the available resources.

A serious analysis of the outcome or progress of any sanitation project must take account of societal norms and attitudes among staff as well as residents. Often the need for training is more urgent among staff than among the so-called beneficiaries. Rolling out a sanitation program just as a technical infrastructure is risky and probably the toilets will not work for long. If a project fails, often the beneficiaries are blamed for not doing their part properly. Such a limited analysis does not help to improve the strategy to ‘*do the right thing*’ next time. If the beneficiaries do not contribute what is expected of them, then the expectation is likely to be faulty. Real learning from failed projects arises from serious reflection about the project itself and its links to the social and economic environment.

A daring experiment is Community-led Total Sanitation, a grass-roots program developed in Bangladesh (slide 2.3-2; Rosensweig and Kopitopoulos, 2010) which starts with the premise that it is up to the community to make changes if it so wishes. If the community does not make the required effort, it is not seen as a project failure since there was no decision to go ahead. In such cases the approach was not operational and the challenge remains to come up with an alternative one. Experience tells that there may not be an effective strategy in the short term that is also sustainable.

There are many potential derailing factors: lack of social cohesion and civil responsibility, poor monitoring, recklessness such as in the world financial sector around 2008, or corruption (Transparency International, 2008). We can lump such factors together as poor governance and define good governance as the presence of: a) general adherence to rule of law,

b) transparency, predictability, and accountability in government decision making, c) decision-making that consistently achieves effective and efficient outcomes for society, and d) decision-making processes that consistently allow for public participation, responsiveness, consensus orientation, equity, and inclusiveness (Halpern et al., 2008). In the real world, such perfection is seldom attainable.

The second requirement is to make the project or intervention efficient by '*doing the thing right*'. Again, it is not an easy requirement due to a lack of good governance which means that vested interests may try to divert attention and resources. The concept of tri-sector partnerships between the public, private and civil society sectors is likely to achieve more than these sectors working independently. In leveraging their own resources, all partners can rely on their core competencies and have other actors fill in any gaps in their skills, abilities or mandates (Jones, 2002).

Monitoring and evaluation is part and parcel of any strategy. One example is the monitoring of national achievements for the ten Millennium Development Goals (MDGs). The mid-term review reports that:

> Half the population of the developing world lack basic sanitation. In order to meet the MDG target, an additional 1.6 billion people will need access to improved sanitation over the period 2005-2015. If the trends since 1990 continue, the world is likely to miss the target by almost 600 million people (UN, 2007).

The report writer recommends:

> In order to achieve the MDGs countries will need to mobilise additional resources and target public investment that benefit the poor. … Several developing countries are demonstrating that rapid and large-scale progress toward the MDGs is possible when strong government leadership and policies and strategies that effectively target the need of the poor are combined with adequate financial and technical support from the international community.

This result-based assessment only advocates additional resources and strong leadership to reach the goal. The goal is not questioned, nor is the recommended strategies. It is hardly helpful to ask for good governance and to blame the leaders without exploring alternative strategies or approaches. The International Water Association, IWA, representing professionals in the water sector, has a task force for analysing the development of the sanitation sector and advising on possibilities and improvements (IWA 2007). Their first report identifies some key failings in the current approaches which result in a mismatch between the stated objectives of investment and the outcomes. They state that the current technical planning and design practices, based as they are on logical normative technical planning approaches, seem to be failing because:

- the objectives upon which decisions are based are distorted by special interests, or by a poor understanding of the real needs of the population
- the normative technical planning approaches result in plans which do not respond to the rapidly changing urban context and diverse conditions which pertain in modern urban spaces
- they fail to make a realistic assessment of short-term inertia which impedes capital investment
- they result in systems which place an unrealistic management burden on all levels of the city (IWA, 2007).

This kind of assessment of failures addresses various challenges for real-life situations. Each point provides several avenues to enter a discussion about how to revise plans and make them more effective and efficient instead of wishful thinking such as that presented in the mid-term review above.

2.3 - 5

A strategy deals with approaches, means, and processes that are applied to reach a goal. For example, a strategy for the public sector to improve sanitary conditions comprises:

- Facilitation, such as training of professionals and other staff, providing information to residents, builders and others, stimulate technical and other development, help solving conflicting interests in the field (land deeds etc.)
- Legislation defining the rules of the game through laws, by-laws and punishment
- Control/monitor and assess the conditions in the sector.

There have been major shifts in recommended strategies over the years, and some of these are mentioned in the picture above. These shifts are not all-encompassing however, and may coexist with previous strategies. There is often a competition between stakeholders who have a vested interest in one strategy or the other. For instance, the pro-poor water strategy has moved from emphasising hardware and infrastructure to emphasising soft issues and social resources. Yet, the implementation seems to work in the opposite direction, not least in periurban areas, because of vested interests.

The emphasis on either hardware or software is closely related to whether the approach is supply-driven or demand-driven. Today, the scarcity of virgin water sources makes demand-management options more attractive for utilities and often they introduce software approaches and manipulate the demand. The sanitation sector still struggles with this issue of demand and supply strategies. There is a growing awareness in the sector that just building infrastructure does not guarantee success. A too common outcome is that toilets are not used as intended: "*In Maharashtra, of the 1.7 million toilets constructed between 1997-2000 only about 50% were being used for the intended purpose*." (MoRD, 2004).

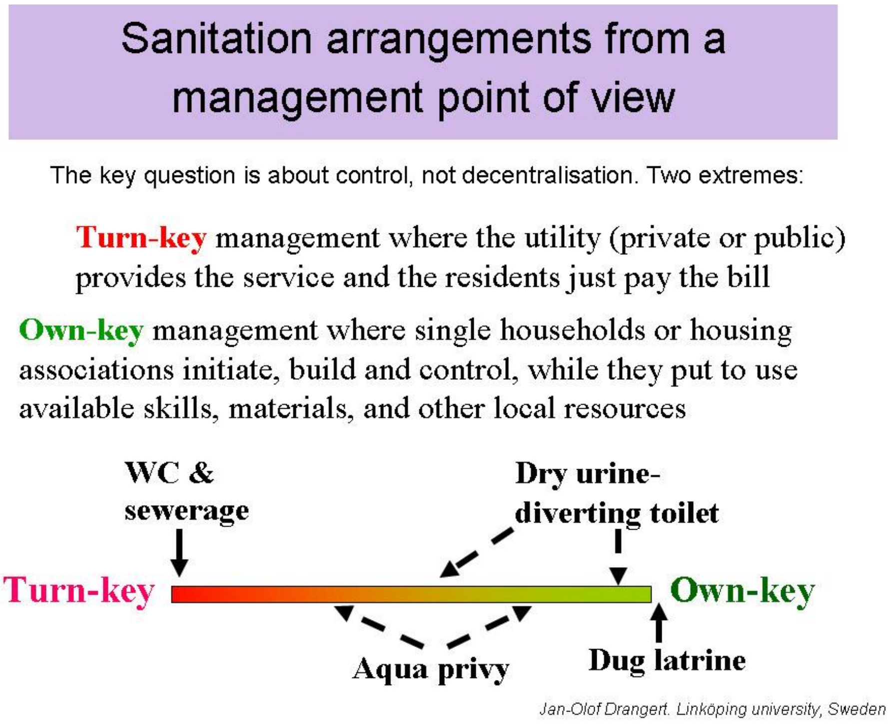
It is often said that the poor do not demand improved sanitation. This assertion has to be investigated. The reason may be that the poor have experienced that the authorities and donors are prepared to supply water, but not wastewater treatment or an efficient solid waste collection or stormwater drainage. Water is an immediate need for the poor and the rich, whereas the effects of no measures to improve sanitation differ. The difference is that the poor live in squalor while the rich transport their wastes outside their living area. A demand management strategy for sanitation would include reducing the waste flows from the households e.g. reduced volumes, avoiding non-degradable goods, recycling products, and selecting where to dispose of the necessary outflows.

The question of subsidies has been part of the water and sanitation sector for a long time. There is a valid argument that subsidies will make it affordable for households to install toilets or be connected to a piped system. However, the operation and maintenance costs are much higher than the initial investment cost. The selected technical solution may therefore end up to be difficult to maintain. The charged fees tend not to be enough to cover all the costs and the infrastructure tends to be poorly maintained as evidenced by large not-accounted for water. An emerging alternative strategy is to promote market-based approaches. That implies that the arrangement is less costly and most of the initial financing is done by households (micro loans) and the private sector and the latter is more motivated and able than a political organisation to collect necessary fees from the users.

There is a growing awareness of the importance of the operation and maintenance of infrastructure. Decision-makers now consider the cost over the life-span of an arrangement and know that this is much higher than the initial investment. Most cities in developed economies cannot afford to replace malfunctioning sewers and water pipes. With the present rate of retrofit in Swedish towns it will take more than 300 years before all have been replaced. The lifespan of a pipe is estimated to be 60–80 years. The low capacity of wastewater plants of City of London results in overflows of untreated wastewater to the Thames sixty times per year.

The financial burden that rich or poor communities are to carry after being provided with a new supply or sewage is rarely affordable, and the result is likely to be an inefficient system of service delivery. A more open approach is required to make households and decision-makers keener to build long-term affordable arrangements (slide 2.3-6). An immediate measure is to monitor construction so that when it is ready the unit is easy to operate and maintain.

2.3 - 6



A crucial question is; **who** is to take on the responsibility for managing the various parts of a sanitation arrangement? There are two extremes:

Turn-key management. A utility (private or public) provides all services, while residents only pay. Piped water and sewerage, presently the most coveted arrangement, can provide a household with one cubic metre of water "from the wall" and get rid of the same amount of wastewater "through the floor" each day without bothering anyone in the household. This is one of several attractive properties of the piped system. A positive perception of this technology has also been transferred successfully to almost all groups, including residents with no such service in developing countries.

Own-key management. Single households or housing associations initiate, build and control the arrangement. They put to use available skills, materials, and other local resources. Such a system is robust and provides services since the users are in full control. There are many up-market technical arrangements as is shown in Module 2.1.

Own-key management does not necessarily imply decentralised management and turn-key management does not necessarily imply centralised management. There are examples of rather small *turn-key* systems as well as large-scale *own-key* arrangements. The qualitative difference lies in who is responsible for initiation, implementation and who operates the system. The user may be proud of his or her arrangement for different reasons. A WC brings status and comfort, while *own-key* solutions make their users proud of being in charge. The user can often rectify operational problems with an *own-key* arrangement, while the WC often requires a specialist to repair it. Sanitation management at household level is not very different from food preparation; some people prefer to go out to restaurants and pay for the service, while others prefer to cook and eat at home. The reasons are multiple and include, among other things, whether the user has more time or more money.

A possible new principle is to implement and operate a sanitation system at the lowest appropriate management level (Schertenleib et al., 2003). The priority would be to start the planning process by investigating what the household or community could manage. This approach is radically different from starting with a specific technology and then finding out who can manage it. The links between policy-governance and the physical arrangements on the ground can be called the strategic space. This space is explored throughout this sourcebook.

2.3 - 7

Market-based strategies are gaining ground. If an individual would like to purchase a toilet or wastewater treatment unit, it would be helpful if the whole unit can be seen and purchased at the same outlet. The picture shows a 'one stop shop' for a toilet with a septic tank.

A market-based system involves a range of suppliers of various services such as retailer, wholesaler, and manufacturer on the one hand and construction, transport, credit services and training on the other (see diagram). Markets for sanitation products seem to grow by themselves in rich parts of cities all over the world, and there is a willingness to spend private money on interior arrangements, while the handling of wastewater does not fare as well. The product market for the poor, on the other hand, does not seem to develop by itself, and residents typically put money or labour into digging the disposal pits. The interpretation is that the existing markets push ahead with what they already provide, and there is little innovation to reach new markets with new products for the poor.

Some interesting new initiatives are being tried out to open up this avenue. For example, the International Development Enterprises (IDE, 2006; Sijbesma, 2010) has developed a market-based, no-subsidy approach to improving sanitation. IDE firstly invests in developing a range of sanitation technologies that suits local needs, aspirations and finances. At the same time, IDE invests in building a strong private sector supply chain that provides materials and services to build toilets (see diagram). They also build the capacity of local organisations such as women's unions and health workers to promote improved sanitation and to inform residents of the social and health benefits of hygienic toilets. This three-pronged approach aims to make toilets a priority for household investment.

A broad range of information and data is required to feed into building up a market. A study in the poor upland area of Yen Bai province in Vietnam assessed the potential to develop a market for sanitation (IDE, 2006). The study mapped out various components of the sanitation market, analysing the opportunities and constraints of the market's demand and supply by addressing the following:

(1) Is there a viable market for sanitation products in Van Yen district?

(2) How to increase the demand for sanitation among local residents?

(3) How to strengthen the supply chain so that suppliers can market their products?

(4) How to facilitate the interaction between latrine buyers and sanitation product suppliers?

(5) How best to build the capacity for local partners?

Interviews, observations and available statistics and documents were used to address these questions. The IDE analysis showed the following key constraints and opportunities that might influence the development of the sanitation market (IDE, 2006):

Opportunities:

- Sanitation supply networks exist at all levels (provincial, district, and commune).
- There are many suppliers and the competition helps to improve the quality of their services.
- Market potential is huge (especially for masons) given the low number of hygienic latrines.
- A health network exists at hamlet/village level.
- Increased population density results in limited space for open defecation.
- There are many revolving-fund groups to help members to perform economic activities.

Constraints for the whole market:

- Basic infrastructure such as roads, electricity and communication are still weak.
- Local authorities at provincial, district, and commune level do not give due attention to sanitation and environmental problems, and lack clear direction/strategies for dealing with sanitation issues.
- Households and authorities depend on external subsidies and financial assistance.
- Existing latrine models lack features that the local people desire such as low cost, durable, well ventilated (no odour) toilets that allow excreta to become a fertiliser.
- Since the common dug latrine is not so durable, the coverage of household latrines is declining
- The development of new toilet models requires time and money.

Market Supply Constraints:

- Present demand for toilet construction material (bricks, cement) is only 3% of total demand for these products, and so many suppliers do not pay attention to developing the sanitation market.
- Often, all the necessary construction materials are not sold under one roof. The market is still dependent on mobile retailers.
- Toilet construction is a small part of the local masons' incomes, so they do not bother to look for new customers who want toilets.
- Profits for sanitation construction (materials and labour) are very small, so many suppliers are not interested in marketing sanitation products.
- Masons lack basic information of various hygienic toilet-related technologies (e.g. septic tank) so most cannot advise or persuade customers to build hygienic toilets.
- There is a lack of proper direction and investment by local authorities in hygiene promotion
- Grassroot-promoter networks do not have sufficient awareness of hygiene and sanitation, and have few means for promotion and marketing.
- There is a lack of information about different affordable toilet technologies.
- Most local promoters at the commune level do not own hygienic toilets and thus they cannot set good examples for others or convince others to purchase toilets.

This example shows the challenge facing local staff and decision-makers when they are analysing all this information and have to come up with a feasible strategy to overcome the constraints. Another sticky issue is whether they are interested and if there is a career to be made by such an involvement. If not, this will constitute another serious constraint to overcome.

Social marketing - nothing strange

2.3 - 8

When toilets are sold on a market, residents will ideally have some designs to choose from. In Trichy in India, there is a sanitation exhibition with a range of full-scale units and also models of various toilets (right). They offer an option for every pocket, and the visitor can make informed decisions about which toilet they would like.

This is part of social marketing to increase the demand for hygienic toilets and encourage hygienic practices. A formal definition was given by Weinreich (1999): "the use of commercial marketing techniques to promote the adaption of a behaviour that will improve health or well-being of the target audience or of society as a whole". The strategy is partly based on information and partly on an emotional process. Improving hygiene does not seem to be a motivator for investing in sanitation, but improving housing and social status do act as incentives. The emerging new culture of sanitation is a result of a carefully designed strategy based on the findings of consumer research. Messages to potential customers are tested and revised until it is believed that they can effectively stimulate the customer to change behaviours. At the same time, local mass media and government officials such as local health workers and mass organisations are trained to effectively communicate the messages and mobilise the local people. The initiative 'Alternative Pro-poor Sanitation Solutions' in Peru found that in rural areas people want to live in clean communities with fresh air and no garbage. In urban areas there is a strong vision that progress is based on individual effort. The motivational strategies are adjusted accordingly (Baskovich, 2008).

A particular challenge occurs when marketing a new product such as waterless urinals or urine-diverting toilets. The promoter/seller needs to address all possible counter-arguments that neighbours and professionals may put forward in order to make the homeowner confident in his/her choice. The picture (left) shows a plumber's shop in Sweden with a wide range of urine-diverting toilets that he sells and installs in customers' houses. He has sold and maintained hundreds of such toilets and can share with the customer his knowledge of the operation and maintenance of each brand. The customer can make an informed choice. In this case, the plumber also retains some standing in the community as the customers know him and his business depends on his good performance.

The Vietnam study (previous slide) further identified several **Market Demand Constraints** which are part of a social marketing analysis:

- People are vaguely aware of the health hazards associated with human faeces and the importance of using hygienic toilets.
- Ethnic people living in remote villages, particularly the Dao people, have the habit of defecating in the open. They do not use latrines because they think latrines are unsanitary. They associate latrines with dirtiness, bad smells and flies.
- Most Kinh people use human manure to fertilize their fields so their main reason for digging shallow latrine pits is to collect and store/compost the human waste before applying it.
- Young households do not have the financial means to purchase toilets. They usually share toilets with their parents, if they live nearby.
- Some households can afford a new latrine but prefer to wait until they can save enough money to fix other construction jobs in the house at the same time. They think that doing so saves money. So even if they have to live with a broken or temporarily unhygienic latrine they prefer to wait.
- Households with unhygienic single-vault toilets do not want to spend money demolishing them.
- Some poor households wait for external financial support.
- People lack information on the various models of hygienic toilets, which leads to delays in building low-cost hygienic toilets.
- People overestimate the prices of hygienic toilets. Many believe that only septic tanks and concrete toilet buildings are hygienic. They think septic tank toilets cost over three times more than the actual cost (IDE, 2006).

Studies have found that corruption is pervasive in the water sector, and significantly increases costs (Halpern et al., 2008). Opportunities for corruption arise where there is a ‘value for grab’ without a strong owner, in particular the case of a monopolistic public owner. Lack of ownership means that this value can be appropriated. Hot spots for corrupt activity are particularly in sector processes where money or contracts change hands or discretionary decisions are made.

Halpern et al. found that “in less developed countries providers seldom operate with high levels of profits.” Instead, such providers may charge high rents which they justify by pointing to their inflated costs, including inflated prices paid to contractors, or by claiming they suffer from high levels of inventory loss, or by claiming they have to pay for unaccounted-for water. In other words, inflated contract prices provide kickbacks to staff, and the costs are passed on to customers and taxpayers. The cost of theft or non-delivery of services is likewise passed on. Lack of competition means customers have no choice but to pay prices that are inflated by corruption. They pay them directly, or as taxpayers funding the losses.

The market-based approach to sanitation is thought to reduce corruption (Halpern et al., 2008). However, staff of any utility may supplement their low incomes by demanding bribes in return for turning a blind eye to illegal connections, fixing meters or omitting billing data. They may also charge extra to install new connections. Also, officials who can influence the awarding of construction and equipment contracts may get a kickback of a percentage of the contract value. Such corruption in capital projects is generally financed by private contractors inflating the price or reducing the quality or reducing the amount of the work (or all three). The public sector ends up paying more to the private contractor than the work is worth (go to http://worldbank.org/, select “Countries” section, and click on the particular country of interest).

Orangi sanitation project in Karachi, Pakistan

2.3 - 9

Part of the Orangi area in Karachi in the flat, flood-prone area

Digging for sewers in Orangi

Ready underground sewer in a lane in Orangi constructed by self-help work under the guidance of OPP project

Source: Pervaiz, Rahman and Hassan, 2008

Karachi has grown rapidly from about 400 000 residents in 1940 to 15 million 2007, and some 60% live in low-income settlements on State land. Less than 15% of the wastewater and sewage is treated. Official record tells that 40% are connected to a sewer, but in reality almost 90% are serviced, of which half has been built by communities on a self-help basis (Pervaiz, Rahman and Hassan, 2008). Orangi was a new suburban low-income settlement in Karachi in the early 1970s. Ten years later there were about one million inhabitants. The government programmes had failed miserably and had the capacity only to upgrade one per cent of the country's low income areas and slums annually (Khan, 1998). A non-government organisation, the Orangi Pilot Project (OPP), started a low-cost sanitation programme in 1980 to address the poor sanitation conditions with bucket latrines and soakpits for excreta and open sewers for disposal of greywater.

The innovative OPP programme first analysed the constraints and possibilities in the community. Four barriers were identified: official agencies were believed to provide sewerage free of charge, sanitary latrines and sewers were beyond the paying capacity for low-income families, the families and masons did not possess the necessary skills for improvement, and the necessary social organisation did not exist. OPP addressed these barriers by developing low-cost technical solution, a bank for loans, and trained masons and families.

Orangi managed to demonstrate that, with some organisational and training support, residents could mobilise their own financial and managerial resources. By 1995 the resident had constructed 80 000 indoor flushed sanitary latrines and 400 km underground sewers (pictures). The government constructed connecting main drains and in some cases wastewater treatment plants (Khan, 1998). The residents retain responsibility for operation and maintenance of the community system. Ten years later almost 90% of Orangi settlement, altogether 108,000 households with 865,000 residents, are connected to sewers built in 7 600 lanes (Pervaiz, Rahman and Hassan, 2008).

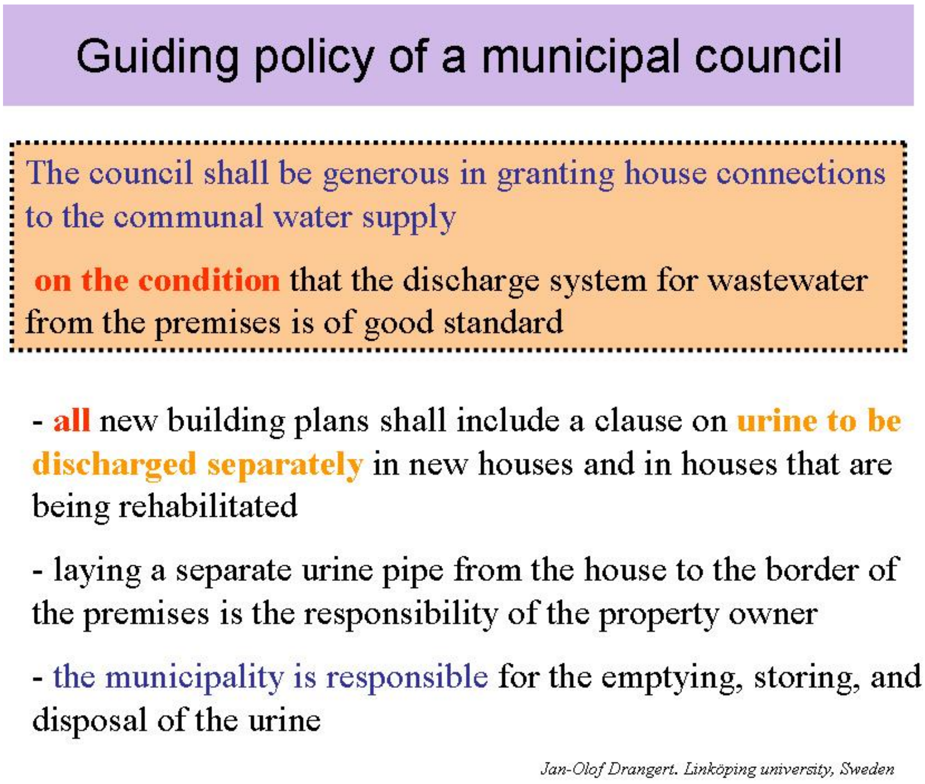
Infant mortality in the Orangi area dropped from 128 per thousand live borne in 1984 to 37 in 1991, and the cost for treatment of diseases went down drastically (Khan, 1998; slide 1.1-19), This was achieved with a collective investment by the communities of US$ 1.7 million or 2 US$ per capita (Khan, 1998).

The OPP's strategy focussed on scaling-up people´s initiative through support of small NGOs, community organisations and young activists to organise and promote the OPP methodology and programmes. In addition, the OPP helps to arm these groups with knowledge and ideas so that they can monitor, supervise, and keep account of the work they and the government agencies are doing in their areas, and by presenting the government with cheap and appropriate option for those aspects of development that they cannot undertake themselves. A main result seems to be that "*... they now prevent government contractors working in their localities, or contractors appointed by them individually or by their community organisation, from doing substandard work or work that is technically faulty. This has made the relationship between local government, the informal sector and the people more equitable*." (Khan, 1998).

Since 1999 the OPP works together with central and local governments and communities. In 2006 the government adopted OPP´s component-sharing model for sanitation improvements as part of the National Sanitation Policy. Already in 1999 OPP managed to convince the government to cancel a big conventional sewerage project to be financed by the Asian Development Bank loan of 70 million US$. They instead agreed to use a community-approach. In this way they intend to address the challenge posed by a need for some 80,000 housing units per year (Pervaiz, Rahman and Hassan, 2008).

Pervaiz, Rahman and Hassan attribute the ad hoc and piecemeal development and maintenance to lack of information about existing infrastructure. They argue this has "... opened the door for corruption and a waste of resources in large sewerage and drainage infrastructure projects. Collusion between government officials, engineers and contractors leads to substandard yet expensive work. Proposals are regularly overdesigned and overpriced, while implementation is generally of poor quality, lengthy, and without proper technical supervision."

2.3 - 10



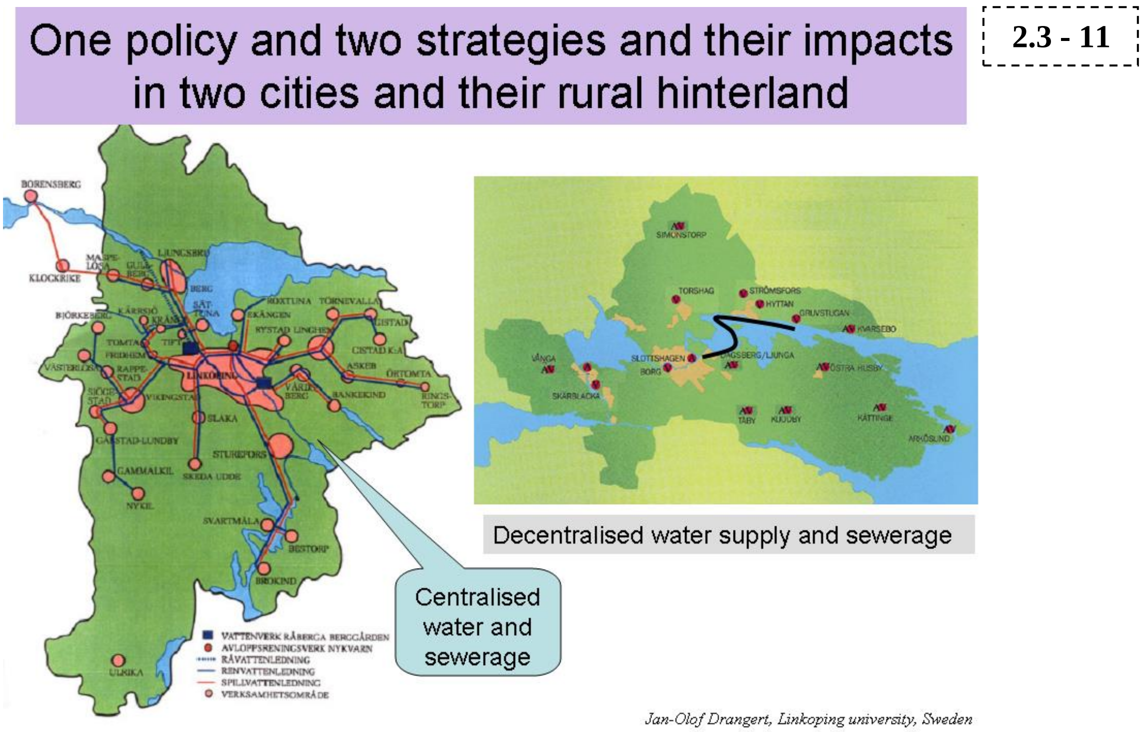
Tanum is a coastal community in Sweden with 12,000 permanent residents. The population reaches 60,000 in the summer. The seasonal population adds to local tax collection and contributes to high service levels for the permanent residents for the whole year. But, the municipal council is faced with problems of eutrophication of the water bodies. In order to remain attractive to tourists and to be able to increase the number of summer cottages, they had to do something about the wastewater discharge.

The landscape is dominated by bedrock which would make it very expensive to lay long sewers. Urine contributes about 50% of the phosphorus and 80% of the nitrogen in ordinary household wastewater (Module 4.1). The council estimated that they would reduce eutrophication to the desired level if they handled the urine separately, and faecal matter was composted and greywater treated in a septic tank or soil-bed or a cooperative treatment unit. Tanum municipality became famous for its 1992 decision to request all new houses and rehabilitated houses to be fitted with urine-diverting toilets and a urine pipe to the street. The council took responsibility to collect, store and transport the urine to surrounding farms. The house-owner paid a reduced fee for greywater connection and operation if he/she voluntarily secured a satisfactory system for disposed products.

The objective of the new five-page policy (see www.tanum.se) was to support politicians and professionals to execute uniform and widely understood decisions on:

- Physical planning
- Provision of communal water and sanitation
- Screening applications for private installations and monitoring private installations

The municipal council will, according to its policy, be generous in granting house-owners connections to the communal water supply, even if this means that the water capacity has to be increased. A precondition is that the household's discharge system for wastewater is of a good standard. Further, the use of water should be minimised and reserved mainly for drinking, hygiene use, and the production of food. Storm and drainage water is to be returned to nature without using extended pipes. Local handling of greywater is recommended. Also, the aim is to recycle the nutrients in sewage back to agricultural land. All these requirements were met.



A national strategy may produce different outcomes depending on local circumstances. The following is an example from the water and sanitation sector in Sweden.

There were some 2,300 self-governed municipalities in Sweden in the 1950s with populations ranging from a few hundred to half a million. The cities had utilities to manage water and sanitation services, while smaller communities and villages had their own combination of single household and community-run arrangements. At this time cities were about to build wastewater treatment plants in order to reduce rampant pollution of water bodies and groundwater.

To facilitate development planning and to enhance implementation capacity, the Swedish parliament enforced amalgamation of groups of previously self-governed municipalities into 283 larger ones, each containing a town as its central service unit. The scattered professionals in utilities were expected to come together and plan, for example, the water and sanitation networks in an integrated way (slide 2.5-10). The government provided subsidies for large conveyor pipes to facilitate centralised solutions and sometimes for establishing wastewater treatment plants.

A comparative study was conducted of two neighbouring cities with about 100,000 inhabitants each. Large stretches of rural areas (in green) and scattered villages were now part and parcel of the cities. The two cities were similar: same landscape and climate, same size of population, wealth, infrastructure and access to water sources. The aim was to analyse the impact of the amalgamation on ensuing development of the sanitation and water sector.

The two cities opted for very different strategies to improve the supply of water and treatment of used water. Linköping city (left) took a firm grip over the incorporated villages and used the government subsidies to connect them to a centralised network. The villages and their residents were encouraged to join by being offered low connection fees (conveyor pipes were heavily subsidised by central government). This was a time of low energy costs before the world oil crises in 1973 and 1975. Thirty years later, all villages except one were connected to the centralized water supply (dark blue) and sewage (in red). The tariffs for services have increased due to rising energy costs for pumping water back and forth. At this stage, it would be too costly for a house-owner to disconnect and build a private system. They would not receive a subsidy and the utility would fight such a move in order to retain subscribers.

The other city Norrköping (right) opted for a decentralised system and did not make much use of the government subsidies. After 30 years their network is minimal and has three nodes while most villages retained and further developed their local systems. All villages improved their water supply (V) and only four, on the rocky north side of the lake, connected to the treatment plant in the city centre (blue coloured pipe laid in the sea!) The picture also shows that they have a local WWTP (denoted A).

The reasons these cities chose opposing options are manifold, despite a common legal and economic background. The explanation cannot be differences in wealth, infrastructure etc. so other reasons must have been decisive.

Linköping is an old administrative centre for the county government, national church, and military. Thus, the surrounding villages had close connections and cooperation with the old city. Norrköping, on the other hand, was an industrial hub which competed with village industries and had no natural links to the surrounding countryside. Norrköping even faced opposition from the communities to be incorporated in the new city, to the extent that the national government had to intervene. Another important difference was that Linköping turned the water and sanitation department into a city-owned company, while Norrköping retained the municipal department for water and sewerage. In Linköping, historical relationships and the organisation of the water and sewerage sector were decisive in the choice of a more commercial approach which involved a centralised structure for all water and sewerage services.

Managing sanitation through effective policies, strategies and sustainable arrangements

2.3 - 12

- Match policies with the level of governance
- Coordinate responsibilities for water, wastewater, stormwater, sanitation and solid waste
- Devolve responsibilities to the lowest level starting with what the household can do
- Make sure the resources are adequate to perform the tasks at the intended level
- Reuse recovered resources (water, urine, faeces, etc.) on soil, not in water

Jan-Olof Drangert. Linköping university, Sweden

Policies give guidance as to what the public sector intends to do. They give rise to strategies that identify the main ways to achieve the desired goals. Such strategies take into account local conditions. They may achieve the intended outcomes or they may be adjusted or derailed due to vested interests among stakeholders. They aim not only at better health and environmental outcomes, but also include sustainable global resource use (economic, ecologically and socially).

It seems likely that in an environment with good governance it is relatively easy to fulfil plans and objectives. In a society with poor governance, however, it becomes even more important to understand the social forces at work. But sanitation can be improved even where governance is poor. Here, effective approaches may involve more local projects and systems which are transparent and give users a better chance to rate the services rendered. Public utilities typically are more difficult to scrutinise and monitor than smaller or localised ones (slide 2.2-5). Own-key options may have a better chance to succeed than turn-key arrangements. SMART policies (Specific, Measurable, Achievable, Realistic/ Resource-related/Result-oriented, and Time-bound) can be assessed properly.

Sanitation issues are becoming more and more pressing due to population growth and increased consumption of chemical products. Households must be part of improved resource management in communities since utility services alone cannot cope effectively with these problems. Any system has to be informative and provide feedback about the impact of its routines, product use, and discharges. There is usually no policy requiring urban residents to save on water or to avoid polluting water while using it. If all residents were careful with what they put into water, it could be easily treated and used again. If a person is given 40 litres to use in one day and does not pollute this ration, 38 litres can be treated and reused (with 2 litres transpired and urinated in other places). If the same person is given just 2 litres the next day, he or she will still have access to another 38 litres. Such self-contained sanitation arrangements are described in Module 2.1. In conclusion, there is plenty of water available for household use, and scarcity in urban areas is man-made. We have only just begun to explore ways of reducing consumption and increasing recycling.

Recent trends in sanitation shift the focus from ‘supply-driven’ to ‘demand-driven’ approaches which create low-cost sanitation facilities with affordable operation and maintenance costs. The approaches include social marketing, total sanitation to eliminate open-defecation through community dynamics, and stimulating a sanitation market with stores that sell hardware to individual customers.

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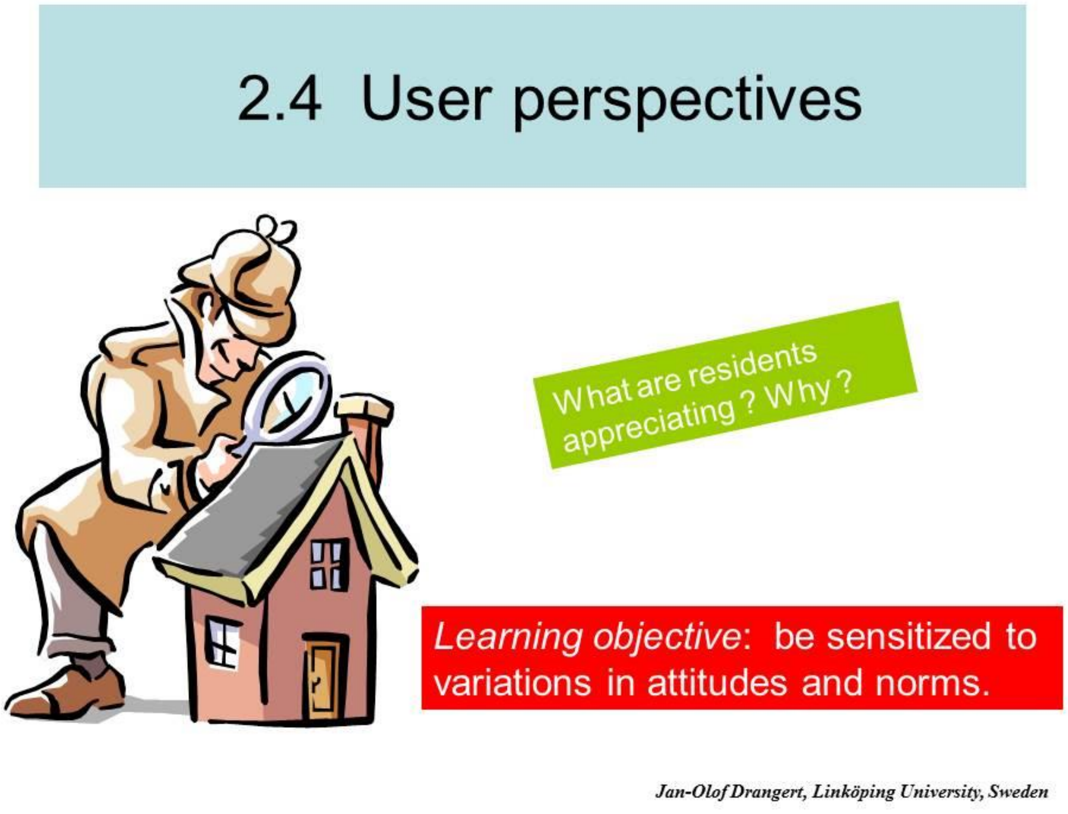


Piped water and sewerage appears to be rated as the most appropriate technologies for urban areas, which shows that a positive perception of this technology has been transferred successfully to almost all groups, including communities with no such services. Piped systems can provide a household with one cubic metre of water ”from the wall” and get rid of the same amount of waste water “through the floor” each day without bothering anyone in the household. These are two of several favourable properties of the piped system.

A typical water bill in Sweden covers about one-third of the total cost, while the rest is paid as part of the house rent and meets the costs of initial connection fees and installations in the kitchen and bathroom. The total cost for a day’s household water consumption of about 1 m^3 is some US$6 to $7 which is equivalent to an ordinary net income for half an hour’s work. This, in turn, equals the average time spent every day by rural women in Tanzania to fetch water for their families (Drangert, 1993). The difference is that the Tanzanian family gets perhaps 50–100 litres of water of lower quality. Piped systems provide good service, and their main limitations relate to the high investment cost and poor operation and maintenance in many countries.

Even if the investment cost for sewerage were to be subsidised in poor periurban areas, there is often insufficient water to service the number of toilets that would be needed. The ever increasing investment cost to develop new water sources affects decisions both in the North and South. It is being recognised that it can be more economical to manage the demand for water and provide various user groups with incentives to reduce their use of water. In this way the heavy investment involved in opening a new water resource can be postponed (e.g. slide 2.2-6). So far, some town councils have managed to defer new intakes by promoting devices like water-saving showers and pour-flush toilets and by separating rainwater from sewage so that rainwater can be used as a water source for households.

In this module we deal with the views of residents and how they are likely to be involved in the anticipated substantial changes to the management of sanitation arrangements in the future.

2.4 - 2

Often, our experiences of local conditions contribute significantly to the formulation of our attitudes and norms. For instance, poor solid waste collection triggers the response that the council should do more, rather than that residents should throw less trash onto the streets. Even rarer is the response that we need to change our consumption patterns. Often we – professionals as well as residents – need a global perspective to get a feel for resource flows, scarcity and depletion issues.

The left picture shows the globe in the daytime. It looks inviting with much water and large green areas, and it does not convey any message of limited resources. But, if we view the same globe in the night-time picture (right), we see large illuminated parts. This shows that we use enormous amounts of energy to light our houses, streets, and public places – to an extent that can easily be seen from the moon. Now, this informs us that although each of us contributes only a small bit, together we have a huge impact on the globe. Therefore, local or individual experiences are not always helpful for understanding environmental impacts. The period when we were just millions of humans on the globe is long gone, and now seven billion of us will live in a crowded world where nature is strongly affected by human activities.

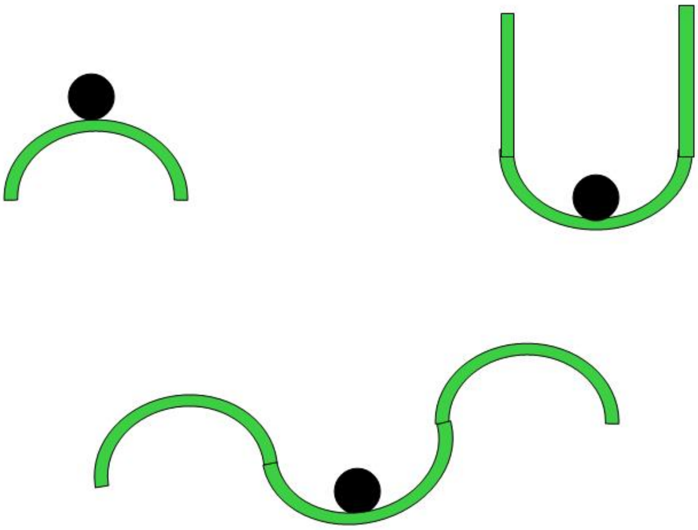
The impact is easy to understand if we take a global perspective. Climate researchers have confirmed this by their calculations of emissions and the effects of greenhouse gases on the thin layer of atmosphere around the globe that for so long has protected us from heavy radiation from the sun. Climate change is the first truly global environmental issue. Today, the question is “Did we create global warming because of something we did?” This is very different from the question in earlier millennia: “Did God create that hurricane because of something we did?” In earlier days we believed that only a supernatural power could create catastrophes in nature – in order to punish us for misconduct. Today, we know better – WE can cause catastrophes.

It matters what each one of us does in daily life since there are so many of us (slide 1.1-15).

The same conflict between local and global perceptions applies to all resources that human beings use: energy, metals, nutrients, etc. After use we move the waste products to places where it is difficult to process them for renewed use. We prefer to focus our thinking on the problem we solved but not the one we created. A global perspective tells that the food chain contributes some 20% of the Earth’s greenhouse gas emissions (Module 4.4 on biogas). The present sourcebook takes a global view of resource flows in order to form perceptions about where to start planning and organising our resource use in a more sustainable manner.

How nature´s resilience can be viewed

2.4 - 3



Jan-Olof Drangert, Linköping university, Sweden

Most people entertain an idea of how our human activities may affect the environment – and nature's resilience (Schwarz & Thompson, 1990). For example, can human activities make the ice caps melt? People's opinions vary, but if it happens, all agree it is irreversible, since it would take millions of years and favourable conditions for an ice cap to build up again. The picture above presents graphically three fundamentally different ways of thinking about human impacts. The top-left represents a person who thinks along the lines that any activity (= hitting the black ball) will disturb and irreversibly change the equilibrium in nature. The ball will end up somewhere, and possibly in a new equilibrium, while nature has changed for good.

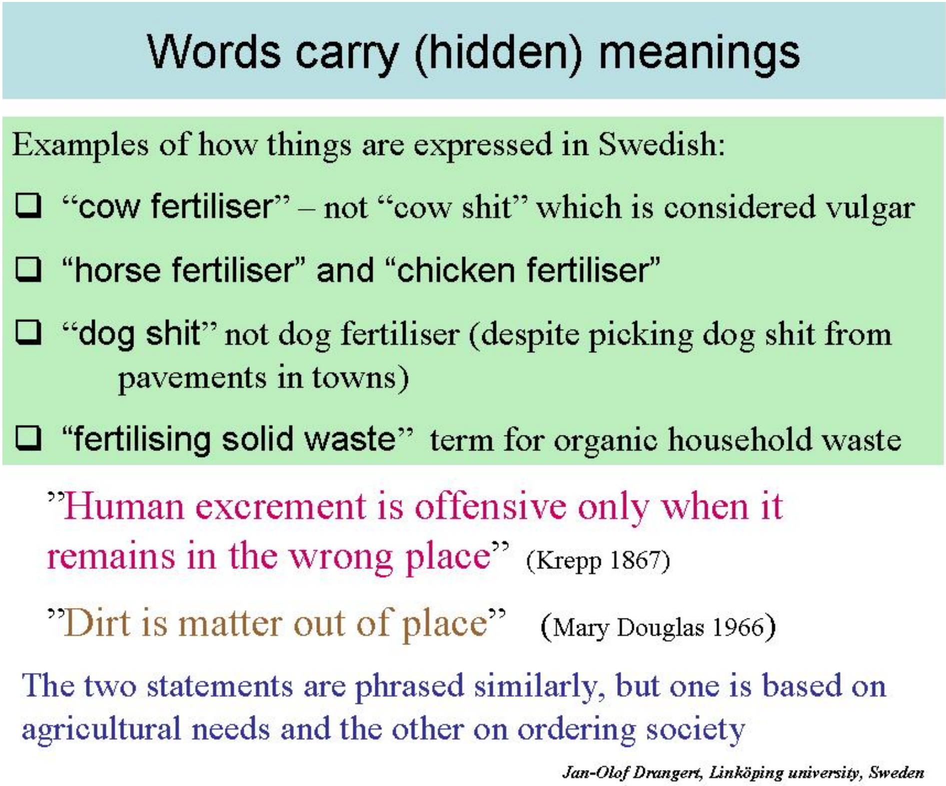
The top-right person believes that it does not matter what we do (kicking the ball in any direction) nature will always come back to the same equilibrium (the ball to its original position). This implies that this person is not worried that there will be lasting environmental problems – at most there will be temporary ones.

The third picture represents a person who thinks that nature is resilient enough to accommodate many, but not all, actions. Most actions will not change the equilibrium, but too much pressure may cause a permanent change. That means that if we are careful with our activities, nature will not be pushed away from equilibrium (see slide 1.1-16).

Understanding our underlying perceptions about human impacts on the environment may help us to grasp how difficult it can be to persuade another person. The increase in number of deniers of climate change or any other controversial issue illustrates the role of doubt. Media and other sources of information do not need to win the argument to succeed. It is enough to cause as much confusion as possible about the issue and doubts make people lose direction. There are examples of this tactic being used to discredit sanitation options. If someone claims that dry toilets cause bad odours, the doubts among listeners may make them decide not to install such a system. A vulgar attempt to stop the spread of odourless toilets in an HIV-inflicted area was to spread a rumour that using a dry toilet would cause HIV infection.

Another obstacle to raising awareness is when the consequences of poor environmental management do not affect an individual directly. For example, residents connected to sewerage are often unaware of on-going pollution simply because its impacts on nature are invisible. This ignorance of the effects of a technical system may be unintended, but is still perhaps the most important obstacle when it comes to raising awareness.

2.4 - 4



Words can carry meanings beyond their immediate definitions. Inbuilt meanings help us understand culture. Some words become obsolete and others are created when society changes, for instance from an agricultural one to an industrial or consumer one. Basic perceptions and societal norms may alter the language. The concepts of dirt, danger or reuse are interesting since they are embedded in the words we use. We focus here on words about excreta and wastewater. The Swedish language has a word for excrement from a cow – the literal translation being “cow fertiliser”. It is not called cow excrement or dung. This indicates that the matter is so intimately associated with being spread on the fields that reuse is embedded in the definition of the word. The same goes for horse excrement and chicken droppings which are called horse fertiliser and chicken fertiliser. Dog excrement, however, does not have the same connotations and so it is simply called dog shit/poo. This implies that dog shit has never been seen as a useful resource.

An interesting aspect of our relationship with dirt and danger is that our perceptions depend the location of the substance being described. The Dutch engineer Frederick Krepp (1867) wrote about the right and wrong place for excrements during the period when flush toilets were being introduced in Europe. He viewed excreta as being in its right place when used as fertiliser, and promoted the collection and use of human excreta in agriculture. He saw excreta as offensive when transported anywhere else, since that disrupted the prevailing closed nutrient loop between households and agriculture (1850s and 1860s). A century later, the anthropologist Mary Douglas (1966) makes a similar but more general theoretical statement when she says ‘dirt is matter out of place’. She contends that perceptions of what is dirt help to keep order in society. Without order one cannot talk about anything being “out of place”. Excrement used as compost or in a biogas plant is not dirty or offensive. However, the same matter in a public space is.

Solid waste collection and reuse was made more efficient in Sweden at the beginning of the 20th century. It was sorted in ‘*fertilising solid waste*’ (= organic waste including urine and faeces) and ‘*trash waste’* (= all other waste). The wording reflects that much of the organic (present-day vocabulary) waste was returned to agriculture as a fertiliser (slide 2.2-3). On the other hand, there is no word to denote the reuse of wastewater in Sweden, which reflects the fact that wastewater almost never has been used for irrigation or fish-farming.

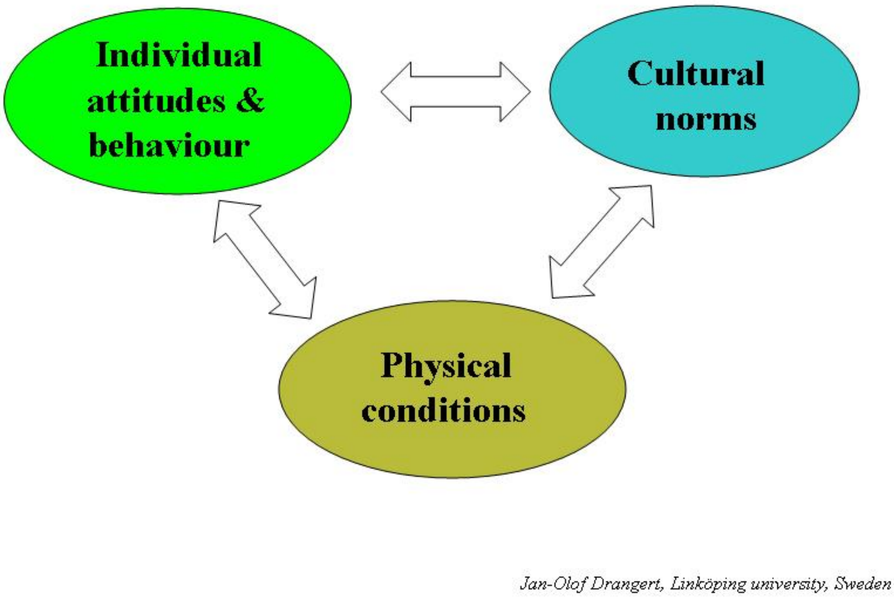
Every culture seems to have its own definitions of dirt and waste and therefore it becomes important to understand how these are linked with danger and reuse. The term ‘open defecation’ evokes strong feelings but its meaning is disputed (slide 1.1-10). Lay and professional views about what is considered ‘dirt’ and ‘out of place’ often differ. We define ‘open defecation’ as defecating in the open and leaving the excreta exposed (Kar and Chambers, 2008), like dogs (but not cats) do. A range of defecation practices do not qualify as open defecation (Drangert & Bahadar, 2011). Women going out in the dark to a designated place are not seen defecating, and they do cover the faecal matter. A man defecating behind his robe is not seen defecating, but any passer-by understands what is taking place. If he covers the faecal matter it is not counted as open defecation. The next level of being seen is when someone defecates behind a straw or mud wall; no one can see what is going on but everyone understands that the person goes to that place for urination or defecation. If there is only a ‘cat hole’ there, then this situation is little different from going to a toilet. If there is a pour-flush toilet, the discharge goes to a pit or to a sewer, or an open drain or to the street. The latter two cases represent a kind of delayed open defecation since the excreta end up in the open.

According to this definition, very little open defecation takes place among adults. However, children are often seen defecating indiscriminately, and their faeces are collected only when inside the house compound (slide 2.4-8). This indicates that although adults in all parts of the world view excreta negatively, children are not necessarily taught at an early age to shun excreta. The general perception is that children’s faeces are more or less harmless, and adults would find it difficult to take care of babies if they were repelled by their excreta. Therefore, in many societies child excreta are not considered to be in the wrong place when they are found in public places.

Covering faecal matter and washing hands after defecation are two crucial measures from a health perspective. Elderly people who follow the Sunna or the Bible and defecate in the open and afterwards cover the faeces and perform ablution follow a practice with low health risk to the person (WHO, 2006) and the health risk from buried excreta is minimal (Waterkeyn and Cairncross, 2005).

Components and relationships to consider

2.4 - 5

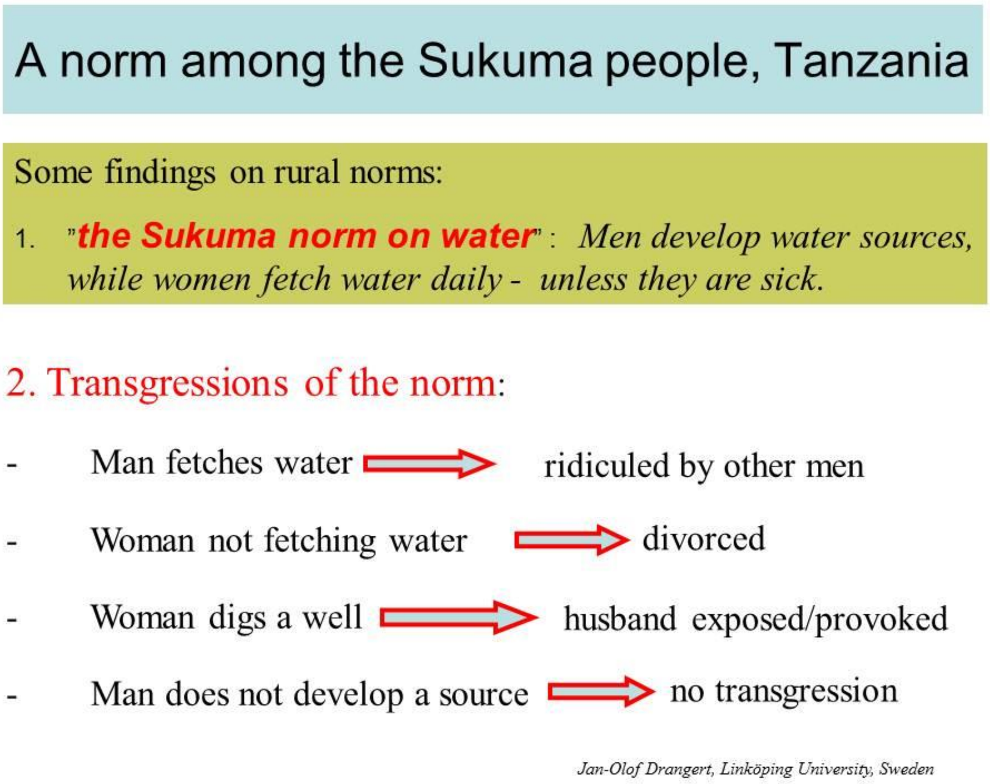


Our perceptions or ways of thinking are influenced by personal experiences and behaviours, by prevailing norms in society, and by physical conditions. The interrelationships between these influences are shown in the picture. Every community has norms about what is expected of its members. Such norms are inculcated from childhood and they are often reinforced in various ways via radio, churches, political statements, elders, peer influence, laws and regulations, etc.

As members of communities we have a choice of whether to adhere to norms or to transgress them. The community response to transgression varies from frowning to strict punishment – in serious cases the person may even be ostracised. If there is no visible response the norm can be neglected more easily. Also, sub-groups may formulate their own norms that are different from the general ones.

Any norm and behaviour is supposed to take physical conditions into account. If there is a water shortage, one would expect austerity in using this resource. If dirty neighbourhoods are known to bring disease, one would expect action to clean them up. However, reality often tells another story, and logic is not in actual situations so straightforward. We need to discuss this phenomenon more in detail.

It is also a fact that norms are not cut in stone, but are prone to revision from time to time. In the next slides some examples are reported from the water sector that tell us about norms, attitudes and transgression.



2.4 - 6

We provide here an example of a societal norm and what happens when it is broken. The Sukuma people occupy the area to the east and south of Lake Victoria in Tanzania. Today they number more than 5 million and many live in villages. Anthropologists have studied their culture and practices. Of late, a study of perceptions and practices concerning household water summarised their norm on water as follows: *men develop water sources, while women fetch water daily – unless they are sick* (Drangert, 1993). This corresponds to similar norms in most rural societies, where tasks are distributed according to gender (Whyte, 1980).

There are essentially four ways to transgress this norm. Men can fetch water if the wife is sick or handicapped, but if a man fetches water under other circumstances, he is ridiculed by other men. To avoid this embarrassment, a caring husband with an ox-cart may say he is fetching water for his animals, while he at the same time brings along an extra drum of water for the household.

If a healthy woman refuses to fetch water, it is reason enough for a divorce. She can not expect to receive any support and the toughest consequence of the divorce is that the husband becomes the sole caretaker of their children. No such transgression has been reported.

Women are not supposed to dig wells, only to excavate pits in the dry river bed from where to get water. This is not a man's task since the hole collapses and has to be excavated every time water is drawn from the dry river bed. However, there are reported cases where women come together clandestinely to dig a well without the knowledge of others. In this way a woman may avoid exposing or provoking her husband, which would be tantamount to telling him that he is not fulfilling his obligations.

The fourth transgression is when a man does not develop a household water source. The norm prescribes no consequences when that occurs and the husband himself can decide whether the situation is grave enough to prompt him to act. His inactivity is certainly not followed by any punishment by society. The situation is totally different from that faced by women, whose inescapable chore is to fetch water every single day.

A societal norm, and more so the punishment for not fulfilling the requirements of the norm, guides most people. Therefore, norms are important and can determine the behaviour of individuals. This is obviously the case for women in the example above but it is also true for the men, since a lax norm gives them the option of remaining inactive. This may explain why so few private wells exist in many rural communities.

When women in Sukumaland were asked what would happen if *men* were to fetch water, they said laughingly that a man could not carry the bucket and after a day he would refuse. There are several possible explanations for women's reluctance to the idea of men fetching water. Men do not know that women often use water from different water sources for different purposes, so they suspect men to bring the wrong water quality. The women may also have been worried that their husbands could become a laughing stock or that they could be attracted to one of the many women they would meet at the communal well. Also, if a woman no longer had to fetch water, she would lose the opportunity to meet with female friends outside the home. She would also lose an important task in the family that brought her responsibility, power and dignity.

When men were asked the same question, they all responded that women had always fetched water and it cannot be otherwise. Had men fetched water from the beginning it would have been okay, but not now. Some pressure was exerted to get them to really think of what would be the outcome. For instance, what if God decided that from tomorrow the men were to have the task to fetch water? They responded that "God cannot decide that." After some time the men agreed to think through the outcome, but after a few seconds they gave the answer: "Then I would dig a well near the house!" Instead of being determined by their culture, their thinking became driven by the desire to save effort and time. It would take them a week to dig the well but save hours every day. This indicates that norms and expectations have to be adjusted in order to achieve improved access to water.

An interpretation of the responses is that the interviewees are harmony rational rather than time rational. Some readers may be surprised by this interpretation since they expect a couple to be an integral unit and not an assembly of a husband and a wife with partly separate agendas. As an integral unit the couple is expected to be time-rational for the unit and decide to dig the well since it will save time and reduce daily chore. On the other hand, if the couple is viewed as rather independent parties it seems likely that the couple is harmony rational and avoid to quarrel about who is to fetch the water every day. Harmony is a common aspiration for the parties, but it puts the burden on the female in this case.

The need to develop water sources and fetch water also applies in urban settings. Men have actually taken on the task of providing water to urban households, but this time as engineers developing a piped supply. The crucial difference is that men are being paid to do it, and they are probably not thinking they have taken on a female task, but are proud of having contributed to better services. This concern with money and self-image among men turns out to be an obstacle to voluntary work in urban areas. Groups of men doing voluntary work are unheard of, whereas there are women groups involved in various development activities.

A norm among Pashtuns in rural Pakistan

2.4 - 7

In rural Pakistan where in-house sanitation arrangements are rare, these are the norms among Pashtuns for excreting:

> 'Men excrete outdoors in designated sites or in the privacy of a *chadar* (cloth), while women excrete inside the house or compound, or outside in the dark under strict privacy from men.
>
> Children may excrete anywhere.
>
> Women take care of their own excreta and those of children and the sick.
>
> **There are no explicit norms for the use human-derived nutrients as fertilizer.**'

Jan-Olof Drangert, Linköping university, Sweden

When this norm evolved a long time ago, the population density was low and the amount of excreta available for agriculture was small. Simple but hygienic rules about where not to defecate and how to cover faeces with soil were sufficient. The whole issue of defecation in designated areas, and more particularly in agricultural fields, fits well with Mary Douglas's theory: order is maintained when human-derived nutrients are considered to be disposed of in the right place (Douglas, 1966). The norms do not involve building anything; they only require walking to the appropriate place, not being seen by the other sex, and observing ablution rules.

There are few transgressions of these norms. Skipping ablution or neglecting to cover faecal matter is a religious offence. If a woman was seen defecating by a man, she would be socially punished. However, none of these potential transgressions have been reported. These norms now need to be adapted to more densely populated villages and the new pour-flush toilet seems to be a common response. These toilets are being installed by men.

The fact that there is no expressed intention to reuse humanure in agriculture is not the same as saying there is no such practice. Waste heaps with excreta and other organic household waste were observed to be left lying in the open for months and even a year before farmers would collect and apply the partially decomposed material on their fields. They viewed this material as a nutrient-rich manure called *desi fertilizer* (Drangert & Bahadar, 2011).

Untreated wastewater is *najas* (impure) but the wastewater usage decree by the Council of Leading Islamic Scholars in Saudi Arabia supports the reuse of wastewater for irrigation. Interviewed farmers who were not willing to apply their own urine and faeces as manure on their fields were prepared to pay a high price for irrigation water. This is in line with studies showing that farmers pay a high price for raw sewage to irrigate crops in parts of Pakistan due to its high nutrient content (Ensink et al., 2004). This is an example of how perceptions may change due to the desire for the financial rewards of increased crop production, which seems to be a stronger incentive than potential health risks and religious rules about excreta.

Nowadays fewer villagers are farmers, and so their views on defecation practices are bound to change. Non-farming sections of the communities have no experience of nutrient loops, so they may adopt more restrictive views on what is acceptable. Reuse is becoming less common and is likely to fade away as pour-flush toilets rapidly replace dry latrines and defecation in the open. Interviews and discussions about urine-diverting toilets and reuse of urine and faeces indicate that many villagers are unaware that most plant nutrients are in the urine rather than faeces (Nawab & Cassandra, 2008).

2.4 - 8

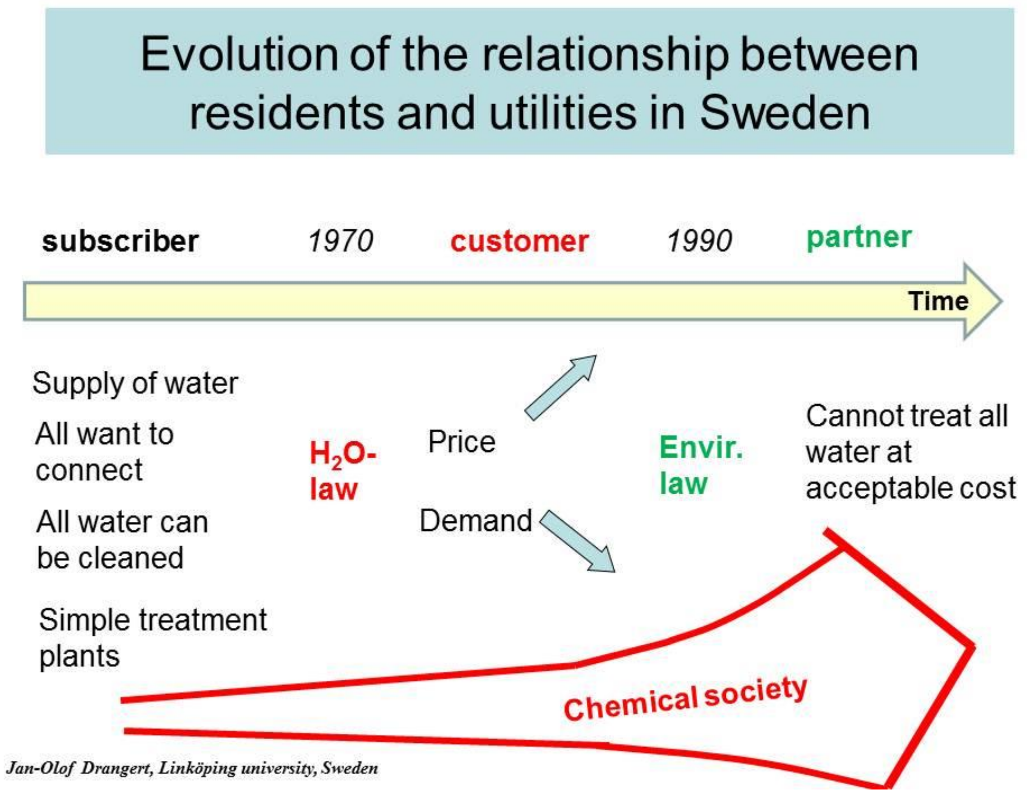
In Bangladesh Dr. Kamal Kar introduced Community-Led Total Sanitation (CLTS), a unique method to achieve excreta-free communities as a result of residents' own initiatives. Its basic idea is that even some open defecation is a health hazard to the whole community. CLTS focuses on igniting changes in residents' sanitation behaviour rather than constructing toilets. It does so through a process of social awakening using mapping, transect walks and provocative public discussions (Financial Times, 2008).

CSLT applies participatory methods to enable local communities to analyse their sanitation conditions and collectively understand the often terrible impact open defecation has on public health and on the entire neighbourhood environment (see picture). The approach takes only one perception into account – people's disgust for fresh faeces. The trick is to force the residents to see things they have become blind to. The eye-opener is to observe the current conditions.

The background is that open defecation close to living places has increased as urban and rural populations grow and properties are fenced in. In line with Mary Douglas's theory, faeces along the roadside are so common that it has almost become the right place for them. This is true for children's faeces since they are viewed as harmless. Residents go around inspecting not covered faecal matter and observing the flies feeding on them and later entering people's homes and landing on their food. Kamal Kar managed to break this norm about child faeces by making it likely that people eat other's faeces. No human being can stay indifferent once they realise they are ingesting other people's fresh shit. This new approach provokes the residents by calling excreta by its local name and visiting the dirtiest parts of a village. It surprises residents to learn that many villagers visit these poor and dirty areas for defecation, believing that by doing so they avoid the hazard. By analysing their own practices, residents are disgusted and feel shame.

This is provocative and also fun. The CLTS campaign encourages residents to use their own judgement at all times and initiate locally appropriate approaches and tools to enhance community participation and empowerment, leading to total sanitation and beyond (Kar & Chambers, 2008). The policy of not providing subsidies for hardware, and leaving decisions and actions to the community, often provoke urgent collective local action to become a totally excreta-free community. The no-hardware subsidy approach makes communities, not the campaign, responsible for the outcome of an intervention. Whether the community decides to act or not is entirely up to its residents.

2.4 - 9



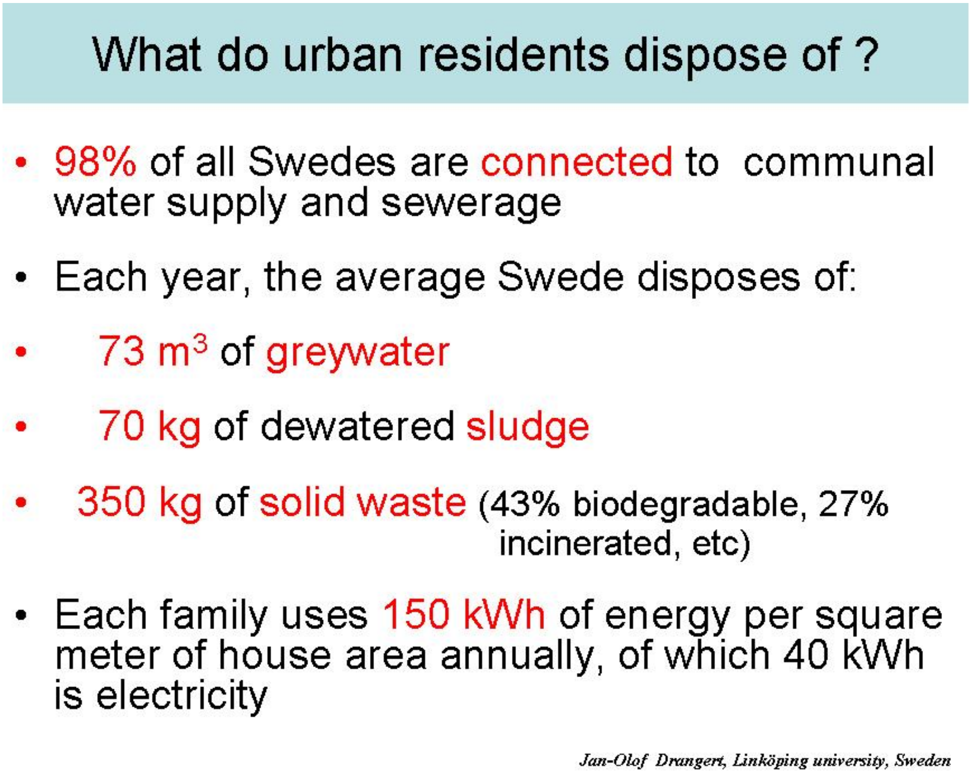
The urban situation is addressed in this picture. The relationship between residents and utilities is a dynamic and interesting one. It changes slowly over time for various reasons, and here we follow the example of Sweden for the period 1950 to 2000. Other societies are likely to experience a similar evolution but the time period may be somewhat different. As is usually the case, development patterns are surprisingly similar – at least at the level of material flows.

The decades prior to 1970 were characterized by supply management thinking (slide 2.2-5). Utilities had the capacity to supply water, and were often given some form of subsidy. In the Swedish case, the central government subsidized trunk lines for water and sewage, and, in some years, it also provided soft loans for house owners to retrofit. The general view in society was that all wastewater could be cleaned well, and simple treatment plants mushroomed in small communities. All house owners wanted to be connected to utility services, since it was seemingly cheap (if they did not take into account that they had to pay via government taxes). Householders were treated as subscribers. They paid a fee for water and expected the utility to provide all the services they required (*turn-key* arrangement as defined in slide 2.3-6).

Then, in 1970, a revised water act was passed which stated that no cross-subsidies were to be given to the water and sanitation sector. Therefore, the municipal-owned utilities had to increase their fees drastically to cover the interest rates on the loans they took in order to build infra-structure. This was not a problem for the utilities since they were monopolies and house owners could not leave the system. What residents, and to a greater extent industries, could do was to reduce water use to cut their costs. As a result, utility incomes dropped and they had to raise tariffs even more. The utilities tried to arrest the drop in demand by informing users about the good quality of the supplied water and by claiming that they treated the wastewater so well that the raised tariffs were justified. In other words, the utilities had to start treating the users as customers, not only as subscribers. It took about 15 years of adjustment before the utility's incomes covered their costs.

In 1990, the utilities faced another challenge. A new, stricter environmental law forced them to improve the quality of the effluent from the wastewater treatment plants. At the same time, consumers have gradually shifted toward more complicated chemical products, which eventually end up in the WWTP. In a fully-fledged chemical society, it became obvious that not all wastewater could be treated satisfactorily (see Module 4.5). This was not because the treatment plants did a bad job, but because the content of the wastewater they received from households contained too many chemicals. The utilities have had to start to cooperate with households in order to reduce the load of unwanted ingredients in the wastewater. The only solution is for householders to become partners in the process to improve the quality of the effluent. Therefore, many prevailing norms and expectations among households and staff need to change to fit this new paradigm.

2.4 - 10



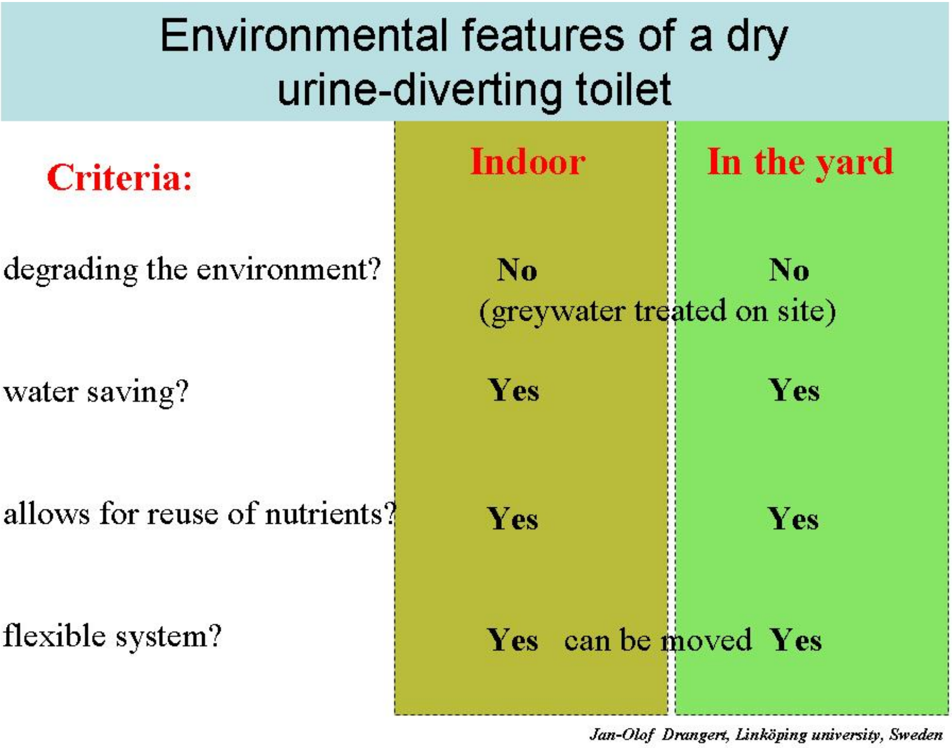
One individual does not dispose of waste in volumes that can harm the globe, but together we do. What volumes are we talking about? Well, it differs between societies and the picture shows some discharges from an average Swede. As mentioned in the greywater chapter, wastewater is by far the largest waste in terms of volume, and the partly treated water is discharged to rivers and lakes. After treatment some 70 kg of dewatered sludge remains in the treatment plant. In a town of 100,000 inhabitants, the utility needs to know what to do with 7,000 tons of sludge containing all kinds of pollutants that would otherwise destroy the receiving water body. This sludge is composed of the items we have put into the water while using it. Had we not mixed unwanted substances in the sink and WC, the treatment plant would have a very simple and manageable task.

The solid waste from households is to a large extent biodegradable, which means that it can be composted and recirculated gainfully to the soil. As much as 27 % is incinerated to produce heat, but it also leaves contaminated ashes behind in the incinerator. Some pollutants will also leave through the chimney and add to greenhouse emissions and other gases.

The energy use is considerable in a cold climate like Sweden's. Warming up the house or flat and heating tap water takes about two-thirds of the energy, and the rest is electricity for lighting and equipment such as stove, freezer, radio, and computer. Most energy sources, other than hydro, wind, and solar power, produce waste products that have to be taken care of. Nuclear waste is the worst.

People usually agree that one should not be wasteful with natural resources, but they would hesitate to reduce their comfort for the sake of a better environment. Again, it takes a global understanding to raise the awareness of resource scarcity and depletion (Module 5.1 on phosphorus).

2.4 - 11



As more and more people move to urban areas, the requirements on ecological sustainability increase. The criteria for assessing private toilets can be divided into two categories. One is about the socio-cultural and management aspects related to the toilet and toilet room, and the other category is about environmental aspects. In slides 2.4-11 to 2.4-13 the flush toilet is compared with an indoor urine-diverting toilet, and two outdoor options, the pit latrine and the outdoor urine-diverting toilet. We start by assessing dry urine-diverting toilets.

Sustainability criteria related to the environment may include the ones in the picture above. Demand for water, nutrients and energy is increasing, so sanitation systems need to contribute to resource conservation and recovery. Therefore, new requirements have been appearing for the water and sanitation sector: as little degradation of the environment as possible, saving on water, recycling and use of nutrients, and flexibility of the system.

The urine-diverting toilets are designed to meet these requirements. As can be seen in the picture above, the indoor and outdoor versions perform equally well. The faecal matter and urine is contained and later used with no leakage to water bodies. The small volume of ablution water can be infiltrated or treated in a wetland. No water is needed except for hand washing. The nutrients in urine and faecal matter are easy to transfer to urban or conventional agriculture.

The dry toilet system is very flexible. The pedestal or squatting pan can be moved easily, there are no water pipes to retrofit – only a plastic hose for the urine collection. The collection system where urine is collected in jerry cans or by a vacuum truck can easily be changed or adapted to new management structures, and so can the collection and treatment of faecal material.

This and the following slides can be used as an exercise. The participants are divided into groups of 6-8 in each, and there is no limit to the number of groups. If there are many groups, the reporting can be organised so that each group only reports one response or only the criteria that has aroused discussions. The participants are requested to individually fill in Yes or No in the four (emptied) columns from slide 2.4-13. After that, the group members compare their answers and discuss the options where they disagree.

If the schedule allows an extra hour or so, the exercise can be extended by asking each group to start by discussing whether the criteria cover the most important aspect. The participants should be encouraged to suggest alternative criteria.

2.4 - 12

Several common criteria or requirements concerning socio-cultural and management are given in the picture. Yes/No assessments are suggested, and they tend to be more value-laden here than for environmental aspects.

Smell is an important issue for users, and the general perception is that a toilet should be odourless. Some people may even use deodorants to reduce or hide foul smells. The urine-diverting toilet evacuates foul smell immediately so that it does not spread in the toilet room. Users also demand that the toilet be free from flies and maggots – flies because they can transmit diseases and are a nuisance and maggots because they look disgusting (Drangert, 2003).

Users also value a toilet which gives them some control and security. Control can refer to privacy and controlling who uses the toilet and who is responsible for cleaning etc. Security is a high priority in many densely populated areas where women especially are at risk of harassment and rape when going for defecation in the yard – in some peri-urban areas even when the toilet is on their own premises.

If the toilet room is neat and clean people will like it more and use it more. Many public toilets are so filthy that workers and school children postpone their visit till they get home. A pre-condition for cleanliness is that the task is relatively easy, in the sense that floors are smooth and fittings well made – and that the toilet is close to the home and preferably indoors.

Hand washing has been on the agenda for a long time. Yet, it is not generally practised even in modern bathrooms with taps and basins. Outdoor toilets without water are much more likely not to promote hand washing.

Closely related is hygienic handling of urine and faeces. If fingers are soiled with faecal matter, hand washing is of prime importance. When the toilet has to be emptied by someone or a blockage in a sewer has to be cleaned out, it must be done in the safest possible way.

The cost of installing the toilet has to be affordable if it is to be commonplace. And, lastly, indoor toilets take up space that may not be available, but it could also be attached to the house with an entrance from one of the rooms. Moreover, toilets in the yard also require space (2.6-6).

In the table above, the columns for dry toilets indoors and in the yard are filled in with general information from field experiences. The two kinds of toilets differ on four aspects and are equal for four. It is obvious that the indoor toilet allows for better hygiene and management.

Comparison of options

2.4 - 13

	WC	Dry urine-diverting indoor	Dry urine-diverting in yard	Dug latrine
Socio-cultural features:				
- smell?	Yes	No	No	Yes
- flies and maggots?	No	No	No	Yes
- control and security?	Yes	Yes	No	No
- Safe and easy to clean and maintain?	Yes	Yes	No	No
- hand washing facility?	Yes	Yes	No	No
- hygienic handling of urine & faeces?	Yes	Yes	Yes	Yes
- affordable to most residents?	No	Yes	Yes	Yes
- space required indoors?	Yes	Yes	No	No
Environmental features:				
- degrading the environment?	Yes	No	No	Yes
- water saving?	No	Yes	Yes	Yes
- allows for reuse of nutrients?	No	Yes	Yes	Yes
- flexible system?	No	Yes	Yes	Yes

Jan-Olof Drangert, Linköping University, Sweden

Now, we compare the two kinds of dry urine-diverting toilets with the 'ideal' flush toilet and the common dug latrine. We use the same set of criteria as before.

It turns out that the dug latrine has many features in common with the dry urine-diverting outdoor toilet. The two differ when it comes to odour, flies and maggots. This is because the faecal matter is almost dry in the urine-diverting collection unit (vault, bucket or other bin) and is also emptied more frequently than in the case of dug latrines. One may try to have a fly screen on the vent pipe of the VIP latrine, but the general experience is that it will corrode quickly and is very difficult to replace. So, in practice the fly screen does not perform well (see alternative in slide 2.1-9). The dug pit is likely to pollute the groundwater, while urine-diverting toilets do not.

In short, the dry urine-diverting outdoor toilet performs better than the dug latrine.

The WC and the indoor dry urine-diverting toilet have most socio-cultural features in common, while their environmental features differ for ALL criteria.

The issue of odour could be argued as follows. The water seal in the WC does not prevent the creation of bad smells when the faecal matter drops from the anus to the water, and the odour has to be evacuated by the ventilation system in the bathroom. We tend to accept the smell from our own faeces, but prefer to delay entering the toilet after somebody else has used it. The urine-diverting toilet is designed to draw all air down through the drop-hole immediately and exhaust it above the roof top. Therefore, there is no smell at all in the bathroom.

The other issue that is often discussed is whether a urine-diverting toilet is easy to clean and maintain. Cleaning is done with a damp piece of paper that is thrown into the drop-hole afterwards, whereas you may use a brush and flush the WC. A key question is about maintenance including collecting urine and dry faecal matter. This is easy once you get the habit and overcome worries. Unfortunately, many interviewers ask potential users of dry toilets whether they are prepared to deal with fresh faeces, and the answer is always negative.

The proper question should be whether they are prepared to deal with composted or dry faecal matter. The answer is then often more positive. As in the case of WCs you may also pay an entrepreneur to do this service. The dry urine-diverting indoor toilet has an advantage over the flush system in that it is affordable for many more people.

The sanitation system must not degrade the environment. Examples of degradation are leaking latrine pits, septic tanks and sewers. Untreated wastewater disposed of into water bodies may contain contaminants such as endocrine disrupters, nitrates, and hormones. In the case of urine-diverting toilets, both faeces and urine are contained.

The system should also conserve water and nutrients. Dry toilets use no water. The design of a flush toilet determines the volume of water for each flush. Dual-flush toilets use only a fraction of the water used by earlier models. The inclination of pipes decides how much water is needed to prevent blockages, but more important are the types of products we flush down the pipe in our homes. Leaking joints and taps constitute a major portion of the water we ‘use’. So, both design and maintenance routines are important elements in water saving.

Wastewater treatment plants are faced with the problem of reducing the nutrients in the wastewater, in particular nitrogen and phosphorus. The consequence is that receiving water bodies are eutrophied with algal blooms and as a result they contain less oxygen for fish and other creatures. The nutrients from our food could instead be recycled as fertilizer for plant production after being collected directly from our homes. In that way communities can contribute to improved ground and surface waters, reduce the burden on utilities, and postpone the looming scarcity of phosphorus in the world.

A sanitation system lasts for several decades; a latrine pit may last for ten years while a flush toilet probably lasts for 30–40 years. Therefore, it is important that the system has some flexibility to adapt to technical and other developments without exorbitant cost.

The comparison shows that a dry urine-diverting indoor toilet has one or two socio-cultural advantages over the flush toilet. As for the environmental features, the dry indoor urine-diverting toilet out-performs the WC on all counts.

Consider the changing local culture

2.4 - 14

Residents: Reuse requires space and also enough motivation to do so. Many societies do not practise urban agriculture, but when given the opportunity many residents become involved and accept the idea of recycling human waste in gardening. A major reason is that sanitised urine and treated dry faecal material is used, not fresh excreta.

Professionals: Well-maintained urine-diverting toilets are odour-less and can be installed indoors. However, professionals often believe that toilets in poor housing areas have to be in the yard. Repeatedly it has been shown that residents prefer an indoor toilet, once they are aware of the odour-less option.

The benefits of indoor toilets are for example better privacy and security, easy to clean and maintain, convenient for sick and disabled, etc. From a health point of view the indoor toilet increases the likelihood of hand-washing after defecation.

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If the users are uninterested in, or rejecting a sanitation arrangement, it will not be taken care of. However, cultural views are rarely cut in stone, and tend to adjust to new realities. When farmers move to town, a number of rural conventions are modified or done away with. Men and women start using the same toilet – even young men and their mothers-in-law. Strong norms such as having large families begin to have less impact and the numbers of children are reduced, sometimes drastically. Therefore, projects which try to introduce new technologies or behaviours should be culturally sensitive without assuming all prevailing traditions and attitudes to be rigid.

Increases in the prices of food and fertilisers may gradually change people's understanding and attitudes about alternative fertilisers as well as urban agriculture. Today, a lot of food is produced around several cities in the world. In many European cities there are allotment gardens and roof-top cultivation (slide 2.1-20). During the "World" Wars in Europe most urban areas were heavily cultivated. Food security has always been a strong incentive for urban agriculture.

Knowingly or not, professionals tend to propagate sanitation systems that they view as beneficial to their careers and status. This human instinct can lead to vast improvements in sanitary arrangements. However, it can also prevent improvements from taking place, in particular in areas with little prospect of successful public interventions. In the case of urine-diverting toilets, experience shows that professionals tend to talk and think about fresh faecal matter rather than composted or dry faecal matter. Therefore, they tend to promote odourless urine-diverting toilets to be sited in the yard away from the home. They may also entertain the view that poor residents should not have an indoor toilet similar to the WC. The fear may be that if dry, urine-diverting indoor toilets work well, the case for installing WCs, with the water supply and sewerage system they require, would be much less convincing.

There is certainly room for all kinds of decent technologies in a world where more than two billion people lack proper sanitation. There is no risk of professionals becoming jobless. But if professionals continue to promote WCs indoors and latrine pits in the yard, billions of people will end up with inferior, inconvenient arrangements which threaten their health.

When professional pride takes precedence, experts offer hopes for future improvement, but no immediate remedies. Mankind has progressed further than just hiding the excreta in a pit (which is a good thing) and now we can improve hygiene and health by providing hand washing facilities to most residents. This cannot take place with a toilet in the yard. Professionals should be ethically bound to promote indoor toilets for this reason.

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2.5 A way forward …
a tool for selecting sustainable sanitation arrangements

How to obtain all the information we need?

Learning objective: selecting a sustainable arrangement is more than just choosing between technical solutions.

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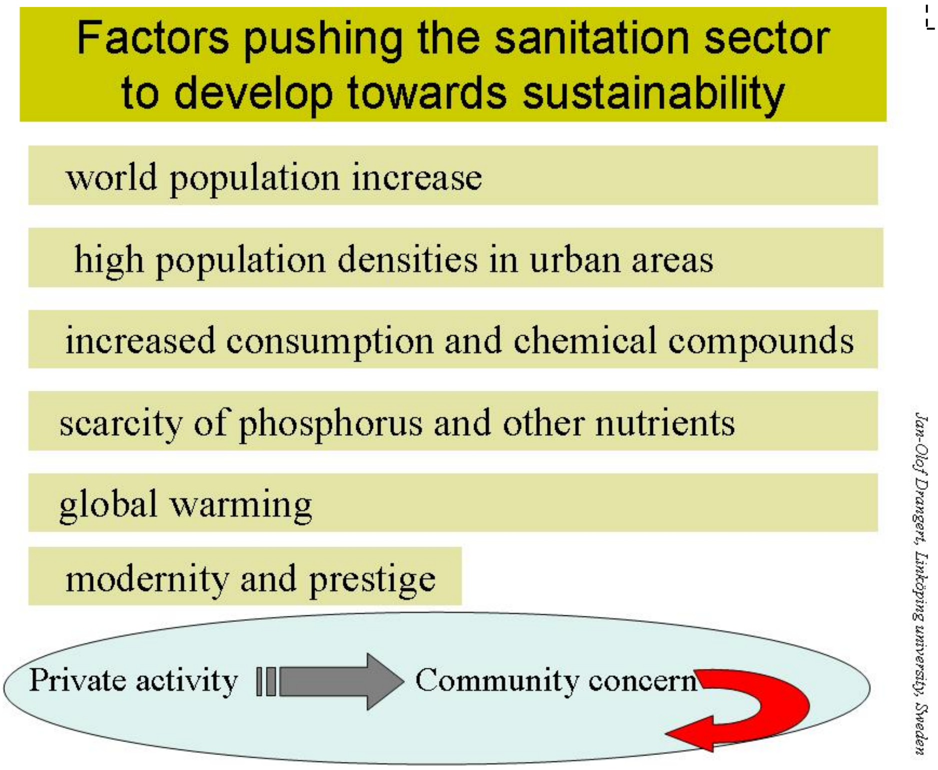
In this sourcebook we focus on systems and arrangements for water, wastewater, storm water excreta and (organic) solid waste. A good system requires that the parts fit together into a well-functioning whole. We need criteria and methods of thinking and acting in order to select a desirable system that will provide services and not add pressure on natural resources. Only after defining service levels, acceptable environmental impacts and pollution levels is it time to select the technical bits and pieces of the entire arrangement.

We discuss systems for new housing areas with a focus on selecting the system as a whole, not just choosing parts to be added to an existing system. Keep in mind that as many NEW urban houses as there are houses today will be built within the next generation! This is a golden opportunity to erect more sustainable cities.

Most of the new houses will be built in the developing and urbanising world. In 2008, a rapidly urbanising China built 2 billion square metres of floor area – almost half of the world´s total built floor area for that year (*The Straits Times*, 2009). Chinese construction companies must apply for a Green Building Certificate which gives an assessment of their environmental footprints with respect to a range of indicators, including energy savings, reduction of air and noise pollution, smart water usage, carbon dioxide emissions and impact on surroundings.

A joint assault on the silent sanitation crisis facing many countries around the world is not only a municipal council responsibility. Researchers, sanitary engineers, architects, plumbers, manufacturers of sanitary ware, farmers etc. are all involved – and so are the residents themselves. In this chapter we are not restricted to poor communities, because the need to choose sustainable sanitation applies to all residents all over the globe. The emissions from our sanitation systems, be they centralised or not, are substantial and have to be reduced. This was part of the agenda at the climate change summit in Copenhagen in 2009.

2.5 - 2



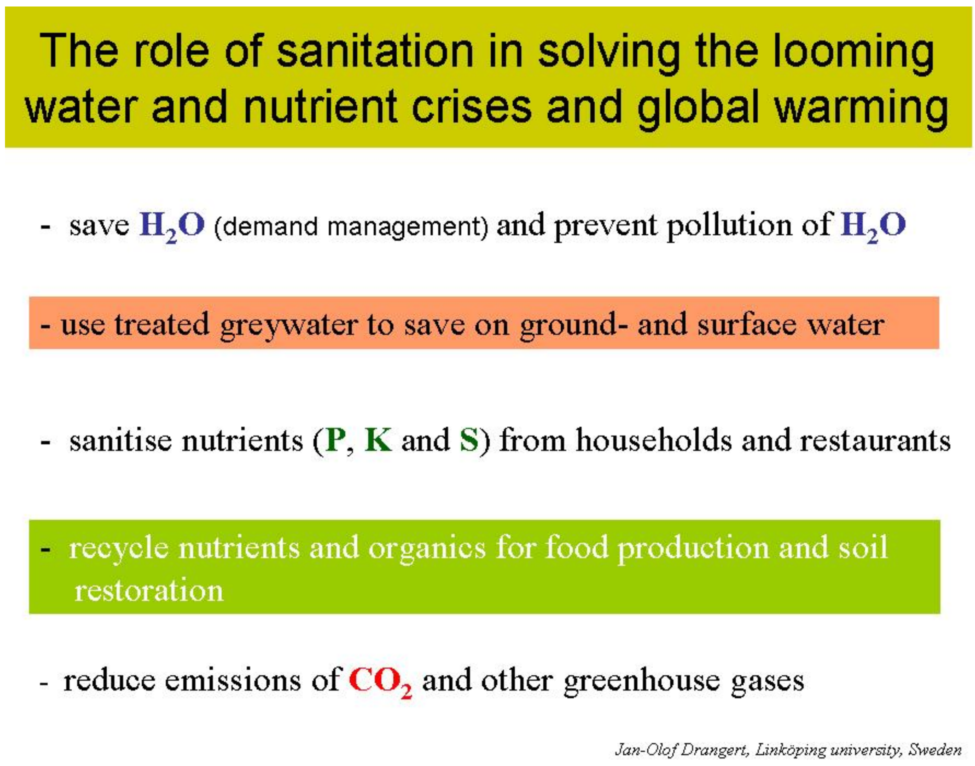
The resource flows are gradually changing in volume due to increases in population and wealth, and in composition due to new consumption patterns and products. With the looming scarcity of (virgin) resources and rising discharges/emissions of undesirable waste products (slide 1.1-?) new requirements are forthcoming. Our point of departure is such recent global experiences which push for more sustainable sanitation arrangements. The private activities of defecating and disposing of used products become a community concern which – in turn – may restrict these private activities.

Urban living requires inputs of food, water and energy. Resources are transported from other parts of the globe to urban areas which implies imbalances, unless these resources are returned to agricultural fields and water bodies. One such imbalance that was recently ‘discovered’ is the looming scarcity of phosphorus, an essential ingredient in food production and products – and thus in food waste (see Module 5.1). In a world with some millions of people this problem would not mean much, but when we are 7 billion people and soon 9 billion, the imbalance really matters. If planners and decision-makers do not act quickly, the consequence will – again – be widespread food shortages and famines. Such man-made shortages should not be allowed where the solutions are easy to access.

Changes in resource usage are closely linked to the influence of the perceived modernity and prestige of products on residents’ self-esteem. Unfortunately, the life-span of conventional water supply and sewerage is a hundred years, and therefore it is not possible to anticipate what kind of consumption we will have at the end of the period – and appropriate treatment system.

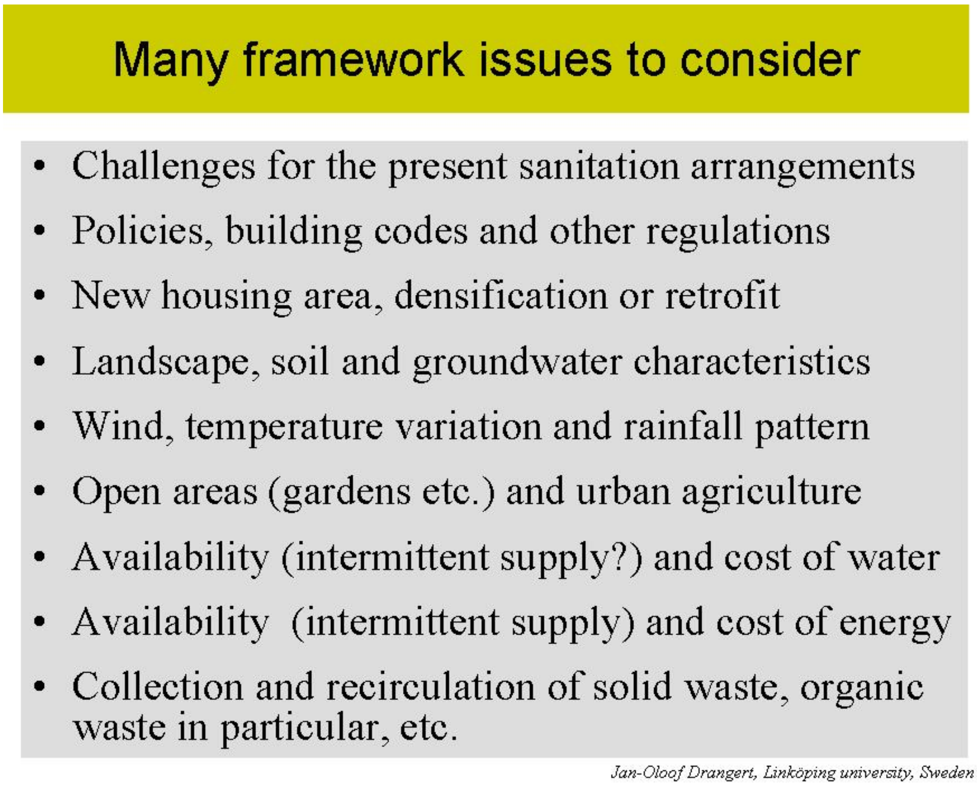
To grasp what the future holds one can make rough estimates of the increase of each factor in the picture above. For example world population will increase 50% in the next 50 years. Even without improved diet and energy intake, the world will need to produce 50% more food. If China and India, with close to half of the world’s population, continue to increase their gross national product (GNP) by 10% per year today’s GNP will double in seven years. Their demand for oil and other natural resources will continue to grow and prices will go up. This will spur innovation of new resource usage and reuse. This also applies to their demand for water and fertilisers which will make recycling common – and necessary for survival. There will be little room for wasteful practices. These countries may well spearhead sustainable development out of necessity.

2.5 - 3



The potential contribution of the sanitation sector in reducing pressure on virgin fresh water and chemical fertiliser is substantial and the sector can also reduce atmospheric emissions. So far authorities have not set up very strict environmental regulations for the sanitation sector. Emission limits are confined to what is measurable and what the existing technology can achieve. More proactive laws and regulations would determine what the sector shall do in a planned future, and ethical values tell what should be done. There is a difference between doing that which you have a right to do and doing what is right to do (Friedman, 2009). Therefore, individuals as well as the private sector and municipalities could go ahead and do what they think is right to avoid the looming crises of water scarcity, nutrient scarcity leading to food insecurity, and global warming.

The most important priority in urban areas is to prevent pollution of water while using it. This will facilitate treatment and directly reduce the use of chemicals and energy for the processes. Depending on the quality of the treated water and the sludge, these resources may be used for useful purposes. Collection of organic matter at the source will reduce water pollution and facilitate recovery of nutrients and recycling. Lastly, all these measures will also reduce emissions of greenhouse gases.



2.5 - 4

The selection of a sanitation arrangement involves many considerations and some of these are shown in the picture. One can acquire a fair understanding of the general capacity of a society by looking at what challenges the existing sanitation arrangements are facing. If wastewater is not being treated, and solid waste not collected, it may be due to a heavy influx of people or poor fee collection, or a lack of skills and resources available to remedy the situation etc. Such limitations and hurdles are likely to show up when introducing new sanitation arrangements, and need to be addressed in the selection process. If such circumstances are not taken seriously, the next system is likely to suffer from a negative path dependence with similar shortcomings.

Future-oriented policies on aims of building codes can assist builders to know what the council is promoting. The policies may differ between retrofits, densification of existing housing areas, and opening up new areas to be developed. The codes hopefully provide many sustainable options to be applied in new areas.

The shape of the landscape can be utilised for gravity flows and siting of collection tanks, vaults and bins (Module. 2.6). The groundwater level and soil properties are crucial for the choices of storage tanks, infiltration of treated wastewater and siting of water and rainwater infiltration wells. Soil and water also indicate prospects of urban food production. Wind and temperature gradients decide what natural and forced ventilation solutions are feasible.

Rainfall patterns determine the extent to which residents can rely on rainwater harvesting, and the need for irrigation of plants and lawns. If there are open areas and gardens in the neighbourhood, much of the greywater and urine can be used productively. The composted faecal matter and organics can also be used. If the space is very small, these products have to be transported out of the community, or collected and first fed to a biogas reactor.

If tap water is available but not supplied 24 hours per day, there is reason to go for dry sanitation. The same is also true if the water tariff is high. If energy is intermittent it becomes risky to have forced ventilation, and one should try to use the wind and temperature difference between outdoors and indoors to drive ventilation. If there is an efficient collection system for organic waste, the collection of faecal matter could become part of it. So, where do we go from here?

Up to now the WC has set the standard, but from now on the resilience of nature will do so

2.5 - 5

El Grand Canal, Mexico City with ”treated” effluent
Courtesy of Ian Adler, IRRI-Mexico

Wastewater and stormwater drainage in Bangalore, India
J-O Drangert, Linköping university, Sweden

The impression from information gathered in urban and rural areas is that ‘*almost everyone would like to have a flush toilet* ’. The reasons are probably multi-facetted, but have not been studied. A first step in addressing the popularity of the WC is taken in Module 2.4 where the flush toilet is compared with other options, using a number of criteria that are often referred to. The preliminary findings are that the flush toilet displays a number of convenient features for the user, but it often receives a poor rating on environmental indicators (pictures).

A new era is now emerging where nature’s resilience to human activities will guide sanitation standards, not the flush toilet (slide 1.1-16). This is a radical change, and the sooner it is implemented the better. New qualitative regulations such as reducing fresh water use by, say 80%, and recovering 90% of the nutrients in household organic waste, etc. will improve the performance of stakeholders – planners, architects, and builders in facing up to the challenge to increase the environmental efficiency of buildings. Such achievement-oriented rules make it possible for developers to find technical and management mixes suitable for the area where they are going to build. Such a function-based approach may lead away from approaches with a single technical solution. A successful example from the transport sector is that thanks to binding legal requirements on fuel efficiency, technical development succeeded to make a small car today run some 15 km on a litre of petrol, while thirty years ago the car would only reach 5 km (Friedman, 2009).

Similar progress may be possible in the sanitation sector. For instance, a requirement that 90% of nutrients be recycled would result in more efficient technical design. Architects would have to design kitchens with proper storage places for food remains (including ventilation), and collection and composting facilities in the neighbourhood. Another contribution may be to collect urine separately and use it as a fertiliser. However, greater recycling of nutrients could be achieved in other ways as well. For instance, by not using phosphorus-based detergents, shampoos, etc. and by providing disposal places for household chemicals instead of the sink or toilet so that sludge could be recycled with less treatment. The flush toilet could still have a place among toilet options if it fulfils such recycling and other legal requirements.

Such requirement-driven rulings would have a profound impact on professionals as well as daily routines of common people.

2.5 - 6

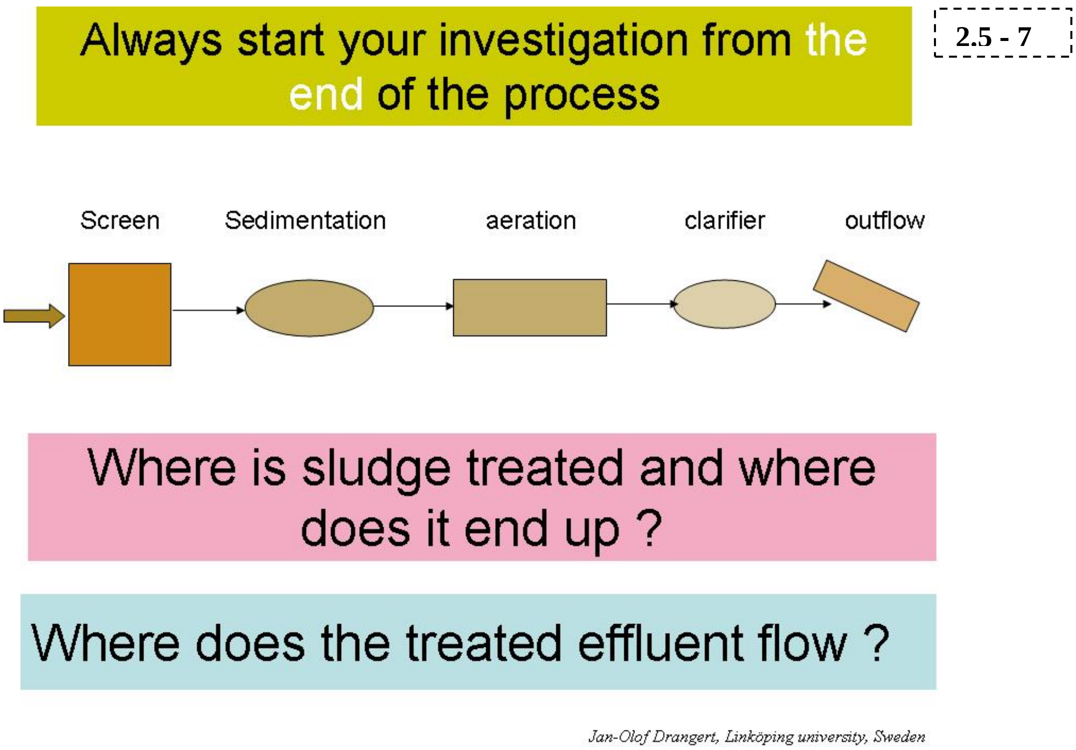
Oceans, forest and deserts look endless, but there is a growing awareness that even so, they are not big enough to make waste disappear. Today, plastic residues are floating in every sea and forests are affected by acid rain. The new realisation is that already human demands exceed what the globe can provide (Brown, 2011). The present generation's impact on the globe as a result of linear resource flows through communities will restrict the livelihood of future generations (Weizsäcker et al., 1998). The current crises also provide guidance for sustainable improvements. New approaches tend to be contested and create a lively political process leading up to new rules to meet environmental challenges. The present Millennium Development Goal to halve the number of people without proper sanitation and water has to be achieved within a sustainable framework.

The good news is that the sanitation goals can be achieved with limited environmental impact if we manage our resources wisely. A resource that has been used once must go back as an input in new production and use. Nature can show us the way, as in the case of renewable water. Dirty and contaminated water is evaporated to the atmosphere and in the process salts and most impurities are left behind and the raindrops provide a decent quality of water for human use.

We can help nature by not adding unnecessary chemicals to the water we use and by keeping excreta separate from other organic waste. If we do so, we can treat and reuse all used resources again and again, and there will be no scarcity. The corollary is that we face food and water scarcity only if we manage the already available resources in a wasteful way. Already, recycling is becoming more common. People's attitudes towards and responses to recycling therefore become more familiar with time. In the final analysis, residents are the most important actor group in managing the new helpful devices and systems.

There is an inherent difference between water and wastewater; individuals can always manage to discharge fair-quality wastewater, but not everyone can secure enough fresh water. Individuals can select household products that are environmentally friendly and also treat the disposed water to a good-enough quality for reuse. If and when almost everyone applies such good management practices there will be no scarcity of water or fertiliser.

So, let us start our thinking from the final output from a system or arrangement.



A simple and productive idea is to start your thinking and planning process from the output or end point of the contemplated sanitation system. For instance, if we want to understand and assess a conventional sewerage we can line up the processes in the WWTP (see slide). We decide what quality of end products we would be prepared to accept in this case.

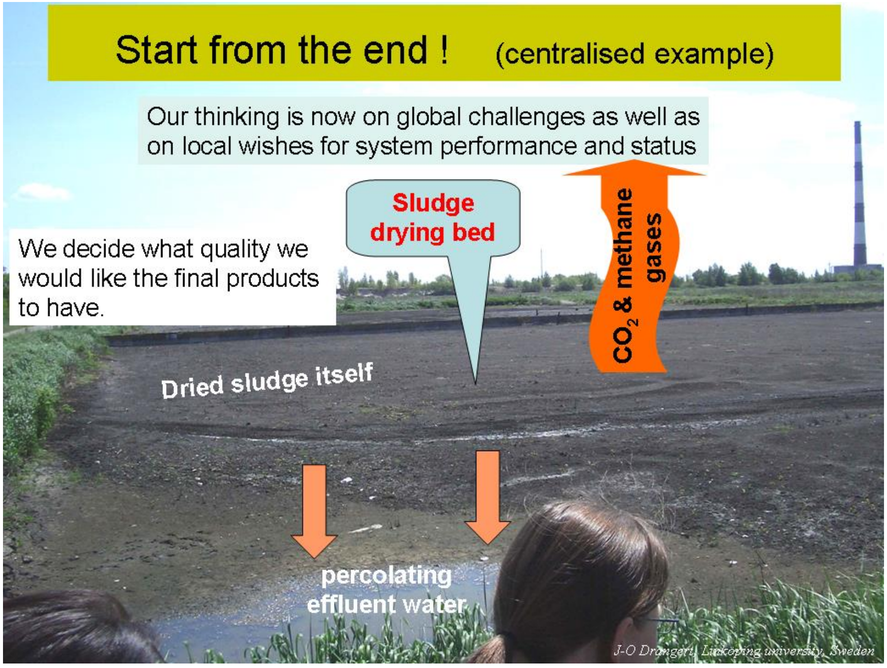
The sludge consists of matter that has been taken out of the wastewater, but still the wastewater contains a variety of compounds that have not been removed. For instance, some nutrients and most pharmaceuticals, hormones and heavy metals remain in the effluent. This means that the effluent was only partly treated and is perhaps not safe for reuse. One has to know more about what has been added to the water while using it. This is difficult and costly to find out for mixed wastewater from various places in town, but easy for individual households.

A decentralised system tends to be easier to manage simply because householders usually know what products they have discharged into the wastewater. It is also easier for people to adopt eco-friendly practices if they themselves are affected by nuisances due to polluting practices. It may be possible for small housing units to negotiate with fellow residents to use only non-harmful detergents and to restrict the use of other chemicals in their households.

Partly treated effluent causes less damage if applied on soil than if discharged in water bodies. The reason is that there are lots of microorganisms in the soil that can decompose compounds such as hormones (Module 4.6). Also, nutrients belong to the soil, not to water.

Any sanitation arrangement can be overloaded and therefore malfunction. During heavy rains wastewater treatment plants often receive too much wastewater and they have to let some pass by without treatment, or worse, it flushes the treatment units, causing sludge to leave the WWTP. Household treatment units may also be overloaded, but in this case the household will soon notice it and take measures to reduce the flow. Next time they have many guests, they will plan ahead to cater for the expected volume of wastewater. Next time they buy a washing machine they will select one that saves water and energy.

Treatment of wastewater always produces sludge which contains products which are harmful for the environment. The better the treatment, the greater the amount of sludge produced. The treatment and potential reuse of sludge is dealt with next.



2.5 - 8

We start from the end point of the flow through a community. The end point could be where the effluent and sludge leave the wastewater treatment plant, or before the greywater, urine or composted organic material is applied on plants and soil in the garden. This picture of only a sludge drying bed is suitable as a short exercise to find out what the participants think of when they look at it.

The picture shows an ordinary sludge drying bed, and one may ponder about what comes out of the bed. The bed releases a number of gases into the atmosphere, including harmful greenhouse gases. We may decide that not more than *x* tons of carbon dioxide should be released per year, and less than y tons of nitrous gases. Also, the bed is likely to leak and the leachate is commonly highly polluted. Often the utility has a set of monitoring holes in the ground to be able to test the leachate quality. The leachate should be treated as wastewater before it is allowed to infiltrate the soil. The volume of percolating treated leachate which goes into the groundwater may be acceptable up to *z* litres per square meter and year provided it contains no more than w mg of heavy metals, etc.

In addition to emissions and leakages, the dried sludge itself contains high concentrations of chemicals and nutrients, often too high to be accepted by farmers as a fertiliser (Module 4.8).

The interesting question is how all requirements on sludge and emissions can be met. The leakage can be contained by an impermeable layer underneath the drying bed which withstands the hydraulic pressure from the sludge. The leachate is collected in a sedimentation and aeration tank and then goes to a vegetative wetland which is not harvested for fodder.

The emission of CO_2 originates from aerobic (composting at the surface) as well as anaerobic (digestion in the interior) conversion of starch in the sludge. Also, methane is produced during digestion. We want as much of the organic matter as possible in the wastewater to be trapped as sludge and not to remain in the effluent. So either we need to have less organic material in the water coming to the treatment plant (residents would be responsible for this) or to try to collect the emitted gases in a kind of tent covering the drying bed.

The quality of the sludge itself can only be economically improved by changing what residents put into the water while using it. Sludge can also be incinerated at a high cost. This issue is dealt with in Module 4.5.

This example shows the strength of the back-casting approach. Other questions come to the fore and you decide which compounds to follow backwards all the way to the household. This is more comprehensive than trying to calibrate a given system to get acceptable end products.

2.5 - 9

The effluent is usually clear and transparent (see bottle) which indicates that much of the organic material has been reduced. However, a more sophisticated process would be needed to take away microorganisms (viruses, helminth eggs etc.), heavy metals and other contaminants (see greywater module). The “stairs” or small waterfalls (left picture) add oxygen to the effluent that helps aerobic microorganisms to degrade the remaining organic material.

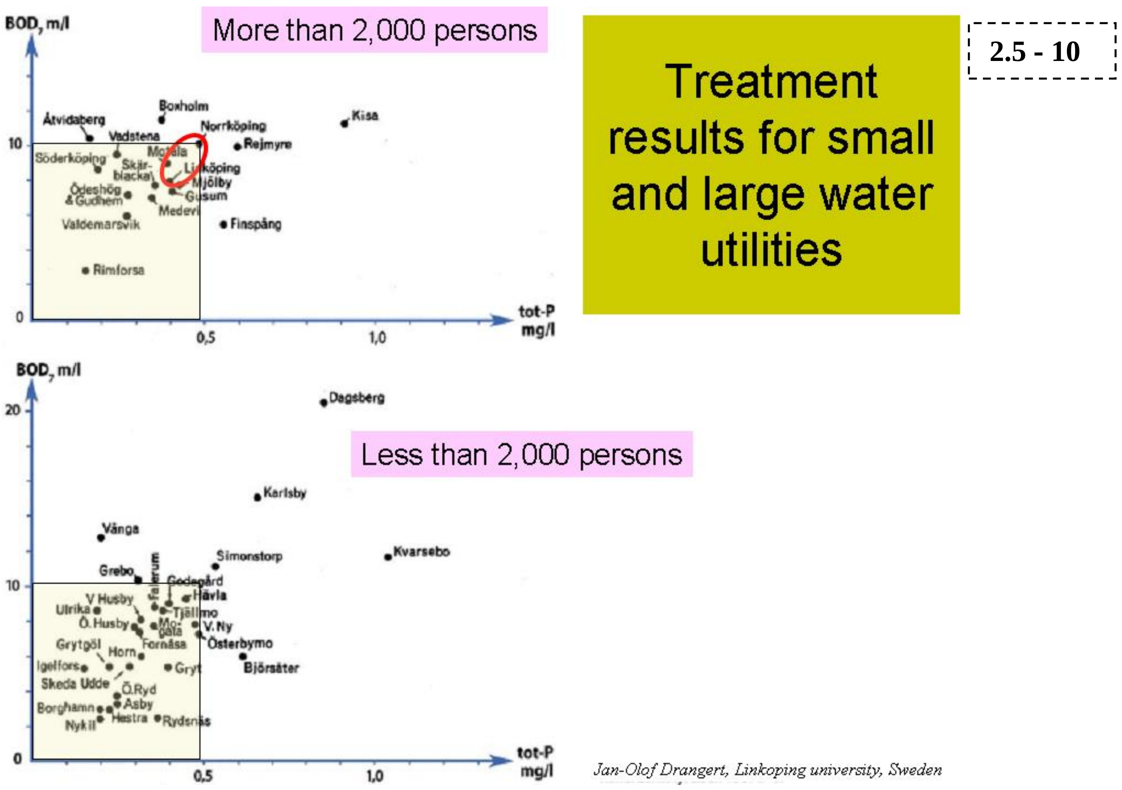
An alternative to the conventional sewerage comprises a sustainable system for a single household or group of houses which can be wholly self-contained as described in Module 2.1. A house may have an indoor urine-diverting dry toilet and a garden compost system for organic material, and greywater treatment.

The urine from a single family can, according to the WHO Guidelines, be used immediately as a fertiliser in the garden with very few precautions (see Chapter 3). Plants will take up the nutrients and if a person’s daily urine volume is applied on a new square meter every day, the plants can utilise these nutrients productively (see Module 4.8).

Faecal matter mixed with toilet paper stored for a year is hygienised and ready to be applied in the garden (WHO, 2006). It may also be co-composted with kitchen waste. When the mature material is worked into the topsoil it will provide much-needed soil improvement (see Module 4.3). There is nothing left to take care of since we have only returned the organic material we ate earlier. However, both urine and faecal matter may contain medicinal remains such as endocrine disruptors and pharmaceuticals. Such chemicals will most likely be degraded by micro-organisms in the soil in a rather short while, and they are not taken up by plants (WHO, 2006).

The kitchen water is screened in a grease-trap before being treated in a soil filter (see greywater chapter). Solid organic particles and fat/oil/grease will be trapped and can be added to the compost of organics and faecal matter, and later applied to the garden. What remains in the greywater is further sieved by soil grains and degraded by microorganisms in the soil. If only a few chemical products have been added to the water while using it, the greywater does not contain a lot of chemical compounds and can be used for underground irrigation of a hedge or trees. The capacity of the soil to treat wastewater depends on the permeability of the soil and the water uptake of plants (evapotranspiration). Assuming that the household does not pollute the water too much and tries to conserve water, the emissions and rest products from the sanitation system can all be gainfully reused for soil improvement, and as feed to microorganisms and plants.

There are no fees or other expenses incurred, only some work to be done by householders. Whether it is well paid or not depends on income levels, but more important is perhaps the satisfaction of leaving no sludge and minimising emissions to the air.

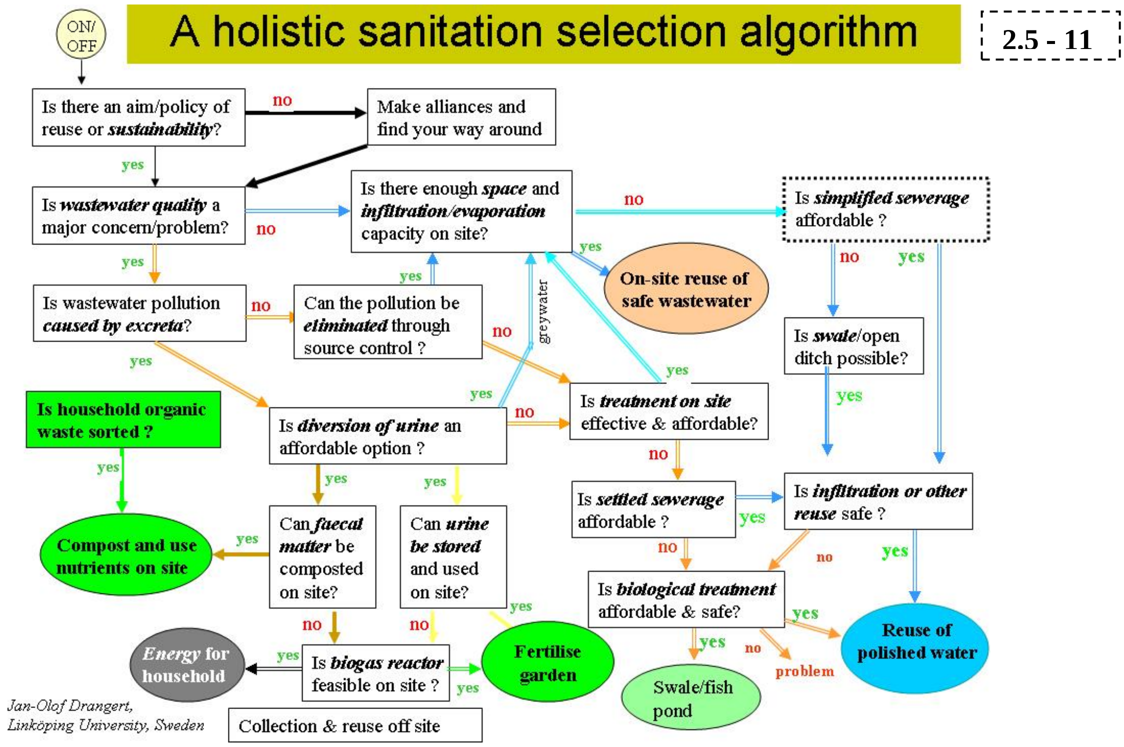


A powerful standard argument in favour of centralised networks is that a large-scale utility will use the latest technology, have better trained staff to operate and maintain the system, and can provide cheaper services for its customers. Research and development of wastewater treatment has focussed on large units, and household options such as septic tanks attract almost no R&D. Yet, there is evidence that the large units in practice do not necessarily improve the effluent quality above what the small systems can achieve.

The picture above shows a comparison of treatment results for small and large wastewater treatment units in a Swedish county (slide 2.3-11). Two important indicators of effluent quality, BOD and total phosphorus levels, were selected and the findings are presented for 18 communities with more than 2,000 persons and for 26 with less than 2,000 person equivalents (picture). Linköping and Norrköping cities have by far the largest WWTP serving about 100 000 inhabitants. The BOD-levels in their effluent is 10 mg/l, and the total P level is 0.4 and 0.5 mg/l respectively. Only three communities with some thousands inhabitants served by small WWTPs had higher values, while ten had clearly better results than the cities (inside the coloured rectangle).

The communities with less than 2,000 inhabitants also exhibit better treatment results than the two cities with three exceptions (far outside the rectangle). The finding that small and middle-sized communities fare so well is not because the industries are located in the two cities. That could have been the case for other compounds but not for BOD (organic matter) and P. The conclusion is that bigger treatment plants do not guarantee better treatment results. Since then, more research has gone into small treatment units down to household level and today, treatment quality is not an argument in favour of centralised solutions.

In the future, when households are acknowledged partners in managing the waste flows, it will still be easier for residents to make meaningful contributions in a small system than a large one. This contribution is likely to have a huge bearing on reuse management.



The number of requirements placed on a sanitation system is overwhelming, and we need some kind of guidance on how to sequence our thinking. The above flow diagram shows such a guide. The question or issue raised in each box has a yes or no response. The answer guides you to the following box etc. Blue arrows indicate fairly good wastewater quality, while the yellow colour indicates a concern of its quality.

The first issue is about policy. A good environmental policy is likely to permit alternative sanitation arrangements. However, if the community does not have a progressive legal framework, you need to find ways to align with other stakeholders to implement your sustainability ideas.

You start your '*thinking journey*' from the end product wastewater and its quality. The concerns about the quality of the wastewater – determined by tests or just by residents' perceptions – is fundamental. It is mainly a matter of perceptions since we rarely have solid knowledge about the health and environmental impacts of various wastewaters. Therefore, the precautionary principle (and compound substitution) should be followed (slide 2.3-3). Available methods to treat wastewater are detailed in the greywater chapter and in Mara et al., 2007.

If there is no concern about the quality of wastewater, it can be used on site – given there is space enough for irrigation (pink oval) and/or infiltration and evaporation. The risk of ground-water contamination is minimal, since the wastewater is considered safe. However, if space is limited, the wastewater has to be moved outside the plot through a simplified sewer – if affordable – otherwise in a swale or open ditch to a site where it can be reused (blue oval). If the quality has deteriorated during the transport e.g. mixed with solid waste, it has to be treated before use in a swale or fish pond (white oval). If this is not affordable, there is a real risk of degradation of the environment (named problem in the picture)

In conclusion, if the wastewater is relatively clean it can almost always be used productively on site or nearby.

Now, we go back to the box in the top left which asks ‘Is wastewater quality a major concern/ problem?’ If the quality is considered a problem, we need to know the perceived reason. If it is thought to be caused by chemicals or solids other than excreta, such as grease, paint residues or smell, the first question is whether residents can eliminate the problem by simple source control. If they agree to be more careful with what they put into the water, the wastewater quality improves and again is considered ‘safe’ regarding chemicals. The line of investigation follows the one above and the wastewater can be used on site or nearby.

However, if the quality cannot be improved through source control, the wastewater has to be treated somehow. If treatment is affordable and effective on site (simple treatment unit) the effluent can be used on site – if space is available (pink oval). Otherwise, the wastewater has to be transferred to a settled sewage pond followed by reuse – if this option is affordable.

If the quality problem arises from excreta, a simple source control measure is to divert urine and faeces. If a urine-diverting toilet is not affordable, treatment on site will not be affordable (since it is more expensive) and nor will settled sewerage or biological treatment. So, there would be a genuine problem. However, there are urine-diverting toilets costing from zero to several hundred US dollars. Where faecal matter can be composted on site, it is done together with organic waste, while the urine is collected, stored and used in the garden. If there is no space for this storage or no garden, the products can be transported off site for treatment, or to a biogas reactor that takes care of faecal matter, greywater and organic waste on-site or off-site (see Module on biogas). The gas is for cooking and lighting, and the effluent goes to farmland if treated enough.

This algorithm gives first priority to source control (slide 1.3-8), and to on-site no-mix arrangements (slide 1.3-24) and recovery/reuse/recycling of the treated wastewater. The reason is simply that small systems leave a less polluted product and can often cater for reuse on site. This is in line with the household-centred approach that Eawag/Sandec promotes (Schertenleib et al., 2003).

The questions in the algorithm deal with the functional appropriateness of each step in the selection process due to landscape characteristics, density, affordability, and other important factors. The answers will decide what solutions are possible at each step. Even after finding a possible option there is often more than one technology device that can bring the desired services. At this stage the search starts for sustainable technical options that are manageable.

Among all the possible solutions you eventually make your choice. At this stage you are supposed to reflect on why you perhaps denounce some feasible options and favour others. The algorithm makes the process more transparent and any resident or house buyer can ask proper questions about what options there are under the local circumstances, and decide what could be an appropriate arrangement for him or her.

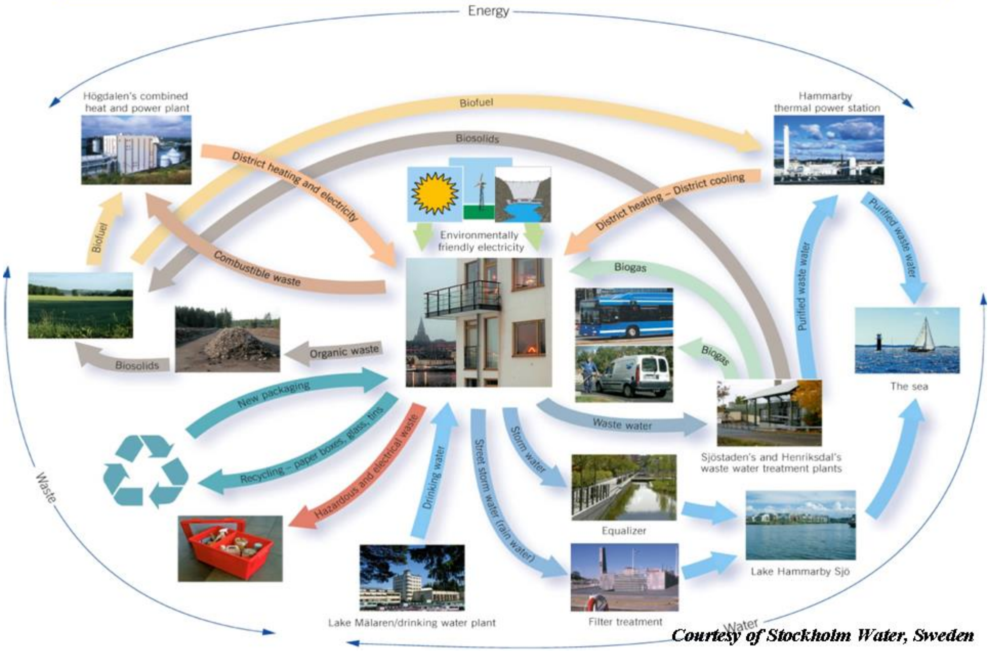
Module 2.1 provides examples of eco-friendly arrangements in urban areas: for a single house, to small communities and all the way to a town district. If there is water scarcity or irregular supply of water or electricity, there is a strong case for collecting rainwater, and treating and using greywater in order to secure a constant supply of water. The pressing demand on groundwater and surface water will lessen through such measures, and the sustainability will improve.

Many of the decisions on planning and zoning are based on an early choice of technology and not on a proper analysis of how this stands in comparison with other solutions. The new strategy is to solve the sanitation arrangements as close to the household as possible. This approach makes the households partners in reaching the development goals and also reduces the use of scarce resources ranging from funds to administrative capacity in the municipality, both for primary construction as well as for operation and maintenance. We have also mentioned several times that environmentally sound behaviour is strengthened when negative consequences affect wrong-doers directly.

One additional point should be made here. Since the future is not known, there is good reason for constructing new sanitation systems in such a way that they can (easily) be adjusted to new technologies or management solutions. For instance, preparing for solar heated water on the rooftop, pre-preparing for urinals in the toilet rooms, and making appropriate space available for water meters to be installed later are all valid and cost-effective installations. Another example of such pre-preparation is to install dual water pipes in all new houses in areas with water scarcity. This would make future investments in high-degree treatment of wastewater and recycling of secondary-water quality affordable, since no retrofitting will be needed. In the same vein, the builder could install a pipe for future connection of a separate urine collection system. Such measures would be VERY cheap and worthwhile to do even if they are never used. The added value of making the arrangement more flexible is worth the small investment.

A new housing area in central Stockholm

2.5 - 13



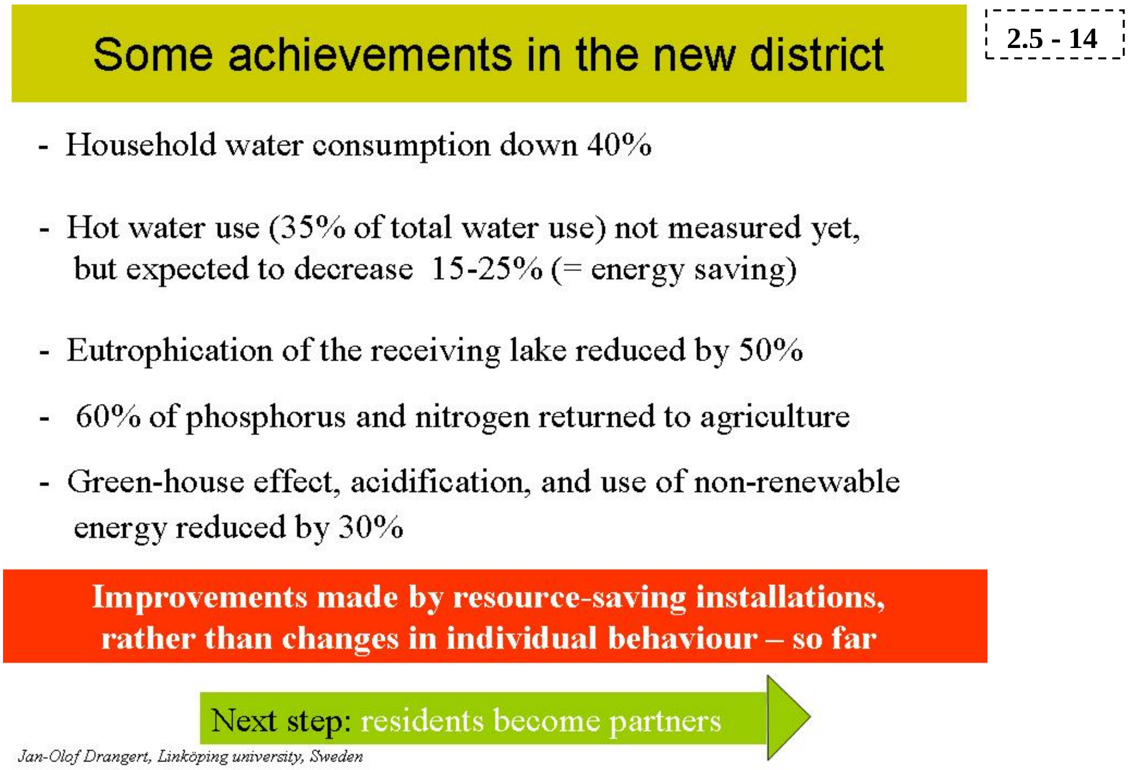
Courtesy of Stockholm Water, Sweden

The Stockholm city council decided to build a new housing district, Hammarby Sjöstad, in what was a cottage industry area near to the city centre. They seized the opportunity to build a sustainable housing and office area where resource flows were geared towards reuse. The municipal agencies in charge of water, wastewater, energy and solid waste handling coordinated their planning activities so that each single flow was viewed in a holistic fashion irrespective of which utility had the formal responsibility. The goal was to become *'twice as good as conventional buildings*'. That meant using only half of the usual amount of water and half the energy, reducing eutrophication, heavy metals etc. by half, but an 80 % reduction in person transport with individual cars. This model shows how sewage processing and energy provision interact, how refuse can be handled and the added-values society may gain from modern sewage and waste processing (http://www.hammarbysjostad.se/).

The incentive to envisage such a radical shift for a new district with 9,000 flats and offices and public services came in 1996 during the initial planning to apply for the 2004 Olympic Games. Stockholm wanted to show a green face and use some of the housing for the games. The detailed planning went ahead and, although Stockholm was not selected to host the games, the housing project continued with slightly lower sustainable ambitions.

The project was an invigorating experience for many professionals in that they could pool their competences and achieve better results. The cooperation between the utilities was partly driven by a politically appointed steering group. When the energy company owned by the municipality was sold in 2001 the new multinational company that purchased the unit was not as interested in investing more. Towards the end of the 10-year construction phase issues about operation and maintenance took precedence. Yet, the municipality set additional environmental goals for Hammarby Sjöstad in 2005 for improved designs and formulated new roles to households in order to engage them to a greater extent (Lind, 2006).

Almost a decade later, when another new housing district was planned to be built in 2010–20 many of the sustainable ideas survived but the cooperation between the utilities was not as close. Still, the Olympic project has had a long-term impact on building practices in the city by introducing a programme of environmental adjustment of water and sanitation which integrates lifestyles, technology and conscious planning. A new interest-arousing idea is needed in order to take the next leap in sustainable urban housing. Maybe the need to lower emissions of greenhouse gases will create this momentum?



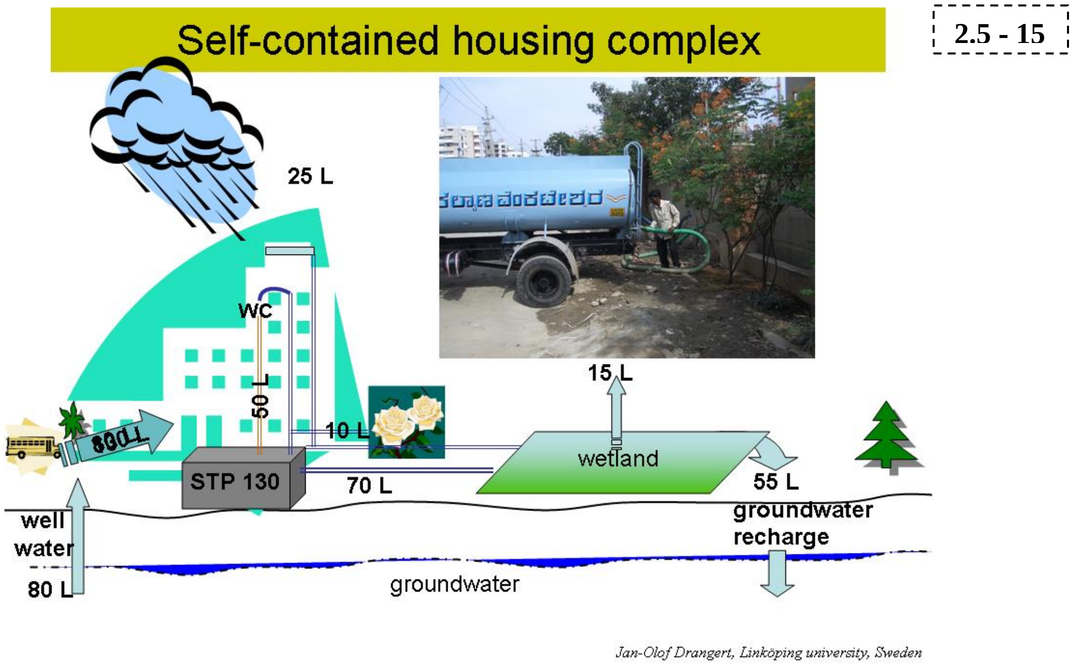
The selection of sanitation arrangements has profound impact on resource flows and resource use in urban areas. In the case of the sustainable housing district in the capital Stockholm the arrangements led to a reduction of resource use and negative environmental impacts:

- Water use fell by 40% compared to a comparable housing area without eco-installations. If dry toilets had also been installed (these were too new and not sufficiently tested when this project was begun in the 1990s) another 30% reduction would have been achieved.
- The use of hot water decreased by about 20%, which is an important energy saving and a reduction of the energy cost for the household – all achieved without affecting comfort levels.
- The housing area is situated on a lake, and the reduction (compared to ordinary houses) of eutrophication by 50% will gradually improve lake water quality and make bathing possible in the future.
- In this case 60% of the nutrients are returned to agriculture, and it could have been more if some of the organic waste was not incinerated for heating purposes.
- Emissions of greenhouse gases and acidification of the air was reduced by one-third. This is not seen by residents, but is very favourable for the environment.

All these improvements were achieved with careful selection of flows and technical outfit.

The next step to improve sustainability will be to involve residents as partners. Once they start being more cautious about water usage and use more environmentally friendly products, the achievements will be even better. It is not wishful thinking to strive for zero emissions and ultra-low use of natural resources. The energy sector can inspire new thinking, since it is closing in on zero-energy houses in cold climates.

A globally important decision was taken in China in 2006. Beijing authorities issued new building design regulations that mandate new building to adopt energy-saving technologies for cooling, heating, ventilation and lighting. The stated target is to cut building energy use in all cities by 50 per cent by 2010 and 65 per cent by 2020, compared with buildings constructed in the 1980s (*The Straits Times*, Dec 7, 2009). A similar visionary regulation is required for the sanitation sector, but this has not yet gotten the attention of the authorities or the industry.



A water balance calculation is helpful in exploring and assessing different strategies to achieve sustainability. Wasteful behaviour is common, since humans have had little experience in measuring water volumes, and even less in estimating the volume of flowing water. A person could leave taps gushing while doing other things. Practical demonstrations of how much water is flowing from an open tap per hour shows that 100 litres is easy to waste (slide 1.1-18). This is equal to the water used by a normal user for all his activities in a full day. Our poor grasp of how much water can be saved or lost, may explain a large part of present wasteful use of water.

Let us assume a design volume of 130 lpcd (litres per capita per day) which is deemed to be enough for all water-related activities, including flushing the toilet. Any demand in excess of this amount can be eliminated by demand management measures such as higher tariffs. Initially we can imagine that this amount was planned to be brought to a housing complex by a truck (top right and slide 2.1-18). This was deemed to be too costly and the resident decided to treat their wastewater in a mini-sewage treatment plant (STP) in the basement. The treated effluent is used for toilet flushing and watering the garden. An average resident uses 50 litres for toilet flushing, so they needed to truck only 80 litres of ‘fresh’ water from the well 2 km away.

All 130 litres used by the person in this example are treated in the mini-STP and 50 L goes back to the flush toilet, some 10 L is used in the garden and 70 L remains. In order not to waste this treated water, they decided to treat it further so that it could be used for washing, bathing and cooking. The main alternatives were to treat it in a more advanced WWTP, or biologically in a wetland – if space is available. Some water in the wetland would evaporate; say 15 lpcd, while the remaining 55 litres would recharge the groundwater together with 25 lpcd of rain falling on the housing area.

In this scenario, 80 lpcd can be withdrawn from wells in the garden without compromising the groundwater level. And no need to truck water. The quality of the well water can be further secured by adding a simple treatment (Module 4.7) before it is distributed to the flats in separate water pipes. The quality of this water is better than the truck water that would otherwise be delivered to the housing complex. No wastewater or stormwater leaves the compound, but the sludge has to be treated in situ or sent to a WWTP. The saved fees for water supply and wastewater treatment are used to pay for investments and operation of the system. No changes are required in resident behaviour.

The volume of used water can be reduced further and the quality of the water going to the mini-STP can be enhanced further by installing dry toilets with separate handling of urine and faecal matter. Such a system would also retain the valuable nutrients from the water flow and make them available as a fertiliser for the gardens.

2.5 - 16

A vision for sanitation arrangements

National and local governments provide guidelines for installation and operation of eco-friendly arrangements.

A single household or a housing company can find eco-friendly products in ordinary hardware shops and outlets for contractors.

Small and large contractors, plumbers and engineering firms, architects are familiar with the requirements of eco-friendly installations.

Jan-Olof Drangert, Linköping university, Sweden

Sanitation for the world's growing urban population requires new eco-friendly devices and management solutions that involve residents. Not only do residents need to be aware of resource-saving arrangements, they need to have easy access to them. Therefore, the professional groups engaged in the sanitation and water sector should provide these services, and not just provide or copy earlier environmentally unfriendly arrangements.

The vision is that national and local governments will provide guidelines to reshape the sector so that it plays its part for a more sustainable society and city. This will translate into local decision-makers on building boards being knowledgeable about new technologies and management options, and being able to assist and advise builders and residents.

A family looking for a house or flat should be provided with green data on what is on the market, so that they can make an informed choice.

Planners, architects, and builders should face the challenge of increasing the efficiency of buildings through qualitative regulations such as reducing fresh water use by, say 80 %, and recovery of nutrients in organic waste by 90 % etc. Such achievement-oriented rules make it possible for the developers and manufacturing industry to find technical and management mixes suitable for the area where they are going to build the houses – without distorting the housing or sanitation market.

Once such regulations are in place, the whole sector will adjust and adapt by coming up with craftsmen and O&M staff who can handle the new technical and management arrangements.

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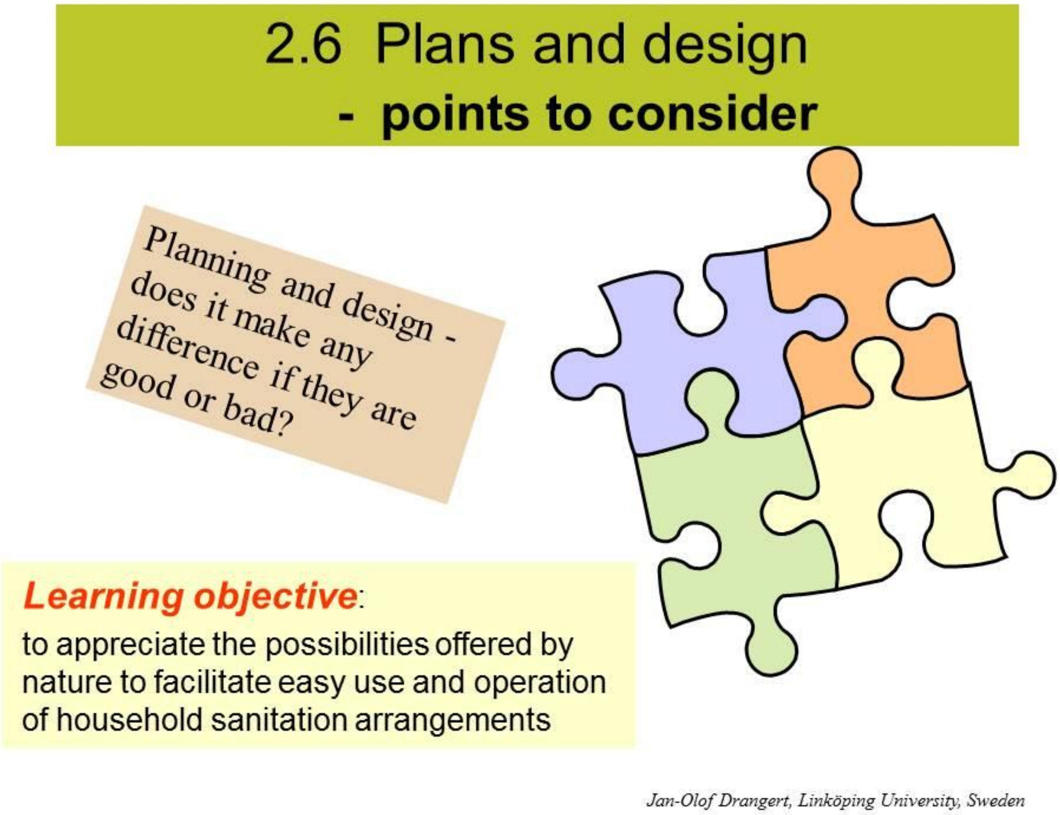
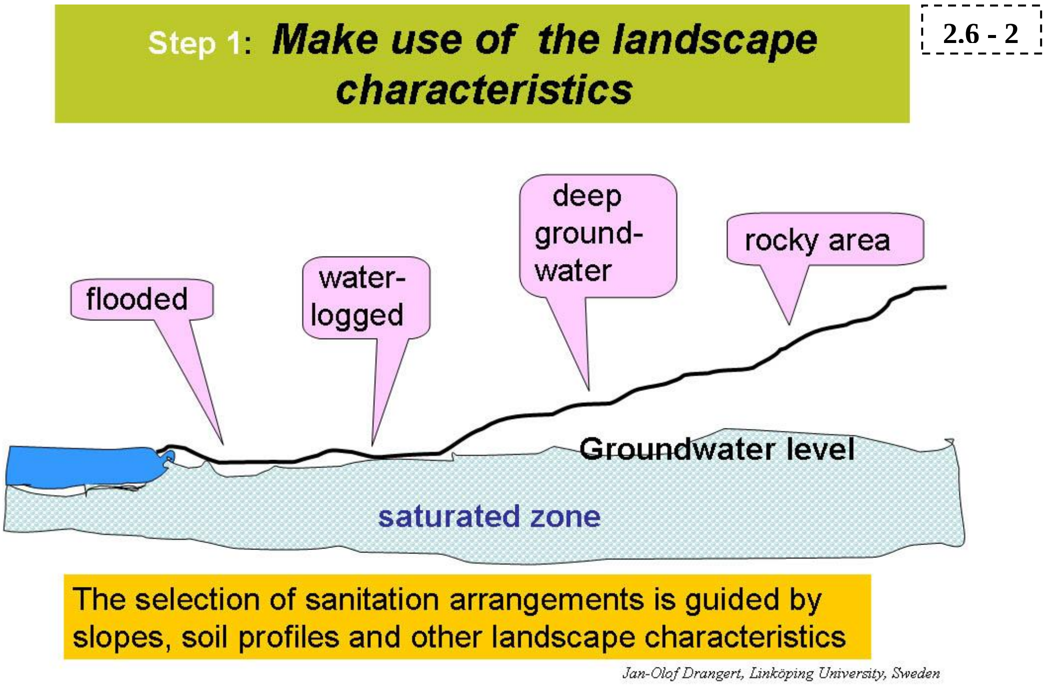


This module provides guidance for development practitioners on how best to utilise natural physical conditions for the benefit of users and to secure easy use and operation of the sanitation arrangements. The next module focuses on design and technical installations to facilitate use and to enhance health and sustainability management.

The introduction of a new technology or installation often requires modifications in the practices of those who use them. Designers run the risk of forgetting about the normal wisdom required to make the unit user-friendly. A common problem is that if a urine-diverting toilet is built with a vault above ground, the toilet itself may have to be elevated and the designer often forgets that having to climb steps to reach the cubicle will make use more cumbersome for many user groups – for as long as the toilet exists. Another example is that latrine pits are usually placed far away from the house because of foul odours, and therefore projects often also place odourless toilets at an awkward distance from the home. A third example is greywater pipes leaving the house at a level that does not allow gravity flow of the water to the garden.

In this module we put forward design criteria that should apply to any sanitation installation, be it a toilet or a greywater treatment system. The criteria deal with easy access and require no extra effort to use or operate the unit. We may also allow the technical historian Thomas Hughes to remind us about the difficulties of introducing new technical systems. Hughes writes (1983)

"*In sum, it is difficult to change the direction of large electric power systems – and perhaps of large sociotechnical systems in general – but such systems are not autonomous. Those who seek to control and direct them must acknowledge the fact that systems are evolving cultural artifacts rather than isolated technologies. As cultural artifacts, they reflect the past as well as the present. Attempting to reform technology without systematically taking into account the shaping context and the intricacies of internal dynamics may well be futile. If only the technical components of a system are changed, they may snap back to their earlier shape like charged particles in a strong electromagnetic field. The field also must be attended to; values may need to be changed, institutions reformed, or legislation recast*." (p. 465)



Physical environments vary considerably and there is no single sanitation arrangement suited to all situations. Sanitation arrangements include the handling and reuse of treated solid waste, urine and faeces, and wastewater. Sustainable sanitation arrangements have to be designed to suit the water sources and physical conditions of the landscapes in which they are constructed.

In areas with seasonal or occasional ***flooding*** most sanitation arrangements will break down temporarily. Dug latrines and twin pits overflow and so do sewers and this may cause diarrhoea and in the worst cases – an epidemic. The immediate solution may be to have the toilet on high ground such as a railway bank or on the roof top. Any general long-term solution must, above all, prevent faeces from spreading into the environment.

In ***waterlogged*** areas the groundwater level is very shallow and it becomes difficult to dispose of any kind of wastewater or to dig a pit. There is a high risk of contaminating the groundwater, which is particularly problematic where it is being used for the household water supply. Also, the groundwater may intrude into the sewer pipe and add to the volume of wastewater, thereby making the treatment less efficient and more expensive. Drainage and latrine pits may also fill up prematurely and spread excreta on the ground. Therefore, the solution is – again – to keep excreta away from water. It is not nature that causes the human suffering but poor design of the toilets that allow overflow to take place.

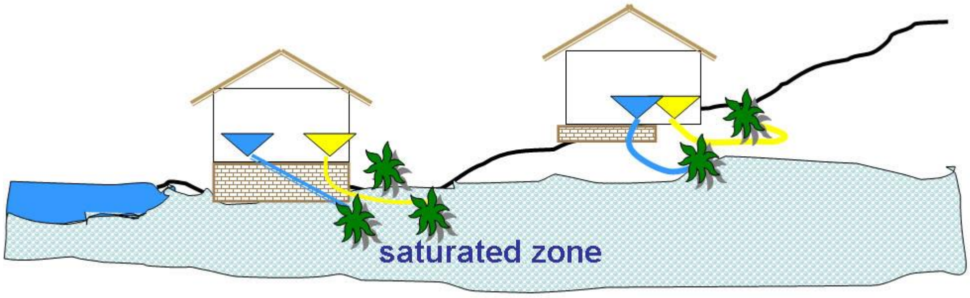
In places with ***deep groundwater*** levels and/or less permeable soil, the risk of contaminating the groundwater is small. Most infiltration arrangements can safely be installed in such areas. However, in clayey soils infiltration of wastewater, ablution water, and urine is very slow and may create puddles. Here, one may need to rely more on evaporation to dispose of liquids.

Rocky ground makes any kind of digging tedious and expensive. The difficulty of laying pipes on rocky ground means that individual solutions are needed for each house rather than lying pipes in long trenches. The kind of rock determines if it can hold water or not. Fissures may cause rapid infiltration of wastewater to the groundwater. Leaking pipes and pits can also become serious sources of groundwater contamination. This calls for above-ground sanitation arrangements, in particular where groundwater is used by households.

In conclusion, the physical conditions that nature provides have to be considered and we should not ignore them and think that they can be overcome by our technological skills. If we do not pollute the ground and surface water we can avoid long-term costs for water treatment.

Step 2: Take advantage of sloping ground and raised house foundations (fluids)

2.6 - 3



Make use of gravity to discharge fluids

Jan-Olof Drangert, Linköping University, Sweden

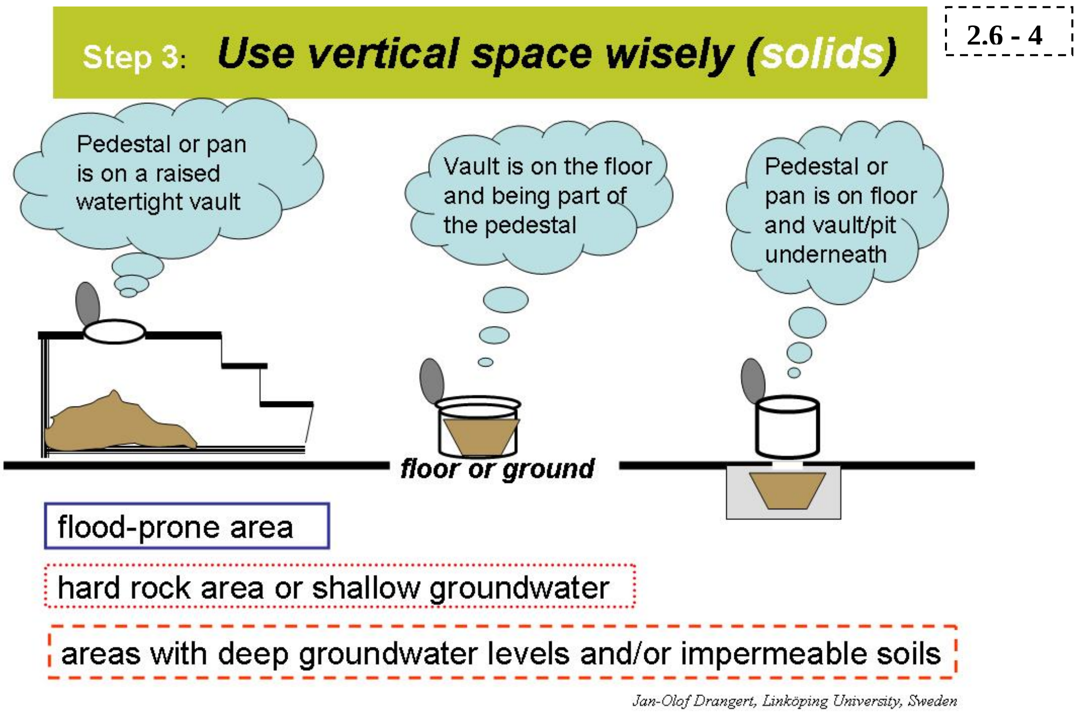
The three fluids; urine, greywater and ablution water should leave the house by gravity to minimise energy usage and health risks. The house foundations may be raised to prevent inundation, but also to make it possible to use gravity to move fluids (see picture). If this is done, large volumes of wastewater can be discharged through a pipe with much less work than it would take to carry the valuable contents in buckets. Therefore, the kitchen, bathroom and toilet should be positioned so that all fluids can flow out of the house to the highest point of the surrounding area to where it is needed.

Also, if the greywater is treated in a septic tank or reed bed it is beneficial to let the inflow be at the highest point so that the outgoing effluent can move by gravity to any infiltration area.

If the ground is sloping (right house), the kitchen and shower should if possible still be placed in the corner of the house closest to the highest ground so that gravity can transport fluids to the garden. The toilet room, on the other hand, can be placed anywhere if an appropriate toilet design is selected (see next slide).

If the urine has to be stored before it is applied as a fertiliser, a urine tank may be located on the ground near the house or it may be dug into the ground and emptied with a simple hand pump (see Module 4.2).

The ablution water can safely be directed separately to a soil filter with plants, or be mixed with other wastewater and treated and percolated into the ground.



We now show how the toilet can be designed to fit the physical conditions presented in the first slide by making use of available vertical space. We deal primarily with urine-diverting toilets and partly with twin-pit toilets, because WCs and vacuum toilets are less dependent on gravity and dug latrines are in the yard. We disregard the toilet superstructure, which is for privacy, and focus on the substructure or inside part of the toilet unit.

In ***flood-prone areas*** the pedestal or squatting pan must be on top of a watertight vault for excreta or just faecal matter and paper (to the left). When the floodwater rises it cannot enter the vault and its contents are unaffected. In this case a urine-diverting toilet is ideal, since the entire structure is indoors and secured from flooding in the same way as the house itself. The urine tank, if there is one, is airtight and does not let flood water in. Even if some water enters, it does no harm. If the house is elevated (flood-proof) the vault can be on the ground and yet there is no need for steps to climb the toilet.

The pit latrine, twin-pit and WC are not suitable for flood-prone areas since they will overflow.

Where digging is prevented by ***rocky ground or shallow groundwater*** it is possible to use the same solution as for flood-prone areas. However, a urine-diverting toilet with a bin for faecal matter inside the pedestal is also a suitable option indoors (slide 2.1-11). There are no steps to climb. The dry faecal matter can be removed from outside the house (by the family or a contractor) and brought to a composting station where it is converted to a soil conditioner.

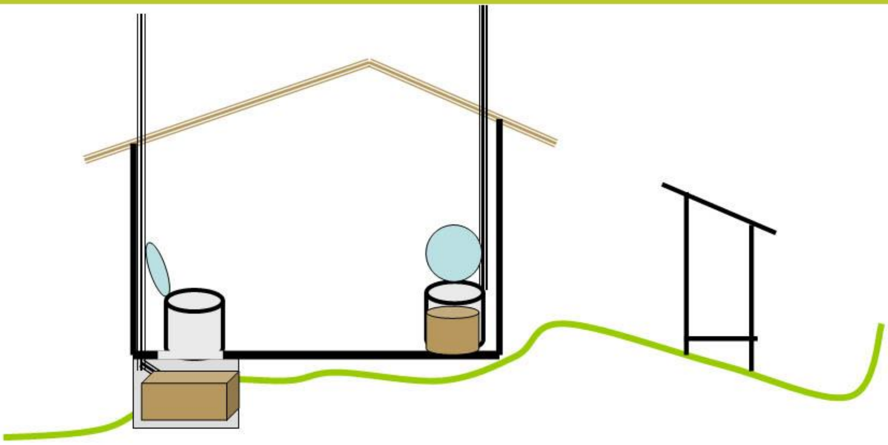
In this case the twin-pit system could be built on a mound to avoid the rock or to stay above the shallow groundwater. A pit latrine is not an option here, nor is the WC because of the difficulty to dig for the sewer.

In areas with ***deep groundwater and/or impermeable soil*** the two previous options do well, as do some additional ones. There is no danger of overflow or groundwater pollution, so the vault can be under the floor or in the ground if it is easy to reach by a door on the outside.

The simplest in-the-yard arrangement is a shallow pit, arbour loo, which is covered with soil when full and a tree planted on top to utilize the nutritious content. If enough water is available a pour-flush twin pit toilet can be installed from which liquid infiltrates to the soil. Ablution water should in all cases be treated in a sand-bed before being let out subsurface to plants or trees.

2.6 - 5

Step 4: *Minimise the number of steps to reach the pedestal or pan*



No steps are needed to reach these indoor pedestals

Jan-Olof Drangert, Linköping University, Sweden

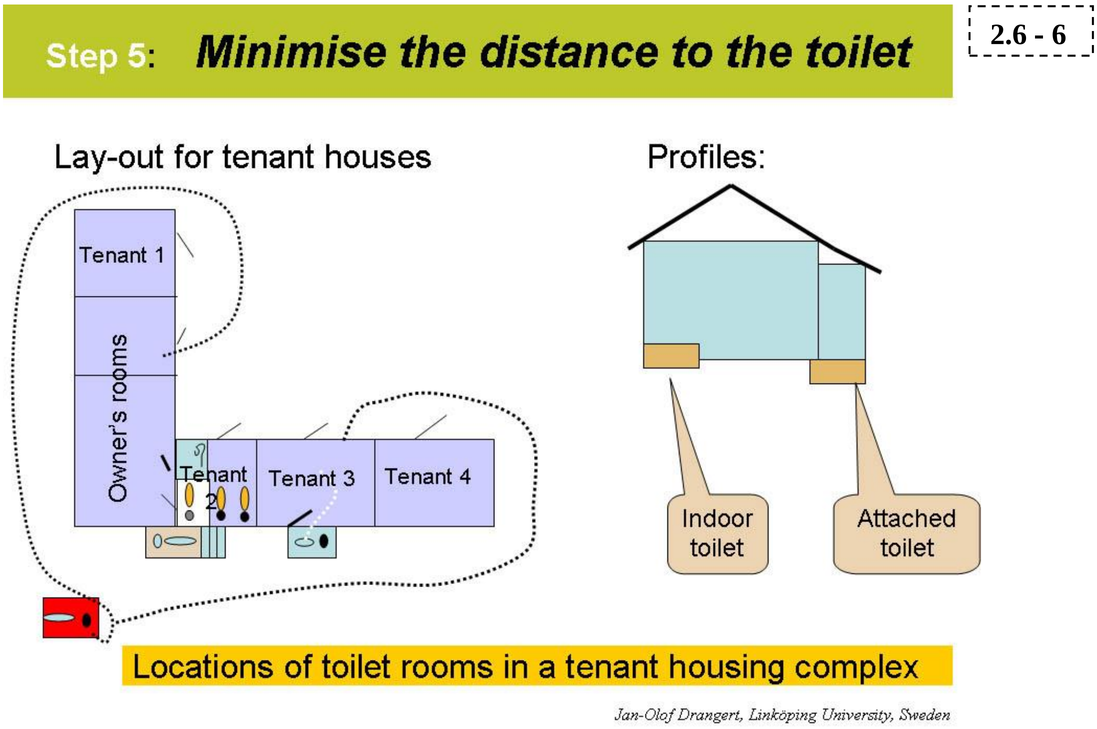
The toilet substructure should be selected so as to avoid having to use stairs to reach the pan or pedestal – whenever possible. The previous picture showed it is primarily in flood-prone areas that stairs have to be used, in cases where the house itself is not elevated. Another competing requirement is that the substructure should be easy to open and empty. The house owner has to strike a balance between these two requirements while ensuring that gravity can be used to transport the urine and wastewater. Remember that climbing stairs is done several times a day by every user, while the emptying is done once a week or less often. The picture shows that the pedestal toilet can be placed in any corner of the house with no need for stairs, and the vaults are still easy to empty. The urine container may be placed anywhere. The toilet to the left could also be a squatting pan with no steps. However, siting of a squatting pan to the right would require some 3–4 steps to be reached and is not in an optimal location. Urine and water for hand washing is easier to discharge over the plot by gravity in the right-hand option since it is on high ground.

The pour-flush twin-pit toilet is also most appropriately sited in the right-hand corner since this will enable the overflow from the pits to be distributed by gravity over a larger area.

The choice between the two positions shown in the picture may be influenced by a desire on the part of the resident to hide the vault and its contents. But in both cases there are toilets with a flap beneath the seat which closes when you rise and thus hides the inside contents (slide 2.7- 7).

The bins may be emptied every week when they are still lightweight, and this also prevents flies from breeding (they need two weeks to hatch). More details about the options for bins are discussed in Module 5.5.

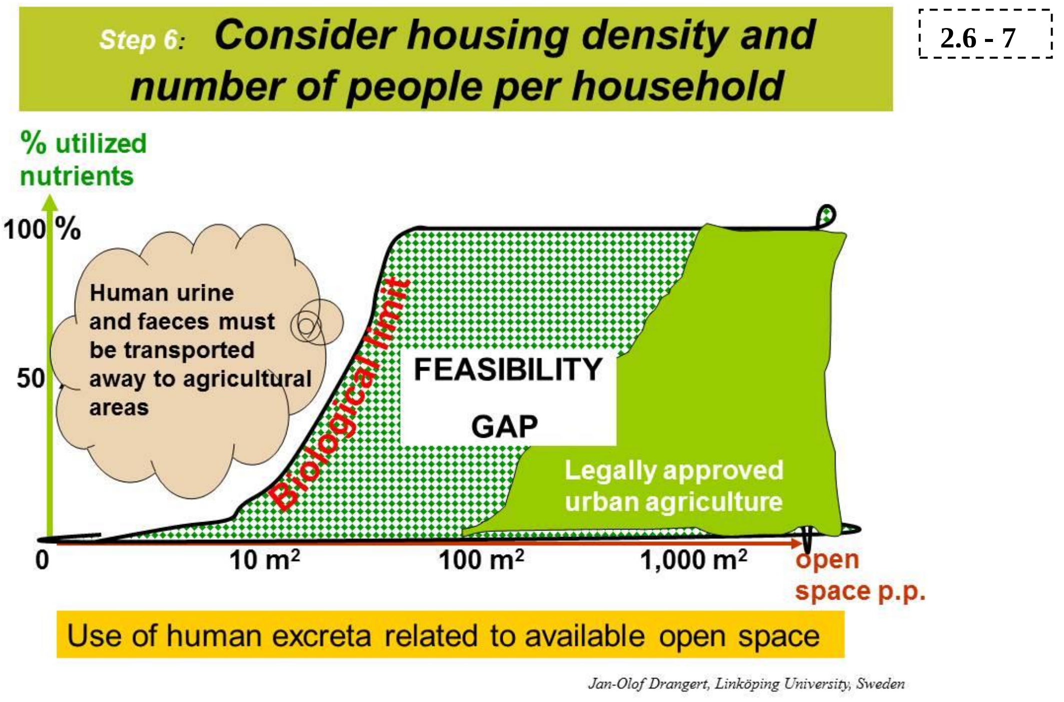
A neighbour's latrine in the yard is also included in the picture, but is not recommended due to less comfort as highlighted in the next slide.



The most common site for a dug latrine is behind the house (red latrine in picture). The walking distance is long and unpleasant if it is raining or you are in a hurry. The position makes it very cumbersome to use for children with diarrhoea. Also, the hand washing facility is not likely to operate properly. The common argument for locating the toilet in an inconvenient place is that the toilet smells. So, if the toilet does not smell, it can be built indoors.

The toilet room can be placed in several positions – inside the house as in the case of a WC, or if indoor space is limited it can be attached to the house with the entrance inside the house (right). Sometimes one may find the toilet attached to the home, but without taking advantage of direct access from the house. This is likely if the builder's perception is that any toilet smells. However, an odour-free urine-diverting toilet or a pour-flush twin pit is appropriate to locate indoors. A door is opened in the wall of the house to get direct access to the attached toilet room. This is more convenient and makes it easy to clean the toilet, help infants and the elderly, and make sure the hand-washing facility is functioning.

The ideal for the tenant housing shown in the picture is to have one toilet for each family with direct access. Available space and economy may allow the owner to sacrifice only one room and the rent from that room. On the other hand, the owner can probably charge higher rents for the remaining rooms, since the standard has been improved. The vacated room can be converted to two toilets, one for the tenants and a toilet and shower room for the owner's household. If dry toilets are installed, there is no need for water for flushing but only for hand washing. A simple hand-washing facility can be added inside or outside the toilet room. Residents who are washers will also benefit from such a dry toilet, since they do not need to bring water along when visiting the toilet. All these improvements are fairly easy to make – including in existing houses. They are likely to improve kids' health and everybody's comfort and security (slide 2.4-13).



The possibilities for gainfully disposing of urine, hygienised faecal matter and greywater locally depend on the amount of open space available for cultivation. The picture shows what proportion of a person's excreta that can be used gainfully in a garden or elsewhere. Note that the axis with open space per person is logarithmic.

First of all, there is a biological limit for reuse. If there is just a square meter or so of land available, only a negligible portion of the nutrients can be used in plant production on that spot. The area can be extended by making a "growing wall" with pots on the wall, or pots with plants on the roof, or a "growing tower" (see Module 4.8). Most urine and faecal matter from such a congested area need to be transferred off-site to a farm where the nutrients can be recycled.

However, if there is, say 100 m^2 or more per person, most nutrients can be gainfully used and fertilise several crop yields per year (right graph). In such low-density areas where conditions are similar to those found in rural areas, the city council should allow "urban" agriculture.

In areas with a population density between, say, 10–100 m^2 of open space per person, it is biologically possible to carry out agricultural activities, but many cities prohibit any food production within the city limits. This '**feasibility gap**' between what is allowed and what is biologically possible can provide food for people, not least vegetables, and also take care of the human-derived nutrients in a sustainable way.

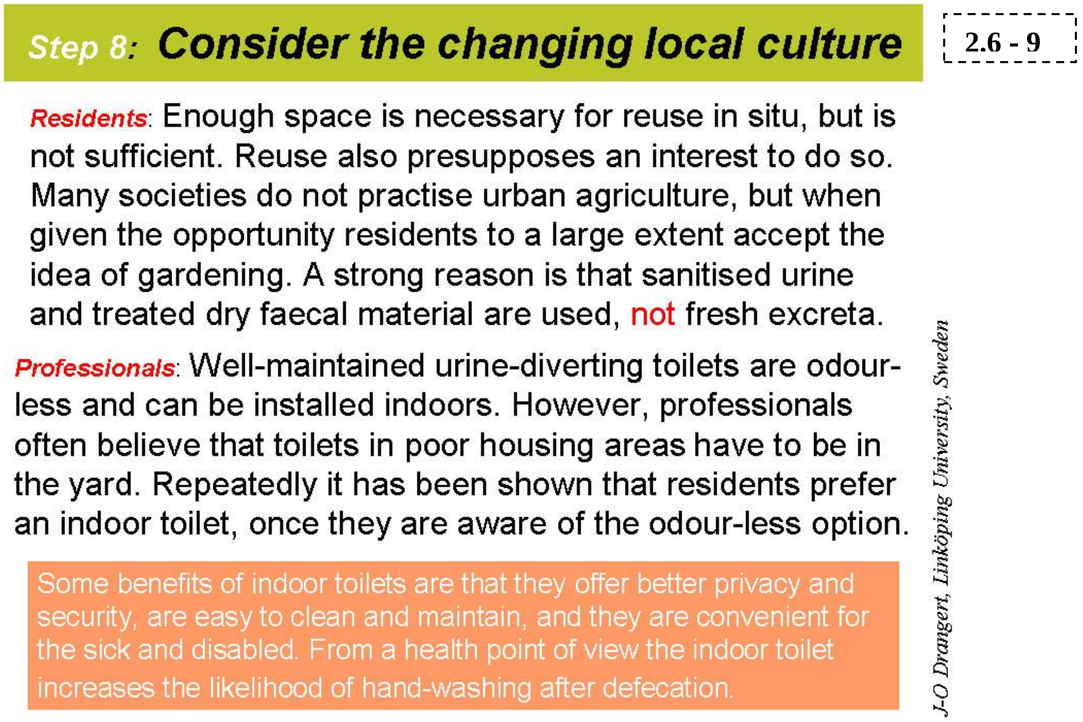
The fact is that such production is already vital for many cities (UNDP, 1996). Surveys show that some 50% of the food in Dar es Salaam, Moscow, Jakarta and other cities is produced within the city borders. Such cultivation not only helps to achieve food security, but also helps reduce carbon emissions by minimising transport of food.

Urine alone would be useful to recycle in dense settlements, since it contains most of the nutrients in human excreta (see Module 4.2). Urine makes up 90% of the volume of excreta and the remaining small volume of faecal matter and paper is easy to transport away. A urine equation tells us that "an adult person eats 250 kg of cereals per year, which has been grown on less than 250 m^2 and fertilised to perhaps fifty per cent by the person's urine." (Drangert, 1998). If an intensive urban production gives two or three yields per year, the urine from one person can be productively used by plants on a much smaller area.

Reuse on-site is a household task, while transport and use of urine and faecal material off-site can be managed in a number of ways. It may be partly or entirely organised by an entrepreneur with links to farmers. The municipal council provides guidance, allocates land for a treatment unit, and monitors the activities. In rare cases it involves itself directly in such activities.

The pictures show examples of collection of faecal bins in Kimberley (left) and co-composting together with horse manure and straw (right). The system came about in a newly built area with dry urine-diverting toilets in all houses. A worker at the building site saw a business opportunity to collect the dry faecal matter from the households and compost them on a nearby site. He offered his services for a small weekly fee that almost all the 114 households found reasonable. His income for a day's work per week earned him more than his previous salary for a full week's work. Importantly, the housing association agreed to collect the fees when they collected the rent from each participating household. The entrepreneur was relieved of the burden of having to ask customers for money every time, and instead he could collect the fee once a month at the office. At the same time the association ensures that the entrepreneur collects the bin contents and returns the bins properly washed.

The composted material is taken back by the residents to fertilise their gardens. This puts no burden on the council or the wastewater treatment plant. This was also the objective of the whole housing project; the council did not want to receive any wastewater from these households since the existing treatment plant was overloaded (Drangert , Duncker, et al., 2006).



If the users are not interested or do not accept a sanitation arrangement, it will not be taken care of. However, cultural views are rarely cut in stone, but tend to adjust to new realities. When farmers move to town, a number of rural imperatives are modified or done away with. Men and women start using the same toilet – even young men and their mothers in law. Strong norms such as the number of children per family lose their power and numbers are reduced, sometimes drastically. Therefore, projects which try to introduce new technologies or behaviours should be culturally sensitive without assuming that all prevailing traditions and attitudes are rigid.

Increases in the prices of food and fertilisers may gradually change people's understanding and attitudes about alternative fertilisers as well as about urban agriculture. During the "World" Wars in Europe most urban areas were heavily cultivated. Food security was a strong incentive.

Knowingly or not, professionals tend to promote sanitation systems that they view as beneficial to their careers and status. This human instinct can lead to vast improvements in sanitary arrangements. However, the instinct can also prevent improvements, in particular in situations where there is no public intervention to change values, reform institutions or recast legislation as Thomas Hughes alluded to in 1983 (slide 2.6-1). The case of urine-diverting toilets shows that professionals tend to talk and think about fresh faecal matter rather than composted or dry faecal matter. Therefore, they tend to promote odourless urine-diverting toilets to be sited in the yard away from the home. They may also entertain the view that poor residents should not have an indoor toilet similar to the indoor WC. If such toilets work well, the power of the argument for installing WC, water supply and a sewerage would weaken.

There is certainly room for all kinds of effective technologies in a world where more than two billion people lack proper sanitation. There is no risk of professionals becoming unemployed. But if professionals continue to promote WCs indoors and latrine pits in the yard, billions of people will end up with an inferior arrangement which leaves residents with poor health and discomfort.

When professional pride takes precedence, we are likely to be offered hope for future improvement rather than immediate remedies. Mankind has progressed beyond just hiding excreta in a pit (which is a good thing) and now we can improve hygiene and health by providing hand-washing facilities to most residents. This cannot take place with a toilet in the yard. Professionals should be ethically bound to promote indoor toilets for this reason.

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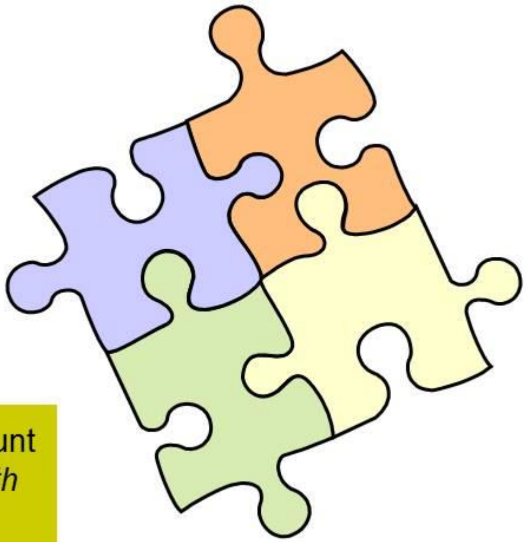
2.7 Construction and monitoring
- save on scarce resources

What bottlenecks are there for councils and residents? Are there ways to go about it?



Learning objective: the paramount role of *good* construction for *smooth* operation. How to raise ambitions without stretching council capacity

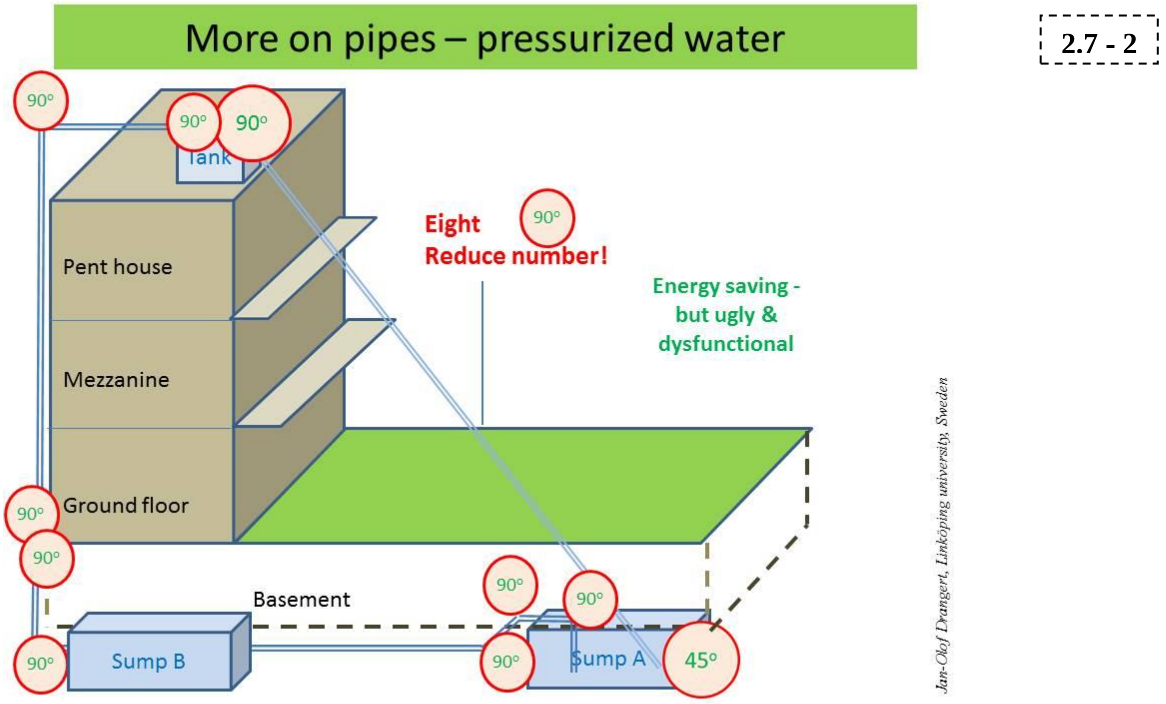
Jan-Olof Drangert, Linköping university, Sweden

This module provides guidance for development practitioners on how best to engage residents to monitor the construction of sanitation arrangements so that they can reap all the benefits of their new arrangements. In most installations worldwide, there are quality problems. They include obvious wrong connections of water pipes to sewers, rough cement floors that are difficult to clean, and vaults for faecal matter which leak air, defeating any ventilation effort. Who is expected to ensure that construction and installation are done properly? Theoretically it is the builder, contractor, municipal inspector, and product controller at manufacturing firms. But the present control measures are not effective, as shown by the many design and building faults which occur. The truth is that only the house owner and residents are deeply interested in getting everything right.

Toilets built by small contractors can have minor or major faults that could have been avoided. It takes more information than a drawing of the construction to make masons competent to perform their task. Inspection quality must also improve. In many cases, visits by inspectors are rare, presumably because of a lack of transport – a problem that will not go away. The suggestion here is to mandate house owners and school staff to take on the immediate responsibility of daily inspection at the building site, since they are there all the time.

This strategy will be successful only if all stakeholders have a common understanding of what the final outcome of the construction should be. A good technical drawing is promising first step, but not enough to provide all details. Only photographs can give a complete understanding of how things should look at each stage of the construction. A pictorial manual is therefore as important for those who build the installations as it is for the residents monitoring the process. The purpose is to avoid conflict and make the installation cheaper for the contractor and the house owner.

Simple building errors can ruin a toilet by making it smelly or difficult to keep clean and by making greywater handling messy. Inviting eager home owners to assist in inspections makes use of a locally abundant human resource without straining scarce professional resources. This module indicates what a manual for such inspections could contain.



A 4-storey house is presented to introduce ways of designing and constructing sustainable water supply for a house intended for rainwater harvesting. It is built with a collection sump below the basement and a gravity-distribution tank on the roof. A submersed electric pump brings the water to this tank. By clever design of pipes and tanks the energy use could be minimized. Likewise, the risk of leaking joints is minimized. Four possible “solutions” are compared.

(a) A straight water pipe from sump A: s bottom to the roof tank would cause minimum of friction and thus require least energy. With only one 45^{o} - and one 90^{o} -elbow a 2% increase of energy usage compared to no elbows. However, such a visible pipe in the garden would look ugly and becomes an obstacle to activities in the garden.

(b) An architect proposed to take the water pipe horizontally along the ground and then vertically up to the tank. In this case, the drawing shows eight 90^{o} -elbows which together increase energy usage by 5-10%. This will increase the operational cost and also increase the investment cost for the more powerful submersed pump.

(c) If the architect instead had placed the water sump under the main part of the building, only one 90^{o} -elbow would be required. However, such a placement of the sump would increase the risk of cracks in the sump from the weight and movement of the house. It is not worth taking such a risk.

(d) Next alternative shows the sump placed just a few meters away from the main building in order to avoid faults. A slightly slanting pipe is laid from the sump to the house wall and continues vertically up the wall. Only two 45^{o} -elbows and one 90^{o} -elbow is required in this case. This alternative uses the least energy and does not disturb activities in the garden nor risks unwarranted cracks in the sump or leaking joints.

In the case of pumping water to the roof tank, the height from the sump is most influential on the magnitude of energy required (Table below). Second most important consideration is the efficiency of the pump, since that can range from as little as 5-10 % to more than 60 %. This implies that the energy bill increases by a factor 10 between the two extreme pumps. The investment in the energy-efficient pump should be compared with the life-time saving on running costs.

Table 2.7.1 Pressure reduction and pump power when pumping water in vertical pipes.

			Water velocity 0.1 m/s				Water velocity 1 m/s			
Inner diameter of pipe	Pressure reduction due to gravity	Pressure reduction due to 8 90° elbows	Pressure reduction due to pipe friction	Total pressure reduction	Flow rate	Pump power (net)	Pressure reduction due to pipe friction	Total pressure reduction	Flow rate	Pump power (net)
(mm)	(kPa)	(kPa)	(kPa)	(kPa)	(l/s)	(W)	(kPa)	(kPa)	(l/s)	(W)
22	150	2.0	3.1	155	0.038	5.9	21	173	0.38	66
28	150	2.0	1.9	154	0.062	9.5	16	168	0.62	104
35	150	2.0	1.2	153	0.096	14.7	12	164	0.96	157

[Pa (Pascal) is the SI unit for pressure. 1 Pa = 1 N/m$^{2.}$ (1 kPa = 1000 Pa)]

The third most important consideration is the dimension of the pipe and the water velocity. Sub-optimal arrangements may raise the energy use by some 10 %. The rules of thumb are that (1) the smaller the pipe dimension, the larger is the energy required, and (2) the higher the velocity, the more energy is used (increases by the square of the velocity). Therefore, it is beneficial if the roof tank is big enough to cater for at least a day's total consumption, and if the pump fills the tank by a whole night's slow pumping of water through a relatively big pipe.

The extra energy required for many elbows is relatively small (some percentage points), but is heavily influenced by the pipe dimension and the smoothness of the inside surface of the elbow. Therefore, these aspects together with the size of the tank and regulating the flow rate should be in focus.

There are tables and calculation programmes that can assist in calculating energy and cost savings. The Table below provides some guidance (in the case of this house):

Table 2.7.2 Water velocity and energy requirements to pump water in vertical pipes (Water velocity =1 m/s)

Inner diameter of pipe	Flow rate	Pump power (net)	Time to pump up 1 m^3	Energy (net) to pump up 1 m^3	Energy (gross) to pump up 1 m^3 for pump with efficiency η=0.40	Energy (gross) to pump up1 m^3 for pump with efficiency η=0.20
(mm)	(l/s)	(W)	(s)	(kJ)	(kWh)	(kWh)
22	0.38	66	2632	173	0.12	0.24
28	0.62	104	1613	168	0.12	0.23
35	0.96	157	1042	164	0.11	0.23

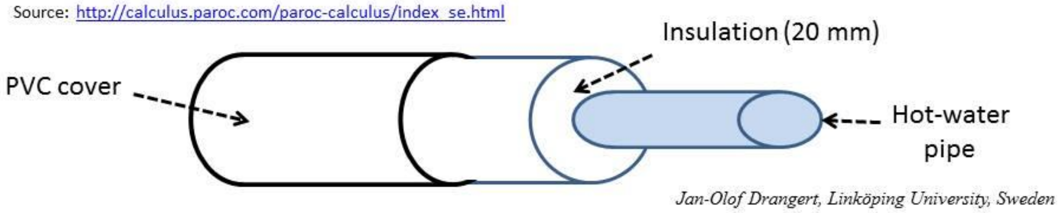
Water velocity in pipes is often in the range of 0.1 – 1 m/s, or 0.038 to 0.38 litres per second in 22 mm pipes. This provides about 8 m^3 to 80 m^3 per 24 hours, or 1 and 10 m^3 respectively in three hours. As for the energy required to pump 1 m^3 to the roof tank 15 m above the sump in a 22 mm pipe is 0.12 kWh or 0.24 kWh respectively depending on pump efficiency (η= 0.4 and η= 0.2). The local cost per kWh now gives the cost of pumping 1 m^3 to the roof tank in local currency.

2.7 - 3

Calculating the impact of insulating hot water pipes

Pipe diameter (mm)	Insulation thickness (mm)	Energy loss [kWh/(m·y)]	Energy saving **with** insulation [kWh/(m·y)]
22	No insulation	250	
22	20	51	199
22	60	32	218
35	No insulation	350	
35	20	66	285
35	60	41	309

Source: http://calculus.paroc.com/paroc-calculus/index_se.html



Heating household water requires energy, while cooling the hot water is a process where the heat dissipates into the surroundings. A common situation for Swedish households is that a third of the used water is hot water and the cost of heating is high. Fortunately, a lot of this energy can be saved by not letting the water cool down and requiring re-heating before use.

The proposed energy-saving installation is to insulate all hot water pipes from the heater/geyser to the taps. This can be done in several ways. A pre-insulated pipe may be available in shops or the plumber adds insulation on site. The plumber can fix a piece of readymade insulation around the hot-water pipe. Furthermore, in order to protect the insulation from weathering, the insulated pipe can be inserted into a second larger PVC-pipe as a shell.

The table above shows how much energy can be saved per meter insulated pipe in a year if the hot water temperature is 55°C initially and outside ambient temperature is 20°C.
The table indicates two "rules of thumb": The first is that a thin layer of insulation of 20 mm saves several times more energy than additional 40 mm insulation. The second rule is that the larger the dimension of the pipe is, the greater is the energy loss.
For greater temperature differences between the hot water and the ambience, the energy saving for properly insulated pipes will be even greater.

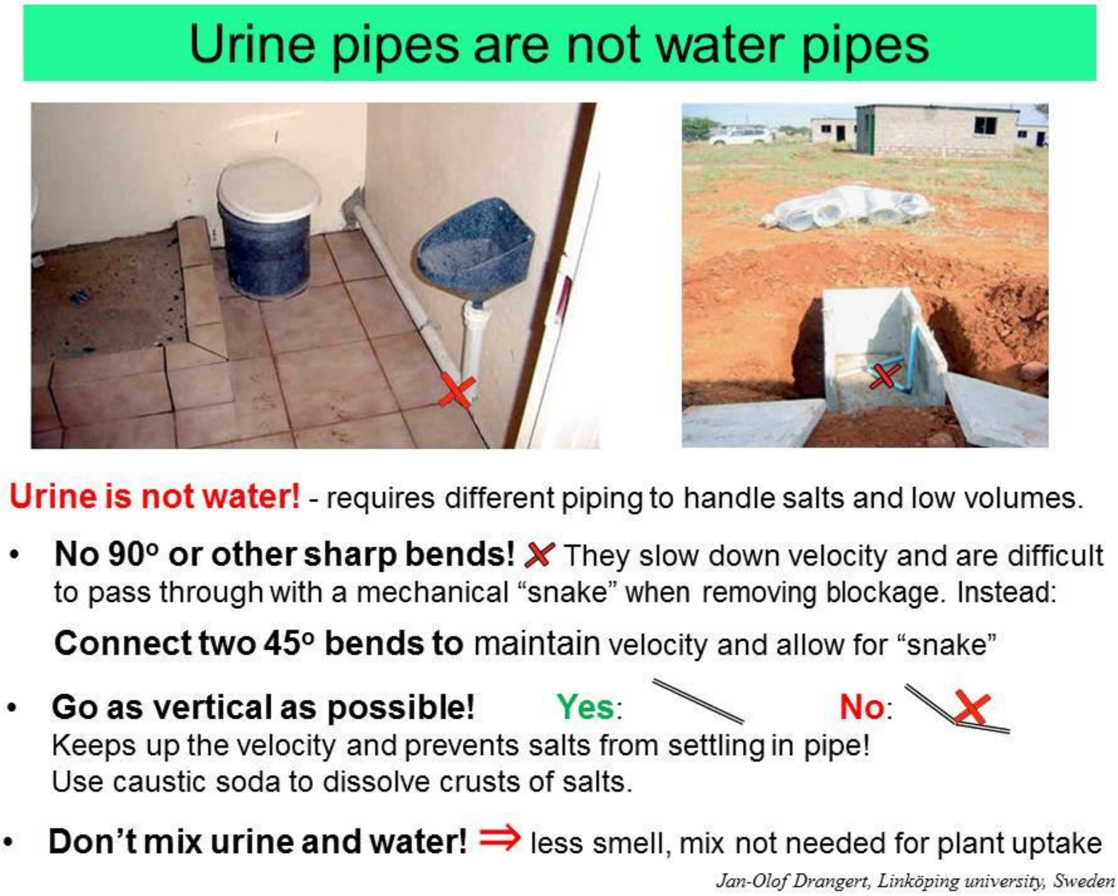
The required investment cost for insulating pipes with 20 or 60 mm thick insulating material should be compared with the savings in energy cost.

Another suggestion for multi-storey buildings is to let hot water circulate in a "closed loop" and whenever a hot-water tap is opened the hot water comes immediately. This is very different from the common case where several litres of lukewarm or cold water (that has cooled off while standing in the pipe) have to be discharged before the hot water appears. This improvement requires only an additional pipe when building the house.

A small heat exchanger in the bathroom placed at the drain pipe trap where the hot water after bathing is draining off could pre-heat cold water going into the heater.

All three provide strong case to insulate all hot water pipes to save on energy and money.

2.7 - 4



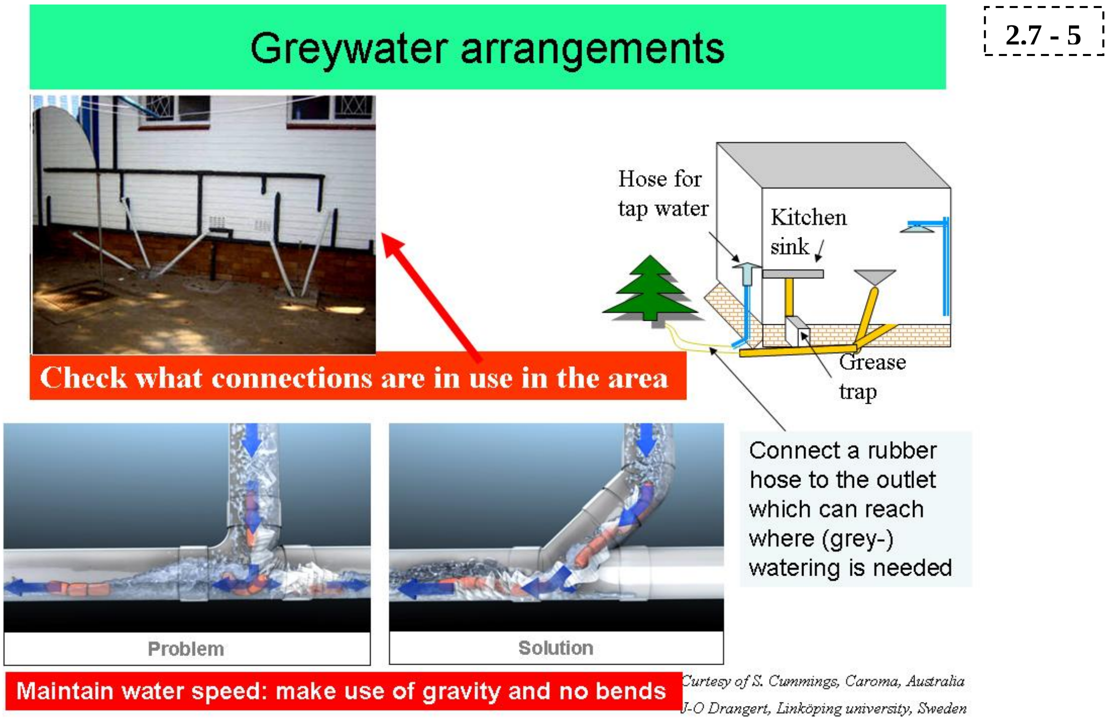
A common mistake is to think that the same pattern of piping can be used for urine and water. The volume of urine is small and irregular; say 0.2 litres twenty times in a day. This gives an average of 0.4 litres per hour and almost zero in the night. Thus, salts in the urine have time to settle unless we design for good slope and velocity. Experience shows that horizontal urine pipes cause unnecessary problems with crystallization. Fortunately, caustic soda can be used to dissolve most blockages. In severe cases a mechanical snake is needed, but the pipe breaks easily when the snake is forced through a 90-degree elbow.

'*Go as vertical as possible*', and not as in the left-hand picture where the pipe is vertical and then horizontal. The pipe should be as short as possible. In this case the pipe could instead slant between the urinal and the hole in the wall. If an elbow is unavoidable, make sure it is not 90^{o} since this reduces the velocity of the urine to almost zero. It is better to connect two 45^{o} elbows which slow down the velocity much less and also allow to insert a mechanical snake more easily.(Please see slide 2.7 - 4 above)

The right-hand photograph shows a disastrous prefab design (several 90^{o} elbows and horizontal sections) that will make the urine crystallise. The blue-coloured pipe dimension is also too small. The recommendation is 25–35 mm for vertical pipes, and 45–70 mm if sloping.

The design of the urinal bowl towards the hole should be like a funnel which does not allow urine to stay anywhere, and thus no smell is emitted. There is no agricultural or other reason to mix urine and water – in fact the mixture smells more than just urine. Also, if water is added the storage container has to be much bigger – or emptied more often.

All these design and construction recommendations will facilitate operation and maintenance for the benefit of the users. Good design and installation is not more expensive, and therefore there is no excuse for poor design of urine pipes.



Finding a robust, simple and affordable solution for on-site greywater treatment is a challenge if the household is not conscious or does not take care about what they put into the water while using it. The better the greywater quality, the simpler the treatment method.

Greywater can be used for watering the garden after little or no treatment, depending on the degree of contamination from kitchen and shower. The household is in control of the quality of its wastewater and knows what they have added to the water before use in their own garden. Treatment methods for other uses are dealt with in the module on reuse (Module 4.2).

The picture (top left) shows a home where they use all the greywater to water a nice garden, which would otherwise wilt during water restriction periods. They have connected all pipes – except from the toilet – and can direct the greywater whenever they need water in the garden. Keen gardeners are not likely to contaminate the water when using it, since they apply it in the garden afterwards. Not only do they save on fresh water and money, but they also reduce the volume of wastewater to the municipal treatment plant.

The bottom picture shows how solids in the transparent pipe behave in different elbows. Most of the solids passing the 90^o elbow continue as intended, but some solids are pressed backwards in the horizontal pipe. A combination of two 45-degree elbows instead of one 90^o elbow is superior – not only for greywater but for urine and air as well. All solids flow in the intended direction. The two-elbow version also retains a high flow velocity for the greywater.

In addition, to secure enough gradient for gravity-driven irrigation (top right) the house could be built on a raised foundation, and with a raised floor in the shower. Pipes should slant as much as possible from the entry point to the highest point in the garden in order to maintain the velocity of the greywater (slide 2.6-3). This extra supply of nutrient-rich irrigation water is good for gardens with food crops and trees as well as pleasure gardens.

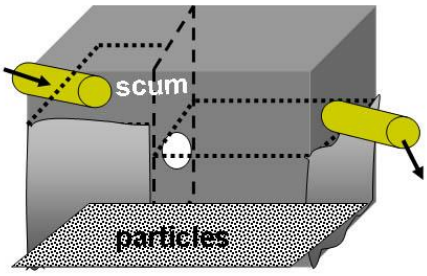
The last part of the irrigation pipe should be a rubber hose (flexible pipe) that can be placed where water is needed (top right). It is also helpful if a piped water tap can be connected to the rubber hose (blue vertical pipe top right) to be able to flush the flexible pipe occasionally.

Grease trap for kitchen water

2.7 - 6

The white pipe from kitchen sink distributes the water between two (black) boxes. Each contains a lilac plastic screen to catch coarse material (easy to empty). The water sinks through a layer of coconut fibre in which organisms live from nutrients in the greywater.

A common grease trap lets the greywater through two sections slowly enough to allow grease to float up (scum is removed). The coarse particles sink to the bottom where some degrade.



Jan-Olof Drangert, Linköping university, Sweden

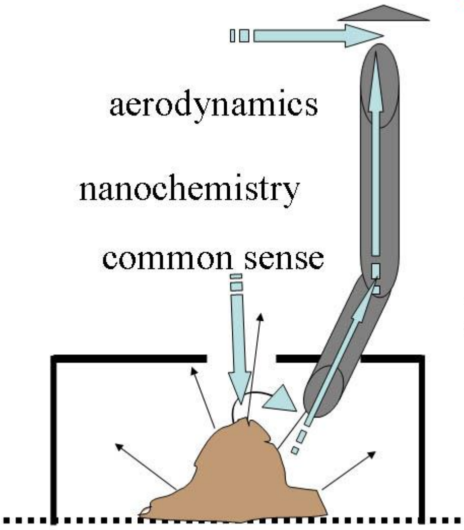
Kitchen water requires an extra effort of cleaning due to a high load of organic material. Warm dishwater and detergents dissolve fat, oil and grease (FOG). A conventional grease trap (right) is intended to allow the dishwater to cool down and FOG to float, and particles to settle. The retention time must be long enough for this to happen. FOG forms a scum on the surface and has to be removed regularly. This task is a bit messy, but the FOG is a valuable input to any compost or biogas reactor. A better way would be to reduce the valuable FOG content by wiping off grease from plates and cooking pots and add it on organic waste compost.

The degradation of organic matter at the bottom of the box (to the right) is mainly anaerobic and may produce some smell if not emptied occasionally. A smell indicates that the system is overloaded and if a thick black slime layer develops, the process becomes totally anaerobic and non-functional.

An improved grease trap with a mulch filter (to the left) was developed in Kimberly, South Africa. Its function is, firstly, to take away coarse particles in the wastewater from the kitchen sink e.g. food residues and fibres in a pre-filter or screen. Secondly, the water passes through an aerobic adsorption filter of coconut fibres where macro and micro fauna live and digest the carbohydrates, FOG and other easily biodegradable organic material in the water passing through. The aerobic process is odourless and easy to maintain by emptying the plastic screen in a separate organic waste bin. The unit is also educational in the sense that residents know that if they throw food remains in the sink, instead of in the waste bin in the kitchen, they have to empty the screen more often. The outgoing water with a reduced BOD level is rapidly drained in a connection pipe to other greywater and treated further (see Modules 4.5 – 4.7), after which the treated greywater can be used or infiltrated. The Kimberly unit was tested for more than a year, and found to perform very well, in spite of the heavy spring rainfall in 2006 which exceeded all previous records (Ridderstolpe, 2004).

Ventilation: Let us follow the bad smell

2.7 - 7



Think of this to reduce bad smell

- ❑ Vent pipe intake close to heap & drop hole
- ❑ Bends cause friction and lower air speed
- ❑ Any air leak on the box lowers air speed
- ❑ Vent pipe vertical otherwise more fiction
- ❑ Diameter of vent pipe 110-150 mm for optimal natural air flow-not smaller, not larger!
- ❑ The vent pipe should be at least 1 m above the highest point of the roof to catch wind and temperature difference
- ❑ Vent pipe outside the toilet room to be heated by the sun only in warm climates, but not if nights are cool. The vent pipe above the roof should be insulated.
- ❑ In cold climates vent pipes should be indoors and insulated above the roof.

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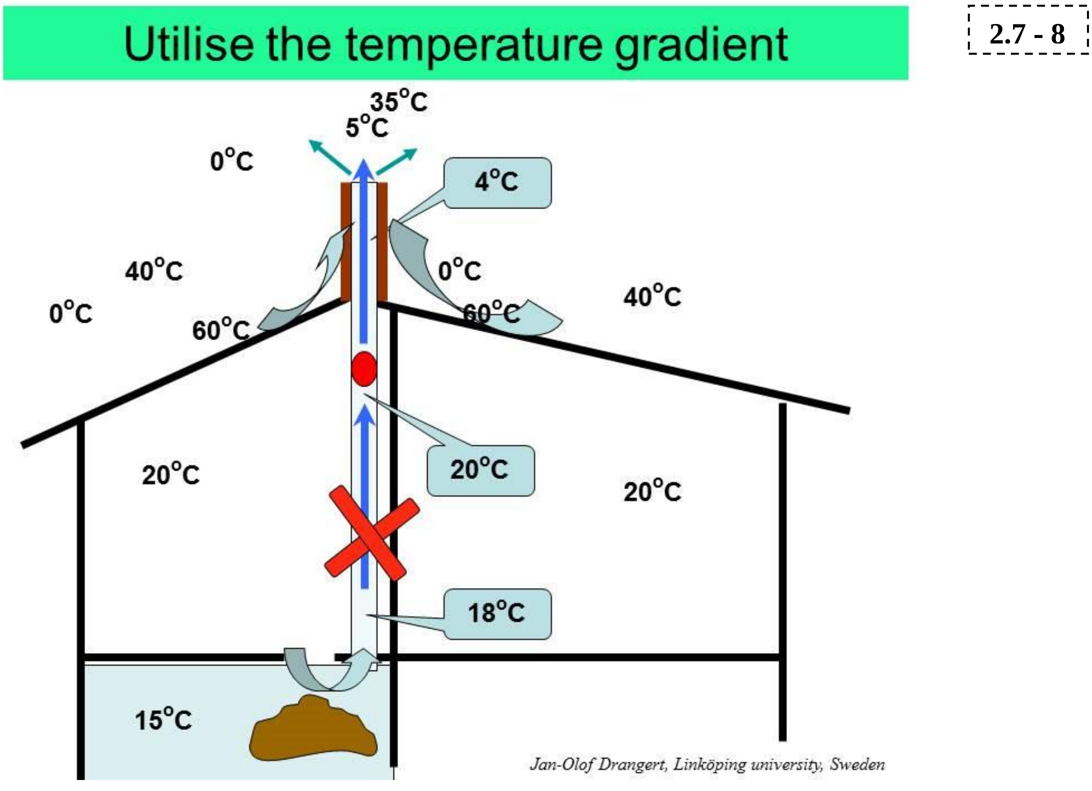
Bad odour is not appreciated and it has to be prevented by proper ventilation. Fortunately, natural ventilation is usually sufficient, provided proper design has guided the installation.

We learn at an early age what odours to like and dislike. Odour is a complicated biochemical issue involving the delicate sensors in our noses which can register very small particles released from the faecal matter (National Geographic, 1986). We will not delve into this, and instead look at how bad smells can be reduced by technical means. Common sense tells us that if we put an airtight box over the faecal heap, no smell will come out. But we need a drop hole in the box for the faecal matter. This allows gases to leave unless we open a second hole in the box and connect it to a vent pipe which goes above the roof. When air gets sucked up the vent pipe, it causes a downward draft of air from the toilet room to replace the air leaving the box. The downward draft must be strong enough to prevent emission of bad odours up through the drop hole. If so, no smell will be detected in the toilet room, only above the roof.

Air moves up the pipe for two main reasons. If a wind blows, the air current will create an under-pressure in the pipe above the roof, and air from the box will fill the void. The other reason is due to temperature differences. The warm air in the box has less density than the often cooler outdoor air, and will therefore move upwards. In both cases air in the toilet room enters the drop hole into the box and from there leaves through the vent pipe. If there is no wind or temperature difference, the air in the box will stay put and the odour-causing substances may enter the toilet room even if the toilet lid is closed. When the door to the toilet room is opened, an under-pressure occurs in the toilet room and air from the box enters the room. Fortunately, the degree of odour can be reduced by adding a drying agent on the fresh faecal material.

The above draft processes will not occur if the box is not air-tight (except for the two holes) since the suction down the drop hole will decrease. The best suction results will be achieved if the vent pipe is close to the heap and drop hole, and if the pipe has no elbows. The pipe diameter should be 110–150 mm to optimise air flow. The pipe should reach at least one meter above the highest point of the roof, and the outdoor part should be insulated. There is no reason to add a net to trap flies, because it is easier to trap the flies in the box itself (slide 2.1-9).



The previous slide explains how to optimise air speed in the vent pipe and thereby lower the risk of bad smells if the toilet room is inside the home. If the toilet is in the yard there is no need for a vent pipe. The trick is to ensure that the draft in the drop hole is always downward. Experience tells us that there may be some bad odour in the mornings in areas with big differences in temperature between day and night. The same problem occurs in cold climates. The reason is usually faulty design and lack of insulation of the vent pipe above the roof.

It is easy to understand the air movement if one thinks about the density of air rather than temperature. The density or weight per litre of air decreases when it gets warmer. An increase in temperature of ten degrees equates to a reduction of about 3% in weight at normal air pressure (760 mm Hg). We give three examples of temperature gradients in order to discuss what can happen. There is no fan or forced ventilation.

Example 1: The first picture shows a situation in which the outside temperature is 0°C. The room temperature is 20°C and the box (faecal chamber) is a bit cooler, say 15°C. Therefore, the air in the box is some 5% heavier and tends to stay still unless forced to move. The air in the toilet room is lighter than that in the box, and will not go down the drop hole unless forced to. Bad odour may enter the toilet room. But, the air starts moving above the roof because the light air in the pipe (20°C) moves up through the cold outdoor air (0°C). When air moves upwards in the pipe, the air in the box is sucked out and is likely to be replaced by air from the toilet room via the drop hole, and move on top of the colder air in the box. Because the air flows from the room to the box rather than from the box to the room, there is no foul smell in the room.

However, if the pipe is not insulated above the roof, the air inside the outdoor pipe will cool down towards 0°C while it is still inside the pipe. This metre of heavy cold air will prevent the underlying warm air from forcing its way upwards because it is not light enough to push the heavy cool air column upwards. Therefore, without insulation there is a likelihood of bad smells in the toilet room. Bad odours increase when the toilet entrance door is opened, causing the pressure in the room to fall and air to be sucked out of the box.

A strong wind outside can also cause the pressure in the toilet room to be lower than the pressure in the box, particularly if windows are open or not airtight. It is easy to check the air movement by following the smoke from a cigarette. Keep the lit cigarette above the drop hole and if the smoke tries to go downwards the design and temperature is okay. But it is also vital to check what happens when the pressure in the toilet room changes. Ask somebody to open and close the door to the toilet room while you observe the air flow in the drop hole. It may happen that the air/smoke flow turns upward due to the momentary under-pressure. The smell then also enters the toilet room. If that is the case, action should be taken (slide 2.7-7). Three first-aid remedies are: to make the door less air-tight by cutting it or drilling ventilation holes in it, or to open the door very gently to allow time for the air to enter the room, or to have the door opening into the toilet room (see school toilets slide 5.3-8 for more information).

Example 2: The next situation has an outside air temperature of +40°C and an indoor temperature of 20°C and the box temperature is 15°C. This time the 20°C air in the pipe needs some support to move upwards through the 6% lighter outdoor air. With no wind it is still likely to move because the roof itself is heated by the sun to much more than 40°C, say 60°C. The heated air near to the roof moves upwards around the pipe, and creates an under-pressure inside the pipe. The air in the pipe starts moving slowly upwards and in turn sucks air from the box and ultimately from the toilet room. This time it is more uncertain whether the air flow is strong enough to hold back smell from the box.

The above discussion presupposes that the box is airtight with an airtight door (for emptying), which means that the air from the toilet room moves through the box into the vent pipe up above the roof. The ventilation pipe of plastic (to avoid corrosion) is vertical. In this case it is not necessary to attach a separate exhaust fan to move the air from the box (still, it is advisable to install an electric outlet for possible future installation of a fan). The section of the pipe outside the house must extend at least one metre above the roof in order to catch the wind – and be insulated.

Another small solution is to attach a heating jacket for the last part of the vent pipe. This can be designed with a small energy foot print of no larger than 20 W or even less, and will ensure constant movement of air. The jacket is particularly useful at the 'neutral' point in the vent i.e. when the air neither moves up nor comes down because it has attained equilibrium both of thermal equalisation and weight equalisation.

Another kind of protection against bad odour from a dry toilet is to cover the fresh faeces with a drying agent such as ash, sawdust, soil, lime, sand, cut straw, or dry food waste such as flour, starch, and dried crust.

Pressure reduction and flow rate for ventilation pipes at different air velocities

2.7 - 9

Pipe diameter	Pipe height	Pressure reduction due to:				Flow rate	Fan power (net)	Fan power (gross) η=0,40
		Height	Each 90° elbow	Friction	**Total**			
(mm)	(m)	(Pa)	(Pa)	(Pa)	(Pa)	(l/s)	(W)	(W)
Air velocity 1 m/s								
75	15	177	6	4.6	188	4.42	0.83	2.1
110	15	177	6	2.8	186	9.50	1.77	4.4
75	10	118	6	3.07	127	4.42	0.56	1.4
110	10	118	6	1.87	126	9.50	1.20	3.0
Air velocity 2 m/s								
75	15	177	6	15.3	198	8.84	1.75	4.4
110	15	177	6	9.35	192	19.00	3.65	9.1
75	10	118	6	10.2	134	8.84	1.19	3.0
110	10	118	6	6.24	130	19.00	2.47	6.2

Hans Wessgren, Sweden

In the case of ventilation of air through pipes, the situation is different from that of pumping water through pipes (See tables 2.7-1 & 2). Air is light and is easy to push. Therefore, resistance in pipes and elbows become dominant aspects of design. Losses due to friction are some 40 % less in the larger pipe. As in the case of water, it is the velocity that influences the amount of energy used to move the air.

The Table above gives some values of pushing air vertically upwards through 75 and 110 mm pipes some 10 to 15 meters. Height remains the single most important parameter, while friction in the pipes is the second-most important. In this case, also the velocity and number of 90-degree elbows are important.

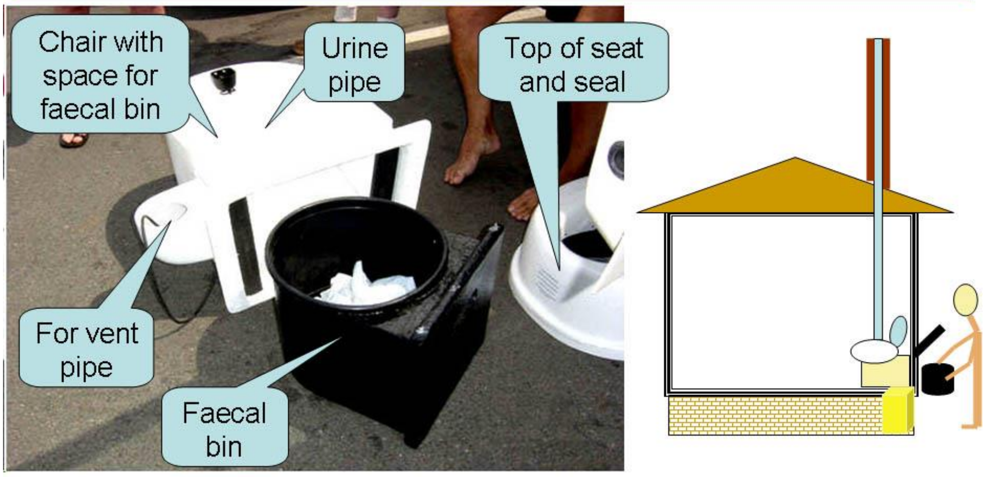
A velocity of 3 m/s pushes 13 litres of air per second, and requires about 75 second to push 1 m^3 through a 75 mm pipe. A 1 m/s velocity requires four minutes to push 1 m^3. The corresponding times for a 110 mm pipe are 35 seconds and 105 seconds, which shows that this pipe dimension has about twice the capacity of the 75 mm pipe. This, in turn, translates into higher energy usage for smaller dimensions.

Composting toilets have a potential to save on fan ventilation. Let us first consider the WC with its water seal preventing smell from faecal matter once it is submerged. However, the odour released to the toilet room during the fall from the user´s bottom to the water seal has to be evacuated regularly. A common building norm tells that all air in the room should be replaced every second hour. Let us imagine a 2 by 3 meters toilet room, which has an air volume of some 15 m^3, half of which is to be evacuated in an hour. A fan with the capacity of 3 m/s would take less than 4 minutes to evacuate through a 110 mm vent pipe. This is too often.

A composting toilet has to evacuate the small air volume in the collection box of some 1 m^3. The ventilation requires only one-fifteenth of that of the WC. Moist from showering can be reduced by removing water drops from walls and floor with a rubber scrape instead of with air.

Waterless toilet – the Kimberley type

2.7 - 10



- no water in the faecal bin
- throw paper in the bin
- under structure air tight
- empty often to avoid flies
- empty often so that bag is light
- instruct children and visitors
- co-compost faeces with organics
- keep vault and pile dry

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There are hundreds of designs of dry urine-diverting toilets in the world (Module 5.4). Many are suitable to install indoor in the house. The one in the picture is a South African model which is a modified Separett toilet made of hard plastic (www.separett.se).

The whole pedestal stands on the toilet room floor and is fixed to the wall (right). The faecal ‘bin’ is hidden under a sliding cover that opens when you sit on the ring. The bin is removed through an opening in the wall of the house (right sketch). Both the bin and the urine container can be picked up by someone without having to enter the house or flat. Ideally, the household has a biodegradable bag in the bin (or just newspapers) to protect it from being soiled but also to make emptying easy. A knot on the opening of the light bag and it can be placed in the compost directly or stored or collected by a farmer.

Urine (which comprises 90% of the total volume of excreta) either fills a plastic container or is diverted through a hose straight to the plants to be fertilised. The latter may cause clogging of the hose unless it is washed out from time to time. Also, a flexible pipe allows distributing the urine anywhere in the garden and thus avoiding over-fertilisation of one specific area.

The ventilation of this dry toilet is through a pipe attached to the chair just under the sliding cover (picture). There is no drop hole and in order to be on the safe side this toilet has a built-in electric fan to assist nature to exhaust foul air from the pedestal.

2.7 - 11

a) Urine-diverting pedestal in plastic, South Africa

b) Urine-diverting squatting pan in fibreglass, China

c) Urine-diverting chair in porcelain, Sweden

More indoor toilets

d) Old urine-diverting toilet in wood and porcelain, Sweden

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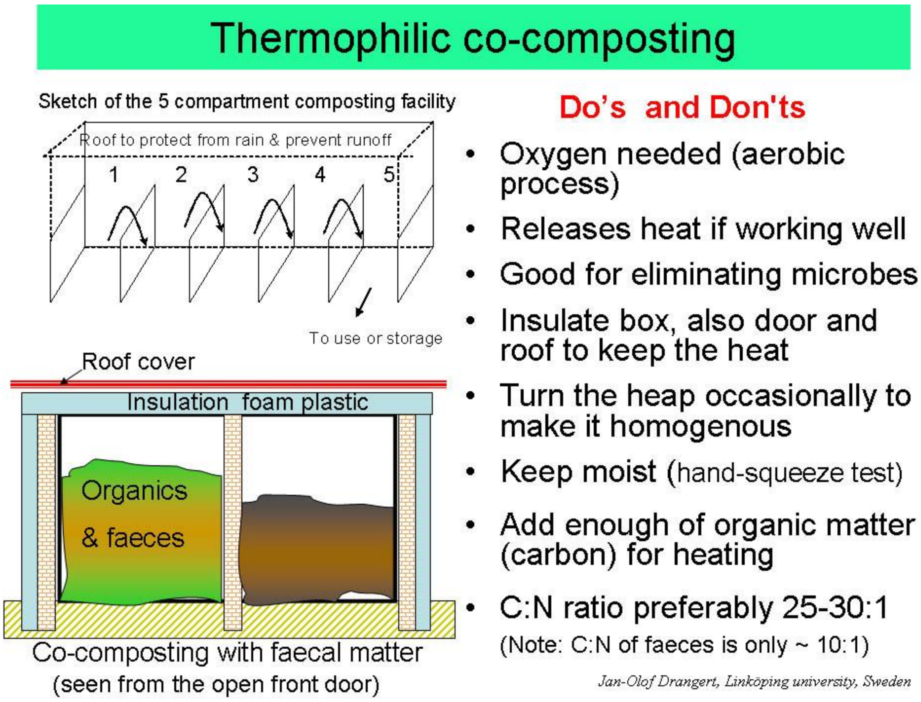
There are several million urine-diverting squatting pans in rural China (b) and over one hundred thousand urine-diverting toilets with an attached urinal in South Africa (www.envirosan.co.za). The more than 100,000 urine-diverting toilets of various makes in Sweden (c) are found mainly in summer cottages.

In the year 1915 one-fourth of the flats in Stockholm, the capital of Sweden, were equipped with dry urine-diverting toilets indoors (d), while almost half had outdoor toilets with buckets, and one-third had flush toilets. The revival of the idea of diverting urine at the source was partly inspired by the 19th century invention of toilets with two bowls; the front one for urine and the rear one for faeces.

Urine-diverting toilets can also be installed in larger housing complexes with collection of the urine in one shared underground tank. The content is transported to a farm where it is stored in a urine tank until being applied as a fertiliser on farmland in the appropriate season (Module 2.1). The faecal matter and cleansing paper may be collected in a biodegradable plastic bag and disposed of in the same manner as organic waste from the household (Module 5.4).



2.7 - 12

Co-composting of faecal matter with garden and food waste can be carried out using a row of boxes (see top left sketch). Each box is roughly cube-shaped with each side being about a metre and the front wall not shown in this picture. The structure can be made of almost any material that stands the weather and coated with an insulating material (lower picture). A layer of fresh garden waste (no faeces) can be put on the earth floor of all boxes, since this lowest part of the material will never reach a high sanitising temperature. Food waste and sturdier organic material such as garden waste is added to the pile, and occasionally faeces and whatever cleansing material, and again food waste. This mixing of material continues till the box is full. In this way, food waste and faeces are mixed right from the start with some sturdier organic material. Thermo-tolerant micro-organisms in the heap have easy access to air (oxygen) and they decompose starch and other organic material and this process releases heat (see Module 4.4).

The composted material is moved stepwise (see top left sketch). The stabilised compost in the last compartment (5) is taken out to be used or stored further; the material in compartment 4 is then moved to compartment 5, and so on. If there are, say, 5 boxes and the retention time is two weeks in each box, the material has been composted for more than 2 months and turned four times or more. However, this process gives enough hygienization only if the temperature has been above 55^{o}C for four days in the whole heap (WHO, 2006). If you are uncertain about whether the material is hygienic enough to use, a good precaution is to let it rest for another few months before applying it to the garden.

Access to oxygen, the right moisture level and enough carbon are necessary for successful co-composting. If the compost is too wet, there is too little oxygen for the microbes, and another group of less efficient microbes which prefer anaerobic conditions may take over. In this case fermentation starts, and the heap releases a bad smell from methane and other gases. Unfortunately, the pathogens do not die off fast under anaerobic conditions since the temperature will hardly be above ambient temperature. Smell can therefore be used for a crude assessment of the process and if smelling, dry organic carbon-rich material should be added to make the heap aerobic. It is thus far better to keep the compost on the dry side, rather than too wet.

When the material is moved from one box to the next, its moisture content can be checked by a simple hand-squeeze test. Take a handful of the material and squeeze it gently. If it drips, the material is too wet and some dry material should be added. If the material in your hand falls apart, it is too dry, and you can add water to the compost. Lastly, if the material keeps its shape, but is brittle after being squeezed, then the moisture is just right (50–60 % moisture content). Thermophilic bacteria thrive in this environment and actively degrade all kinds of organic material. The volume of the material shrinks by 70–90 % (WHO, 2006).

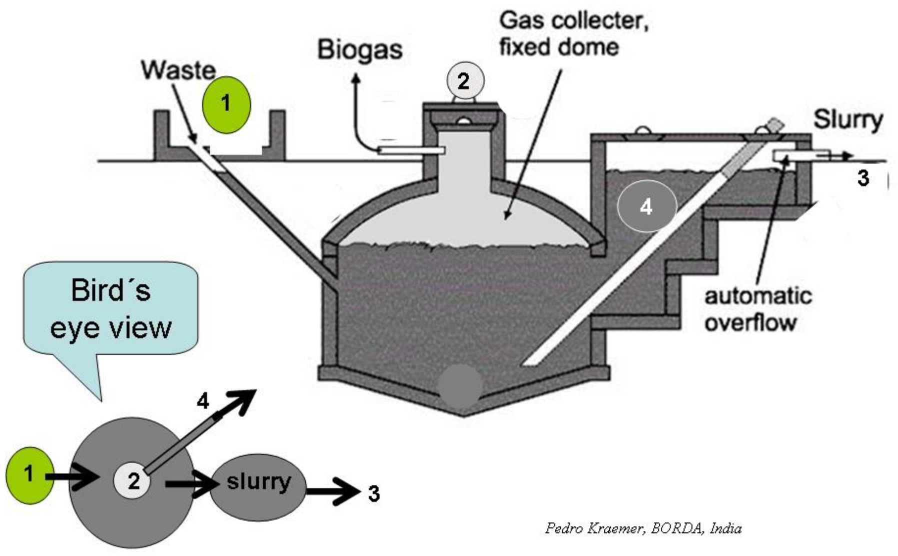
If the heat is over 55°C for a few days, all the pathogens will die off since they are not thermo-tolerant (WHO, 2006). It is therefore crucial to keep the heat in the box or else it will dissipate through the roof and the composted material will cool down. The insulation material (plastic foam) of a thickness of at least 10 cm on walls and even more on the roof will increase the temperature by 10 to 20°C. Without insulation there is no hygienization of the faeces, unless the operator is very skilful.

There are a number of recommendations for how to achieve high sanitation standards in operating the compost. The faecal bin (and the bin for organic waste) should be lined with (news)paper so that the bin is easy to clean. Tissue paper is organic but will take slightly longer to decompose in the compost. The fork or spade used to move the material can be cleaned with grass or paper and water, which goes into the first box and the fork is placed in the sun and UV-rays will sanitise it. It will not re-contaminate the sanitised compost in compartments 5 and 4 next time when the material is moved. If the faecal collection container is soiled it is cleaned with grass or paper and water and the cleansing material goes to the first box.

Vermi-composting is popular for ordinary composts, and some people claim that the worms speed up degradation. However, this method is not appropriate for faecal composting because of high moisture content of 70–90 %, and a low temperature in the range of 15–25°C which is far too low to hygienise the compost by killing off the pathogens.

Fixed-dome biogas digester

2.7 - 13



A totally different way to handle waste streams from households is to decompose the mix in a biogas digester. There are several designs of biogas plants (see Module 4.4). The Chinese invention of a fixed-dome digester (picture) has the advantages of low initial cost, simple operation since the scum layer breaks automatically, and low maintenance. There are no moving or rusting parts so it has a long life. The downside is fluctuating gas pressure. Qualified and experienced masons are required to build the gas-tight fixed-dome digester.

Organic solid waste including manure and faeces are mixed with wastewater to a watery mass with a 10% dry matter content. This is fed to the digester where anaerobic bacteria decompose starch and other materials to form methane gas and other products (Module 4.4). The movement of the substrate relies on hydraulic pressure from the added feed.

The gas rises through the scum layer to the upper part of the fixed dome. As pressure builds up, the liquid content in the digester is pushed down and will escape as slurry (no. 3). If the gas is not let out (no. 2) it will start seeping out in the slurry chamber, when the substrate level is at its lowest position. So, it is easy to know from the smell when to empty the gas. Once gas is taken out (no. 2) the liquid substrate rises again and the crusty scum layer on top breaks into pieces when it is pressed up against the upper part of the dome since the diameter of the dome is ever smaller. This makes the system very robust and there is no need to enter the reactor or use a mechanical device to crack the scum crust.

The white pipe (no. 4) is used to empty the degraded sludge at the bottom of the reactor. This pipe is not inserted through the slurry opening as it seems to in the diagram – it enters from another direction (as shown in the bird’s-eye view). This sludge can be used as fertilizer. The slurry (no. 3) is still rich in nutrients (except N) and other compounds that have not been decomposed. Therefore, it is suitable to be used as fertiliser. The digester is not meant for reduction of pathogens, but there is a 90 to 99% reduction of pathogens. Further treatment in e.g. a wetland filter is required to make the effluent safe to irrigate the garden.

(a) Increase ambition without stretching capacity

2.7 - 14

Up to now, we have given technical recommendations on how to build and construct in order to minimise operational and maintenance problems (= nuisances).

We have discussed how to design and install

- ventilation with care to avoid smell
- grease trap with care to avoid smell and clogging
- urine pipes with care to avoid blockages
- greywater pipes with care to be able to use the effluent
- compost with care to assure decomposition and die-off

Sustainability is not only about technology, but equally important are human resources and how to organise, build and operate sanitation arrangements.

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The technical recommendations aim to improve the functioning of sanitation arrangements. This will ensure comfort and save time and money for the residents. It will mean that contractors, builders and others will not be inundated with complaints, and will also reduce the pressure on municipal councils. Poor design and construction, on the other hand, will result in bad smells, clogged pipes and increased health risks, all to be borne by the residents.

Large sanitation projects and large manufacturers of toilets should produce detailed manuals which guide the construction and installation work. Standards, codes and monitoring of these are important tools to assist in getting things right from the start. It is much more expensive to rebuild or retrofit than to install the arrangement correctly in the first place. Training of architects, engineers, plumber and masons is part of the package to improve sanitation arrangements. Codes and standards offer guidance on how to design and build toilets and treatment units, but if the same norms that apply for the house itself are applied to a toilet unit, the toilet tends to become unaffordable. The norms have to be adapted to local circumstances, while still fulfilling reasonably high functional criteria.

It is deemed easier to introduce correct information in a manual than to train project staff and masons on all the nitty gritty details of sanitation installations. The manual includes what has previously been recommended for urine pipes, ventilation, well-ironed and easy-to-clean floors, etc. It also gives advice on the order of tasks to be done. For instance, to make a hole for the urine pipe when building the wall, instead of punching the hole after the wall is finished. Such unnecessary mistakes increase costs and often leave behind spots difficult to clean.

Such a manual could be composed of pairs of pictures, the left picture showing the correct way and the right picture showing the most common or serious fault. These pairs could cover every step of the construction and installation and suggest the best practices to be followed. The mason, the inspector, and the house owner can easily compare the reality at the building site with the two pictures and the mason can rectify any faults immediately. The alternative is to wait till the building is erected and the contractor agrees to partly demolish the structure to get it right. The only person with the time and motivation needed to do such daily “inspections” is the house-owner.

Quality of construction and good finishing of installations requires – beyond skilled masons and plumbers and proper drawings – care and sense of responsibility for the outcome, and not rounding corners. Checking quality of work relies on knowing what to look for and observation skills. However, observation is embedded in culture and often means that only certain things are observed (smell) and others are neglected. Therefore, it is important that both women and men are involved in inspections. Wrongly slanting pipes, too many elbows on pipes, potential leaking joints, and not smooth and easy-to-clean surfaces are examples of faults that will aggravate operation and maintenance. Such negligence occurs more often for new technologies.

There will always be insufficient number of qualified (and honest) consultants, contractors, and inspectors. This scarcity of manpower has to be addressed in any community and any project. The solutions are often found outside the sector, using unconventional approaches. A broad look at the availability of human resources in a community has to be married with the interest among them to get the design and construction right. Sometimes the residents themselves can supply this lacking resource, and sometimes it takes other groups outside the sector such as training institutions.

The following pages provide a set of recommendations which deal with management issues.

(b) Increase ambition without stretching capacity

2.7 -15

Example: **Urban cultivation**

+ fresh vegs or self-image or...
- water consumption goes up
- lack of time (earn more at job)

Solution: lease out allotments

Example: **Invite studies**

+ minimal cost for municipality
+ training opportunity for students
- too few students involved

Solution: invite training institutions

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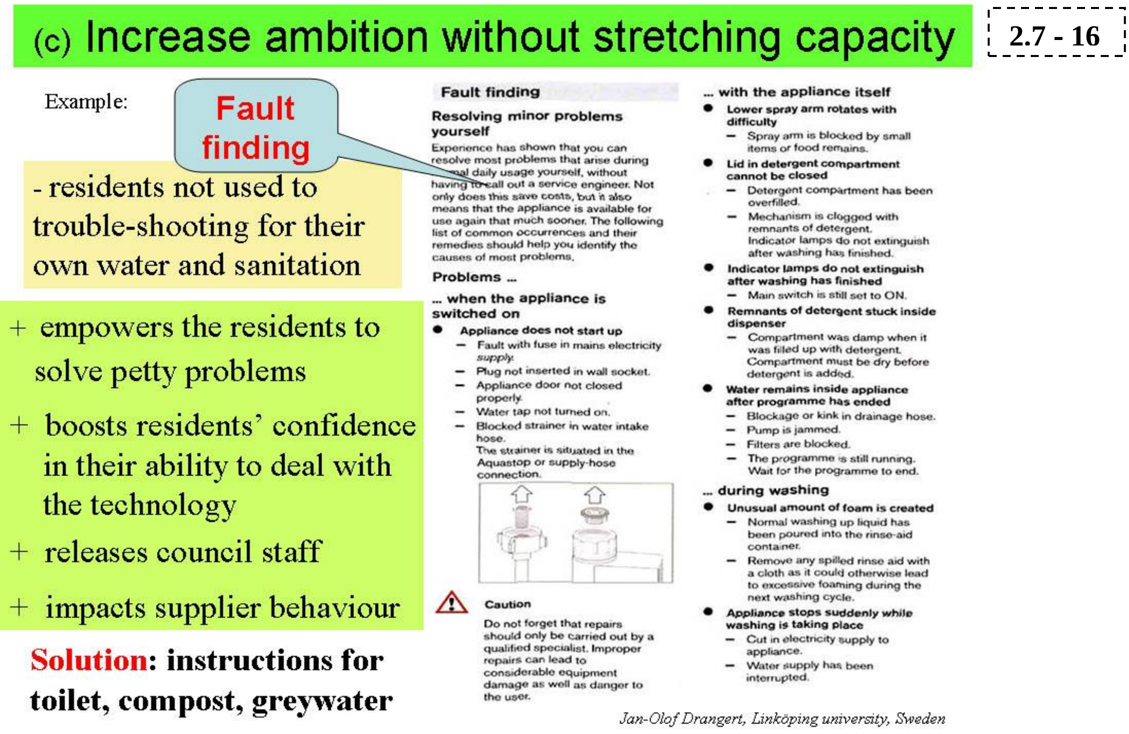
Urban agriculture is popular in some communities, in particular gardening. Nurseries, flower shops, media and study circles provide sufficient support for residents, and there is no need for the municipality to be involved, except for providing supportive by-laws. In many cities by-laws prohibit some or all urban agriculture. They may even prohibit households from keeping a hen or rabbit in the garden. The first step is to revise such by-laws and make sure health inspectors understand the value of food production in urban areas.

In other communities residents are reluctant to be involved in urban agriculture. A political issue is how to encourage urban agriculture to improve food security. If residents are reluctant they may have good reasons, such as poor self-image, noise of a cock in the morning, earns more at work, etc. Instead of trying to push residents, the approach can be to organise garden shows and competitions. Depending on ownership of the plot, it may also be possible to offer some of the open space in a neighbourhood as allotments to interested persons, even to people not living in the area. Reluctant residents will protest against giving others access to 'their' piece of land, and they may prefer to do it themselves rather than have others grow food in the vicinity. Indirectly such measures impact on how urban food production is viewed and this is achieved without a large expenditure of council or housing company resources.

Another way to promote urban agriculture as well as other sustainable household activities is to engage mass media, churches, etc. Their ongoing activities can be complemented by making environmental efforts credible and widely known and thereby modifying social norms.

Most of our training institutions have student projects as part of the curriculum. This is a resource which, for almost no cost, can be used for investigations and small sanitation-related projects. There is a host of possibilities within the environmental field where students can contribute important knowledge and practices to urban agriculture. Municipalities and companies can engage students at a minimal fee to do something useful and exciting by giving them an opportunity to use and extend their knowledge. The right-hand picture shows students doing fieldwork by studying a greywater treatment unit. Such two-sector cooperation is mutually beneficial and will make the students' studies more relevant and add to the competence of the training institution. The engagement will result in better practices in the future with minimal input from the municipality or building company. And not least, residents will benefit from such cooperation.



Why do manufacturers of mobile phones, washing machines, cars etc. provide customers with a manual for operation and maintenance? Essentially in order to have more satisfied customers and to save company money. Let us assume that it takes two hours to manufacture a mobile phone. If we spend twenty minutes in the shop asking simple questions about how to start the phone, or how to delete some information, we have taken 15% of the time to produce the phone, and probably the whole profit margin. The company cannot afford that, so they prefer to spend money on a good manual in order to receive as few uniformed questions as possible from the customers. The customers are also prepared to use the manual because they save time and, if successful, gain self-confidence.

Why is something similar not done for sanitation devices? Well, the market is not very competitive. But more important is who is responsible for answering customer queries. In the case of the mobile phone, you return to the shop or get in touch via internet. But if your toilet is smelly, the builder is not around; you do not know who the plumber was, etc. So, you end up trying to identify the project management – if they are still around. Or you may get in touch with the council or its consumer complaint board. No one really cares whether your toilet is smelling or not. If the toilet was installed as part of a project, the management might even be happy because then they may ask for funds for rehabilitation of the toilets.

The solution is for manufacturers of specific items to provide manuals for each item. And the manual for system issues should be prepared by councils (water and sewage departments or waste departments) or projects or universities depending on the local situation.

An example of a fault/finding exercise is given in the picture (regarding a washing machine). The information may be formulated in different ways, but it addresses one problem at a time. For each problem, the checklist starts with the easy-to-fix faults, and continues with more difficult ones. For each fault there is a suggested measure to solve the problem, sometimes with an explanation.

On the next slide, some indicators are given for the proper functioning of sustainable toilet arrangements, and an exercise on producing a fault-finding manual appears in slide 2.7 - 18

Check-list: indicators for dry UD toilets

2.7 - 17

Toilet room
- 1. Smell?
- 2. Flies?
- 3. Second drop-hole closed?
- 4. Cover for the drop hole in use?
- 5. Ash/other drying agent available?
- 6. Urinal functional? Smell?
- 7. Clean floor?
- 8. Clean squatting pan?
- 9. Cleaning utensils in the room? broom etc.

Outside the toilet room
- 1. Vent pipe insert in floor intact?
- 2. Pipe insulated above roof?
- 3. Fly screen intact?
- 4. Vent pipe properly fixed to wall?
- 5. Quality of door and hinges?
- 6. Lock on door?
- 7. Quality of stairs?
- 8. Urine jerry cans available?

Outside the toilet room (cont)
- 9. Handwashing facility?
- 10. Water and soap available?
- 11. Ablution water treated?

Vault
- 1. Vault door and box airtight?
- 2. Leaking urine pipe?
- 3. Equipment stored in the vault?
- 4. Amount of faecal material in vault?
- 5. Kind of wiping materials?
- 6. Plastic, broken glass, etc. in vault?
- 7. Moist pile, or liquid on the floor?
- 8. Stick to pull down top of heap?

Agriculture
- 1. Reuse of urine in situ?
- 2. Garden suitable for reuse?
- 3. Reuse of dehydrated faecal matter?
- 4. Contract with farmer/entrepreneur?

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The operation of an sustainable urine-diverting toilet can be checked by using a number of indicators. The list above is organised according to location, and brings up points which are likely to cause problems. There are two uses for a check/list. One is for monitoring of the system, and the other is to identify what needs to be included in a fault finding manual. Firstly, some comments are given to the above points.

It helps to distinguish between the smell of urine, faecal matter and wastewater in locating the origin of a smell problem. Our nose is the tool and has to be put close to each corner of the toilet room and installations, just like a detective would do. It is easier to identify the origin of bad odour if the floor, squatting pan, and cleaning utensils are cleaned beforehand.

Flies can be attracted by smell but also by light. Take a look at the toilet room from the fly's point of view. A moist faecal pile or liquid on the vault floor attracts flies. Therefore, it helps to cover the pile with a drying material such as wood ash, sawdust or even dry sand.

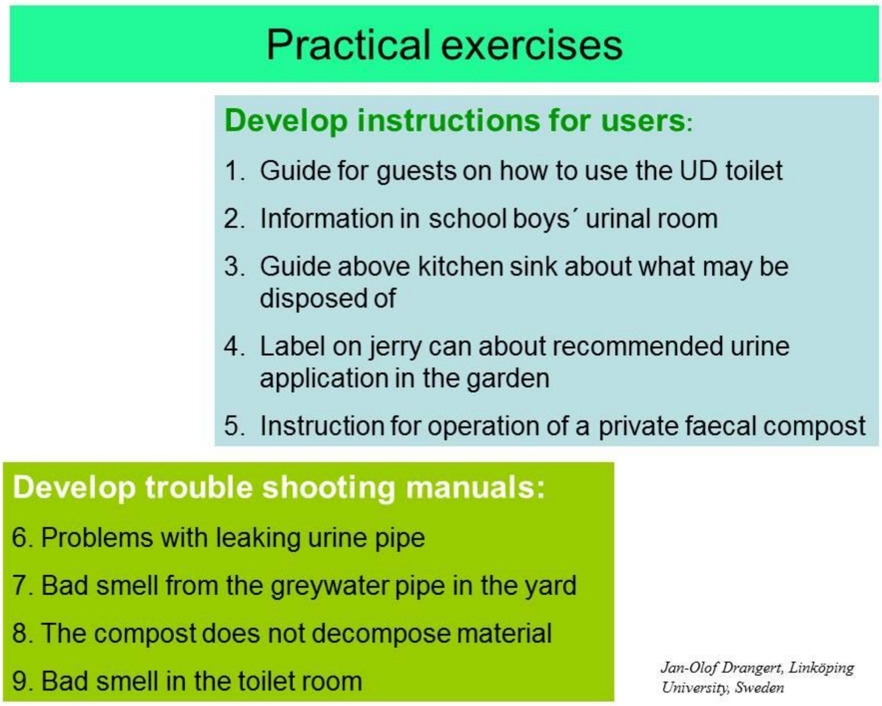
The direction of air flow at the drop hole is easy to establish by watching the smoke from a lit cigarette. If the air current goes in the wrong direction, a cover for the squatting pan or lid for the toilet chair minimises the escape of smells from the vault. Also, the cover and lid increases the speed of the air passing by on its way down the drop hole (slide 2.7-7).

The condition of the vent pipe is decisive for air flow and intruding water. The vault and the door used for emptying it must be air-tight in order to achieve optimal evacuation of air from the toilet room.

The extent of use of the toilet is indicated by the amount of faecal material in the vault and also if there is an alternative toilet on the plot or in the house. Plastic, broken glass, etc. in the vault is an indication of a low appreciation of the unit, and possibly also of a lack of understanding, and a lack of appropriate facilities for the disposal of such waste.

The size of the garden is important for assessing the recirculation opportunities. Is only urine used or only faecal matter?

2.7 - 18



Students, preferably working in groups of two, tackle one of the nine tasks in the picture. The first five tasks deal with instructions to users about how to operate the installation correctly. For each of the five situations there are many recommendations. The task is to select the most important ones, and make a short, easy-to-understand set of instructions. A helpful selection tool is to think through what quality is desirable for the discharges. Work backwards from there to select the measures you find most appropriate to recommend. The instruction should not contain more than two or three messages, since the reader is not supposed to stand and read the instruction carefully, but rather just have a quick glance at it.

The messages can be delivered as a drawing or written text, or as a combination. Remember that pictures can convey additional messages that are intended or wanted. Therefore, the suggested instruction should be tested on fellow students in the groups.

The trouble-shooting manual requires more space and the reader is expected to read slowly. He or she wants comprehensive guidance for finding answers to questions or finding a solution to a problem (slide 2.7-18) for washing machine example).

An example is provided in the following to outline what can be expected as an outcome of the exercise discussions. The chosen problem is that “it smells from urine in the toilet room”.

1. Sniff around the urinal to locate the origin.
2. Find out if the smell is from inside the bowl or from the floor or pipe fittings.
3. If the smell is (a) from the pipe or leaking connections they have to be cleaned and tightened. If it still smells, the search continues.
4. If it is from the floor (b) it should be cleaned thoroughly of standing urine. Test the smell again after the floor has dried up (a long-term solution is to paint the floor to prevent urine from being sucked permanently into the cement. The space between tiles in the floor which have not been sealed with special water-resistant cement or silicon may have to be redone correctly).

5. If the smell comes from the bowl it should be cleaned with some water or acid (vinegar) but not chemicals since these will affect the stored urine negatively. If this measure does not help, pour some hot water or caustic soda into the urinal to remove potential urine crystals/salts which have settled in the pipe and prevent urine to flow freely. If the smell remains, check if the urine pipe into the collection container is above the level of urine. If so, the urine pipe should be inserted further to some 3 cm from the bottom. Now, only the area of the cross-section of the pipe can emit smells reaching the toilet room. If the urine pipe is inserted into the container in such a way that it is (almost) air-tight, bad smells will not reach the toilet room.
6. If the urinal still smells, the only solution will be to prevent air flow in the pipe. Disconnect the pipe under the urinal and attach a rubber (preferably a condom that has been cut at the top and lengthwise with two slits, so that when attached to the urinal pipe the two rubber flaps stick together. When urine comes along the flaps allow it to pass, and then stick together again. In this way no bad air can backflow to the toilet room.

This trouble-shooting can be summarised as follows:

- Find out if the smell comes from the floor, fitting or inside the bowl.
- Clean the floor thoroughly.
- Tighten the urine pipe connections and clean them all.
- Clean the urine bowl with a damp cloth or vinegar.
- Pour hot water into the urinal to remove settled salts.
- Pour biodegradable caustic soda in the urinal. NB. Do not use any chemical since it will destroy the urine in the container and make it useless as a fertiliser.
- Make sure the urine pipe reaches almost to the bottom of the container (to minimise the area that can emit smells).
- Check that the entrance of the urine pipe to the storage container is (almost) air-tight.
- Prepare a condom or other rubber tube to prevent urine odour from flowing back into the urinal.

See also the School toilet Module 5.3.

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