CHAPTER 6

WATER AND SANITATION

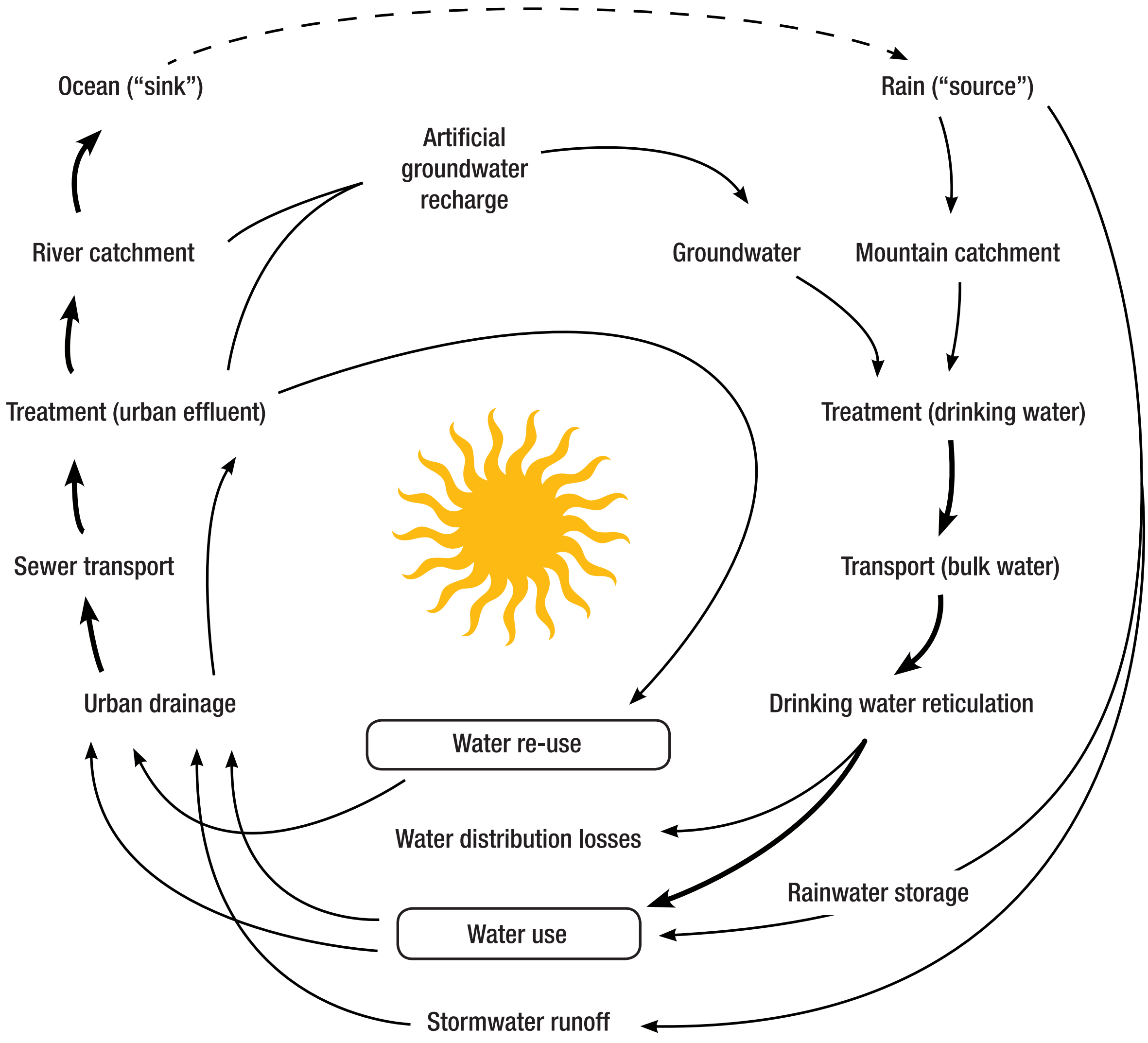
Lisa Thompson-Smeddle, Shannon van Breda (Sustainability Institute) and
Chris Wise (Jeffares and Green Consulting Engineers)

"We forget that the water cycle and the life cycle are one."

Jacques Cousteau

THE WATER CYCLE

Within the water cycle, water from seas and rivers evaporates to form clouds. Rain falls into rivers, dams, lakes and oceans, or it percolates into the ground (known as groundwater). People and animals use water to drink, clean, cook, for recreation and to carry away waste. Treated and untreated waste water re-enters the rivers and seas, and the cycle begins anew. Pollution at any stage in the cycle could prevent the water from being used elsewhere in the cycle.



POLICY CONTEXT

Prior to 1994, little was done to address water scarcity in South Africa. Water allocation and sanitation provision were driven by racial bias and the previous National Water Act 54 of 1956 placed industrial and agricultural water needs above any social and/or environmental water concerns. Although a mismatched distribution of water between various user groups is still evident today, national water policy in South Africa is at the forefront of international thinking and is soundly underpinned by the principles of sustainability, equity, and efficiency. The gap between policy and practice however remains one of the key challenges to water managers in all tiers of government.

WATER SOURCES

South Africa is a water poor country – one of the 30 driest countries in the world. South Africa depends mostly on inter-basin transfers (national and local), catchment run-off, dams, rivers, and groundwater extraction from springs, wells and boreholes for its water supply. Typically surface water is stored in dams, rivers and storage tanks (reservoirs). Groundwater is found in aquifers and is extracted by means of boreholes or wells. There are very few natural lakes in South Africa. Rainfall replenishes dams, is absorbed into the ground or evaporates. In a country like South Africa that suffers from water scarcity, groundwater is an important water source for many communities, and will remain so in the future. As surface water resources are used up, groundwater is increasingly likely to be used to supply urban areas as well. It is therefore highly important that we protect the quality of our groundwater.

In the South African context, feasible alternative sources of water can include:

- **Rainwater Harvesting:** Harvested rainwater can be used in gardens, to flush toilets and in other applications particularly in low-income areas. The choice of roof material (galvanized steel) must, however, be examined since zinc and other metals leached off galvanised surfaces can lead to heavy metal toxicity.
- **Aquifer Re-Charge:** Aquifer recharge puts water back into the ground in order to re-charge the levels of water stored underground.
- **Treated Effluent Reuse:** Treated effluent from sewage treatment plants can be used for irrigation of sports fields, golf courses and non-food agricultural crops instead of using potable water (water treated for drinking purposes).
- **Desalination of sea water:** It is currently estimated that the cost of water from a desalination plant could be in the order of R5 /m^3, excluding the cost of transporting the water from sea level (CCT. 2007). The process is however still heavily dependent on large amounts of electricity being available.

WATER CONTAMINATION

There are numerous potential sources of contamination of groundwater. It can be contaminated by sewage from leaking sewage pipes or shoddily built pit latrines, landfill leachate seepage, burial sites, unregulated animal husbandry sites or from the dumping of pollutants on the ground. These pollutants include substances that occur in liquid form (like oil), substances that dissolve in water (like nitrate) or substances that are small enough to pass through porous soils (like bacteria). Nitrates and nitrites which come from fertilizers and factory pollution can also contaminate groundwater. Ground water that is close to the surface (high water table) or where the soil is very sandy is more vulnerable to contamination.

Surface waters (rivers and dams) are also polluted because of inadequate sanitation or sewage treatment. In many instances communities do not have adequate sanitation or the sewage treatment plants are too small to cope with the amount of sewage. This results in pollution of rivers with organic materials that can include ammonia, viruses and bacteria. Since many communities rely on untreated surface water for their daily needs, it exposes them to a significant health risk.

WATER SUPPLY AND PURIFICATION

The South African Constitution states that all South Africans have the right to an environment that is not harmful to their health or well-being. This includes access to a constant supply of clean, safe drinking water. In South Africa, water is supplied through a network of pipelines, tunnels and canals via gravitational flow and/or pumping stations.

In urban areas the water supply is usually piped to reservoirs, but water may also be drawn from wells, boreholes, springs, dams or rivers. In some areas where water is not accessible or is unavailable, it may be delivered in mobile water tanks or drums.

Water in its natural state is seldom suitable for domestic purposes and has to be purified before being piped to homes. Water that is not treated properly can cause disease. Drinking water should contain no harmful concentrations of chemicals, heavy metals, or micro-organisms, and should ideally have a pleasant appearance, taste and odour. Water that is not stored and distributed properly can form algae and other bacteria that can be harmful to health and to the environment. The purification process carries a financial cost and depends on the nature of the water. Standard purification processes are listed in the box below.

- **Aeration:**

  Water is aerated by pumping in air to address an unpleasant taste and smell due to a lack of oxygen in the water.
- **Coagulation/flocculation:**

  Water that is cloudy or brown in colour because of tiny suspended particles that are negatively charged and repel each other can be stirred and treated with a positive charge, causing the particles to stick together and form flakes which can then be dropped out of the water by means of sedimentation.
- **Water Softening:**

  Water that is too "hard", as a result of the presence of high levels of calcium carbonate. Water softening involves reducing the levels of Calcium carbonate. Correcting the pH serves to mitigate the aggressive (and sometimes corrosive) impact on pipes.
- **Sedimentation:**

  In this application, which is used in conjunction with coagulation/flocculation, suspended particles or flakes settle to the bottom of settling tanks, are then removed to sludge ponds or landfilled.
- **Sand filtering:**

  This application is similar to running swimming pool water through sand filters and entails the filtering of water through sand which assists in the purification process.
- **Chlorination:**

  A small amount of chlorine kills most pathogens (disease-causing organisms) in water sources. Some chlorine remains behind in the water to kill any pathogens that may enter the system between treatment works and taps and can sometimes be smelt in tap water.
- **Ultra-violet light:**

  Ultra-violet (UV) light is an alternative to chlorination and can destroy micro-organisms that cause disease. UV light is applied to water by means of high pressure UV lamps. In contrast to chlorination, UV does not leave a bad smell or taste behind, but does not provide a residual component in the water system, so contamination of the water can occur before arriving at your tap. Ultra-violet lamps also require electricity, whereas chlorination does not.
- **Desalination:**

  Desalination is an expensive process that requires quite a lot of electricity, but it effectively removes salts and other particulate matter from brackish groundwater, saline wells, river water and sea water in areas that do not have access to fresh water. Desalination is used in South Africa mainly for treatment of groundwater for drinking purposes.
- **Boiling:**

  Boiling water for 10-12 minutes can remove many pathogens that can cause gastrointestinal diseases, but boiling will not remove colour, odours, suspended or dissolved particles.
- **Other:**

  Special processes are needed to treat water containing algae.

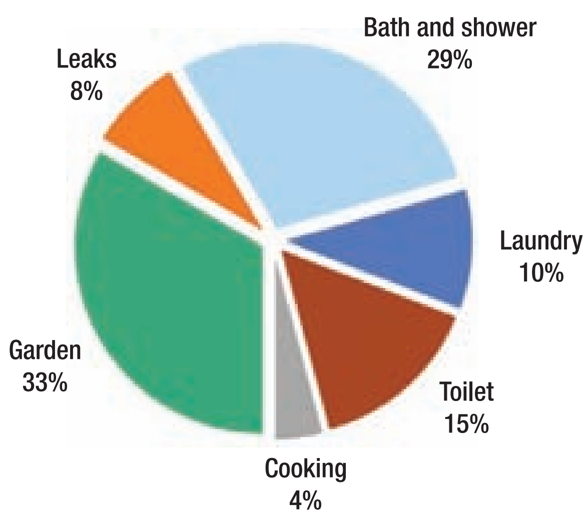
HOUSEHOLD AND NEIGHBOURHOOD WATER USE: AN OVERVIEW

It is important for households to have sufficient water and sanitation to lead quality lives and to prevent ill-health and disease. Households and neighbourhoods generally use water for drinking, cooking, washing, agriculture, gardens, removal of sewage, and commercial activities.

An increase in household water consumption tends to occur when household income increases. Mid to high income households use water more freely as it is piped, easy to use and more affordable. Higher income households also use high water consumption appliances like washing machines and dishwashers; they have a greater tendency to irrigate gardens and to fill swimming pools. On the other hand, lower consumption by low income households can be explained by limited financial resources to pay for appliances, lack of gardens and the sheer additional cost of the water. The 6 kilolitres of free water only applies to households on the piped water supply. So, as provision of basic services improves, and more people are given access to piped water, one can expect the demand on the water supply to increase significantly. The average amount of water used per person can range from 300 liters per person for a high income household to as little as 30 liters per person for a low income household, (Jacobs & Harhoff. 2004).

Guidelines for More Efficient Household Water Use

Studies reveal that an average suburban house can reduce their water consumption by 30-40% without sacrificing any comforts (Jacobs & Harhoff. 2004). In addition, if 'grey' water is recycled for garden use, household water use can be reduced by 60% or more, (Jacobs & Harhoff. 2004).



Typical mid-income household water use (Jacobs & Harhoff. 2004)

Reduce

Water is often wasted thoughtlessly. The largest domestic water consumer (for mid to high income households) is usually the garden followed by the bath/shower and toilet. These are the areas where significant water savings can be achieved by means of very simple interventions. Water used for toilets, washing, laundry and irrigation can be reduced, but this usually applies to households with piped water. Specially designed water-efficient appliances and fittings can also contribute to the conservation of water.

Examples of water saving measures include the following:

Reduce Toilet Flush Volume

Older toilets have cisterns of around 11 to 15 litres, when only half of this water volume is necessary. Modern toilets have more sensible cisterns of around 6 litres, and even this is unnecessarily wasteful for flushing liquids. One can save 100 litres per day (assuming 3 persons per household) by installing a 'dual-flush' or 'multi-flush' device into the toilet. Dual flush devices have two fixed settings, a light setting (3 litres) for urine and a heavier one (6 litres) for solids.

Multi-flush (or hold flush) devices allow households to flush any amount by holding down the handle for as long as is needed to flush the contents. It is important to remember that best results are achieved for a dual flush system when the bowl is also changed to one that uses lower volumes of water. To reduce the flush volume without any new installations, households can put a displacement container in the cistern – a brick, large stone or a bottle filled with sand and water will do the trick. An inexpensive commercial product such as a "Hippo Bag" can also be used.

Low-Flow Fixtures

Low flow showerheads reduce shower water use by 50 - 75%. Comfort is maintained by adding air to the water, providing the feeling of a comfortable shower while using 1/3 of the water. Showering in turn is more water-efficient than bathing, even without the use of low-flow showerheads. Reducing hot water usage through more efficient showering also saves on electricity required to heat the water (water heating is the main electricity consumer in most households).

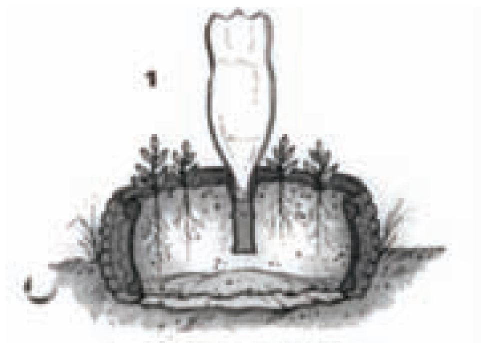
Installation of Tap Aerators

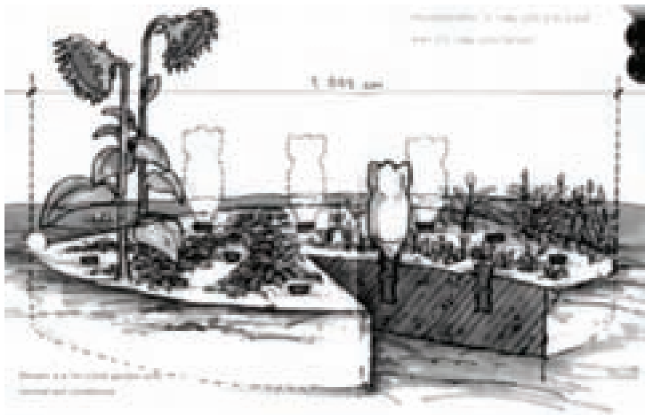
Tap aerators are small screens that are screwed onto the tap, mixing air with the water so it feels as if more water is coming out of the tap while the pressure is maintained. Flow is reduced by around 50-75%. Without aeration, water from normal taps flows down the drain ineffectively.

Drip Irrigation

In middle income households, the single biggest user of water in the home is typically the garden, so this is where the biggest water savings can be achieved. Drip irrigation systems involve installing thin pipes directly to the base of plant, with drippers on the end of the pipes. These drippers slowly supply water to the plant directly where it is needed, so less water is required. Also, since the water is not sprayed in the air, there is no water lost by evaporation. The amount of water used for irrigation can be reduced by 50% or more using such a system. PET bottles (Coke bottles) can also provide a low cost drip irrigation system, as demonstrated below. These are very effective for smaller gardens where filling the bottles is feasible and the home owner has the diligence to do so.

The African dripper





Reducing Lawn Size

Lawns consume twice as much water to stay healthy than shrubs and flowers. Also, indigenous grasses need much less water. If the lawn area is reduced by 50%, the total amount of water used for the garden can be reduced by 30% (Jacobs & Harhoff. 2004).

Repairing Leaks

Leaking pipes, taps, and toilets waste on average 80 litres per household per day (Jacobs & Harhoff. 2004). It is important to fix leaks quickly. The most common leak is a leaking cistern due to a worn out washer in the flushing mechanism. This can be easily identified by looking for ripples in the bowl of the toilet as well as the cistern not easily filling up (i.e. it makes a noise long after flushing). Dripping taps often just require a new washer.

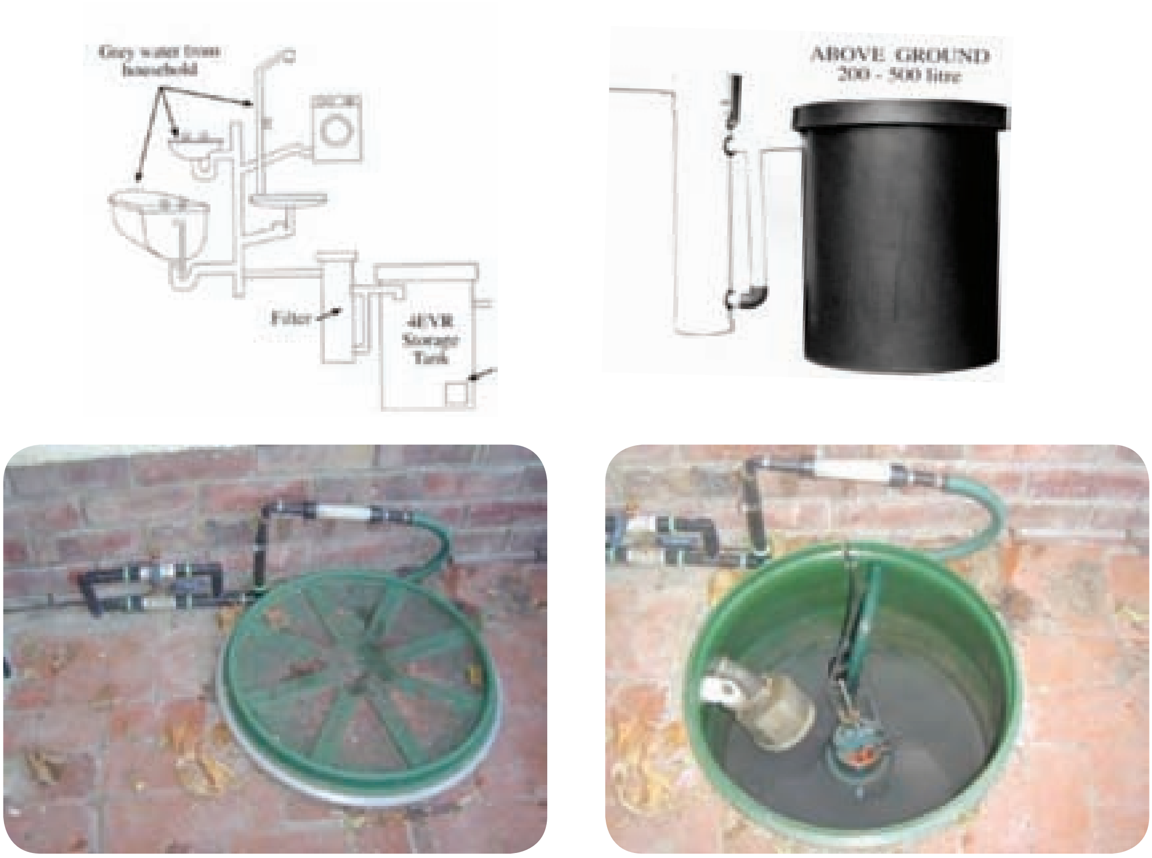
Re-Use

Water recycling is a viable option in any neighbourhood application. Water used for washing (grey water) can be re-used in toilets and gardens. On-site sewage treatment can also provide a water supply for toilet flushing and non-food garden irrigation. Examples of the re-use of water include:

Grey Water Recycling Systems

By installing a system to collect 'grey' water (i.e. from the washing machine, basin, shower and bath), and pumping it onto the garden, most households will eliminate the need for any additional garden watering. This can reduce water consumption by 35% (Jacobs & Harhoff. 2004). These systems need not be expensive, and cost recovery from water saving is ensured.

Example of an installed grey water system



The treatment of grey water depends on how it is going to be used. If it is to be used in a drip irrigation system, then only basic filtering is required to remove solids that can block the irrigation system. If it is used for toilet flushing, a certain amount of disinfection (removal of pathogens) and organic reduction would be required. This can be done by means of any aerobic treatment system followed by a disinfection step. A system such as trickling filters can also achieve fairly high removal rates and require less maintenance. If grey water is going to be stored it should be treated with UV radiation or chlorine to kill pathogens.

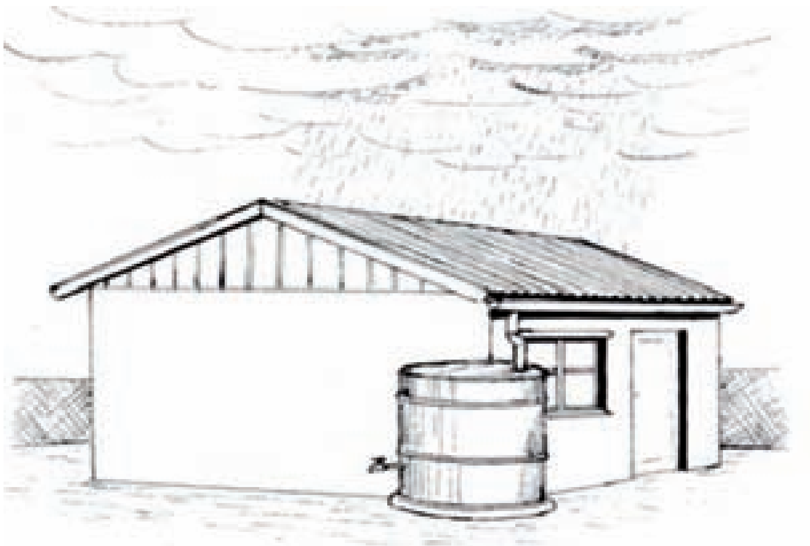
Grey water should always be filtered before being pumped in order to prevent the pump from being damaged. Water from kitchen sinks and dishwashers is not suitable for grey water reuse because of all the solid particles. Also, shrubs and flowers generally do not like the soaps and oils in grey water, but lawns thrive on these nutrients.

One of the disadvantages of grey water systems is that they use electricity to pump the water onto the lawn (usually because the shower and bath are low down and the tank therefore has to be buried to collect the water). However, if it is possible to run the grey water directly onto the lawn this should be encouraged. Grey water systems also require some maintenance, for example, screens must be kept clean and tanks should be flushed on a monthly basis.

Rainwater harvesting:

The collection of rainwater for reuse can be implemented by individual households. This water can provide an important, additional source of water for the home. Rainwater is collected from the roof and stored in plastic tanks via gutters and down pipes. If the water is going to be used for drinking purposes then fiber cement or tile roofs are most suitable. Galvanized steel (zinc coated) and other metal roofs may increase the likelihood of health and environmental damage from heavy metal toxins. Water may also be contaminated with dust, leaves, insects and birds, so it should be filtered and purified before being used for drinking water. Rainwater can easily be used for irrigation. It is important to remember that tank size has much less impact on the amount of water that can be reused for irrigation than the roof collection area.

Rainwater can also be successfully used for toilet flushing. A pump can be installed in the rainwater tank to pump the water up to a separate header tank that feeds only the toilet cisterns. A much smaller tank is required than for irrigation purposes. A typical home (mid income with 4 persons) using a dual flush toilet would only need 50m2 of roof and a 4000 liter tank to supply all their toilet flush water in a winter rainfall area (SA Weather Service and Jacobs & Harhoff. 2004).



Treated effluent reuse:

The use of potable water for the irrigation of sports fields and golf courses is not sustainable. A viable alternative is to use treated effluent from sewage treatment plants for this type of irrigation. The treated effluent can be pumped for the sports fields or golf courses after being filtered via a pipe network. Orange pipes are used to distinguish them from normal potable water pipes. Also strict use of special coupling at the irrigation points must be enforced to prevent cross contamination back into the potable water system. There are many examples of this being done in South Africa.

WATER SAVINGS SUMMARY

The total amount of water savings that can be achieved using a combination of methods is demonstrated in the following table (Jacobs & Harhoff. 2004). Some conclusions: low flow shower heads reduce shower water usage by 67%, and they reduce overall household water usage by 15%, (Jacobs & Harhoff. 2004). Installing a grey water system can save an average 212 litres per day, reducing a household's water consumption by 18%. By combining several methods together, total household water usage can be reduced by nearly 60%.

Income group: High
Household size: 3

	Average Daily usage (before)	**Intervention**	**Average Daily usage (after)**	**Average savings**	**% reduction in unit usage**	**Overall water saving**
	Litres/day		**Litres/day**	**Litres/day**		
Bath (Child bathing)	61		61			
Bathroom Basin	41		41			
Dishwasher	19		19			
Kitchen Sink	40		40			
Leaks	82	Repair leaking cistern	25	57	70%	5%
Shower	252	Install low flow shower head	84	168	67%	15%
Toilet	147	Retrofit dual flush toilet	44	103	70%	9%
Washing Machine	102		102			
Pool Filter	26		26			
Pool Evapora-tion	54	Install pool cover	11	43	80%	4%
Garden – Lawn	212	Install grey water system	0	212	100%	18%
Garden Beds	113	Retrofit drip irrigation	57	57	50%	5%
Total	**1149**	/day	**509**	**640**	**56%**	
	34	kl/month	**15**	kl/month		

WASTEWATER TREATMENT

Household effluent in urban areas, which is usually treated at a central sewage works, can still release bacteria and pathogens into rivers and ground water due to poor management or failure at the sewage works. In addition, discharges from wastewater works are often not treated according to national standards due to overloading of the works. Poorly treated effluent can cause human disease and eco-system damage as excessive nutrient and pathogen levels reach households, rivers, streams, beaches and recreational areas.

All wastewater in South Africa has to by law be treated according to certain set standards laid down by the Department of Water Affairs and Forestry (National Water Act. 1998). This is important in order to prevent pollution of rivers and groundwater which may make downstream water users sick. Water borne diseases are the primary cause death in infants in Africa and accounts for some 70%-80% of all illnesses in developing countries (Chabalala & Mamo. 2001). These impacts can be significantly reduced by properly treating sewage.

Wastewater in urban areas is usually treated using the following steps:

- **Screening:**
  Screens or sieves are used to block large objects such as rags and sanitary pads out of the sewage.
- **Degritting:**
  Sand and other heavy non-organic material are removed by means of grit channels or vortex degritters. The grit is settled out by either reducing the speed of the water (grit channels) or by stirring it which result in a concentration of the grit in centre (vortex degritters).
- **Primary settling:**
  Water passes through a tank at a certain speed. Most of the solid matter sinks and is removed. This is called primary (or raw) sewage sludge. Fats and oils float to the surface and are also removed and added to the sludge.
- **Biological treatment:**
  The organic matter (e.g. food remains or faeces) in water is broken down by bacteria in a biological reactor. Other bacteria in the tank convert ammonia to nitrate. Both these bacteria require oxygen to be effective and so water is aerated to provided them with enough oxygen. Other compounds such as nitrate and phosphate can be removed through more complex biological processes. Nitrate is removed by bacteria that convert it to nitrogen gas and phosphate is removed by special bacteria that absorb it onto their cell structure.
- **Secondary settling:**
  The bacteria are separated from the treated water by placing the mixture in a tank and allowing

the bacteria to settle out. The settled out bacteria are then sent back into the biological reactor to continue their work and the clear effluent is discharged.

- **Sludge treatment:**
  As a result of consumption of organic material in sewage, bacteria continually increase in number. Therefore, a certain amount of the bacteria, or waste sludge, needs to be removed on a daily basis in order to prevent reactors from getting clogged with bacteria. This sludge needs to be dried before it can be handled easily. This is done by either laying it on beds for it to dry in the sun or through mechanical processes that consume electricity. After this it can be used as a fertiliser or, if it is treated correctly, to make compost. If it is not treated correctly and contains heavy metals, it has to be landfilled.
- **Disinfection:**
  The filtered water is then disinfected with chlorine gas to kill the pathogens before it is pumped into the distribution system.

CONVENTIONAL WASTE TREATMENT METHODS AND SUSTAINABILITY

Most of the conventional systems set out below have a degree of sustainability in that they use biological processes to undertake the treatment, but some of these systems can be considered to be more sustainable than others, primarily by virtue of the amount of electricity they use as well as their effectiveness in preventing pollution of water. For example, trickling filters require hardly any power and are simpler to operate and maintain, but they cannot remove nitrate, phosphates and sometimes ammonia and therefore can cause more pollution than say an activated sludge plant which uses more power. Also, aerobic treatment of domestic sewage produces carbon dioxide as a by-product of the biological process.

Conventional waste treatment methods include:

- **Anaerobic Treatment:**
  Sewage can be treated by anaerobic bacteria that grow in environments that are devoid of oxygen. They digest the sewage and produce methane and hydrogen sulphide (rotten egg smell). These can be used on a large scale at a sewage treatment works or on a household level (biodigestors). Bacteria also build up in these digesters and sludge needs to be removed occasionally.
- **Pumping to sea:**
  Raw effluent can be screened and then pumped out to sea (well beyond the point where raw sewage can be washed back inshore. The sewage is broken down anaerobically and the sludge build-up is diluted.

- **On site (e.g. VIP, septic tank):**
  On-site treatment typically uses anaerobic processes that can pollute groundwater if installed in areas where the ground conditions are not suitable. A certain amount of bacteriological treatment can take place in the soil, but this is limited and if a VIP toilet or septic tank is used for too lengthy a time in one location, pollution can occur.
- **Trickling Filters:**
  Similar to activated sludge. In this process, biological reactors are replaced by tanks holding stones. Bacteria grow on the stones and are aerated by wind blowing through holes in the tank.
- **Pond Systems:**
  Ponds were the first forms of formal sewage treatment. Raw sewage is first screened and then flows into a series of large ponds. The first few ponds are anaerobic where a large amount of organic material is consumed. The algae release oxygen together with wand action over the ponds to allow other bacteria to remove ammonia and other compounds. Ponds are very low maintenance and require no electricity but they do however require very large areas and if not properly lined will pollute groundwater.
- **Membrane technology:**
  Water from conventional aerobic sewage treatment plants can be further purified using membranes. Water is pumped through these very fine membranes which are usually made from cellulose acetate. These replace the conventional settling tanks and are used to separate the bacteria from the treated water. They also remove some pathogens.

Another impact on sustainability is the destruction or loss of nutrients for beneficial reuse. Nutrients are usually bound up in the bacterial sludge that is wasted from central treatment plants, but because this sludge is not treated properly it contains pathogens (viruses and bacteria) and therefore cannot be used as a fertiliser. Sludge can also contain heavy metals that come from industries which also discharge into the same sewers. The sustainability of conventional systems can accordingly be improved by using innovative thinking that optimises the uses of the waste products generated by sewage treatments. Some examples are given below.

Sludge composting:

Wastewater sludge is often landfilled thereby taking up valuable airspace, or simply dumped which causes pollution of groundwater. If there is sufficient space available, this sludge can be mixed with chipped garden refuse and composted using the turned winrow method. This method requires no electricity but takes 14 to 28 days to produce good compost. In this way the inherent energy as well as nutrients (nitrate and phosphate), which is bound up in the sewage sludge can be beneficially used for agriculture.

Power generation:

Wastewater sludge, particularly raw sludge from the primary settling tanks can be placed in an anaerobic digester. The anaerobic bacteria that digest the sludge produces methane which is a greenhouse gas and which can be used to generate electricity. It is estimated that one person's sewage will produce 12g of methane per day (Metcalf & Eddy. 2003). The process is not a simple one and requires skilled operation. Apart from the foregoing the process produces a sludge that needs to be disposed of. This sludge is not suitable for composting as most of the energy in the cells has been used up.

Sludge drying:

Wasted sludge needs to be dried (to reduce the water content from about 99% about 85%) before it can be handled efficiently. This can be done by placing 300mm of the sludge on open lined beds (drying beds) to allow it to be dried by means of the sun and wind action. This is often considered the most sustainable method to dry sludge, but drying beds result in odours and do not work well in wet climates (such as the Western Cape in winter). Many wastewater treatment works are also running out of space for such systems which necessitates the use of mechanical dewatering systems, which use electricity.

Brick making:

It may be possible to make bricks out of the dried primary sludge. There is a business in Port Elizabeth that is successfully running such an operation where the sludge (with a high energy value) is mixed with clay before the brick is baked. There are however certain constraints with regard to combination of the type of clay and the nature of the sludge that needs to be carefully considered.

As can be seen there are methods to make urban/communal sewage treatment systems more sustainable. However, other methods can be used to improve sustainability by reducing the load of the wastewater treatment plants.

Ways to reduce the load of the wastewater treatment plants include:

- **Saving water** (see previous section): This reduces the hydraulic load on the plant;
- **Reuse grey water** (see previous section): which reduces both the organic and hydraulic load; and
- **Using alternative sanitation systems** that treat the wastewater closer to the source.

It is imperative that these alternative sanitation systems, the technology of which is discussed below, should do the following:

- not discharge polluted water into the environment;
- use less or no water;
- use biological processes to undertake the treatment;
- not require input of chemicals;
- be affordable (low operating costs);
- beneficially use the inherent energy and nutrients in sewage (e.g. for agriculture);
- preferable not require electricity; and
- be locally managed and maintained (eliminate problem of poor service delivery; and resulting problems of non-payment. Create employment opportunities).

Wetlands

Wetlands are natural filters, helping to purify water by trapping pollutants (such as sediments, excess nutrients, heavy metals, disease-causing bacteria and viruses and synthesised organic pollutants like pesticides). Wetlands are also among the world's most productive environments because they are home to many different plants and animals.

Engineered or constructed wetlands copy the processes that occur in natural wetlands. Decomposer organisms such as bacteria and fungi live on the surface of the roots of aquatic (water) plants and soil particles. They break down organic material into carbon dioxide and water.

All aquatic plants pump oxygen into their stems and roots under the water. This oxygen is used by the decomposers attached to the plants. The plants also can take up the nitrogen and phosphorous from the wastewater. Wetlands have their own special vegetation types, such as reeds and underwater plants (e.g. papyrus and bulrushes).

Natural and engineered wetlands can perform many vital functions such as:

- natural water filtering by trapping excess nutrients and clean water through reeds;
- water storage;
- storm protection and flood control;
- shoreline stabilisation and erosion control;
- groundwater recharge (replenishment of underground aquifers);
- groundwater discharge (the movement of water upward to become surface water in a wetland); and
- stabilisation of local climate conditions, particularly rainfall and temperature.

There are many examples of where wetlands have been used to effectively treat sewage. Certain aspects should however be considered when designing such a system. Firstly, they require large areas, approximately 3 to 6 m2 per person (EPA. 1988), secondly, there are also no clear design equations and as a result they are usually designed using empirical data or by trial and error, and finally, they take a while to get running and up to two years to reach maximum treatment efficiency. Thus, it is advisable to under load them in the beginning.

There is also no reason why wetlands cannot be used as a pre-treatment before discharge into a sewage system which would significantly reduce the organic and hydraulic load on the sewage treatment plants and therefore reduce the amount of energy need to treat the wastewater. It will also reduce the amount of organic carbon that is sent to the wastewater treatment works which will in turn reduce the carbon dioxide emissions.

The effluent from constructed wetlands usually does not meet the required standards for discharge into a natural watercourse. The water thus cannot be discharged directly into a river, but it often meets irrigation standards and can be used to irrigate certain areas such as gardens, pasture lands and orchards.

Biological Aerobic Systems

Aerobic systems use oxygen to degrade organic material in the sewage. A good example of an alternative aerobic system is the Biolytix®, an Australian design with international patent. In this system, the sewage is degraded by means of aerobic bacteria, earthworms and other microorganisms that sit on a humus filter in a PVC tank. The advantages are that it does not require electricity and the nutrients are retained in the effluent and can be used for agricultural purposes. It also takes up a much smaller area than a wetland. A single tank can treat 2.2 m3/day (communications with Biolytix®), which is equivalent to the sewage generated by two average high income houses consisting of 4 persons.

Although the system does not remove pathogens and does not meet the required standards to discharge to a river, it does meet the required standards for irrigation. It is not recommended that above ground irrigation be used since this can lead to pathogens being spread to humans by wind action. In order to address this problem the effluent must be used in a drip irrigation system or disinfected.

CASE STUDY

Biolytix filter at Lynedoch Ecovillage

Biolytix filtration is a biologically complex ecosystem. In essence it is an aerobic, self-sustaining process that uses the organic nutrients in the wastewater to feed a balance of larger decomposer organisms, earthworms and other microorganisms. The filter contains layers of gravel, peat material (from palm leaves), netting and plastic pipes. The wastewater is piped in and sprinkled over the filter material and earthworms. The earthworms take in the solid wastewater material and convert it to a compost material. The effluent outflow is collected in a sump and then filtered via a sand filter to remove further particulate matter. Water that comes out of the system can be used to drip irrigate shrubs and trees. Further treatment can include passing water through ultra violet lit piping to get rid of any pathogens, but this required significant amounts of electricity.

(Courtesy of Biolytix ®)

CASE STUDY

Vertically integrated wetland at Lynedoch Ecovillage

A halophyte filter or constructed wetland has been built at the Lynedoch ecovillage. This system consists of a water column, substrates with different rates of hydraulic conductivity, swamp water plants and communities of aerobic and anaerobic microbes. The purification process occurs as plants uptake effluent nutrients via physical-chemical and plant-physiological processes. Wastewater is fed intermittently through pipes near to the ground's surface. The effluent gradually drains freely through the wetland to its base, allowing oxygen to assist in the cleansing processes. Arum lilies, 'bloedriet' reeds and other nitrogen absorbing plants are selected for this application. A layer of iron filings below the surface also serves to absorb phosphorus. The filtered water is pumped through a carbon membrane filtration system (Trunz) which is powered by wind and solar PV panels. The Trunz system can purify 20 000 litres per day of brackish, borehole, pond and other undrinkable water to potable water quality. After having gone through this membrane filtration system, the purified water is fed into the houses for toilet flushing.

Biological Anaerobic Systems

Biogas or anaerobic digestors utilize sewage, grey water, organic matter such as kitchen waste, animal manure and garden waste and convert them into energy. This is done by anaerobic bacteria that digest the waste and produce methane gas as a byproduct. This gas can be used for cooking (on a gas stove) or, it can generate electricity. It is estimated that around 12g of methane gas can be produced by one person's daily sewage.

If garden refuse is added to the digester, it can produce ethanol which can be used as a biodiesel. Biogas digestors which are safe and effective have been used for centuries in villages in China and India. They can be used on a household level (i.e. one per house) or on a communal level (one per block of houses).

There is a natural public resistance to cook with the gas produced from sewage and these perceptions need to be overcome in order to implement such a system on a communal level. A possible strategy could be to provide communal cook houses where the gas from a communal digester (collecting sewage from 10 to 20 houses) is free for anyone to use for cooking.

CASE STUDY

Biogas digestor Lynedoch Ecovillage

At the Lynedoch Ecovillage, gas stoves have been fitted in all the houses. Though most households currently use LP gas, a biogas digester has been built for several houses on-site. Black water, grey water, kitchen waste, garden waste, and animal manure feed the digestor which produces methane gas. This gas is piped into the house and is used for cooking.

Other Applications: Composting (Urine Diversion) Toilets

Composting or urine diversion (UD) toilets that separate urine from solids were first implemented in South Africa in 1997 and there are over 50,000 UD toilets in South Africa. Heat, fans, solar PV panels and various design option allow the solids to be decomposed and used as fertilizers. Chimney and other forms of ventilation systems draw odours away, and these systems can be effectively used in households.

Nearly 30,000 units have been installed in eThekweni and these systems form an effective part of Durban's ecological sanitation and water resource management programs. Education and training are essential for UD toilet systems to be accepted and effectively used in communities, as this unfamiliar technology may seem less civilised to communities that aspire to water borne sanitation systems.

Service delivery mechanisms in South Africa have created a mindset that waterborne sanitation is considered to be the top of the sanitation ladder. Therefore until urine diversion toilets are used by higher income groups as well, waterborne sanitation will remain the sanitation system of choice for low income groups.

URBAN DRAINAGE

Modern urban drainage systems raise two significant sustainability issues, the quantity and the quality of the run-off water. There are many instances in South Africa where the impact of stormwater has been reduced as far back as 15 year ago and certain municipalities are well advanced in implementing these measures mentioned below.

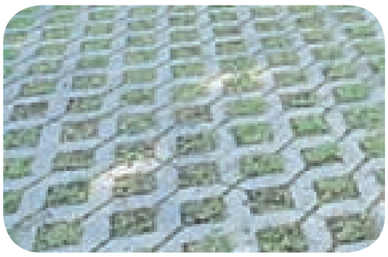
Quantity of run-off water

The traditional way to manage rainwater run-off in the past was to remove it from the area as quickly as possible to prevent flooding. This however results in the loading of downstream rivers with unnaturally large volumes of water which not only disturbs the ecosystems and causes erosion, but also the loss of topsoil and potential flooding downstream.

The new approach is to remove rainwater runoff as slowly as possible to simulate the natural (or pre-development) runoff volumes. Still, even with such “storm water calming mechanisms”, the main aim of urban drainage is to prevent flooding. While houses should be protected in all but the worst storms, the degree to which certain non critical areas should be allowed to flood is debatable. The following methods can be used to improve the sustainability of urban stormwater systems.

Permeable pavements:

Permeable pavement systems, which are standard engineering practice in Europe, are hardened surfaces with holes in them to allow rainwater to seep through the pavement into the ground, much like it would do naturally. Below the hardened surface are various layers of stone and sand to act as a drain to encourage the water to seep into the ground. A variety of concrete paving products, designed specifically as permeable pavers, are available from commercial suppliers. They are particularly effective in parking areas for reducing the amount of surface runoff and simulating natural infiltration. The water seeping through the permeable pavement can also be collected and reused. The advantage to this is that during the filtration process through the drainage layers, a certain amount of treatment can take place.

Examples of permeable paving

Courtesy INCA paving

CASE STUDY

Water harvesting in domestic driveway, Bristol, UK

In this case study, a domestic driveway was surfaced with permeable interlocking paving stones. It consisted of 60m2 of paving with a geotextile layer beneath which acted as a filter. The filtered water collected in a sump at the centre of the driveway and although the water was used mainly for car washing, could also have been used for irrigation for toilet flushing.

Bristol domestic driveway – water harvesting

Courtesy INCA paving

Natural swales and surface channels:

Another way to simulate natural runoff processes and to encourage infiltration is to transport stormwater along unlined surface channels, called swales, instead of sending it through traditional underground stormwater pipes. These unlined channels are planted with grass or other plants to stabilise the soil and retain the shape. Where sediment build-up is a problem, the bottom of the swale can be lined with permeable concrete pavers to make it easier to remove sediment with a spade (it should have a smooth surface so that the spade can slide easily). To facilitate the mowing the side of the swales, side slopes of 1:4 or flatter are recommended. Swales allow some of the stormwater to seep into the ground and improve the quality of the stormwater.

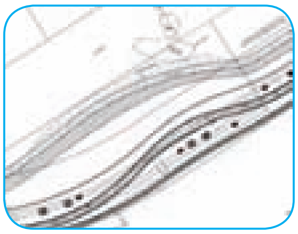
Environmental design of canal systems:

Large stormwater systems traditionally involve concrete lined canals (built to straight lines) that are designed to take the water away as fast as possible. These large canals can be designed considerably differently entailing attractive curves with a varying width to make slower moving and faster moving areas, thereby simulating a natural river. These can be lined with open concrete blocks (such as Terrafix® blocks or Armorflex®) and planted with various reeds and indigenous wetland vegetation. Important to note is that the design should be done in consultation with a freshwater ecologist. Two local examples are the Langevlei and Little Lotus canals in Cape Town. They were both retrofitted on existing concrete canals and therefore are not the ideal, but do give idea of what is possible.

CASE STUDY

Little Lotus Canal, Cape Town

The Little Lotus was a complete redesign of the existing canal. The design has a concrete lined low flow channel to accommodate the summer flow while the remainder of the canal will use very porous lining (> 60% openings) which is planted with local wetland plants. The design is intended to make the canal an integral part of the surrounding communities and not to become a waste area to be avoided. Additional canal width is required in order to allow the design storm to pass through as the vegetation slows the water down.



Little Lotus Canal Design

Courtesy Jeffares & Green

The Langevlei canal was also designed to bring the community back to the water and not isolate it. However, in this instance the existing canal was not replaced and therefore the traditional concrete lined portion remained. However, the area in the photographs show that it was possible to make is look attractive and to create a natural ecosystem in the context of a typical urban area.

Langevlei Canal

Quality of run-off water

Stormwater can pick up any number of pollutants in an urban environment which will be carried into rivers. In some instances, the quality of stormwater can be worse than poorly treated wastewater. The treatment of stormwater is therefore becoming a more common practice in South Africa and certain cities (e.g. City of Cape Town) have written comprehensive guideline documents to ensure proper treatment of stormwater for all new developments. There is a whole host of technologies that can be used to improve the quality of stormwater. Some examples of the technologies that don't require power are given below.

Bioretention:

These systems capture and retain stormwater from small areas in offline vegetated area where it is filtered through a drainage layer. The filtration can improve the quality of the stormwater and also encourages infiltration. Evaporation and transportation also removes some of the water. These can be well landscaped to look attractive and the footprint required for the facility is about 10% of the area being drained. However, it does require a fair amount of fall from the drainage area to the stormwater discharge point for the filtration.

Austin Filter

These are concrete structures that comprise a sedimentation tank, litter trap and sand filter that remove sediment and improve microbiological quality. The maintenance required includes regular cleaning of the litter trap and replacement of the filter sand every year.

Other interventions that can improve the quality of stormwater include:

- In channel litter traps (preferable with declined screens, such as SCS or Baramy)
- Kerb side litter traps
- Wetlands
- Kerbside sand filters
- Kerbside oil/water separators
- Breakaway bags
- Passive skimmers (to remove oils)
- Inline UV filtration
- Vegetated swales

CONCLUSION

Next to air, water is our most precious and valuable resource. South African water policy is considered best practice around the world, however, there is still much that can be done with water efficiency and water conservation in the South Africa context. Reduction in water usage through low flow and other water efficiency applications, water harvesting through rainwater collection, water recycling through grey water systems, local sewage processing for nutrient capture and re-use in agriculture are some of the ways we can make better use of the water cycle, reduce our ecological footprint and release more resources for all.