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)

Jan-Olof Drangert, Linköping University, Sweden

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.
>
> 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.

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.

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

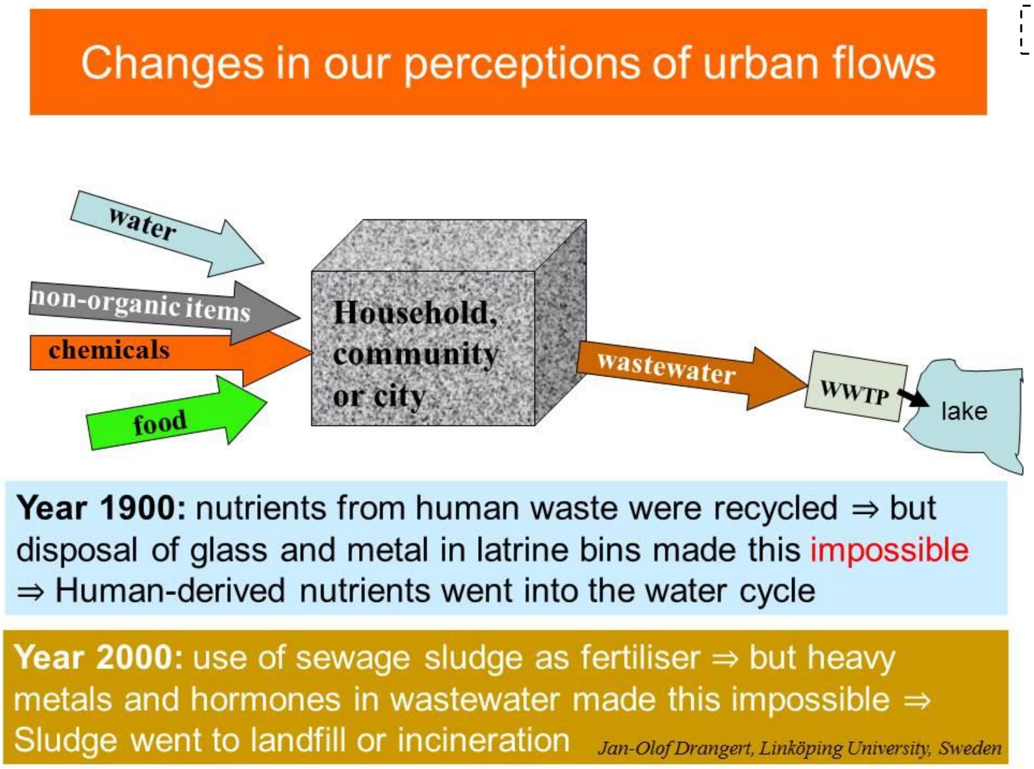
Jan-Olof Drangert, Linköping University, Sweden

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.

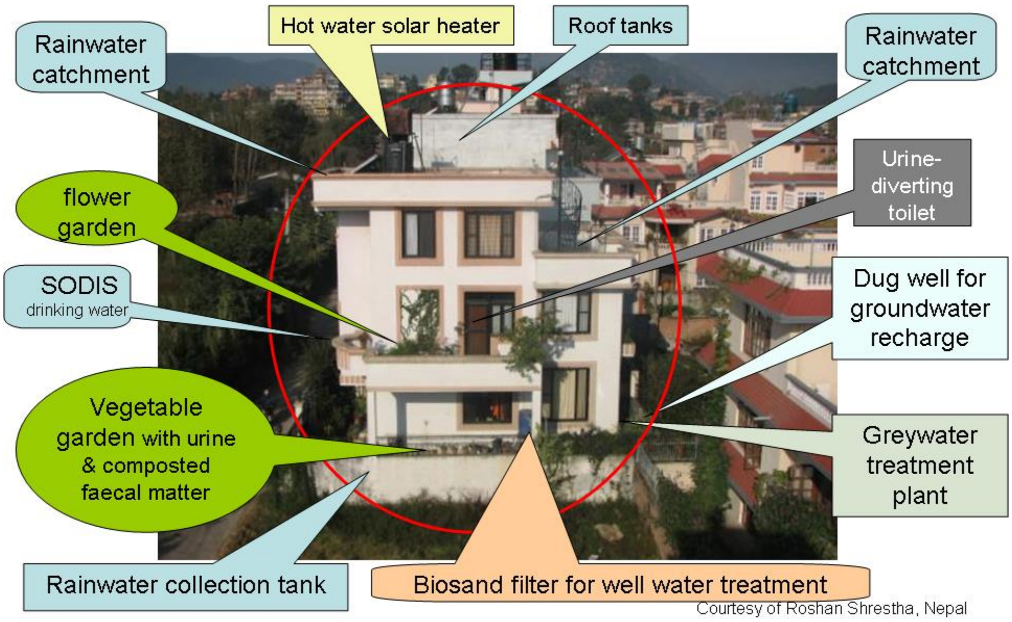
During the period 1950–2000 many biodegradable goods were replaced by new chemical products that were not biodegradable. Soap from vegetable oil was replaced by chemical detergents and washing powder, etc. By the end of the century 30,000 chemical compounds were being used regularly by households. Antibiotics, 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.

(a) An urban eco-house for a single family

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.

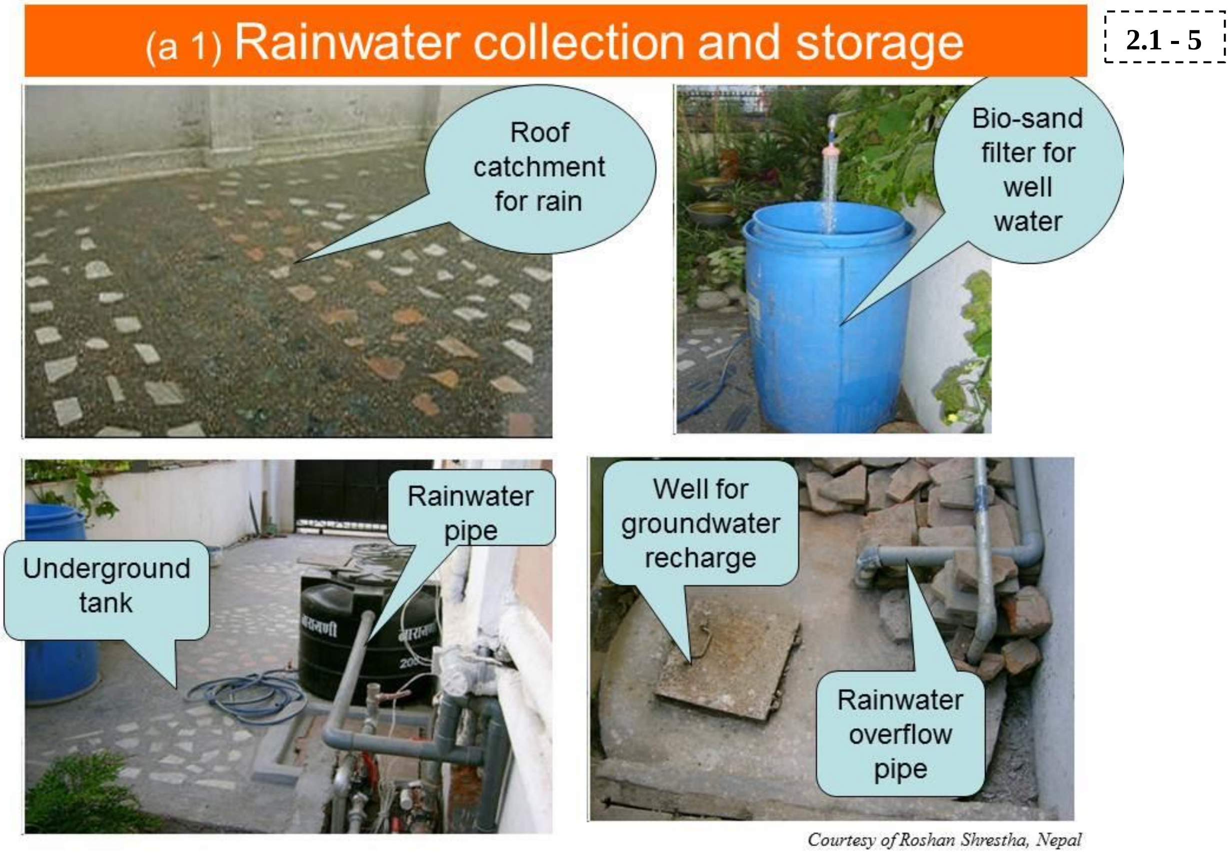
Dr. Shrestha built two underground water tanks before the house was erected, a bigger one of 8 m^3 to collect rainwater for household use and a smaller one of 2 m^3 to store treated greywater. All roofs are flat in order to collect rainwater and he took the precaution of diverting the first flows of 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.



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.

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

2.1 - 7

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.

(b 1) Some ingenious technical details

2.1 - 9

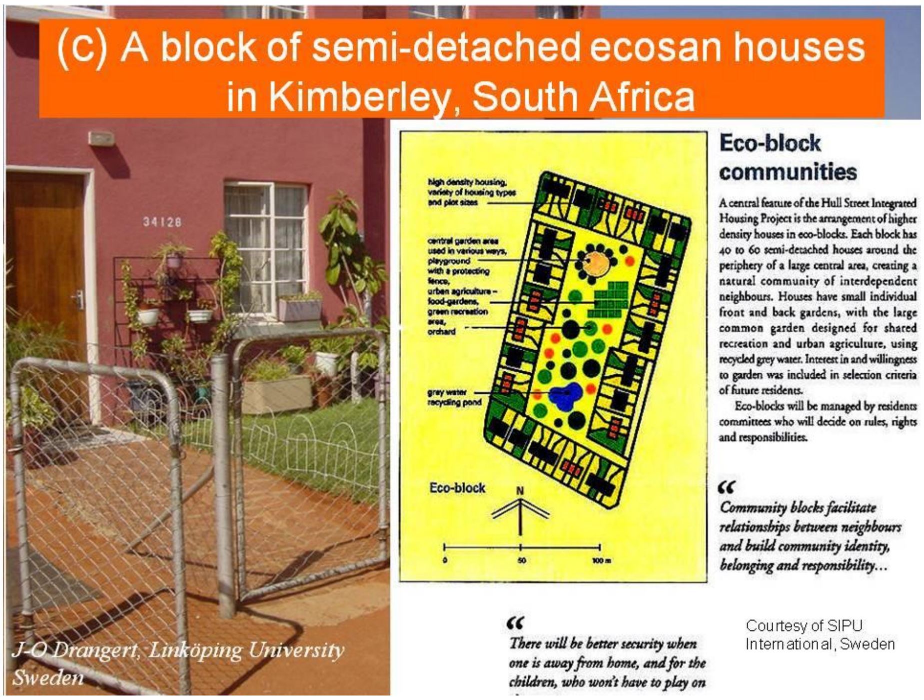
Newly installed container for excreta (Clivus Multrum)

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

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.

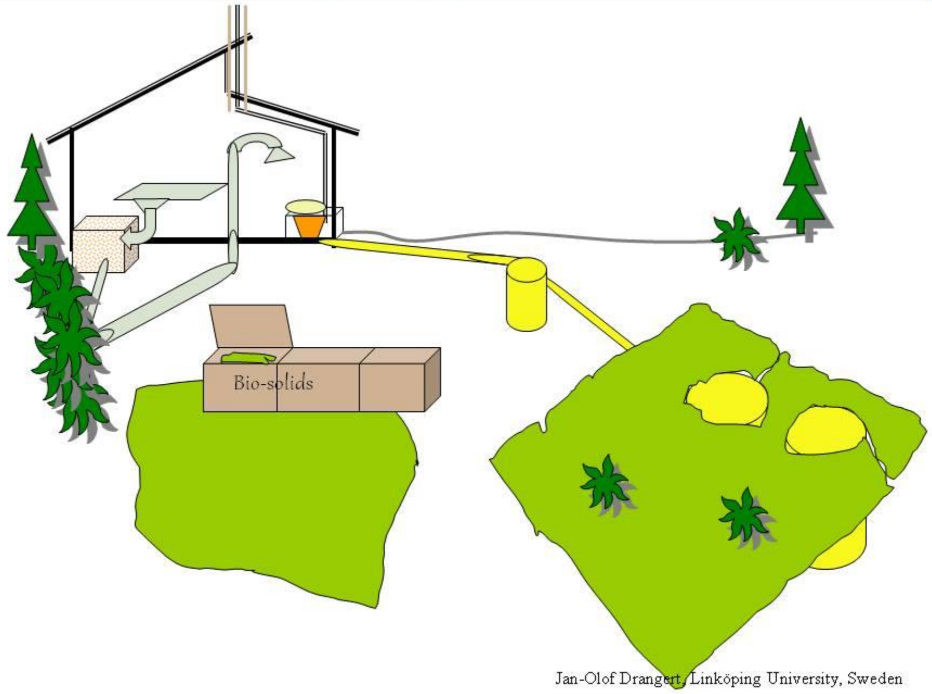
Each household in South Africa is entitled to 6,000 litres of free potable water per month and they are only charged for the amount they use in excess of this. The daily water use in the affluent city of Kimberley is 190 litres per person, of which 115 litres end up in the sewage treatment plant, while 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.

(c 1) The sanitation arrangements at each house

2.1 - 11



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.

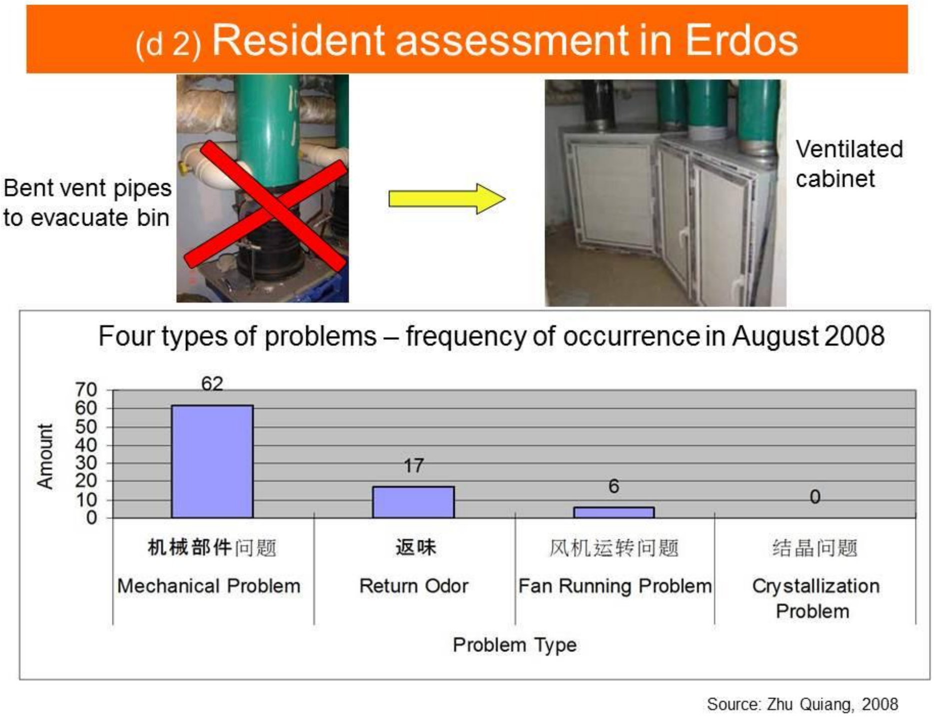
All the flats have a waterless urine-diverting toilet of porcelain (see pictures). They have been developed by the project and are manufactured locally. The “water” cistern has sawdust in it, which is sprinkled on the faecal matter before it drops through the shaft into the receiving blue wheelie bin 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).



2.1 - 15

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.

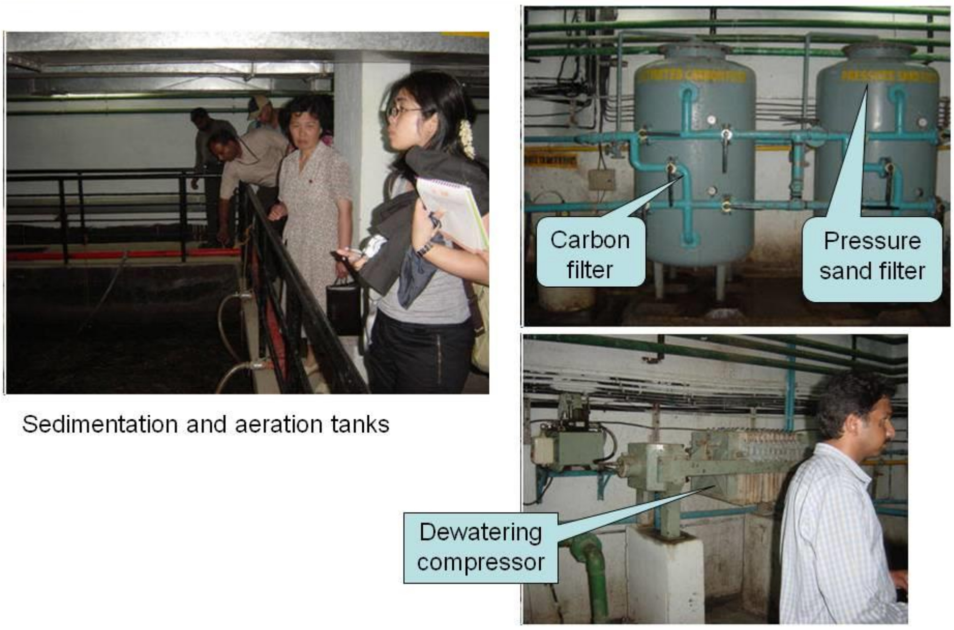
Since there are already 60 such mini-plants in housing complexes in the city (2008), there is a growing demand for trained operators. The State Pollution Control Board is preparing to train operators to be employed in upcoming complexes. There are also older housing complexes with no mini-treatment plant, 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	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)

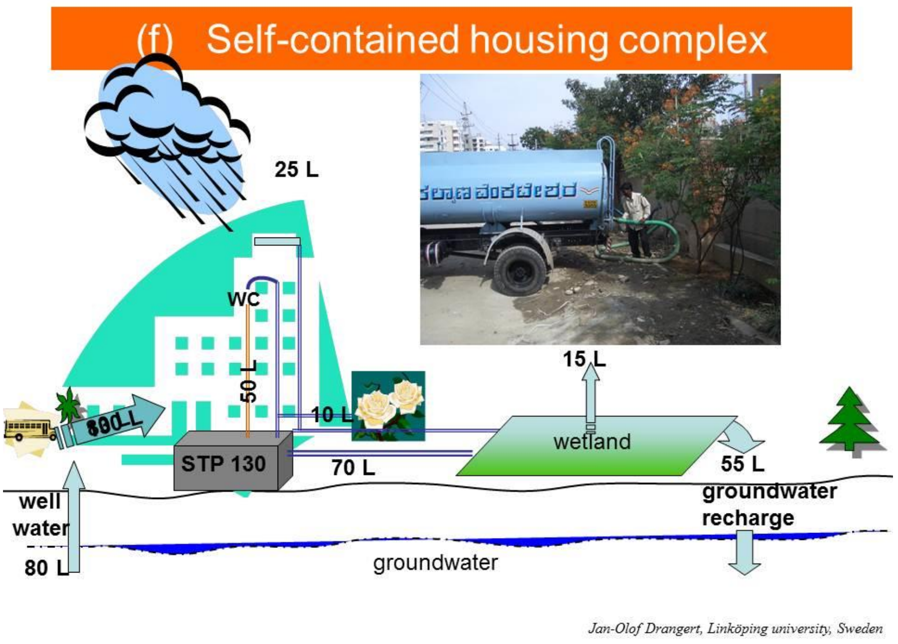
Government regulations require every wastewater treatment plant to self-monitor its performance, and to regularly forward a report to the State Pollution Control Board. The Board can also take its own samples as part of its responsibility to oversee the WWTP performance. If inconsistencies are found 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.

2.1 - 19



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.

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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