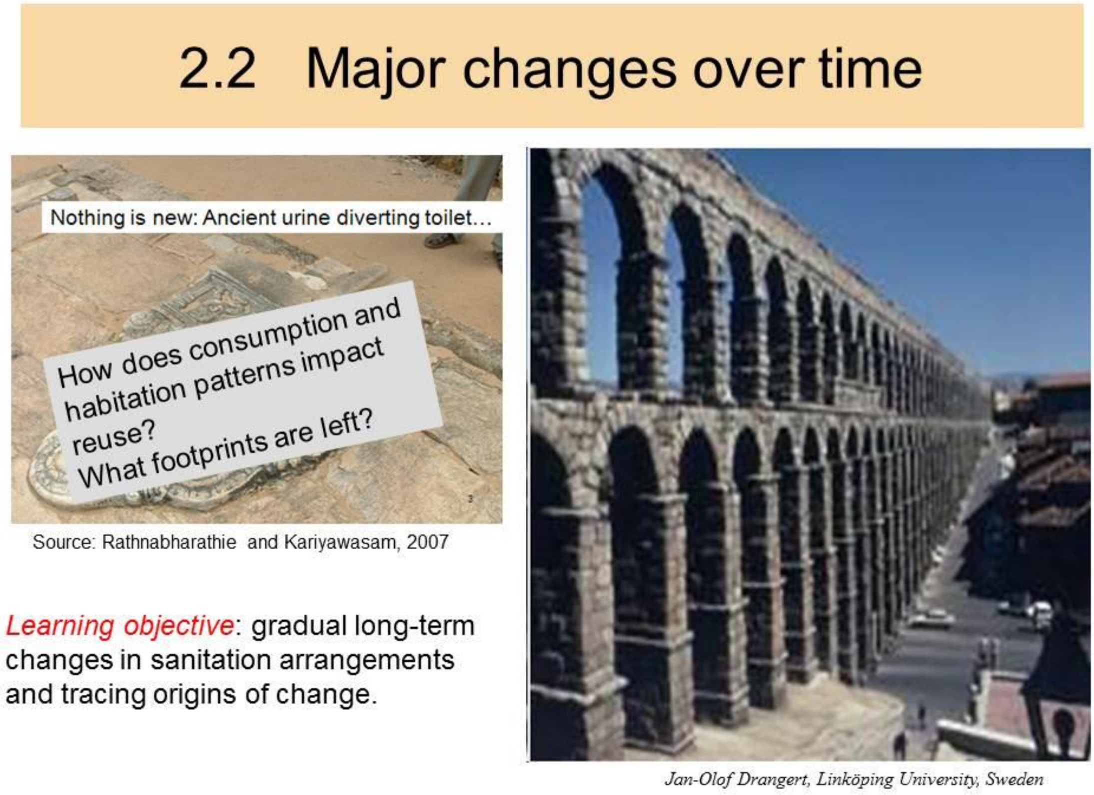

People have always been obliged to manage excreta, greywater, stormwater and solid waste with the resources available to them. They may have focussed on requirements such as 'no smell', making the waste less visible in the house, using organic matter for agriculture, being modern, and complying with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

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

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

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

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

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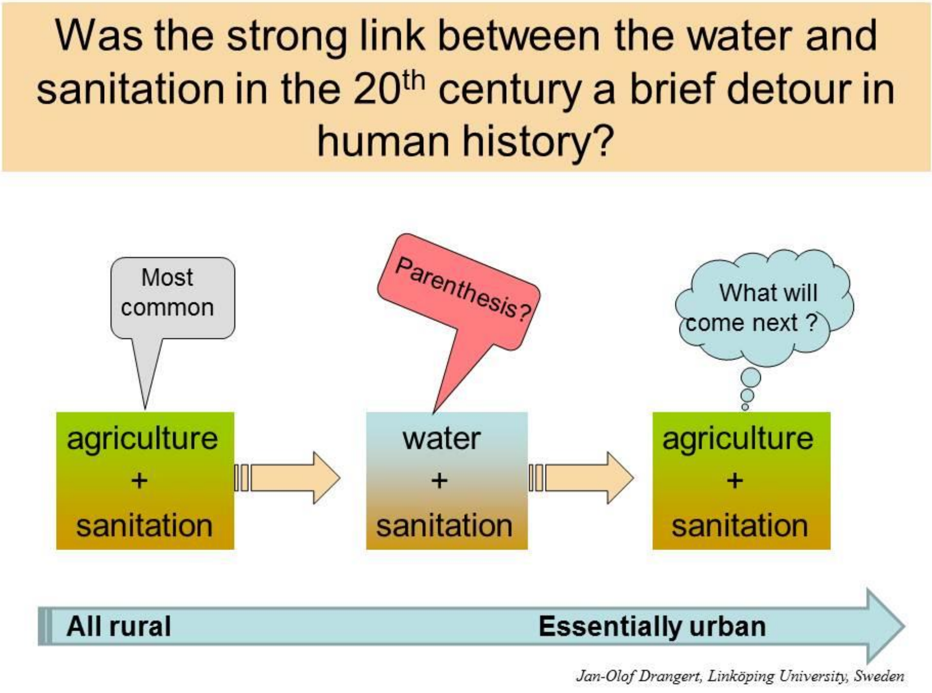
2.2 - 2

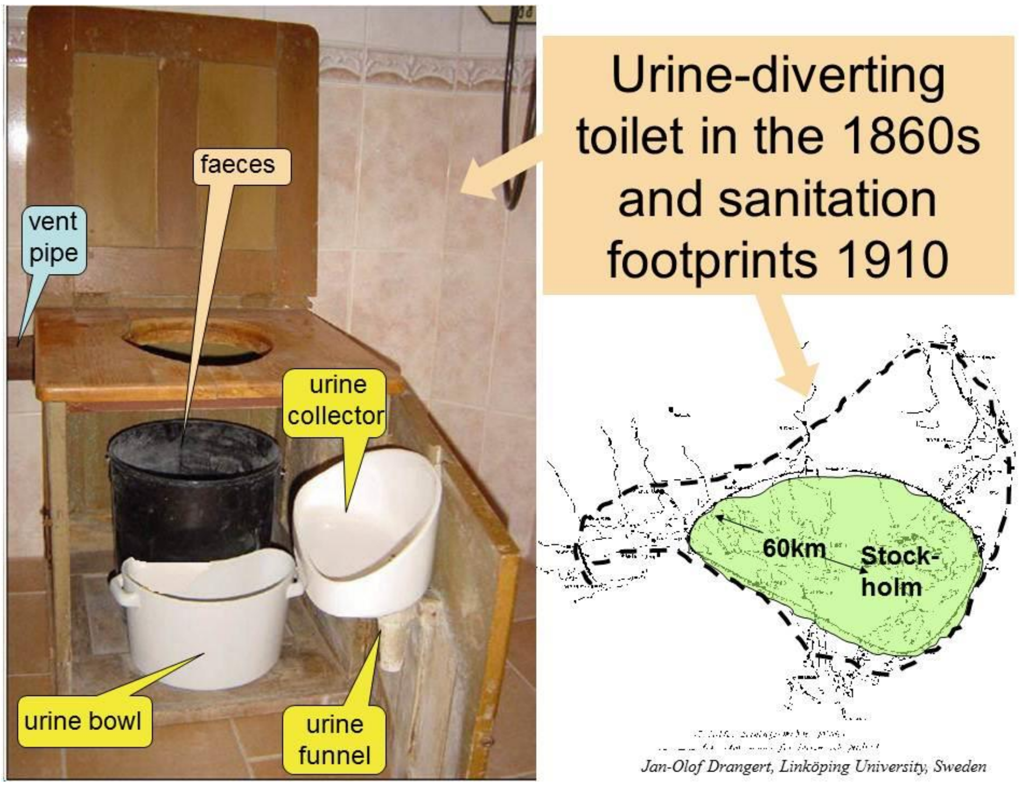


Agriculture and sanitation are closely linked in all agricultural societies, with the obvious exception of large mechanised farms of hundreds of hectares cultivated by a single family. Farmers use all the nutrients they can get hold of to replenish the soils – including animal manure, organic waste,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

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

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

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

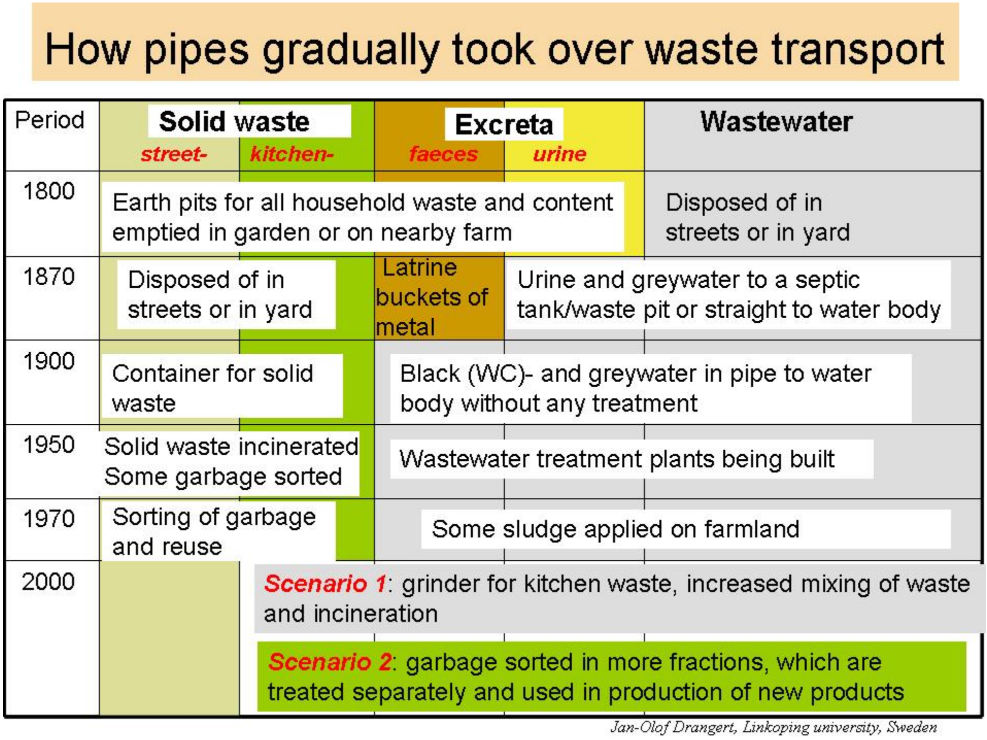


2.2 - 3

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

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

2.2 - 4

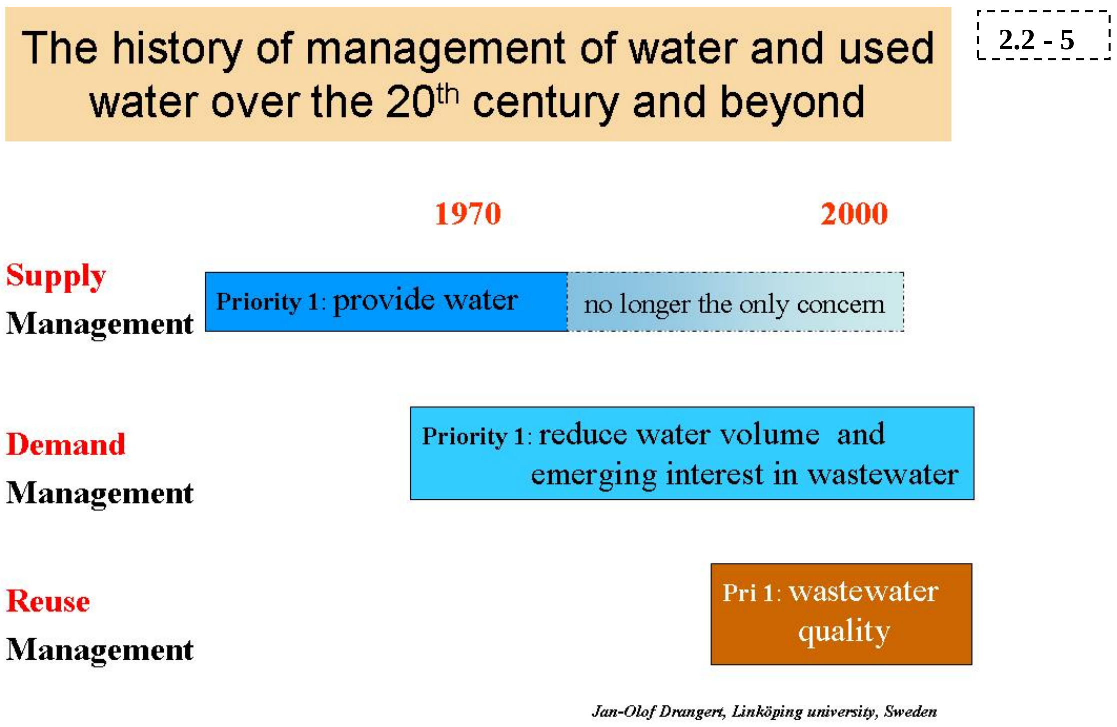


The evolution of urban sanitation seems to have been a constant move towards transporting everything in pipes (the grey-coloured part of the picture). It all started with a short pipe from the kitchen discharging greywater into the street or yard (up to the mid-19th century). By the turn of the century,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

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

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

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



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

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

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

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

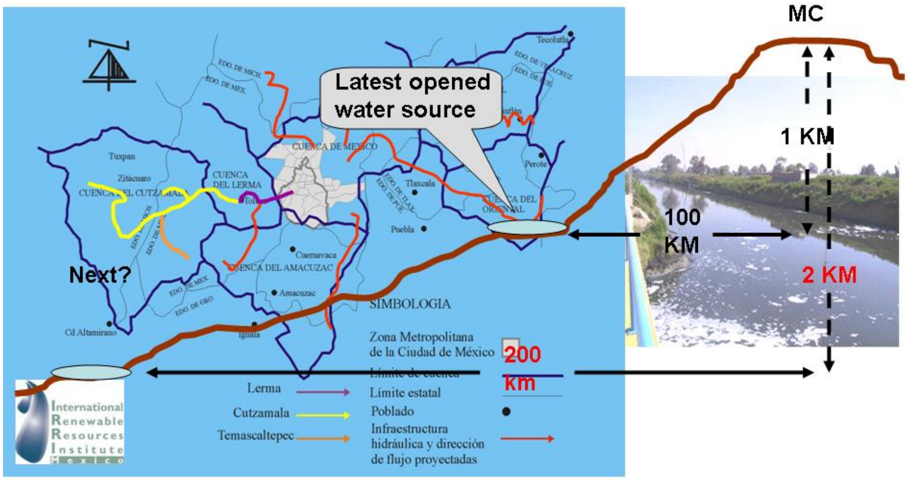
In practice, the three management approaches will go on in parallel. From a resource-point of view, a hierarchy would be preferred where reuse takes precedence, followed by demand management and lastly supply management (slide 1.3-8). This hierarchy requires novel thinking among not least professionals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

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

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

Mexico City now has 20+ million people

2.2 - 6



Courtesy of Ian Adler, International Renewable Resources Institute, Mexico

Jan-Olof Drangert, Linkoping university, Sweden

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

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

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

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

2.2 - 7

What we have seen so far .....

- More pipes and more mixing of various flows has been the mantra for a long period
- But of late, there is a slow shift in focus from supply issues to what happens to water and waste materials after they are used
- New focus: to improve the way we deal with excreta, organic solid waste and wastewater in order to treat and use these resources again
- The future sources of water and nutrients will come from reusing water and waste materials

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

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

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

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

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

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

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