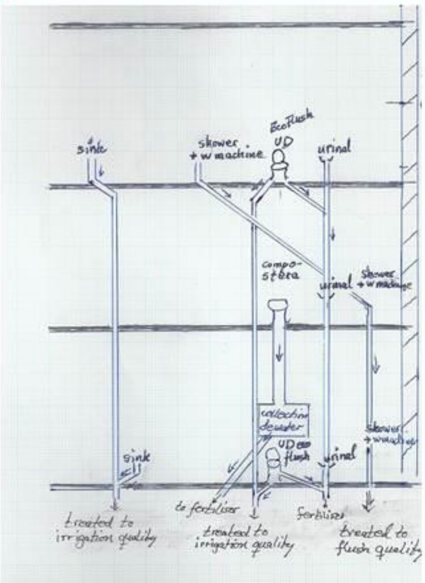
Ch. 5. Applications – sanitation in practice



Segregation of various liquid flows from household

Pupils prepare a meal with produce from school garden

Campaign in India to request bridegrooms to provide a toilet

Spreading chemical fertilizers in a field

The previous chapters and modules in the training material have dwelled on broad issues such as health, management and treatment methods. Remains more topical cross-cutting issues such as food production as part of nutrient loops, school sanitation, public toilets and toilet technologies.

In the wake of global resources boundaries, nutrients for agriculture has come to the fore. Module 5.1 deals with this important issue and applies recycling concepts on recycling of biowaste from utban areas back to agriculture as fertilisers and soil conditioners.

The issue of public toilets poses a challenge to all societies and communities, rich and poor. New planning and management tools are emerging which can enhance the provision and use of public toilets. The same goes for school sanitation. Module 5.3 develops the recycling idea to a local loop for nutrients back to food production and pupils preparing meals from school garden produce.

The last few decades have witnessed a proliferation of toilet designs and functions. Of late, large projects have been launched to address this issue and Japan has gone in the direction of fancy designs with focus on mechanizing wiping/washing the bottom. Gushing of leansing water and drying of bottom with warm air is part of this development. Others focus on reuse of nutrients in excreta and on improving basic hygiene and comfort.

This chapter comprises the following Modules:

5.1 Phosphorus- Food security &food for thought

5.2 Public “*away from home*” toilets

5.3 School toilets

5.4 Toilets and toilet systems

5.1 Phosphorus and food security i

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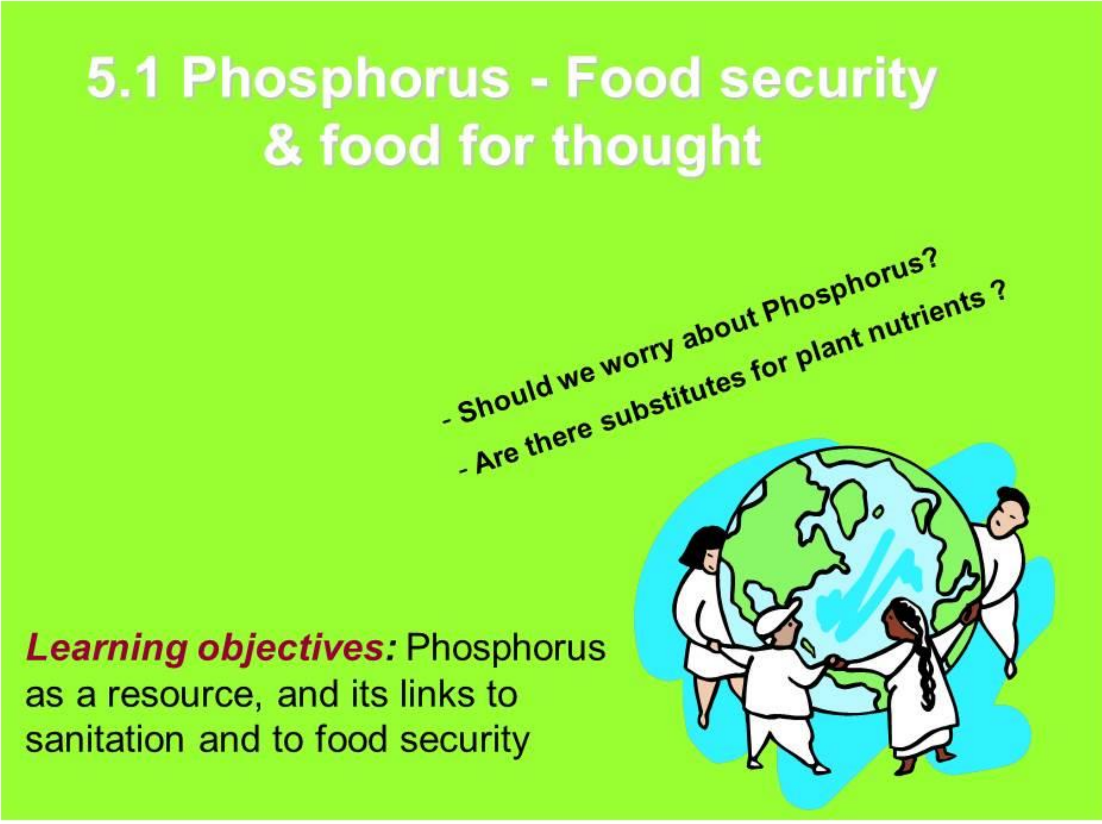


There are more than seven billion people on earth, and so our combined daily activities have a significant impact on the world's limited resources. If, for example, many people acquire and drive cars, oil reserves will eventually become scarce. As we continue to pump large amounts of groundwater for irrigation water tables recede. If we harvest too many fish from the oceans, fish stocks dwindle. The same applies for nutrients – if we all use mineral fertilizers to grow crops, the source of those fertilizers may become scarce. Further, if most humans move to cities where organic waste (such as excreta and food waste) is no longer returned to agricultural soils, we will face a shortage of nutrients (fertilizer) for crop production sooner rather than later.

This module focuses on a particularly important nutrient, phosphorus, or P for short. P is an essential mineral building block for all living organisms, including plants, animals and humans. Therefore, the future availability of P is as critical as energy and water resources for meeting the food demands of a growing global population. Up to now, global environmental challenges related to phosphorus have typically been associated with water pollution and eutrophication. Today we are on the brink of a new global understanding: phosphorus scarcity and the serious threat that this poses to future food security (Cordell, Drangert & White, 2009a; Foley et al., 2011; FAO, 2013).

This module outlines the challenge of increasing global scarcity of high quality and easily accessible phosphate rock. The module first discusses the important characteristics of phosphorus, its role in food production in the past, at present and in the future, including how humanity became dependent on phosphate rock. The increasing political power of countries controlling the world's phosphate rock reserves is highlighted. A simplified substance flow analysis and future scenarios analysis helps to identify potential measures and strategies to secure enough mineral and recoverable phosphorus for food for present and future generations in accordance with the solid waste hierarchy (slide 5.1-13).

The good news is that a crisis due to phosphorus scarcity can be avoided with a concerted effort by the world community. Since P cannot be destroyed there will not be a scarcity unless P is managed in a wasteful manner and is disposed of in places where it is difficult to access.
A world with an increasing population and growing per capita demand will require innovative strategies to use resources more efficiently and ensure their recovery and re-use. Recovery of resources also reduces pollution. Re-use and recycling are particularly critical for resources for which there is no substitute, such as phosphorus and water. Strategies to recover and re-use phosphorus from human excreta, food waste and animal waste are likely to provide a major source of phosphorus in the near future.

Urbanisation, sewered sanitation and global trade affected the flow of phosphorus in the 20th century. In the past, most people lived in rural areas where phosphorus was typically returned to soil in a closed loop (Drangert, 1998). Today, however, agricultural products are transported long distances to feed consumers in cities and in other countries. The organic 'wastes' generated from food consumption (mainly food waste and excreta), therefore, end up far away from where the plants they came from grew. Also, fertilizers are shipped around the world since the phosphate rock is only being mined in a few countries. The average distance a phosphorus molecule moves in the food system from source (such as a mine) to sink (such as lakes or oceans) has thus increased dramatically since the mid-20th century.

If all phosphorus were used efficiently in food production and recycled after use, much less additional phosphate rock would be required and phosphate rock scarcity would be of little concern. However, achieving this will require substantial changes to the way we think about and manage our resources and design our infrastructure and material flows (Module 2.1). Today there is a scarcity of good management of phosphorus resources rather than simply a physical scarcity of rock phosphate. If this is borne in mind, institutional and other constraints can be approached with a better understanding. The European Commission advocates a global strategy for the nutrients NPK (Malingreau, Hugh, and Albino, 2012).

Large-scale application of chemical fertilizers since the 1950s has allowed food production to parallel the rapid population increase. Yields have increased dramatically over this period together with efficiency of phosphorus usage as seen in the table below:

Table: Increases in yield of winter wheat and phosphorus removal between 1862 – 1992

Period	Yield grain (t/ha)	Phosphorus off-take in grain plus straw (kg P_2O_5/ha)
1852 - 1871	2.70	25
1966 – 1 967	3.07	34
1970 - 1975	5.48	50
1991 - 1992	8.69	71

Source: EFMA Phosphorus essential element for food production (2000)

It is noteworthy that little was gained in the 100 years between mid-19th and mid-20th century, and a jump takes place in the second half of the 20th century. This is a reflection of the Green Revolution with irrigation, chemical fertilizers and new improved crop varieties.
In consequence, the off-take of phosphorus in grain plus straw has also increased. The same is true for all other crop nutrients. If soil fertility is not to go down the increased off-take of each nutrient must be matched by corresponding inputs of fertilizers and/or manure. Without mineral fertilizers, agricultural yields around the world would drop by between 30 and 85 per cent (EFMA, 2000b).

Our Globe sets the scene

5.1 - 3

A global view can illustrate the human impact on the globe and the earth's responses. From a satellite, the globe looks blue, green, and generally hospitable in the daytime (left picture). However, the collective impacts of all our individual activities can be more readily seen and understood by looking at the globe in night-time (right). At night, large parts of the globe are illuminated by street, building and house lights. We can no longer tell ourselves that 'what I do has no effect on the globe', because the combined effect of what everyone does '*lit the globe*'. In addition, the emissions from the energy sources required to produce all this light have a great impact on the thin layer of atmosphere surrounding the globe – causing global warming.

A recent estimate by McMichael *et al*. (2007) tells us that 35% of global greenhouse gas emissions come from agriculture and land use. Livestock production alone accounts for about 18% of global greenhouse gas emissions. Livestock-related emissions are caused by: deforestation to clear land for grazing and soya-feed production; soil carbon loss in grazing lands; the energy used in growing feed-grains and in processing and transporting grains and meat; nitrous oxide releases from the nitrogenous fertilizers; gases from animal manure (especially methane); and enteric fermentation. The greenhouse gases from these sources make up an estimated 9% of global emissions of carbon dioxide, 35–40% of methane emissions, and 65% of nitrous oxide emissions. Although they have shorter half-lives in the atmosphere, the near-term warming potential of methane and nitrous oxide is much greater per unit of volume than that of carbon dioxide.

There is little doubt today that the earth is experiencing unprecedented global environmental changes due to human activity – from climate change, widespread eutrophication, deforestation, loss of biodiversity, water scarcity and more (WWF, 2004; Wijkman and Rockström, 2012). Human impact has increased dramatically in the last 50 years, driven mainly by rapid population growth, and even faster increases in the production of goods. We now begin to comprehend that the hydrosphere, biosphere, lithosphere, and atmosphere are directly or indirectly interlinked and that the impact of human activity on one component can have far-reaching effects on the others. We adversely affect the very same components that we depend on. Without vital 'ecosystem services', human society could not exist – it would have no energy, no clean water and no food (slide 1.1-15–16). The following presentation deals with the global impacts of phosphorus usage on food security. Sustainable sanitation is highlighted as one way to ease P scarcity problems.

Water and phosphorus for food security

5.1 - 4

- Water molecules can be made by using a lot of energy
- Water is renewable (sun-driven cycle)
- Water is available in soil and replenished annually by rain
- 70% of global water use is for crop production
- A balanced diet results in the **loan** of 1300 m³/yr to each person on the planet based on current practice. This is 70 times greater than the 50 l/d per person for basic water needs.

- Phosphorus (P) cannot be manufactured or destroyed
- P is essentially immobile and is mined in only a few countries
- P is naturally available in soil and depleted by crops
- 90% of global P extraction is for crop production
- A balanced diet results in the **depletion** of 22.5 kg/yr of phosphate rock (=3.2 kg/yr of P) per person based on current practice. 0.5 kg of this reaches the average person's food.

Source: Cordell, Drangert & White (2009a)

Both are critical to food production, but need to be managed differently

The water molecule (H_2O) and phosphorus-containing molecule (P_2O_5) are vital for food production. The table above compares and contrasts them, and shows that while many similarities exist, the contrasting circulation properties of phosphorus and water mean that they require different approaches to manage them sustainably.

Elemental phosphorus (P) cannot be manufacture or destroyed, while the water molecule requires lots of energy to be formed. The two are similar in that humans can alter their location and affect their quality as they cycle naturally or anthropogenically on earth (see slide 1.2-3). Another common feature is that neither water nor phosphorus can be substituted in plant production. Plants require water to circulate nutrients and for photochemical processes to build cells, while phosphorus is required to build cells and enzymes, and to form fruits and seeds. Hence, deficiencies in plant-available phosphorus and water can severely reduce crop yields and fruit/seed development. An average human body contains about 650 grams of phosphorus. Most of this P is in our bones and teeth, and the rest is found in our DNA, cellular membranes and the molecule adenosine triphosphate, or ATP, which the body uses to process energy. We need an intake of 1 gram of P every day to maintain our body functions.

Soils naturally contain water and phosphorus to varying degrees and, depending on the form it takes, this P may be accessible to plants (P_2O_5). Water and phosphorus-containing molecules differ when it comes to their natural cycles and mobility in the soil and the atmosphere. The sun drives the water cycle and makes water a renewable resource which is partly cleaned through soil filtration and through evaporation and condensation. While water is renewable, the rain may not appear when and where farmers would prefer. Therefore, crops are increasingly irrigated by surface water or groundwater.

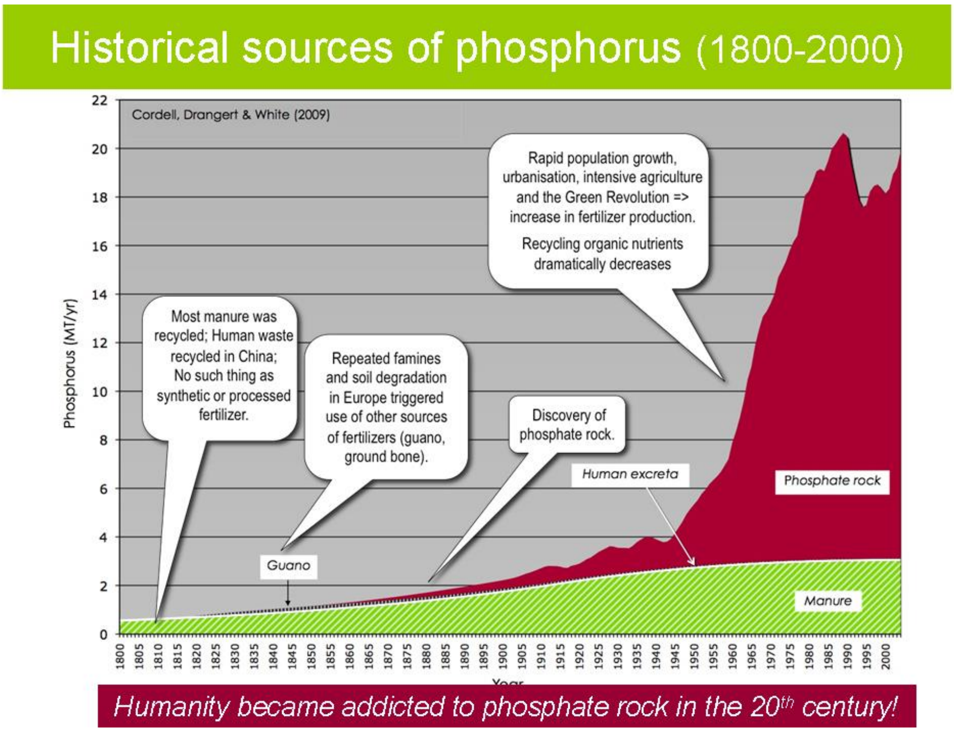
Unlike the water cycle, the phosphorus cycle has essentially no atmospheric phase and only cycles between the lithosphere, biosphere and surface and groundwater. It is practically immobile in soils unless washed away by stormwater or transported by groundwater flow.
In the biosphere P can stay in one place for periods which range from one day to many years.

Phosphorus in mineral fertilizers comes from phosphate rock (PO_4), which is a non-renewable geological resource that has taken around 10 million years to form. Rock phosphate is made from the remains of aquatic life on the bed of the sea and tectonic uplift has moved it onto land (White, 2000). The phosphorus in soils originates from long-term weathering and erosion of the parent rock. The mineral, through further weathering and runoff, makes its way into the ocean, where marine organisms may recycle it some 800 times before it passes into sediments (Vaccari, 2009). After tens of millions of years of tectonic uplift it may return to dry land.

The major human use of both water and phosphorus is in agriculture. Seventy per cent of the water used by humans goes to agriculture while the remainder is used for household and industrial activities (see slide 1.2-5). Based on current practice it is estimated that the agricultural sector will need to double the amount of water it uses, to feed humanity in 2025. However, this quantity of water is not available and thus innovative strategies to achieve 'more nutrition per drop' will be required (SIWI-IWMI, 2004). Similarly, almost all (90 %) of mined phosphate rock is for food production, mainly as fertilizer, animal feed and food supplements. The remainder is used in detergents and industrial applications. It is estimated that the agricultural sector's need for phosphate rock will increase by at least 50% by 2025 compared to the mid-90s (slide 5.1-12). The same goes for other essential macro-nutrients, e.g. nitrogen and potassium. Plants take up the nutrients via their roots, and once plants are harvested, the phosphorus leaves the topsoil for good – unless it is returned as fertilizer or organic waste. The easily accessible non-renewable phosphate rock reserves are likely to be near depletion in 100 or 200 years as for affordable mining and processing (slide 5.1-10). Meanwhile, demand continues to increase.

An important difference between phosphorus and water use is that the water is returned to the water cycle (**renewable**) whereas the phosphorus from mined phosphate rock is usually immobilised in the sediments of rivers, lakes and oceans (or in landfills) and will take millions of years to cycle naturally back to agricultural soil (**non-renewable**). Therefore, different strategies are needed for sustainable use of these two resources. Water used by humans is essentially a 'loan' from nature's hydrological cycle. While the used water may not return to the same water catchment when it falls again as precipitation, it will reappear sooner or later through the water cycle. On average, a person requires some 1300 m^3/yr of water to produce her food, and this water can come in the form of rain or irrigation (SIWI-IWMI, 2004). Phosphorus fertilizer, on the other hand, is mined - but may soon be recycled also from urban hotspots. A balanced diet requires mining approx. 22.5 kg of phosphate rock (PO_4) per person per year. This rock is converted to 3.2 kg of elemental P. About 0.5 kg of this phosphorus is contained in the food we eat and excrete during one year (slide 5.1-15).

5.1 - 5



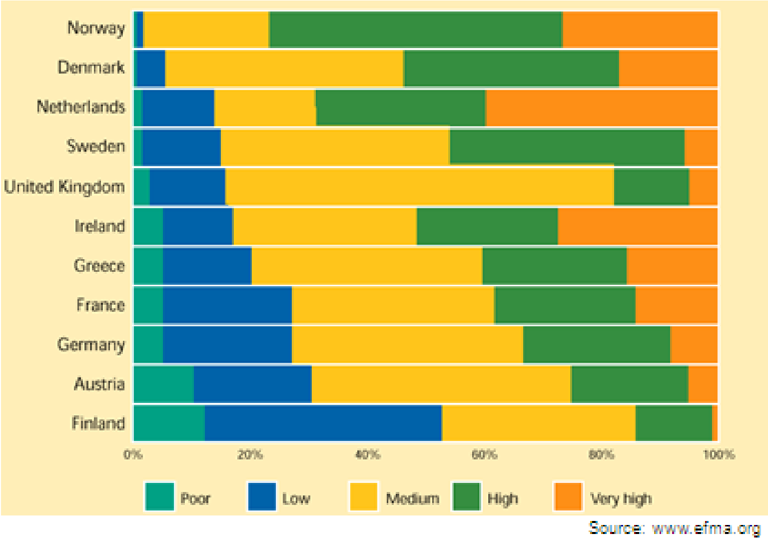
The graph shows the world's usage of phosphorus fertilizers over the past 200 years, comprising manure, human excreta, guano and phosphate rock (in million tonnes of P per year). The graph displays vividly the world's growing dependency on phosphate rock (dark red) over the past 60 years, since the Green Revolution in the 1950s.

Historically, crop production relied on natural levels of soil phosphorus, which comes from erosion of bedrock, with the addition of organic matter like crop residues and manure (shaded green) and, in parts of Asia and Europe, human excreta ('night soil'). Repeated famines and gradual soil exhaustion in Europe triggered the search for other sources of fertilizers, such as ground bone and guano (bird and bat droppings). Island caves and land rich in guano were mined off the Peruvian coast and in the Pacific Islands. However, the obviously limited supply of high quality guano was depleted within decades and other sources of phosphorus were again sought. Already in 1840 the chemist Liebig had discovered that phosphorus deficiency limits plant growth. But, phosphate rock was not mined before the late 19th century. The first half of 20th century saw moderate use of phosphate-based fertilizers, and crop yields increased somewhat. There were still recurrent famines in many countries. The launch of the Green Revolution in the 1950s with large-scale irrigation farming using new varieties of rice and the application of chemical fertilizers improved yields tremendously (IFPRI, 2002; slide 5.1-1). Phosphate rock mining expanded rapidly to keep up with increased P demand due to rapid population growth and urbanisation (Smil, 2000b). Famines due to natural causes were substantially reduced and food security improved.

Thus, a dependence on phosphate rock for food production was established globally. By 1990 the demand and production of phosphate rock and mineral fertilizers dropped somewhat, due to a number of factors. One was an increasing awareness in Europe and the US that over-fertilisation was leading to phosphorus leakage causing algal bloom in lakes and estuarine waters. Another was that the Soviet Union collapsed, resulting in a sudden reduction in the phosphate demand from a previously high fertilizer-consuming region. While demand has receded in the developed world, the rising demand in developing and emerging economies has resulted in an overall increase in the global demand for phosphorus fertilizers. This has occurred despite many poor farmers not gaining access to world phosphate fertilizer markets (Cordell et al., 2009a).

Phosphor status of soils in Europe

5.1 - 6



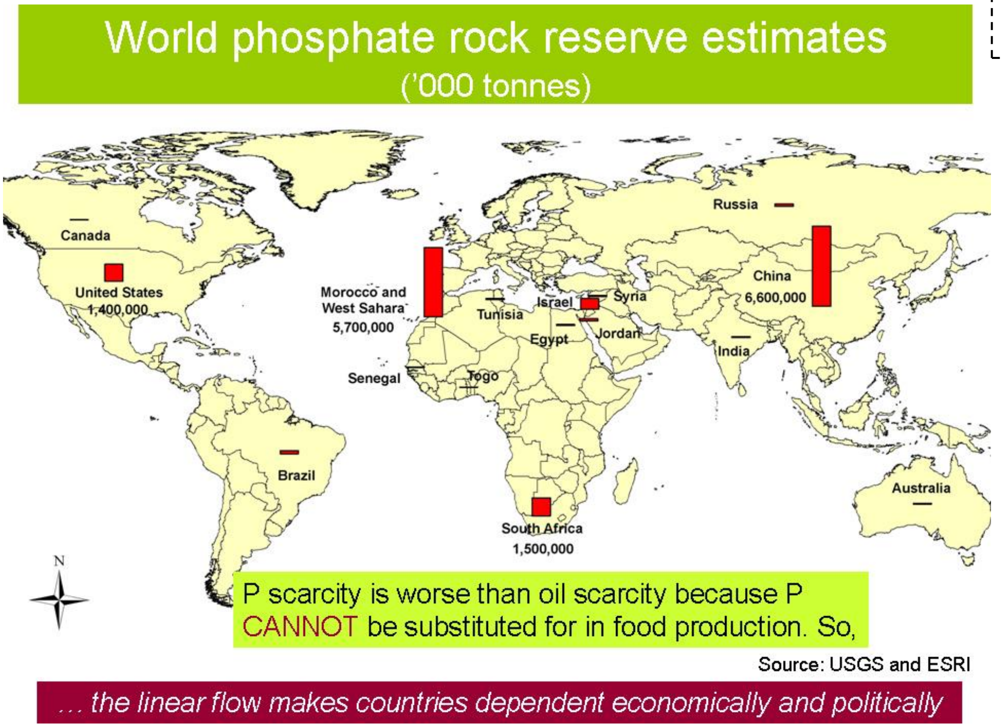
Phosphorus is one of the most common minerals on Earth, but often in low concentrations. The P availability in soils in eleven EU countries is given in the diagram above. A striking impression is that the P status differs quite a lot. For instance, half of the Finnish soils are poor in P, while the P content in the Netherlands is very high in half of the soils. The latter is explained by the fact that Dutch farmers operate large pig farms and have applied huge amounts of manure for many years, while they import the feed from other countries.

In many countries some 25% (5-55%) of soils are very low or low in readily available soil phosphorus. Such soils require application of significantly more phosphorus than is removed by the crop to increase soil reserves and thus soil fertility. Soils with medium phosphorus test values may require a small extra amount of phosphorus over and above that removed in the harvested crop. For many countries some 40% (15-70%) of soils are high or very high in readily available phosphorus. When crops with small, inefficient root systems and a large daily intake of phosphorus at critical growth stages, are grown on such soils it may be necessary to apply more phosphorus on such occasions (EFMA, 2000b). Farmers increasingly take these differences in P availability into account now that the price of P is increasing. They try to strike a balance between application of P and the anticipated yield (slide 5.1-20).

It is well known that African soils are poor in P due to naturally poor parent rocks, or the phosphorus is not readily available to plants because iron oxides (common in African soils) hold the P too tightly. Unsustainable cropping practices further reduce soil P, so that the amount removed through harvesting crops, soil erosion and other factors, exceeds the amounts put in through fertilizers. The Africa Soil Information Service started a project in 2008 to monitor and map changes in soil phosphorus across Sub-Saharan Africa to be able to make suggestions for improving levels of the mineral in the soil. The advocated integrated soil fertility management measures relate to fertilizer application rates, soil organic matter management, use of legumes, and tillage operations in cropping systems. So far, they do not suggest adding human urine (pH>9) to the soil despite that it could raise its pH-level which in turn will weaken the bond of P to iron and magnesium ions and make more P available to the plants (slide 4.6-21). Moreover, socio-economic factors need to be taken into consideration as well (see Module 2.4).

In this module we focus on P but much of the conclusions apply also to other macro nutrients. A deficiency of any nutrient is not only, in itself, detrimental to the plant, but it also affects the plant´s ability to use the other nutrients effectively.

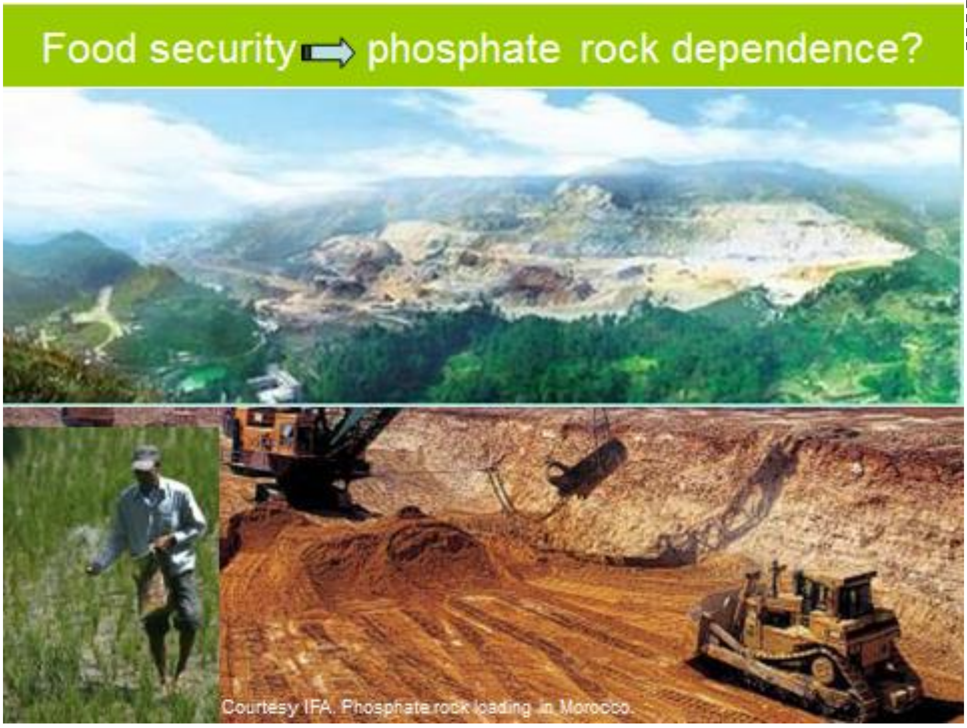
5.1 - 7



While all farmers need access to phosphorus fertilizers, just six countries, China, South Africa, Morocco with its occupied Western Sahara, the US and Jordan are endowed with 90 % of the world's reserves and account for more than two thirds of annual production (Vaccari, 2009). In October 2010, the International Fertilizer Development Centre (associated with the industry) issued new estimates for Morocco and Western Sahara P reserves, claiming the reserves to be ten times bigger (IFDC, 2010). This uneven geographical distribution of phosphate rock resources should concern countries that rely on imports of mineral fertilizers for food production. Imagine if all the world's freshwater resources were controlled by just a handful of countries – national leaders would be much more concerned with securing water from alternative sources to avoid such dependence on imports. Other important global resources subject to geographical concentration, such as oil, can be substituted by other forms of energy, such as hydropower, natural and biogas, nuclear power, wind power, water-current power, or biofuels. However, there is no substitute for plant nutrients such as phosphorus, nitrogen, potash, and sulphur. Yet, up to now there are no widespread political discussions about phosphate rock dependency.

In 2006, China surpassed the United States as the world's leading producer of phosphate rock and China produces 30.7 Mt (million tonnes), the United States 30.1 Mt, and Morocco/Western Sahara 27.0 Mt (USGS, 2008). U.S. marketable phosphate rock production and reported usage dropped to their lowest point since 1965. However, the United States remained the world's leading consumer and importer of phosphate rock and also the leading producer and supplied about 37% of the world P_2O_5 exports. Most of the phosphate shipments from Morocco/West Sahara were used by three phosphoric acid producers located in the US along the Gulf of Mexico (USGS, 2007). This is geopolitically sensitive as Morocco currently occupies Western Sahara in violation of international law and controls its vast phosphate rock reserves. Trading with Moroccan authorities for Western Sahara's phosphate rock is condemned by the UN, and importing phosphate rock via Morocco has been boycotted by several Scandinavian firms due to corporate social responsibility (Hagen, 2008). Western Sahara's P reserve is, in per capita terms, infinitely bigger than the reserves of any other country. However, the world community has not been able to ensure that the people of Western Sahara gain their rightful income from this resource. Instead, a portion of the population is in refugee camps.

5.1 - 8



The first step in making a fertilizer is to grind the mined phosphate rock. The next step is adding sulphuric acid (H_2SO_4) to extract the phosphorus as phosphoric acid H_3PO_4 through heating. This has been the conventional method for much of the 20th century and is still being widely used for high-purity phosphoric acid (EFMA, 2000a). Presently some 50-70 % of the phosphorus in the rock is extracted, and technical development could increase this proportion (Villalba et al., 2008). Typically, each tonne of phosphate (P_2O_5) produced from phosphate rock generates 4-5 tonnes of hazardous phosphogypsum waste (11.5 tonnes per tonne P), which must be stockpiled because its radioactivity levels are considered too high for use. Global phosphogypsum stock-piles are growing by over 110 million tonnes each year. Workers, as well as ecosystems, can be seriously affected and the local groundwater is likely to be contaminated (Wissa, 2003).

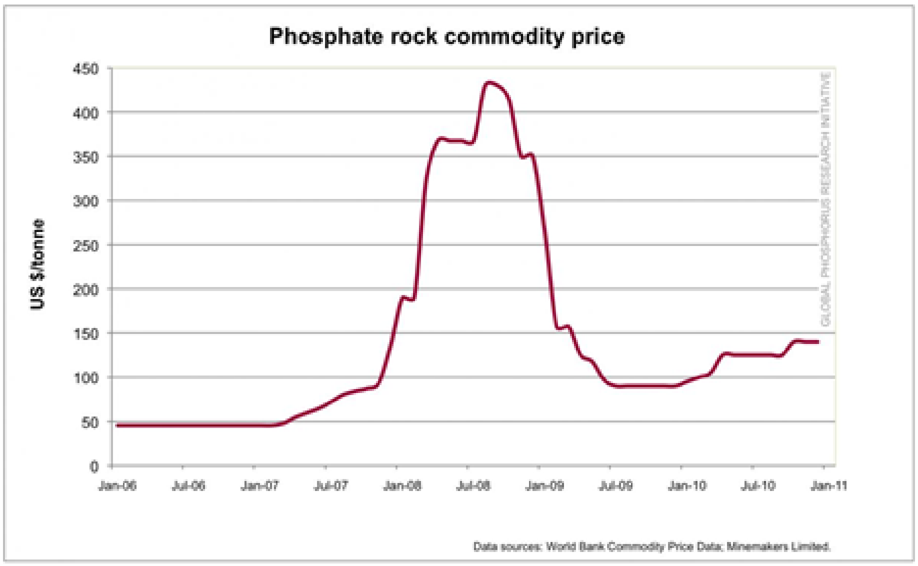
Worldwide, there has been a gradual shift to manufacture high-purity phosphoric acid from a wet-process using chloric acid. This process has lower operating costs than the older thermal process which required large amounts of energy. The wet process actually produces energy. It also discharges less rest product such as phosphogypsum, and contains low levels of uranium, and the sulphuric acid can be reused in the process. The sulphuric acid process has a further advantage being able to use rather low concentration of P_2O_5 (range 25 – 28%), whereas other processes may require 31.5 %. In any case, the phosphoric acid requires further concentration (beneficiation) to provide a good fertilizer. A typical P_2O_5 content ranges between 50-60% of the fertilizer.

Depending on the final use of the phosphorus, the quality grading descends from electric batteries, to food and pharmaceuticals, via animal feed to fertilizers. Fertilizer still dominate the market (some 88%), and the slump for P in detergents has been compensated for by increased usage in animal feed (1.5%) and food additives (OCP, 2009).

New phosphoric acid and fertilizer plants have been built in Brazil, China, Morocco, and Saudi Arabia. OCP also has joint ventures with direct investment by Indian, Pakistani and Brazilian manufacturers who produce their fertilizers at adjacent plants at Jorf Lasfar in Morocco (OCP, 2009).

Access to phosphate markets

5.1 - 9



Future fertilizer price spikes are also possible

Farmers around the world demand 17 million tonnes of phosphorus to fertilise their crops each year. The cost of phosphorus alone represents nearly 30 per cent of farmers´ budget (SPI, 2010). While the quantity and quality of existing high-grade phosphate rock reserves are decreasing, the cost of extracting this resource is increasing. Economic theory of demand and supply predicts an increase in the market price. The graph above shows that in 2008 the world had a first wake-up call when the price of phosphate rock rose dramatically from about US$50 to US$430 per tonne – an 800% increase from previous years (World Bank, 2011).

Analysts indicated the price spike was due to a number of global demand-side factors, including the rising demand for food, increasing trends towards more meat-based diets (particularly in emerging economies such as China and India), and the expansion of the biofuel industry (biofuel crops compete with food crops for fertilizers). Farmers were also holding off purchasing fertilizers, in the hope that prices would come down, and this further reduced the price (Heffer and Prud'homme, 2009).

On the supply side, the International Fertilizer Industry Association suggested the price rise was partly due to an under-investment in new capacity which created a short-term scarcity. Also, unfavourable exchange rates (resulting in the value of the US dollar pushing up quoted prices) contributed to the price spike (IFA, 2008). China imposed a 135% export tariff on phosphate in 2008 to secure domestic supply for food production, which essentially stopped exports overnight (Fertilizer Week, 2008). This step is thought to have exacerbated the 2008 phosphate price spike.

The global financial crisis late in 2008 led many commodity prices, including phosphate prices, to crash (graph). However, the graph shows that prices stabilised at a level three times as high as before the spike.

The fertilizer market is characterised by mergers and acquisitions. Canada refused to sell out its Potash Corp to US bidders in a move to stabilise the fertilizer market. Investments are presently made to increase production. The Moroccan phosphate group "Office Chérifien des Phosphates" (OCP) is the world's number one exporter of phosphate rock and phosphoric acid and one of the major exporters of phosphate fertilizers. OCP embarked 2010 on a major investment programme to triple its production capacity by 2020 from the current 3 million tons per year to more than 9 million tons, making Morocco by far the largest supplier of phosphate rock, phosphoric acid and DAP/ADP (OCP, 2009). OCP already controls around 45 per cent of the world market for lime phosphate, and controls more than 30 per cent of global phosphate exports. It operates three mines and exports around 15 million tons of phosphate rock to markets in Asia, Australia, Europe and the United States. The remaining phosphate is transferred to the company's chemical complex in Jorf Lasfar.

The OCP program also aims to increase the mining capacity from 30 to 50 MT/year, the beneficiation (more concentrated P) capacity gradually from 9 to 38 million tons a year, and expand the port facility at Jorf Lasfar to handle up to 35 million tons of products. Also, in 2013 a new 187 km slurry pipeline replaced the inefficient train transport.

The OCP's CEO explained that "this major investment in increasing our capacity is a prudent response to long-term market trends, and a strong sign of OCP's commitment to do its part to assure stable, reliable supply of this vital resource to global markets." (OCP, 2009). He continued saying that global phosphate demand is projected to grow steadily in coming years, due to the combined pressures of population growth, changing diets among a growing middle class, and the urgent need to improve agricultural yields in developing countries, particularly in Africa, and thereby combat hunger.

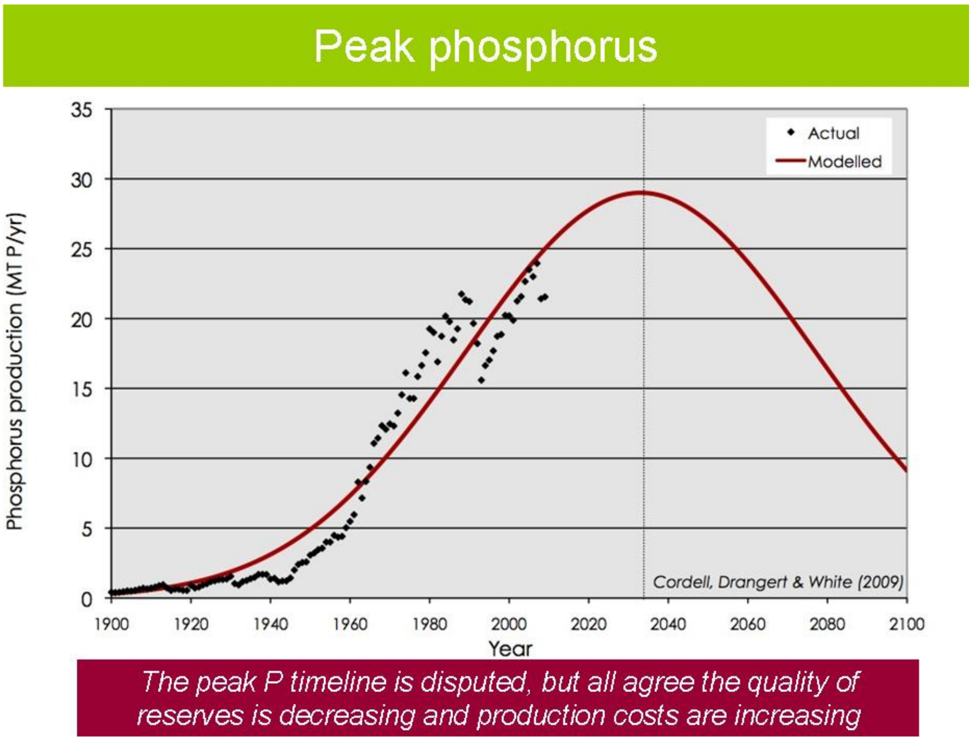
OCP officials and foreign traders hold contradictory views and the latter maintain that the Moroccan company OCP has used its market clout to boost global phosphate prices (Reuters, 2010). Unlike many commodities whose price is determined on a futures exchange, phosphate transactions are mostly negotiated directly between producers and industrial users. According to some sources, the monopoly that IFDC and the US are trying to create in Morocco will give the US considerable control over the global price of this commodity (Rognlien, 2010).

OCP has faced criticism from some foreign civil society groups over its operations in Western Sahara, an area about the size of Britain that was annexed by Morocco in 1975 in violation of international law and is the subject of Africa's longest-running territorial conflict. Critics say the firm should not be exploiting Western Sahara's mineral resources until the sovereignty issue is settled. The CEO of OCP said his company was not in Western Sahara to pursue profits. Company officials say the territory has less than 2 per cent of Morocco's phosphate reserves, and that between 1976 and 2008 the firm made net losses there of about $580 million.

The lack of reliable global phosphorus statistics and analysis prevents farmers, policy makers and urban planners from making informed decisions. Unlike many other mineral commodities, no standard domestic or world price for phosphate rock exists. Average ranges of world prices are published in World Bank Commodity Price pink sheets (e.g. World Bank, 2011) and various industry trade journals (such as Fertilizer Week) are based on a sample of transactions. But the US Census Bureau withholds tonnage and value information for some phosphate rock and fertilizer product shipments, which necessitates the use of other sources of data.

The fertilizer companies that mine ore and produce phosphate rock from Morocco and Western Sahara will be able to influence the market prices as other countries run out of high grade phosphate rock or decide to use it for their own consumption. This means that countries that are dependent on imports, and who continue wasting phosphorus to landfills and water bodies, will be increasingly economically and politically dependent on Moroccan and US fertilizer companies. However, P-deficient countries can improve the efficiency of their phosphorus usage and make use of recycled phosphorus (see slide 5.1-14). An illustration of this is that in industrialized regions, almost half of the total food is squandered, around 300 million tonnes annually, because producers, retailers and consumers discard food that is still fit for consumption. This is more than the total net food production of Sub-Saharan Africa, and would be sufficient to feed the estimated 870 million people hungry in the world (FAO, 2011). Less dumping would increase the supply and dampen market price increases.

5.1 - 10



According to peak minerals theory, first formulated by Hubbert (1949) in relation to US oil reserves, the important point regarding mineral availability is not when the resource is depleted, but when high-quality, highly accessible reserves have been depleted. In this case – peak phosphorus – is the point after which the quality of remaining reserves is lower and they are harder to access, eventually making them uneconomical to mine and process. A peak phosphorus analysis based on US Geological Survey and industry data (see picture) suggests that production of phosphate rock could peak by 2035 (Cordell et al., 2009a). The static reserve life of phosphorus is estimated to be 107 years (USGS, 2008).

The exact timeline of the peak is currently disputed. The fertilizer industry, on one hand, claims that USGS reserve data is unreliable, and that more phosphate reserves exist (Prud'Homme, 2010). Other scientists dispute the timeline because they believe peak phosphorus occurred in 1989 (Dery and Anderson, 2007). In October 2010, the International Fertilizer Development Centre (associated with the industry) issued new estimates for Morocco and Western Sahara P reserves, claiming the reserves to be ten times bigger (IFDC, 2010). Regardless of the exact timeline, there is general consensus that in the remaining reserves, P concentrations (expressed as P_2O_5) are declining, that the presence of contaminants such as cadmium, uranium and thorium is increasing, and that these remaining reserves are physically more difficult to access.

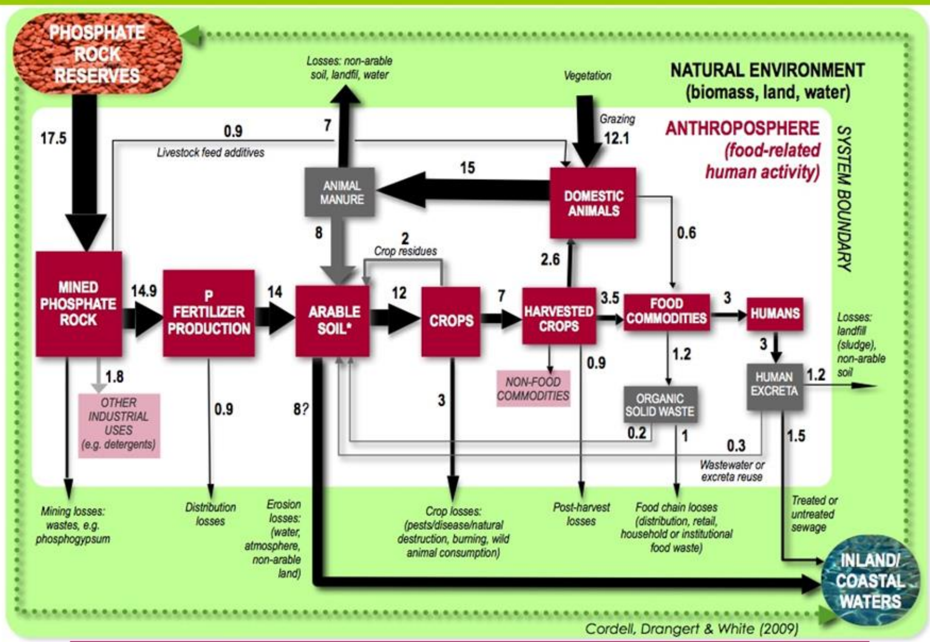
The peak P discussion has helped to put phosphorus issues on the international agenda (Gilbert, 2009). Instead of getting stuck in a debate over the exact timeline for a limited resource, we argue that a prolonged time slot is positive and should be used to gradually lower the present substantial wastage of P in all phases from production to final disposal. It is no human right to waste valuable resources whether they are being exhausted or not.

An on-line tool, the US Minerals Databrowser, allows users to create a variety of plots based on data from the USGS dataset: Historical Statistics for Mineral and Material Commodities in the United States. The data browser includes phosphate and potash as well as 84 other minerals.

The following slides provide examples on how the lifetime of P rock resources can be extended by reducing the rate of losses of phosphorus from the mine to the toilet.

Phosphorus through the global food system

5.1 - 11



Only 1/5 of the P in mined rock reaches the food on our forks!

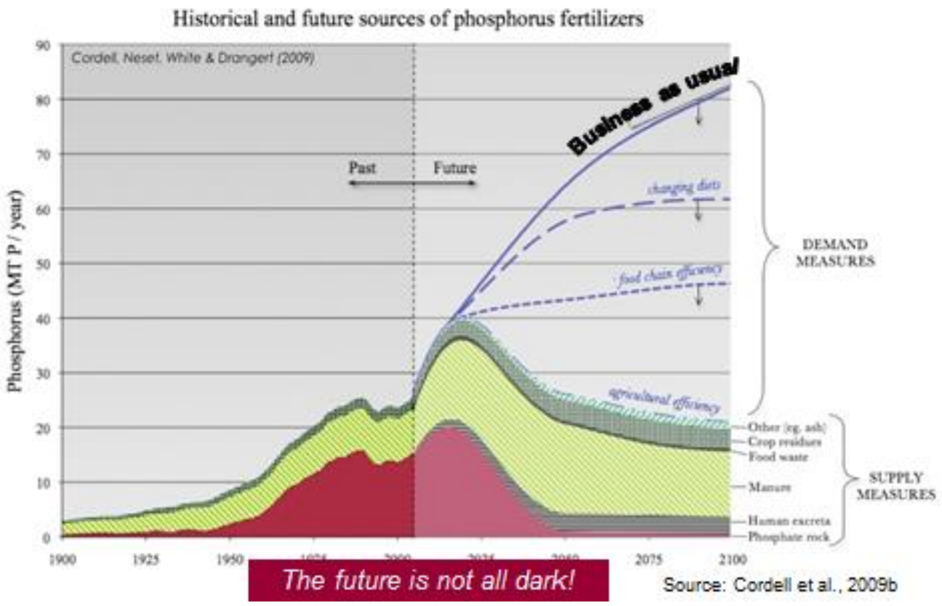
A simplified Substance Flows Analysis (see also Module 1.3) can help us estimate the flow of phosphorus in the global food system. It traces the flow of P from mined phosphate rock via fertilizer and crop production to human and animal consumption (Cordell et al., 2009a). The quantities of phosphorus (in millions of tonnes per year) flowing between these major stages and the losses on the way are shown above.

While some 14.9 million tonnes of phosphorus is used in fertilizer production, only 3 million tonnes end up in human excreta some of which originates from soil P. The flow analysis indicates that there are substantial phosphorus losses that occur throughout the food production and consumption system – from mine to field to fork to toilet. Most of these losses, such as the losses due to the wastage of edible food and loss of P in animal manure, are avoidable (see 5.1–20). Other losses, such as the loss of P through soil erosion, can potentially be reduced if the P is managed wisely. The graph shows that more phosphorus ends up washed away by erosion than ends up in food. In the Illinois River basin, for example, about 1.2 kg of soil with its P is eroded for each kilogram of corn produced (Vaccari, 2009).

A substantial amount of phosphorus is lost as phosphogypsum waste in the fertilizer production. Transport, storage and other production losses also occur between the mine and the farm gate. Phosphorus must be in solution in the soil for plants to be able to take up the nutrient. However, once applied to agricultural soils, phosphorus in fertilizers can quickly adsorb to other particles, making phosphorus unavailable for use by plant roots (FAO, 2008). It has been estimated that plants only take up around 15–25% of phosphorus in fertilizers applied that year (FAO, 2006). The remaining phosphorus is either temporarily locked up in soil (slide 5.1-22), or lost to water bodies via erosion and runoff. Once harvested, crops are either processed for food, feed, fibre or fuels - or traded globally. A substantial amount of phosphorus is lost in these processes, for example through conversion to feed which is then consumed by animals. Only a fraction is returned to the food system as animal protein products due to misuse of animal manure (Cordell, et al, 2009a). Furthermore, the organic waste from households, restaurants and disposal in supermarket dumpsters and household bins, can also be large (FAO, 2011). Only a small proportion is recovered and re-used.

Securing a sustainable phosphorus future

5.1 - 12



This graph combines past and anticipated future sources of phosphorus fertilizers for meeting global food demand. The graph for the future presents results from a 'preferred' scenario generated from a futures scenario analysis (Cordell et al., 2009b). The 'business-as-usual' scenario takes into account factors such as population growth, likely changes in preferred diets, and improved efficiencies. The result is a demand that grossly exceeds anticipated supply.

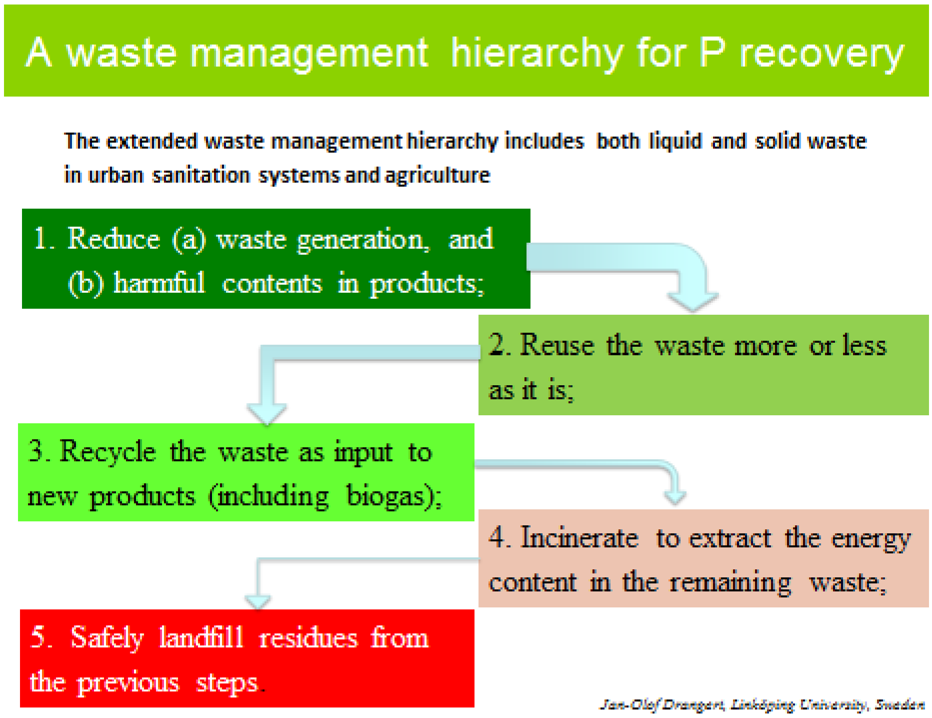
The situation is not as grim for food security as it may first appear, however. Due to the substantial mismanagement and inefficient use of phosphorus in the current food system, there are numerous opportunities to improve current practices in order to avert a crisis. However, there is no single quick-fix solution for ending the dependency on phosphate rock. A scenario analysis shows that a number of different supply- and demand-side measures can together close the growing gap between supply and demand for phosphorus.

The graph shows that ***demand-side measures*** are crucial. The almost universal trend towards eating more meat- and milk-based food doubles the demand for P for an equivalent food intake. Also, the animal husbandry releases 18% of the global greenhouse gas emission. High meat intakes are found to cause health problems. These are three reasons for society to advocate a more cereal-based diet. The demand for P can also be substantially reduced through minimising losses of edible food through wastage during transport, storage, food processing and disposal (slide 5.1-14). A third important demand-side measure is to improve efficiency in agriculture which would contribute to a substantial reduction in demand for fertilizer. Stalks and stems should be returned to the soil to prevent erosion.

The main ***supply-side improvements*** are reuse and recycling measures. The collection and return of animal manure and human excreta to the soil reduces the need for chemical fertilizers. Incentives to change agricultural practices are likely to be more effective than incentives to change diets. More efficient mining processes would prolong the lifetime of rock phosphate reserves, and a higher market price would make more sources economical to exploit. Implementing these measures will require substantial changes in behavior in industry, in agriculture, and among individuals, in addition to new physical and institutional infrastructure.

The demand- and supply-side measures are presented as steps in a waste hierarchy that starts from reduced waste generation and ends with undesired landfilling step (Drangert *et al.*, 2013).

5.1 - 13



In this study material, this extended waste hierarchy includes solid waste and also wastewater in order to developing measures for improved nutrient management in urban sanitation systems.

In a sanitation context the above steps are interpreted as follows. **Step 1** reduces generation of waste-containing nutrients, and thus the need to tap mineral nutrient reserves. This includes reduced volumes and, perhaps more importantly, to minimise harmful and unwanted contents in products and materials. For example, banning the use of phosphorus in detergents fulfils both reduction of used volumes of phosphorus and lessens a harmful content causing eutrophication. By not mixing various waste streams, it becomes both easier and safer to directly reuse (**step 2**) products right away. For example, the nutrients in human urine may be applied directly on farmland through irrigation. However, if the desired compounds in the waste is not safe or not in a state that allows reuse, some kind of conversion into a new product is required (**step 3**). Such recycling will save on virgin resources. For instance, organic waste such as faecal matter and treated sludge could be composted, hygienized and turned into a multi-nutrient fertilizer product. Such recycled inputs often save on energy usage for production and transport of mineral nitrogen and phosphorus in fertilizers. Organic waste may in addition be anaerobically digested to produce methane and biogas while retaining the nutrients in the sludge and slurry for subsequent agricultural use.

Incineration of organic waste is also an option (**step 4**) mainly used to reduce the volume of solid waste and to recover the energy. The ashes and smoke contain phosphorus and potassium (do not burn), but in a form that requires additional energy to become plant available. Also, all carbon and nitrogen are lost which makes the products less valuable for agricultural use. If no components of the remaining waste are possible to recover, at least the energy content may be of interest – if the incinerator is perceived to be affordable. Putting waste on a landfill (**step 5**) should be resorted to only after having exhausted the previous four steps. Even landfilling is made safer by implementing the first step of reducing harmful components and not mixing waste streams. Currently, the most common practices employed in the world´s sanitary systems are steps 5 and 4. But, in many countries there is a rapid evolution towards the first three steps and this study material focuses on these steps.

Can I eat climate-smart and phosphorus-smart?

5.1-14

- ***Think twice when shopping***
  Don't buy more food than you have time to eat
- ***Eat up the food you cook***
  Serve reasonable portions and use the leftovers
- ***Use your senses***
  Look, smell, taste and feel the food. Most foodstuffs last longer than their 'use-by' date if they are stored properly
- ***If you want to eat meat***
  Choose local produce and try to eat fish, chicken and no beef
- ***Eat more vegetarian food***
  Especially root crops and legumes
- ***Choose fruits and vegetables of the season***
  Preferably local products

Source: Sweden's National Food Adminstration Report 2008:9

"In a world of seven billion people, set to grow to nine billion by 2050, wasting food makes no sense - economically, environmentally and ethically," said UN Under-Secretary-General and UNEP Ex. D. Achim Steiner. "Aside from the cost implications, all the land, water, fertilizers and labour needed to grow that food is wasted - not to mention the generation of greenhouse gas emissions produced by food decomposing on landfill and the transport of food that is ultimately thrown away," he added. "To bring about the vision of a truly sustainable world, we need a transformation in the way we produce and consume our natural resources." (FAO, 2013)

According to (FAO 2011), roughly 95 per cent of food loss and waste in developing countries are unintentional losses at early stages of the food supply chain due to financial, managerial and technical limitations in harvesting techniques; storage and cooling facilities in difficult climatic conditions; infrastructure; packaging and marketing systems.

However, in the developed world, the end of the chain is far more significant. At the food manufacturing and retail levels, large quantities of food are wasted due to inefficient practices, quality standards that over-emphasize appearance, confusion over date labels, and consumers being quick to throw away edible food due to over-buying, inappropriate storage and preparing meals that are too large.

Per-capita waste by consumers is between 95 and 115 kg a year in Europe and North America/Oceania, while consumers in sub-Saharan Africa, south and south-eastern Asia each throw away only 6 to 11 kg a year.

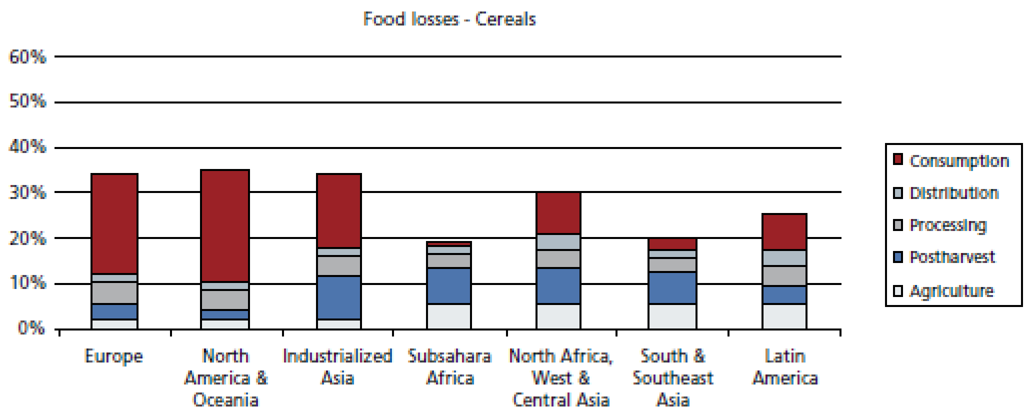
The slide talks about what households and individuals can do to enhance the availability of phosphorus fertilizers and reduce emissions of greenhouse gases. Such climate and phosphorus smart activities are in the hands of all individuals. The following everyday activities will have a tremendous positive impact on the globe if most persons adhere to them:

Measures to reduce volumes include not buying more than what will be eaten up. Expiry dates for products are quite short and can be extended with proper storage. However, milk, meat, fruit, juice, etc. are often flushed away. In a recent review of global food wastage, Parfitt *et al*. (2010) concluded that available data suggest that between 10 to 40 % of the total amount of food produced is wasted, but data are quite uncertain, and figures up to 50 % have been cited. Recently, Quested and Johnson (2009) estimated that about 40 % of the household wastage in U.K. was due to cooking and serving more food than could be consumed. Additionally, a recent study in Sweden estimated that about 20 – 25% of the food wasted in households could be related to packaging, *e.g.* too big and difficult to empty packages (Williams *et al*., 2012). Studies of such food waste give figures from 50% (USA) to 25% (Sweden), and the European Union aims to reduce edible food losses to 20% by 2020 (FAO, 2013).

Eating a diet with less meat and dairy products will reduce the number of animals on the earth, which allows for more forests, and cuts down inefficiencies in food production and emissions of carbon dioxide and methane gas. If you want to eat meat, fish is the most P smart diet followed by chicken and pork which all require less phosphorus per produced kilogram than beef. The medical profession is also getting worried that a heavy meat diet is causing health problems.

The 'Think. Eat. Save.' global campaign (www.thinkeatsave.org/) provides simple tips to consumers and retailers, which allow users to make food waste pledges, and provides a platform for those running campaigns to exchange ideas and create a truly global culture of sustainable consumption of food.

FAO (2011) provide estimates of losses for several food categories, and the graph below presents losses for cereals from agriculture to consumption:



Nutrients in human excreta

5.1-15

Amount of nutrients from an average Swede per year

Important nutrients	Urine 500 Lt/year	Faeces 50 Lt/year	Total
Nitrate (N)	kg	kg	kg*
Phosphorus (P)	kg	kg	kg
Potassium (K)	kg	kg	kg
Total amount i.e. N+P+K	kg %)	kg)	kg %)

The Urine Equation:

An adult eats 250 kg of cereals per year, which has been grown on less than 250 m² and fertilised to more than fifty per cent by the person's urine.

Jan-Olof Drangert, Linköping University, Sweden

Just like plants, the human body requires phosphorus to build cells, enzymes, etc. A normal body contains about 0.6 kg of phosphorus (equals two years´ intake), mainly in the bones and teeth. Since our bodies do not grow indefinitely, an adult excretes about the same amount of nutrients that is eaten. Primarily, the adult body makes use of energy in the eaten food.

The table shows that most of the nutrients are found in human urine, and thus the first priority is to reuse urine (Drangert, 1998). The total nutrient content in human excreta is – in theory – possible to recycle and can fertilize enough soil to produce the same amount of food that has been eaten. In practice, there are some losses but these are small compared to the losses of P in the present chemical fertilizer chain (slide 5.1-11). In addition, P in human urine is in a plant available form and contains only background levels of heavy metals etc.

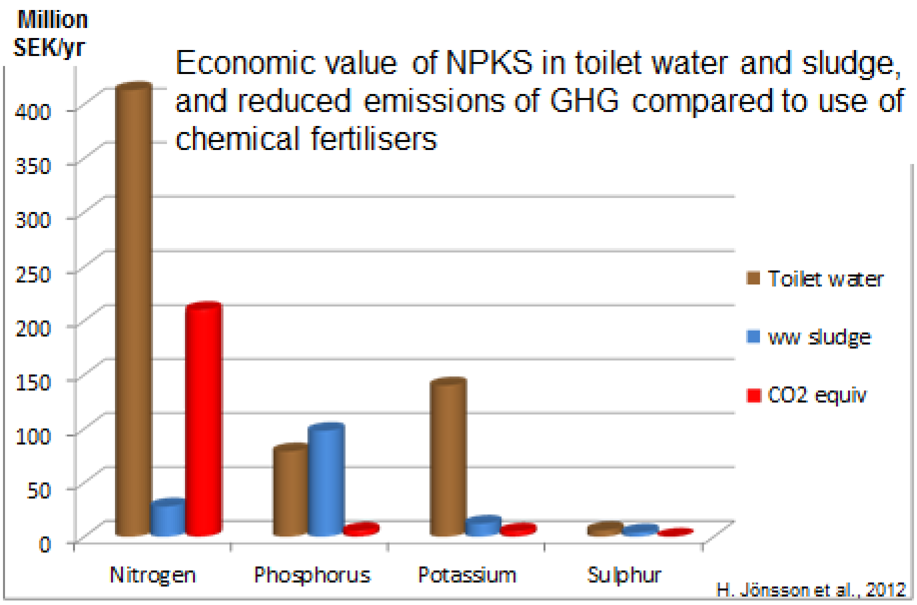
Allowing for some losses of nutrients, it is possible to formulate a Urine Equation (see picture) that connects urination to fertilizer requirement and food production. An adult eats equivalent to some 250 kg of cereals per year, which has been grown on less than 250 m^2 and fertilised to more than fifty per cent by the person's own urine. If treated faeces are also applied, there would be little need to add more fertilizers.

A simple calculation helps to indicate the impact of a urine collection and reuse system. In a city with, say, one million inhabitants, human urine itself could fertilise more than half the food crops needed. Some cities do produce that proportion of their food intake within the city limits e.g. Lusaka, Dar es Salaam and Moscow (UNDP, 1996). The larger the part of the food production that takes place in the city (urban agriculture) the less energy is used for transporting urine as well as the food crops and fertilizers. A town may be planned from the criteria that a certain percentage of the land area is set off to agricultural activities. Collection arrangements would be required and transport to the fields as discussed in module 2.1 and slides 5.1-17&18.

Urea is a naturally occurring compound contained in urine from mammals. It is manufactured in the body by combining carbon dioxide with ammonia and is the most commonly used nitrogen fertilizer worldwide. With more than 46% nitrogen, it has the highest nutrient concentration among the commercially available solid nitrogen fertilizers. It can be applied in a solid prilled or granulated form (EFMA, 2000c).

Nutrient fertiliser values and CO_2 emissions

5.1 - 16

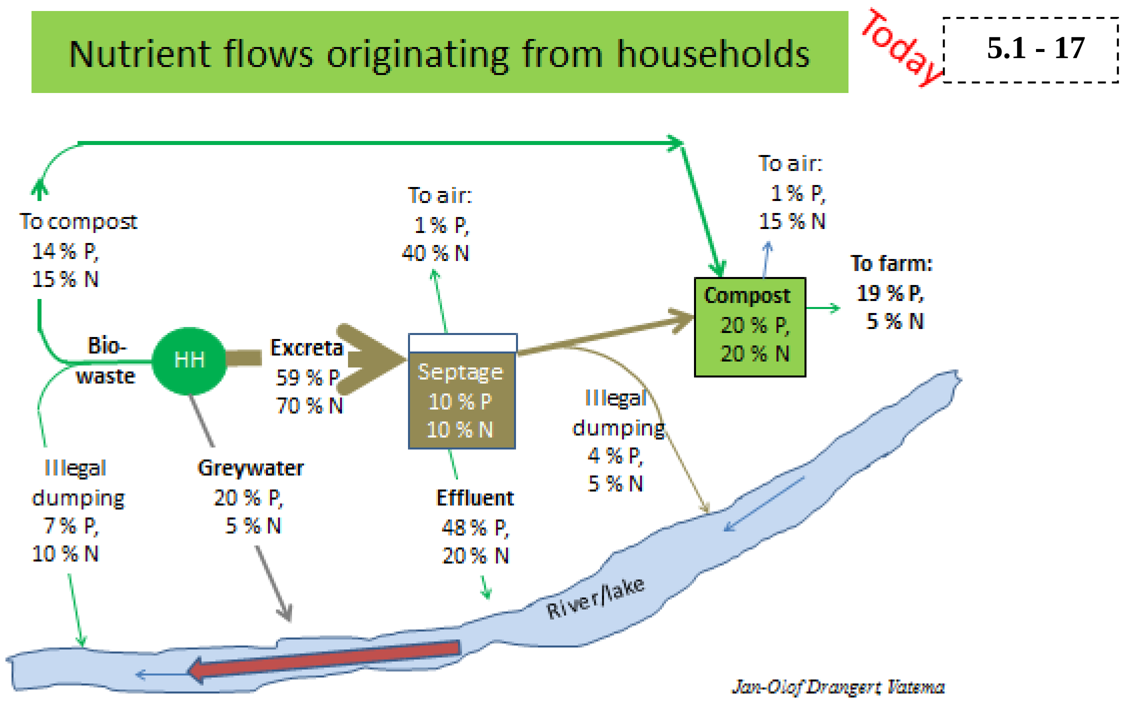


Cities are fast becoming 'phosphorus hotspots' in two senses – as centres of demand for phosphorus (to prepare food to be consumed in cities) and as location of large amounts of phosphorus in excreta and food waste. For example, urine is the largest single source of phosphorus emerging from cities (Vinnerås *et al*, 2006). However, most nutrients in urban waste are not recovered and re-used (see slide 1.3-13). Many town councils collect and transport organic waste to landfills, where the nutrients will remain for uncounted years unless leached to groundwater or emitted to the atmosphere. The situation is similar for urban toilet waste, which in the best of cases ends up as sludge in a wastewater treatment plant. However, sludge is also often sent to incineration or landfills due to its perceived or real toxicity. The more the flow of phosphorus from mine to field to toilet is linear and in one direction only, the greater our dependence on mined phosphate rock and the faster high-grade phosphate rock resources will be depleted. Recirculating urban nutrients such as urine back to agriculture therefore presents an enormous opportunity for the future.

Jönsson *et al*. (2012) calculated the economic value of four nutrients in two theoretical systems for Sweden: for all toilet water (black water) and for all municipal mixed wastewater sludge. The annual values (see slide) are calculated as the value of the corresponding replaced chemical fertilizers (in Million Swedish Kronor). A bit more phosphorus could be extracted from sludge than from blackwater, given a removal rate of 100% in the wastewater treatment plant. This is due to wastewater containing not only the blackwater but also detergents and food scraps with P.

A striking feature is that the economic value of potassium, and more so of nitrogen, is very high in blackwater compared to sludge. This reflects the fact that nitrogen disappears to air on its way from the toilet through the treatment plant. This loss of nitrogen has to be replaced by the very energy-intensive production of nitrogen from ammonia and hydrogen. Also, dissolved potassium is not captured in the treatment plant and is therefore not found in the sludge. The total amount of N, P, and K in blackwater is equivalent to 20%, 50%, and 55% respectively of the amounts of these nutrients in chemical fertilizers sold in Sweden in 2009/2010.

The red bars in the graph represent how much the CO_2 emissions are reduced, if the chemical fertilizers were to be replaced by recycled nutrients from blackwater and sludge: 203,500 tons of CO_2 equivalents per year and 17,000 tons respectively. Again, the nitrogen in the blackwater dominates with 196,500 tons.

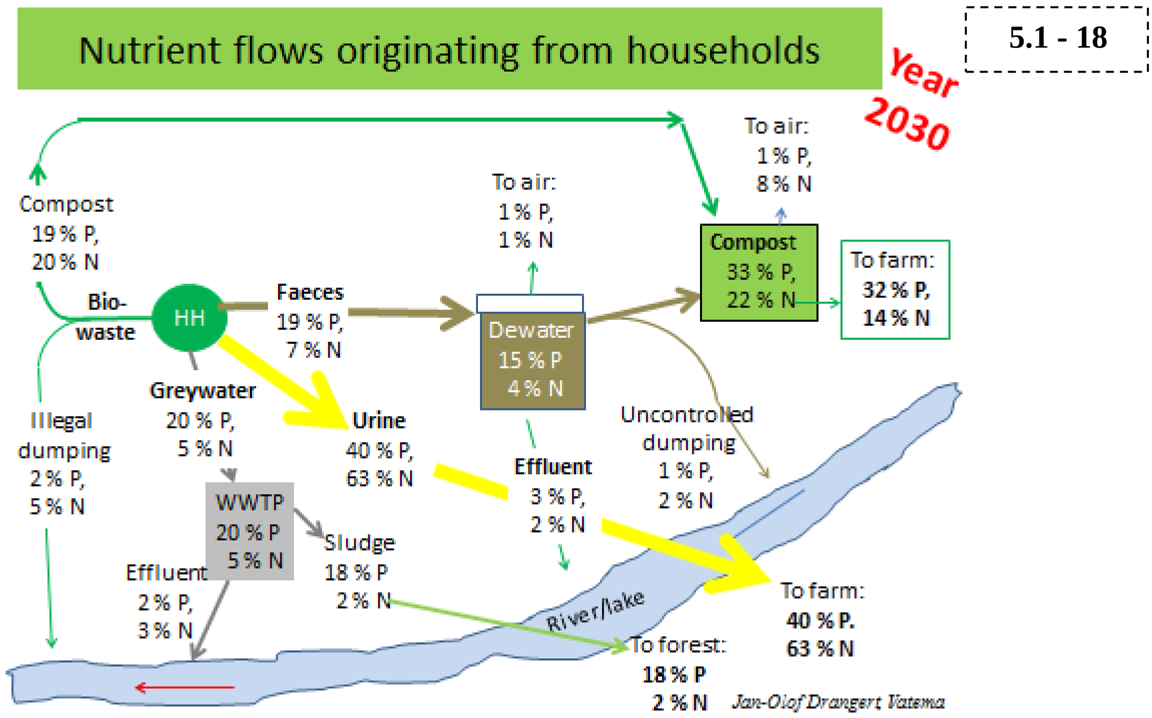


Measures that reduce the environmental impacts from cities and towns include returning organic matter from households to the soil. The picture represents a common situation in today's world where the nutrients are largely discharged to water bodies (red arrow). Flushing away organic matter in sewers will cause eutrophication and algal blooms in receiving water bodies. This may result in less aquatic flora and even dead zones on lake floors and reduced living space for fish.

The picture presents a theoretical calculation of phosphorus (P) and nitrogen (N) flows from households (HH) to the environment. Bio-waste consists of food waste, paper, garden waste etc. It is usually easier to manage solid organic waste than liquid organic waste caught in the sludge after wastewater treatment. So, sweeping away food remains and fat/grease from plates, pan and cutlery into the organic waste bin is preferable as it makes it possible to compost the material and use it as a soil conditioner in the garden or to collect it and use it in agriculture or for making biogas. The alternative is that this fat/oil/grease will eventually clog the sewer pipes, and cause costly repair. The content of P and N as percentage of total P and N leaving the households are given for each flow. Some of the solid waste is illegally dumped while some is composted.

The nutrient-rich excreta are flushed to a septic tank for partial treatment, but much of the nutrients remain in the effluent, while the sludge is collected and brought to the compost. Illegal dumping is commonplace. The co-composted sludge and solid organic waste is available for use in agriculture, but most of the nitrogen has been lost to the atmosphere. A modest one-fifth of the P that households discharge is being gainfully used and only 5 % of the N.

The next slide shows a modified sanitation system with the capacity to improve reuse and recycling considerably.

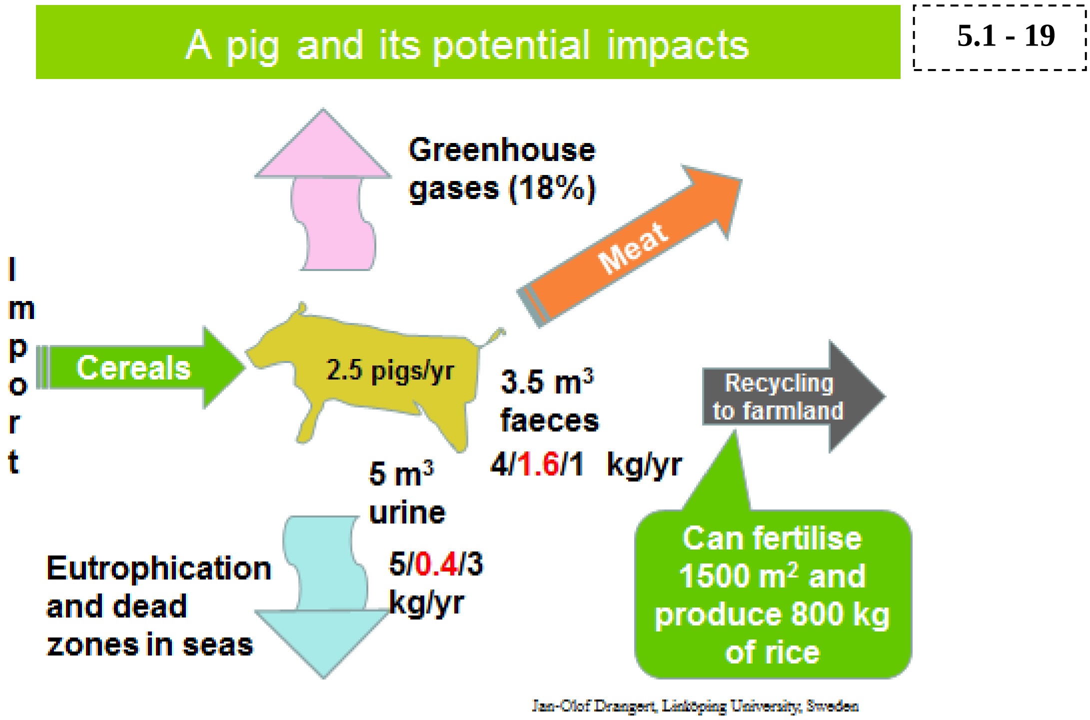


The same city has taken some steps to make it more sustainable. Residents contribute by segregating household solid organic waste and the waste company compost it and this added value reduces illegal dumping. Also, urine-diverting toilets have been installed and urine is collected separatly while faecal matter is dewatered and stored (as recommended by WHO) before being composted. The wastewater treatment plant has improved to 90% P-removal capacity, while the same effect could have been achieved by prohibiting phosphate-based detergents.

This time, the nitrogen-deficient greywater sludge contains polluting compounds that may accumulate in soil, and is therefore only applied on trees. The urine can safely be applied on agricultural soil since it is the least polluted fertilizer available and has an almost perfect composition (Module 4.2). The nutrient loss from well-managed urine is insignificant (Vinnerås *et al*, 2006). Likewise, the quality of the organic compost is likely to be of good quality and possible to apply on soil for food production. The short loop of using urine and composted organic matter in the garden is sustainable, whereas sludge from treated mixed wastewater is more risky and difficult to monitor (see Module 4.5).

Compared to the sanitation system described on the previous slide, there is a significant improvement in reuse/recycling of the nutrients N and P (and surely also all other nutrients). Productive usage of P originating from households increases from 19 % to 90 %, while N increases from 6 % to 79 %. This drastic reduction in wastage also means that water bodies are saved from nutrient pollution and eutrophication.

All these measures reduce production and transportation of fertilizers and thus save energy and reduce air emissions. The required investments in separate urine pipes and composting stations is marginal when new city districts are being build, whereas retrofitting existing houses may be prohibiting expensive (Module 2.1).



One example of recovery of nutrients is the reuse of animal waste practised in all societies. Free-range animals distribute the nutrients in the fields, while stall-fed animals make up hot spots of nutrients. Recycling of animal waste can be analysed in a similar fashion as human waste, keeping in mind that the composition of animal waste differs between different species. For instance, chickens do not pee at all, urine from pigs contains little phosphorus compared to humans, and cow urine contains no phosphorus.

The picture above provides data for pig urine and faeces from an intensive breeding of pigs for meat. A cage in the stable for fattening pigs is used for 2.5 generations of pigs in one year i.e. 2.5 pigs slaughtered per year. The meat may be exported, while feed is often imported from abroad.

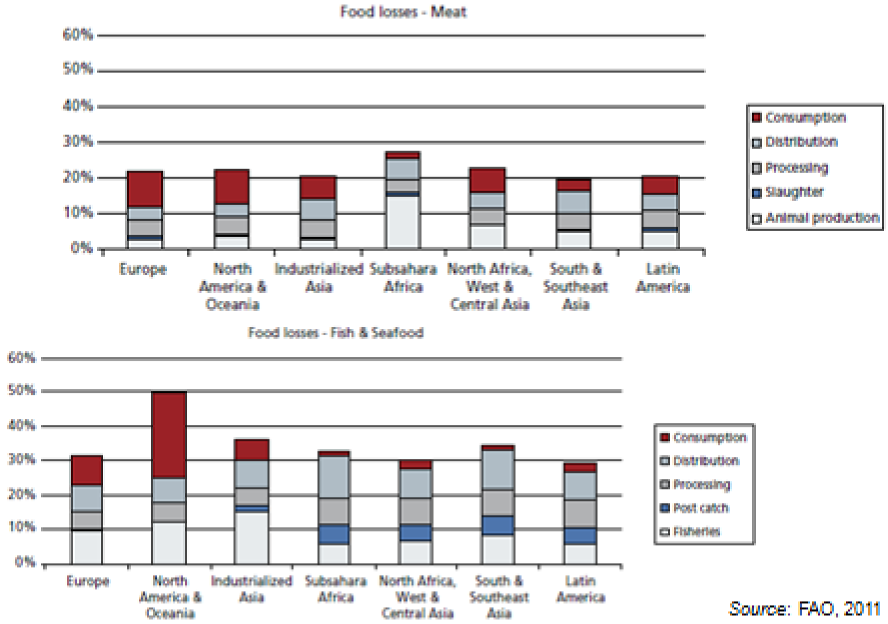
From each cage the farmer collects 1 m^3 of urine and 0.7 m^3 of faeces per year. A sow with her piglets produces 5 m^3 of urine and 3.4 m^3 of faeces. The NPK content is 5/0.4/3 kg in urine and 4/1.6/1 kg in dung, which shows that only 20 per cent of the P is found in the urine and 80 per cent in the faeces (Claesson and Steineck, 1991). It is relatively easy to crudely separate pig urine and faeces and to dewater the manure at the farm. The P in pig manure is to a large extent found in the faeces (80%) as opposed to human excreta where only 33 per cent is in the faeces. This means that the voluminous liquid part can be applied on nearby phosphate-rich soils without adding too much phosphorus. The dewatered faeces are rich in most nutrients and have a high organic content which makes it a good fertilizer and soil amendment. Its small volume is likely to allow for long transport to areas in need of P and carbon-rich soil amendments. The next slide shows the uptake of phosphorus in different plants, and thus how much P farmers may add without over-fertilizing; depending on the crop they plant.

The manure from one sow and her piglets is sufficient to fertilise some 2,000 m^2 from which 800 kg of maize or rice can be harvested. This, in turn, means that the sow and her piglets can get more than 2 kg of maize or rice every day from crops fertilised with their manure - without degrading the soil.

The environmental impact of ruminant livestock is significant, and animals contribute some 18 per cent of the greenhouse gases which cause climate change. Also, if urine and faeces are not managed properly, the high loads of N and P cause eutrophication and dead zones in lakes.

Loss of food in each step of the food chain

5.1 - 20



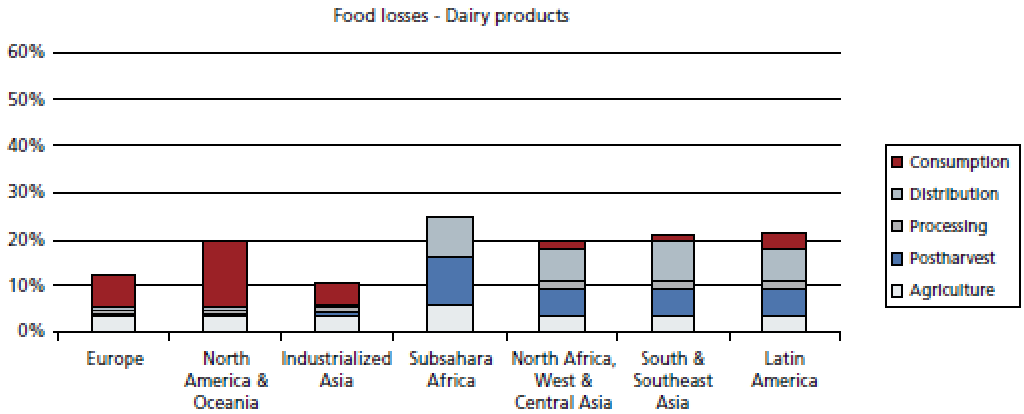
Source: FAO, 2011

FAO (2011) estimated food losses at each step of the food chain for all food categories. They found high losses (45-65 %) for fruit and vegetables, (40-60 %) for roots and tubers, 20-35 % for cereals, and 20-30 % for oil seeds and pulses.

The picture gives data on losses and waste for meat, fish and sea food. FAO found similar total losses of some 20 per cent for meat over the globe with a slightly higher figure for Subsaharan Africa (27%). Waste and losses at the consumption level is high in Europe and the US and makes up about half of the total loss, while big losses in Subsaharan Africa appear in livestock breeding.

The losses of fish and sea food are higher, about 30% and even 50% for North America and Oceania. The three industrialised regions discard 9-15% of the marine catch, and a large portion of the purchased fish and sea food is wasted.

Dairy products are wasted to a lesser extent than meat and fish. In the industrialised countries the main loss occurs in the households, while wastage in the other regions is dominated by distribution and postharvest losses:



Plant requirement and nutrient removal

5.1 - 21

Crop	Yield, kg/ha	Dry matter	N, kg/ha	P, kg/ha	K, kg/ha
Cereals					
Rice, paddy	4,000	88%	60/45	13/11	25
Wheat straw	4,000	85%	70/16	13/ 2	50
Maize	4,000	88%	200/51	35/ 9	133
Sorghum	4,000	88%	120/56	22/ 9	116
Tubers etc					
Cassava root	20,000	36%	125/32	13/ 1	125
Sweet potatoes	10,000	59%	90/49	19/12	12
Potatoes	25,000	23%	115/83	20/13	166
Others					
Soy bean	1,000	91%	125/54	13/ 5	33
Ground nuts	1,000	94%	50/37	7/ 4	12
Banana fruit	25,000	31%	n.a./67	n.a./ 8	n.a.

Source: Håkan Jönsson, SLU, Sweden

The previous slides present the amounts of nutrients that animals and humans excrete, and what can potentially be brought back to farmland. Crop species vary in their nutrient requirements and in the quantities of nutrients that are removed at harvest (EFMA, 2000b). The table above shows normal yields for ten crops, the dry matter content, and the content of nitrogen (N), phosphorus (P) and potassium (K) contained in the entire plant (black) and their edible part (red). Given that the crop residues are ploughed down in the soil, the red figures indicate the amounts of nutrients that are removed with food and feed. Peels of banana, potatoes and cassava roots are considered edible, whereas peels of groundnuts and soybeans are not.

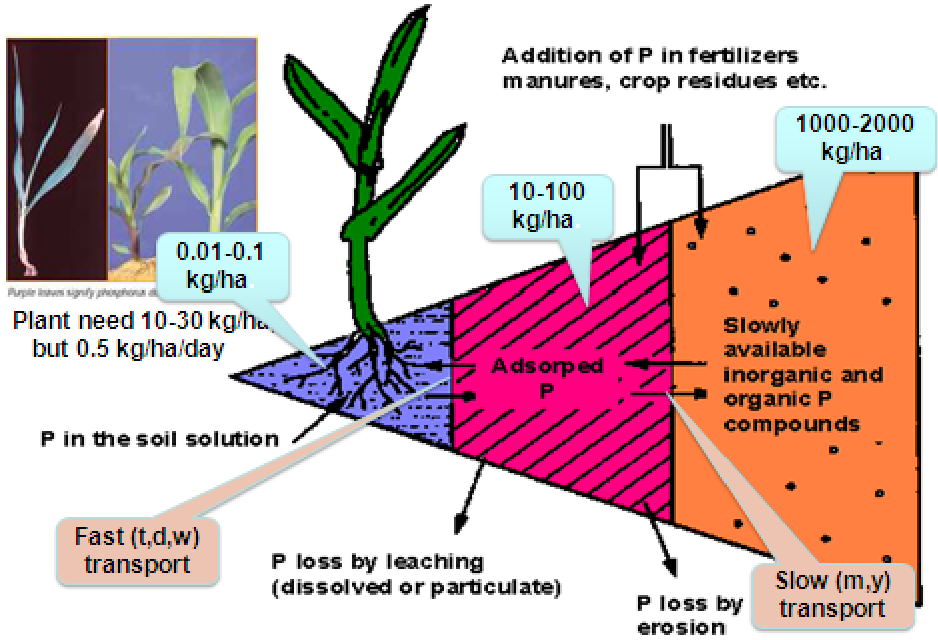
The proportion of P in the edible part as compared to the entire plant varies between 7% and 85%. Conversely, if the non-edible part is left on the field, between 15% and 93% of the P is recycled. The corresponding recycling figure for N varies between 35% and 80%. Such data emphasize the importance of selection of crop given the soil content of nutrients.

The data in the table clearly show that a farmer can benefit from a strategy to select crops which are not requiring so much of a limited soil nutrient as other crops (See also slide 4.1-10). For instance, farming maize and paddy rice yields the same 4 tons per hectare given all nutrients are available to the plants. However, farming maize would require almost three times as much P input as paddy. On the other hand, the return of non-edible parts of maize would provide 26 kg/ha while the non-edible rice plants return only 2 kg per ha. In phosphorus deficient soils in Africa it is vital to plough back the non-edible parts of maize stalks and cobs. This task is difficult and farmers often burn the stalks in the fields (also to avoid pests). But then also much of the nitrogen disappears, and the P in the ashes is not plant available (Schiemenz and Eichler-Löbermann, 2010).

In the long run, all soils will need replacement of the removed nutrients. One source of nutrients is animal manure and another is human excreta. The previous slide shows that a sow with piglets annually provides 9, 2 and 4 kg of nitrogen, phosphorus and potassium respectively. Values in the table shows that this is enough to fertilise 0.2 hectare planted with sweet potatoes or 0.25 ha of groundnuts with a yield of two tonne of potatoes or 250 kg of groundnuts (if all residues are returned). An extended exercise on slide 5.1-23 makes use of data in this table.

Why is it so difficult to apply P?

5.1 - 22



The previous slides may give the impression that it is easy to apply phosphorus and other nutrients to farmland. This is not the case since there are a number of factors influencing what can be achieved. Plants require between 10 – 30 kg/ha and will take up P at different rates during the growing period (slide 5.1-21). A plant may need up to 0.6 kg/ha per day when establishing the roots or setting fruits while much less is needed during other periods (EFMA, 2000b).

All soils contain P (slide 5.1-6) but the concentration may vary much over a field, even over short distances. Also, this P may be easily available to the plants or be adsorbed to soil particles so hard that the roots cannot access the P - usually to iron, aluminium or magnesium in the soil. In acid soils P is fixed to ions or hydrolysed oxides of these metals, while in slightly alkaline soils P is fixed as calcium phosphates. Thus, farmers tend to apply more P than the annual plant/crop takes up in a year.

The top soil (20-30 cm) has a total volume of some 2,500 m^3 or 2,000 tons per ha. It may contain 3-7 tons of P_2O_5, but only a very small fraction of this P is available in the soil solution at any one time (EFMA, 2000b). The P can also disappear from the top soils by being removed by rain and wind erosion. The likelihood of losses of P in this way differs for different soil types, rain regimes, and vegetation cover. The amount may be as much as 0.4 kg/ha annually, and about the same magnitude of P may be deposited on soil from the air (from incineration, soil dust and volcanoes).

The tilted triangle in the picture shows top-soil (blue), the layer below (lilac), and the deeper soil (brownish) (Stouman Jensen, 2010). In the topsoil there is always some P in solution and readily available to plants (0.01- 0.1 kg/ha). This amount is soon used up by plants. Fortunately, the transport of P to and from the next layer is fast, usually hours up to days. The P in the lilac layer (10-100 kg/ha) is however adsorbed to charged soil particles such as iron and aluminium. These compounds are too big for the roots to ingest and require some natural biochemical processes to be transferred to the top soil. The deep soils (brown) contain lots of P (1,000-2,000 kg/ha) but this is in a non-soluble form. The transport of P is therefore very slow and would take months or years to become available to plants. This organic P is typically stored for later use.

The various conditions described above make it complicated to know the need of P in a certain soil and at a certain time of the growing season. Farmers would need a lot of data and experience to succeed in precision-application of P. Sometimes precision agriculture in the form of band or placement of fertilizer, you can save a lot of P to bridge the vulnerable first plant stages with not enough roots (Smit *et al*., 2010).

Equally important is to select crops that can reach the different soil levels. For example, lettuce has a shallow root system and can exploit only about 20 cm of the top soil. Others like sugar beet has roots that extend 2 m or more into the soil and benefit from nutrients and water at that level (EFMA, 2006).

In the soil, urea from urine is converted from carbamide nitrogen to ammonium ions (NH4+) by a series of enzyme reactions. Under normal soil conditions, the ammonium ions are adsorbed by the soil (i.e. become attached to the negatively charged soil particles) and the nitrogen becomes available to the plant, either in its ammonium form or as nitrate following microbial oxidation. Urea derived ammonium behaves in exactly the same way as that from other ammonium based nitrogen fertilizers (Code of best agricultural practice at (efma.org) www.fertilizerseurope.com) This breakdown of urea to release ammonium ions normally occurs within a week. Urea should preferably be spread when rain is forecast, or should be washed into the soil by irrigation in the evening and worked into the soil.

In this context it may be quoted from EFMA (2000b) that "soil nitrogen (N) and sulphur (S) exist in the upper soil layer in organic and mineral (inorganic) forms. The total amount in most arable soils ranges between 3,000 to 10,000 kg/ha for N and 500 to 2,000 kg/ha for S, with even greater amounts being found in grassland soils. Usually at least 90-95% of this total soil N and soil S is in the organic form and is unavailable to plants, with about 2% of the organic N being converted each year to mineral forms by microbial action (i.e. being mineralised). From a plant nutrition point of view only mineral N and mineral S are important, because it is only in these forms that the plant root can take up these nutrients. Mineral N occurs in two different forms in the soil: ammonium-N and nitrate-N. Ammonium-N (NH_4^+) is less mobile and can be fixed to clay minerals. However, this ammonium-N is rapidly converted into nitrate-N (NO_3^-) by soil microbes at soil temperatures above 3 to 5°C (nitrification) unless a specific nitrification inhibitor has been added. As a result nitrate-N is normally the predominant mineral N form in soil during the growth period of crops".

5.1 - 23

Start from the end!

Phosphorus flows: a closer look

Consumption type	Human body excretes P (most in urine)	P content in post-harvest food preparation	P content in harvested crops	Total rock P extracted[83]
Vegetable-based diet	0.3 kg/P/y Step 1	0.45 kg/P/y [if 2/3 eaten and 1/3 is organic waste] Step 2	1.8 kg/P/y [if 1/4 becomes food and 3/4 organic waste] Step 3	0.6 kg/P/y or 4.2 kg rock phosphorus [plant uptake of P comprise 1/3 from rock P and 2/3 from soil P] Step 4
Meat-based diet	0.6 kg/P/y [82]	0.8 kg/P/y [if 3/4 eaten and 1/4 is organic waste]	8.0 kg/P/y [if 1/10 becomes food and 9/10 is organic waste/animal feed]	1.6 kg/P/y or 11.8 kg of rock phosphorus [plant uptake of P comprise 1/5 from rock P and 4/5 from soil P]

Source: Cordell, Drangert & White (2009a)

Stay vegetable-based, and return farm waste, your excreta, household and city organic waste to ***soil !!!***

Phosphorus travels from mine to field to fork – and is finally excreted unless lost on the way. In this exercise students are requested to analyse each step from the end (excreta) and work backwards in order to understand what impact our diet has on phosphorus usage. This exercise requires input of data from several sources found in this training material or – even better – from national data bases. Here we make a few general comments on each of the four steps.

Step 1: The body extracts energy from food, about 2,500 K calories per day, but adult bodies do not accumulate any nutrients only replace some. This means that almost all the phosphorus (98%) consumed with food is excreted in urine and faeces. A vegetarian excretes approximately 0.3 kg P per year, and a meat-eater around 0.6 kg. The reason is that there is more P in meat and milk products and the body does not need all of it (Drangert, 1998).

Step 2: A surprisingly large portion of food is not eaten but ends up as organic waste of leftovers after eating and from food preparation. Other losses occur during transport to shops and from past expiry date. The amount wasted ranges from 10% to 50% in the North (FAO, 2011). In the above picture we conservatively assume that 1/3 of P in vegetarian food is lost in this way and 1/4 of P in meat-based food (slide 5.1-20). Therefore, farmers provide food products that contain 0.45 kg/yr. and 0.8 kg/yr. of P for vegetarians and meat-eaters respectively. Search for country-based data and insert these.

Step 3: The part of the crop that is edible is often small (e.g. the maize on a stem or the banana on a banana tree) and we have assumed ¼ to be the edible part (therefore a total input of 1.8 kg of P), while the rest remains on the farm – if well managed. Producing meat and dairy products involves the production of animal feed and we assume that 10% is converted into food output and 90% is feed and organic waste which remains on the farm. The edible meat therefore would require an input of about 8 kg P. However, accumulation of P in the soil provokes the low efficiency from fertilizer to food (Step 3). Search for country-based data and insert these.

Step 4: Fertilizer application rates differ depending on a number of factors such as soil type, farm practice, economics and crop species. If the phosphorus stock in the soil provides 2/3 of the needed P, 0.6 kg/vegetarian/y needs to be added as fertilizer or 4.2 kg of phosphate rock. Similarly, for meat-eaters some 11.8 kg/p/y of rock P has to be added, if we assume that 1/5 of the P is coming from the fertilizer and 4/5 from the soil phosphorus stock. However, as soil P is gradually depleted, P in residues has to be recycled. Again, search for country-based data.

This simple calculation by hand using guestimates of phosphorus losses should be done with real household, community or country data. It is likely to highlight that a vegetarian diet demands significantly less phosphate fertilizer than a meat-based diet. It also shows that returning biomass from plants and manure from animals to the soil is by far the most important measure to retain soil phosphorus in a meat-based diet. This measure also requires little or no transport. For the vegetarian diet, the recovery of human excreta is the most important measure, but this involves collection and transport of excreta back to the field.

A quick check indicates whether the results are plausible. If we assume that 80 % of the food intake is from plants and 20 % from meat and milk products, an average diet would require 0.8 times 4.2 kg + 0.2 times 11.8 kg = 5.72 kg phosphate rock per person and year. A comparison with info on slide 5.1-3 (7*0.6 kg =4.2 kg) shows that 5.72 kg is on the higher side. For 7 billion people that would add up to some 40 Mt of phosphate rock. This is just a quarter of the global rock production of 160 Mt. The magnitude gives room for losses, but the scenario should be refined by manipulating assumptions and reiterate the calculations.

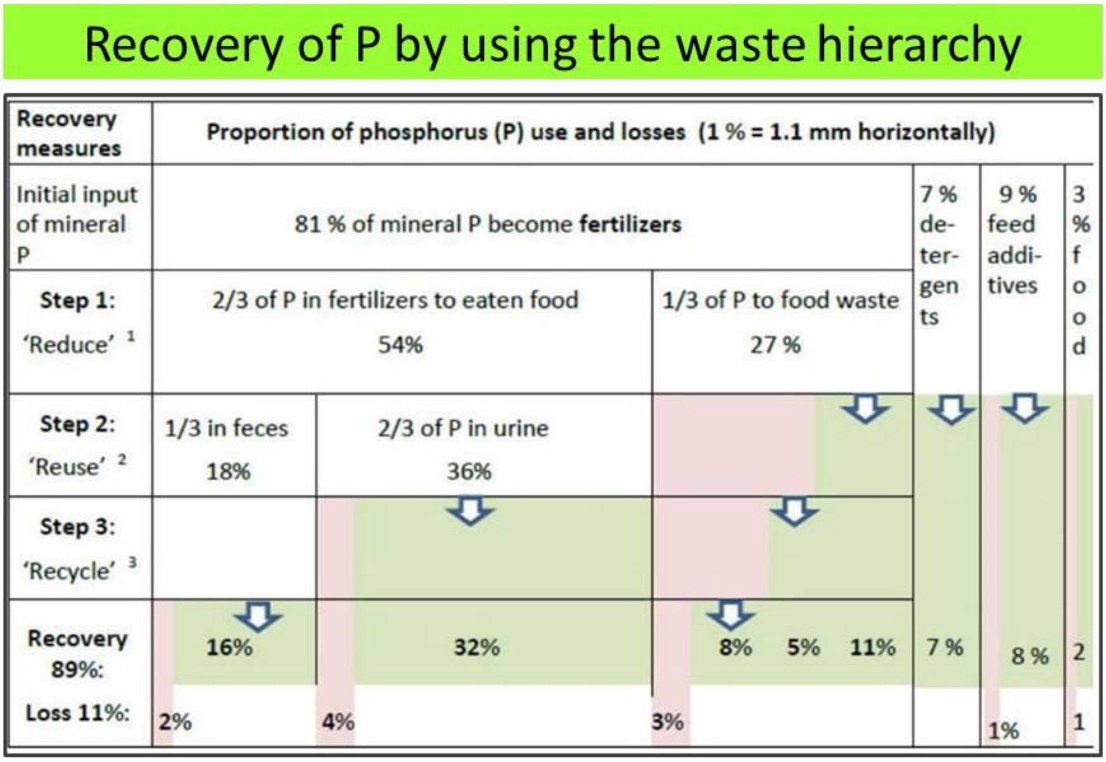
The more data that is available the easier are the above calculations, e.g. country-based data such as the following from China and Hong Kong giving P_2O_5 concentration and per capita consumption for the main food groups for two time-periods. The data shows that the intake of cereals and vegetables go down while those of milk and egg increase over time.

Food group	**P_2O_5 g/ 100 g edible food part**		**g eaten food per capita and day**		**P_2O_5 g eaten per capita and day**		**Hong Kong g/cap/day a**
	1985-92	**1993-06**	**1985-92**	**1993-06**	**1985-92**	**1993-06**	**1997**
Cereals	0.48	0.33	432	356	2.07	1.18	303.8
Potato/tubers	0.08	0.14	56	30	0.04	0.04	n.a.
Vegetables	0.22	0.10	310	259	0.68	0.26	206.3
Fruits	0.05	0.05	74	73	0.04	0.04	292.9
Animal meat	0.47	0.40	61	61	0.29	0.25	352.3
Poultry meat	0.37	0.35	20	23	0.08	0.08	
Milk product	0.55	0.82	23	73	0.13	0.60	231.8
Poultry eggs	0.47	0.41	22	192	0.11	0.79	n.a.
Fish products	0.74	0.59	33	36	0.24	0.21	160.0
Sum					3.68	3.45	

Source: Li et al., 2011 and a) Warren-Rhodes et al., 2001. n .a. = not available

We may also consider an extreme case where all food is produced locally and all organic waste including excreta is returned to the soil. No extra P would be necessary. A small household with a garden of a few hundred square meters could be almost self-sufficient in food (slide 5.1-15). The nutrients in sanitised human urine and composted faecal and other organic matter would return as input for the next crop of maize, tomatoes, etc. These fertilizers only have to be transported a few metres and the work required to prepare them for the garden (storage) is easy. The household could also raise a few chickens and possibly a pig if culturally feasible. Almost all nutrient losses can be avoided. Precision farming will reduce emissions of greenhouse gases. See also slide 1.3 - 13 on the proportions of recycled P over time in a Swedish town.

5.1 - 24



[1] Food waste reduced to 20%, detergents down to nil, use of additives reduced to 2%

[2] Reuse 90% of all urine; reuse 30% of bio-waste.

[3] Recycle 90% of fecal matter and 70% of bio-waste (compost/biogas)

(Jan-Olof Drangert, Linköping University)

A 'waste hierarchy' (5.1-14) and life-cycle thinking serves the dual purpose to grasp the importance of recycling nutrient resources for improved global food security. Data presented in this module are brought together in a comprehensive format in the figure to assist stakeholders to identify wasteful handling of nutrients in urban waste and to suggest measures to better manage those nutrients. Since excreta contain most P and nitrogen in urban waste flows it is included in the calculations to show the possibilities to realize the P recovery potential.

P in biodegradable paper, board and wood waste is not included in the Figure since these flows are already recycled to a large extent for non-agricultural purposes. Garden waste is also not considered due to a lack of reliable data, but it can easily be composted and recycled.

The Figure shows the fate of P through the three fist steps of the 'waste hierarchy'. The mined phosphate rock is mainly used to manufacture fertilizers (81%), feed additives (9%), detergents (7%) and food additives (3%). Reducing P content (Step 1a) is possible for additives and detergents. However, no reduction of mineral P fertilizer use is suggested since this is an issue for the agricultural sector, *i.e.* to improve the fertilizer use efficiency, and not part of efforts to recover urban nutrients. Nor is a shift back to more vegetarian diets suggested, although it could reduce P demand considerably.

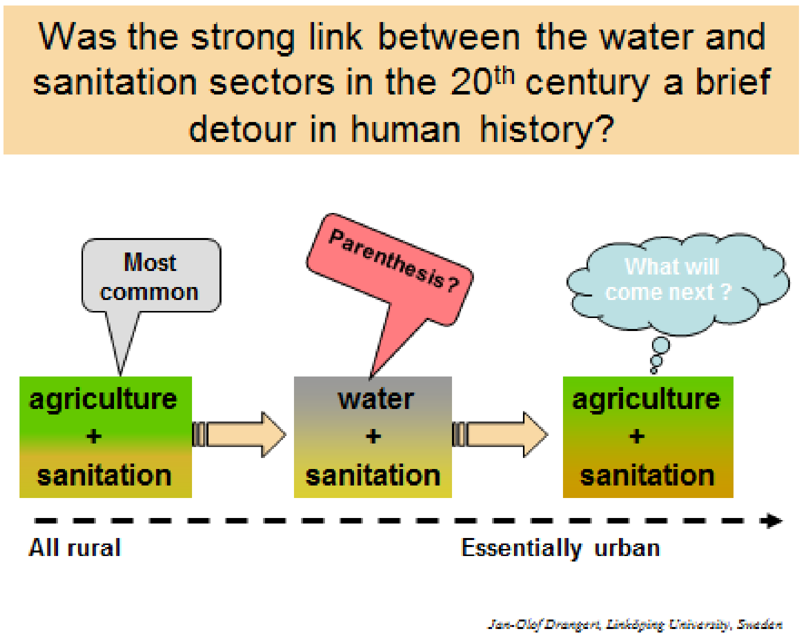
In our chemical societies, the long-term affordable solution to securing good-quality sludge and urine/faeces/blackwater is to design systems that avoid mixing flows (Step 1b). Just like polluting industries today have to collect their sewage in separate sewers and treat it separately, households should also dispose of its polluted greywater (often containing more varied chemical composition than industrial wastewater) in a separate sewer and treat it separately.

Eaten food contains 54% of total P that is subsequently excreted and ends up in sludge. The sludge is presently partly landfilled due to harmful substances in mixed wastewaters and to associated negative perceptions on excreta recycling. With a well-designed city infrastructure it is realistic to recover 90% of P in urine and faecal matter (or from blackwater). Some 30% of food waste can be reused directly (Step 2), and 70% of the remaining food waste can be recycled. Anaerobic digestion and composting (Step 3) allow the nutrient-rich digestants and compost to be used as a fertilizer in agriculture.

The proposed measures increase P recovery from a few percentage points to 89%. 28% of the P can be saved by shifting to using other substances (17%) and to decrease food losses (11%). Another 31 % can be saved by reusing/recycling food P and human excreta. We have assumed that half of the mined P is still lost in the food chain up to the consumption stage, and no change in the role of soil P in agricultural soils. With those assumptions, the time-span with food security is more than doubled and the transgression of planetary P resource boundary is delayed by hundreds of years. In addition, sustainable levels are achieved regarding harmful emissions from food production, consumption and nutrient waste management.

The necessary changes in infrastructure to achieve the above result will continue to the end of this century. EU has shown that this is practically and economically feasible. Now is a window of unprecedented opportunity to design urban infrastructure since houses and infrastructure for an addition 5.5 billion new urban residents in the 21st century have not yet been planned. A win-win situation is imminent, providing both food security and reduced harmful emissions to air, water and soil.

5.1 - 25



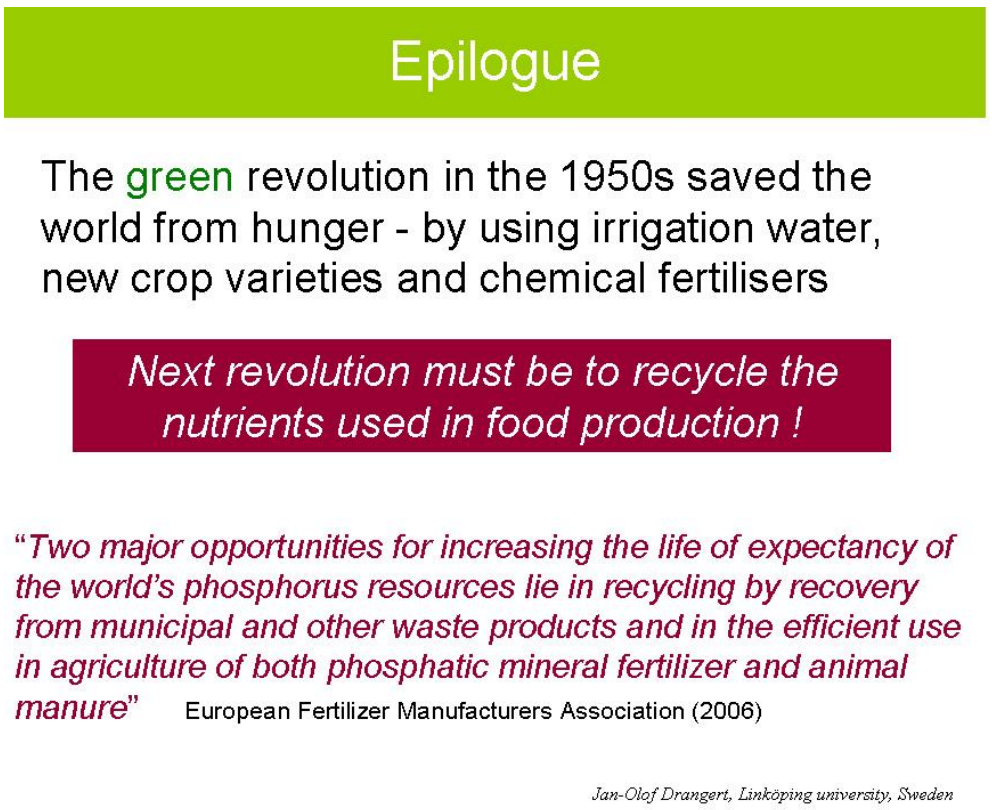
Feeding humanity is a serious global challenge both today and for the future. Today, an unprecedented 1 billion people are hungry – one sixth of all humanity. Global food security is now considered a global priority (UN, 2000). The UN's Food and Agriculture Organization (FAO) states that food security "exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs for an active and healthy life" (FAO, 2005). This definition does not address the emerging health hazard of eating too much. Obesity will soon become as common as malnourishment. Obesity also increases the environmental burden since a fat person is responsible for about one tonne more of carbon dioxide emission than a thin person (Edwards and Roberts, 2009). Lastly, the EU estimates that every citizen accounts for 11 tons of greenhouse gas emissions a year.

A century ago, most people lived on farms and produced their own food nearby with the help of easily recycled organic matter. Today, the conditions are totally different. More than half the world's population lives in urban areas, and there will be another two billion new urban mouths to feed before 2050. Future food security can only be achieved by addressing a number of interlinked social, economic and environmental issues. Innovative ways are needed to meet the food requirements of undernourished urban populations, not least those living in peri-urban areas of mega-cities. Existing decentralised urban food production could be developed further by sustainable communities which recycle nutrients and water (slide 2.1-19). We will have to stop the wasteful linear one-way flow of nutrients from farms to lake sediment.

The kind of food we eat on a daily basis has a dramatic impact on the environment. An illustration is the strong link between diet and land use. The production of meat-based food occupies almost a third of the world's land surface. This consists mostly of permanent pasture but also the third of the world's arable land that is cultivated to provide livestock feed (McMichael et al., 2007). A meat-based diet requires a much larger area of land than a diet of cereals and vegetables. A serious challenge is to keep crop-based diets and not to switch to meat-based diets for status reasons.

Averting future phosphorus and food crises is possible, but it will require substantial changes to our behavior, and to our society's physical infrastructure and institutional frameworks. Sanitation systems of the future, for example, will need to ensure that close to all phosphorus in excreta is recovered for re-use in fertilizers. Hence the sanitation sector will play a vital role in achieving phosphorus security and food security, in addition to enhancing environmental protection and public health.

5.1 -26



Today we are faced with numerous interlinked global sustainability challenges, from climate change, peak oil, water scarcity and poor sanitation to food security. Global phosphorus scarcity presents yet another such globally significant challenge. The good news is that opportunities exist to integrate innovative responses to this new challenge with responses to other challenges in order to create a sustainable, safe and food-secure future. Countries with no phosphate rock reserves can, through recycling strategies from farm to toilet, reduce the demand for rock phosphate to a minimum. Poor countries can prevent price shocks and limit high costs for fertilizer subsidies by subsidising recycling measures instead.

Given the dire consequences of phosphorus scarcity for food production, it is surprising that the role of future phosphorus scarcity is not yet well recognised in the food security debate. For example, the director of FAO, as recently as World Food Day on November 2009, said that food security can be achieved if the rich countries provide subsidies to poor countries so that they can buy chemical fertilizers. The missing debate could be due to a 'lack of fit' between the natural phosphorus cycle and existing institutions and social arrangements. For example, while almost all phosphorus flows from consumed food to excreta in the natural phosphorus cycle, there is little institutional connection between the food sector and the sanitation sector. Phosphorus is perceived quite differently by different sectors. For example, it is perceived as an 'environmental pollutant' by freshwater ecologists, or an 'agricultural commodity' by resource economists, and so on. Up to now, phosphorus scarcity has been a priority to none. It has essentially slipped through the institutional cracks. It is clear that the market alone cannot manage the wider system in a sustainable, equitable and timely manner.

Increasing political awareness about the future of oil in recent decades has resulted in a massive restructuring of investments to reduce oil dependency. The phosphorus sector can learn from such experiences to redirect investments to plant nutrient recycling. This will at the same time reduce energy demand and greenhouse gas emissions.

The Green Revolution saved millions from starvation through the use of irrigation, fertilizers and new crop varieties. The next revolution is a rethink that will require new infrastructure, partnerships and social change to recycle nutrients back to agriculture.

The International Fertilizer Industry Association (IFA) indicates it is committed to a sustainable fertilizer industry and the European Fertilizer Manufacturers Association states: "Two major opportunities for increasing the life expectancy of the world's phosphorus resources lie in recycling by recovery from municipal and other waste products and in the efficient use in agriculture of both phosphatic mineral fertilizer and animal manure" (EFMA, 2000a).

EFMA in 2009 formulated a policy for the industry when developing new products. It reads: "Being committed to Responsible Care, all fertilizer producers should identify the potential impacts of their new products on people, property and the environment. They should satisfy themselves that all reasonable steps have been taken to minimize these impacts and that any residual risk can be managed satisfactorily - taking into account the supply and manufacturing, the distribution, intermediate storage and handling from the factory to the farm, and the farmers' handling and application of the product." (EFMA Product Stewardship for fertilizers, 2009)

The European fertilizer industry has its own regulations for life-cycle analysis of phosphorus in addition to the EU framework (see Module. 4.1.9 in the Product Stewardship for fertilizers). It includes waste minimisation and disposal.

While dependence on mined phosphate rock increased dramatically over the second half of the 20th century, reliance on non-renewable phosphate will need to decrease over the 21st century (due to the phosphorus peak). A sustainable phosphorus future will include a reduced reliance on phosphate rock and efficient recycling measures in all spheres of P usage.

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5.2 Public *"away from home"* toilets

www.go.funpic.humor

Can public toilets be made attractive?
Can vandalism be avoided?

Learning objective: how to plan and implement sustainable toilets in public places.

A public toilet can meet the needs of a range of different user groups. This chapter is about public toilets which are for occasional 'away from home' users such as workers, commuters, tourists and shoppers, as well as local residents who do not have a toilet inside their home. The requirements for such toilets are more complex than for school toilets and toilets at workplaces, as discussed in Module 5.3. Public toilets should be available when the need arises, which means that they have to be strategically sited.

A significant proportion of any population needs to use the toilet frequently – every hour or so – and for many, the need comes suddenly and urgently. This applies to the elderly, the very young, pregnant women, those with incontinence, men with prostrate problems and anyone experiencing illness-related urinary issues.

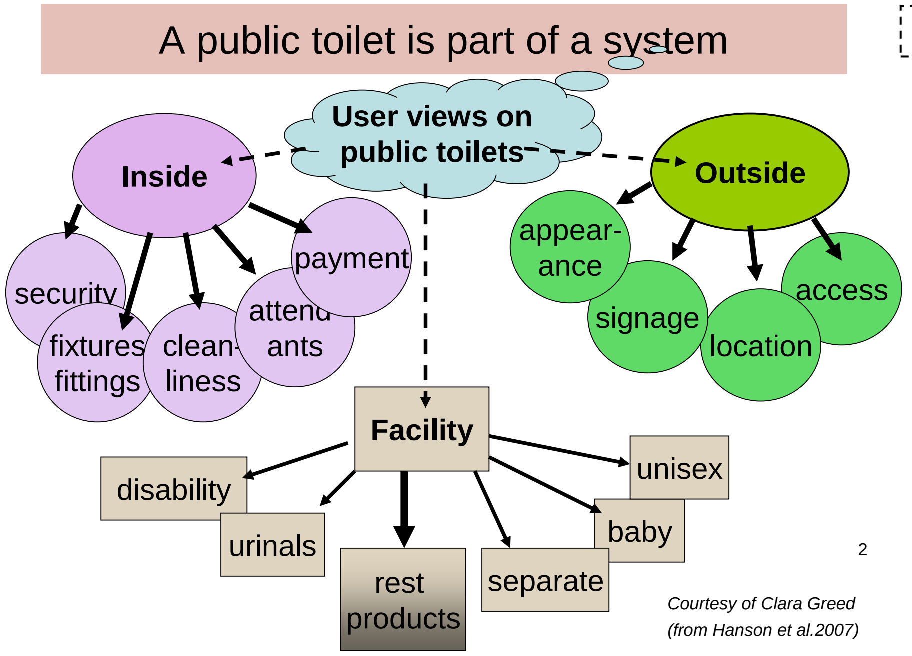
Public toilets present a challenge for every society, but they are a valued and essential service. Anyone who has had the sudden need for one knows that an available public toilet nearby is priceless. At the same time, authorities are cautious about investment and operational costs and want to provide toilets in the most cost-effective manner.

Many restaurants and shopping centres consider it good marketing practice to provide quality toilets to attract customers. Professional offices are now installing exclusive toilets and bathrooms for their staff in order to be competitive employers (*Financial Times*, Dec-08).

Consequently, there is a considerable difference in quality between traditional 'on street' public toilets, and the 'off street' toilets to which customers, guests and employees have access. If the government wants to get people out of their cars and onto public transport or back walking and cycling then public toilets are the 'missing link' in creating sustainable cities.

A chief from a district in Tanganyika (now called Tanzania) was asked what he found most interesting during his visit to the UK in the 1930s. His answer was: the clean public toilets! Things have changed since then! We will now discuss ways to think about planning and implementing sustainable public toilets.

5.2 - 2



A public toilet does not exist in a vacuum; rather, it is part of the urban system and a key component of the built environment. This chapter looks at public toilet issues, highlighting the public toilet block within the wider context of its place in the city in terms of location, distribution and daily and seasonal opening hours. Importance is given to social, economic, environmental and design considerations in deciding on the best solution for a particular locality.

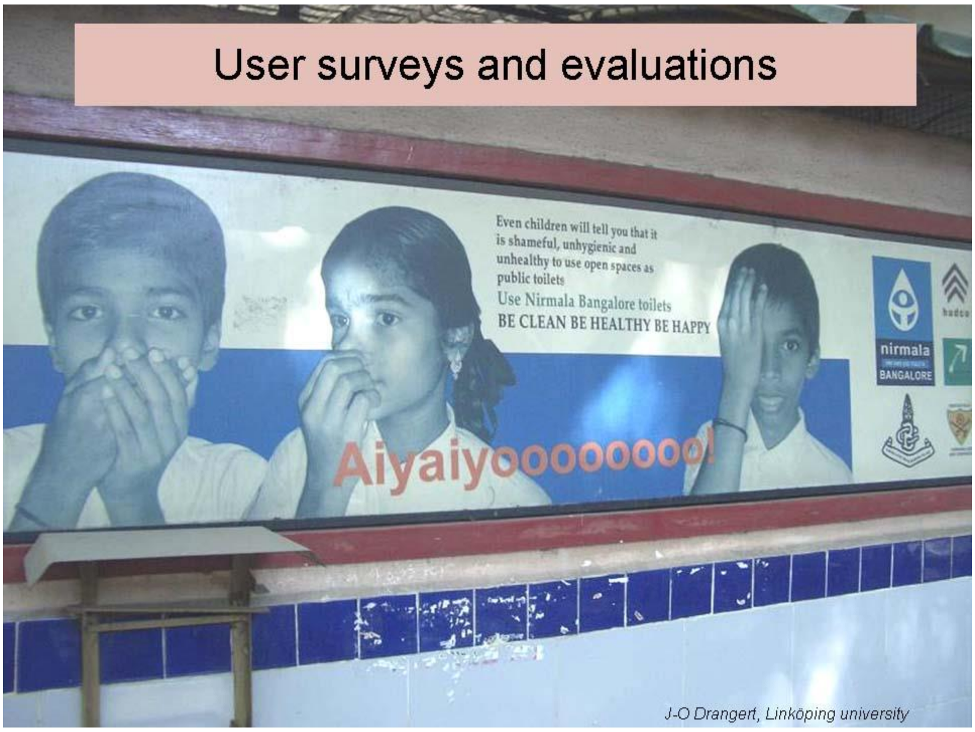
The demographics of different types of users require particular attention. This includes the needs of males and females, of an ageing society, of people with disabilities, and of other groups of people who do not fall neatly into abled or disabled categories, such as pregnant women, those with temporary impairments, physically large people, small people, children and babies. In creating sustainable, egalitarian and accessible public toilets, technical, design, hygiene, environmental, sanitation, maintenance and general management considerations are all important.

The mapping of the movement of people in an area, and estimates of their needs for a toilet or urinal can inform decisions on where to install facilities and how many of each kind. Gender, physical ability, and cultural aspects have to be taken into account. People are deterred from using public toilets if they are dirty or vandalised. Public toilets should be attractive, accessible and safe, so that needy users will visit them.

Even when a toilet block is available, there may be queues to enter and use the facilities. Waiting times may be considerable, especially at women’s toilets. Frustrated users may rush to another toilet in another locality or go to a café and order a coffee to be allowed to use its toilet. All this has much to do with poor municipal planning and the low priority often given to sanitation in planning!

Vandalism is a major problem in public toilets, particularly those without attendants or security to keep an eye on the premises. If the toilet is not clean when users enter they have little sense of responsibility for tidying up before leaving. This is especially the case if people are afraid of catching germs and diseases by touching the toilet; this is all more so if there are no hand washing facilities. Furthermore, toilet design can make access difficult – for example, if entrances are narrow or down steep steps. Internal space standards may also deter users, as in the case of very small cubicles.

We will now deal with each issue shown in the picture above.



5.2 - 3

Public toilets may be assessed from a variety of perspectives including users' experiences, social equality, economic viability, environmental impact, and design suitability. Since excretion is a sensitive cultural issue in most societies, social, cultural and settlement patterns have to be considered in order to provide insight and understanding of the needs and reactions of users.

The poster in the picture above shows users being concerned about appearance, smell, and speech in relation to excretion. Interviews with users can provide valuable information about their perceptions, which are often very different from the toilet providers' perspective. The provider is more likely to be concerned with how to save money than with social considerations such as accessibility and adequate levels of provision. Below is an example of a survey which could be used to obtain information from toilet users. It includes 10 closed questions and one open question

Protocol for interview questions about perceptions among potential toilet users

1. ***Do you know where the nearest public toilet is?*** **Yes / No**
   This question helps the researcher to identify if people know where public toilets are in relation to the area where the survey is being conducted.

2. ***Do you ever use it?*** **Yes/ No**
   This question identifies if the respondent use the local public toilet.

3. ***What kind of condition is it in?***
   For this question the research gives four possible responses. These are: Good, Adequate, Bad, Don't know.

4. ***Do you prefer to use private facilities (café, pub etc.)?*** **Yes / No.**
   This question helps to identify the type of facility people prefer.

5. ***Do you come to this area in the evening?*** **Yes / No.**
   This question establishes the proportion of respondents that may need to use the facility outside normal working hours.

6. ***Do you think there is adequate toilet provision in the evening?*** **Yes / No**
   This question then establishes the actual need.

7. ***Do you think this area has a problem with street urination?*** **Yes / No**
   This question assesses whether inadequate toilet provision at night results in street fouling.

8. ***Would you use an automatic public convenience (superloo)?*** **Yes / No**
   As many of the areas we look at only offered automatic public conveniences (APCs) this question establishes respondents' attitudes to such facilities.

9. ***Do you think there should be more on-street public toilets?*** **Yes / No**
   This question gauges people's views about the adequacy of current provisions.

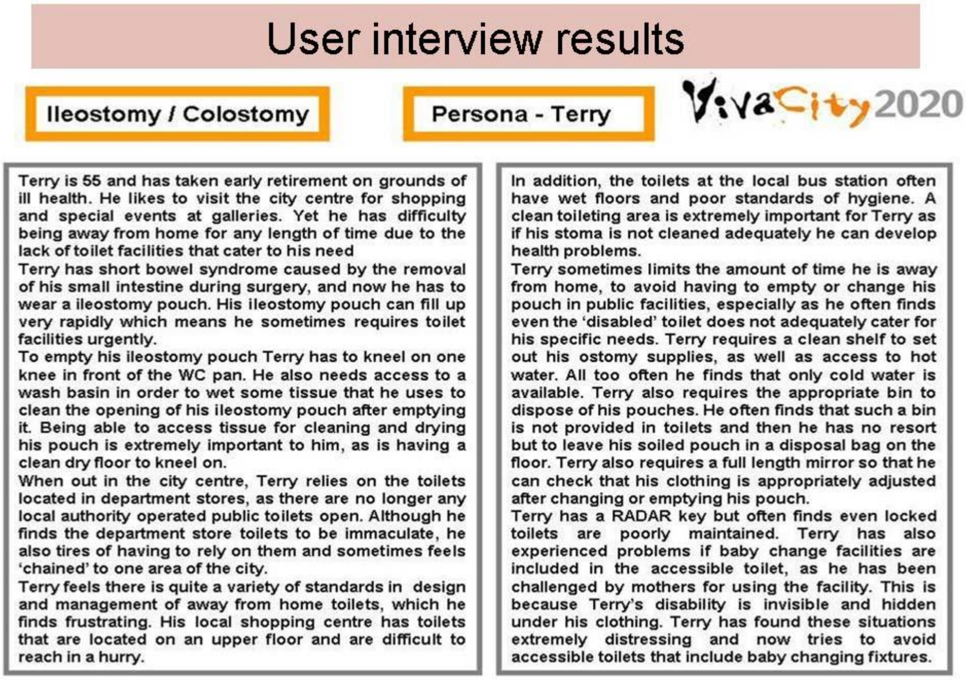
10. ***Would you be willing to pay for well maintained facilities?*** **Yes / No**
    Finally we ask about people's attitudes to paying to use a public toilet. A supplementary question could be included about how much people would pay.

To capture any information people may have wanted to express that was not covered in the survey we add a final open question.

11 Is there anything you would like to add?

See Hanson, J., Bichard, J-A., and Greed, C. (2007) *The Accessible Toilet Resource*. UCL, London

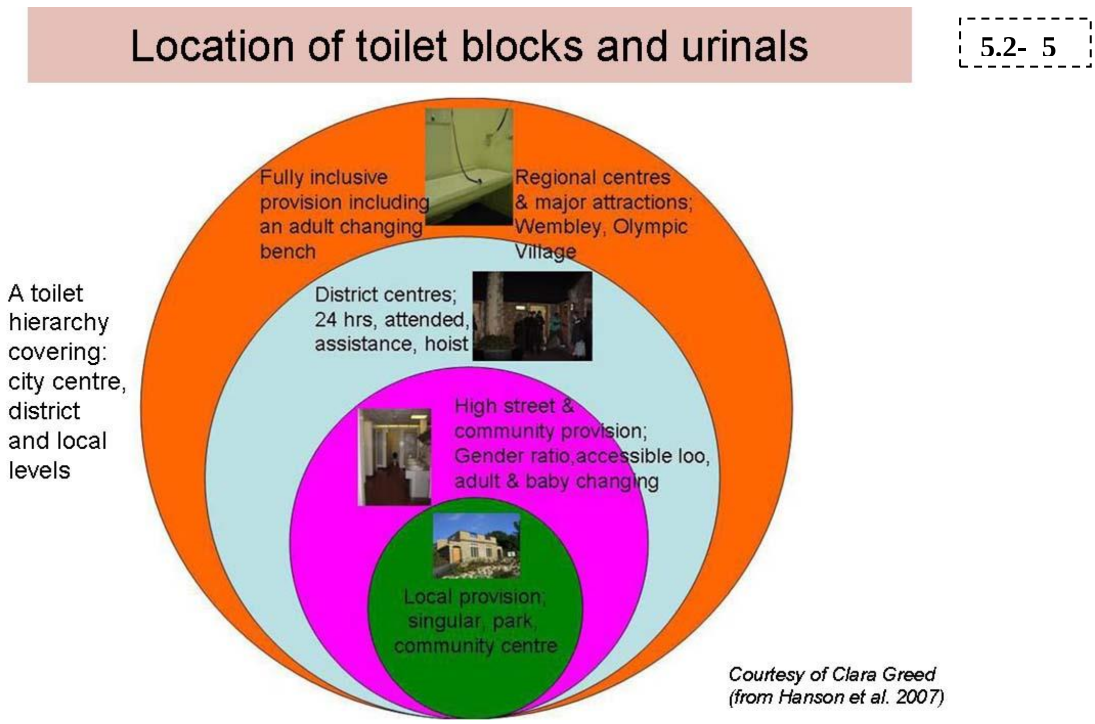
5.2 - 4



Courtesy of Clara Greed from Hanson et al. 2007

Most urban areas comprise people from several cultural backgrounds, both national and international. Longer interviews with various potential users of public toilets will enhance the understanding of the benefits and shortcomings of public toilets, as will in-depth discussions with focus groups comprised of particular categories of toilet users, such as the elderly, ethnic minorities and mothers with small children. The responses will help planners and other decision-makers to cater for groups with special needs when locating and designing public toilet blocks.

Interviews and focus-group discussions, where the group is challenged to discuss contentious issues, can be combined with various participatory methods such as mapping and problem identification exercises. A useful guide for interviews on sanitation issues is the handbook *Actions Speak* (Boot and Cairncross, 1993).



Ideally, a survey should be conducted to indicate the movement patterns and volumes of people in the area and the characteristics of likely users in terms of age, gender and disability. Very often, however, the location is determined according to where there happens to be an available empty building plot. We will never be able to put toilets everywhere – only cars seem to be allocated unlimited space, which is why they dominate our cities!

Research highlights the importance of looking not just at individual toilet blocks in isolation, but at the wider geographical context of toilet provision to seek optimal locations and distribution within the city as a whole (Greed, 2003: Hanson et al, 2007; BTA, 2005). A hierarchy involving city-wide provision (macro level), local district and neighbourhood facilities (meso level) and the requirements for individual toilet block design and buildings (micro level) is shown in the picture above.

In the face of numerous challenges to adequate public toilet provision, including vandalism, disrepair and closure, a new approach has been tried in the UK and elsewhere called the Community Toilet Scheme. The municipality pays an annual fee (at present some 600 pounds per annum in the UK) to pubs, cafés, restaurants, fast-food places etc. if they open their off-street toilets to the public. This approach eases the problem, but there are many groups that may be left out – some religious people cannot visit places where alcohol or non-halal food is served and underage children are not admitted to pubs.

There is still a great need for traditional public toilets. In Western European countries with no strong tradition of public toilets provided by the government – for example, Belgium and Spain – there is already a greater acceptance of the general public being allowed to use toilets in shops, cafes, bars and restaurants without buying anything. In France and Italy, however, owners increasingly seek to restrict use to customers as tourist numbers grow.

A temporary improvement can be to place portable toilet units or urinals in strategic places. Proper planning is needed to find long-term solutions. In the long run tt is usually better to invest in permanent toilet facilities that can meet the daytime needs of commuters, workers and shoppers as well as the night-time needs of drinkers and visitors.

The first step in developing a public toilet strategy is for the local authority to survey the existing public toilet provision. For example, existing, well-used toilet blocks should be identified and those that are under-used or in disrepair should also be noted with a view to reviewing their future. In addition, the survey should identify alleyways and secluded locations where there is strong evidence of street urination and therefore an unmet need – these are known to some as 'wet spots'.

It will be possible to identify optimal locations for new toilet blocks by using the results of these mapping activities and the following additional research:

- Observe and count levels of usage, footfall, levels and volume of demand.
- Conduct social surveys to find out who needs toilets in particular locations. Look at the gender, age, and disability characteristics of users, or would-be users.
- Investigate when the toilets are most frequently used in terms of day, evening, rush hours, night-time usage.
- Investigate the surrounding area, in terms of land use, 'attraction' factors such as tourist features, shops, railway stations, and other centres of human activity that are likely to increase the 'footfall'.
- Distribute a questionnaire to local community groups and to other relevant organisations. These might include public transport users, tourism groups, women's organisations, retail business organisations, disabled and elderly organisations, as well as police and crime-concern groups.
- Analyse findings, weighing different factors in terms of demand, characteristics of user groups, local patterns of activity and rush-hours etc. Work out the optimal location, opening hours, and use of resources, recognising that resources are generally limited in terms of finance, plot availability and ongoing management and maintenance costs.
- In association with the local city planning department, highways and transportation departments and other relevant agencies, take all these factors into account to produce a plan for city-wide toilet provision. You can then use this in considering district and local demands, including actual design requirements of individual toilet blocks.

References for calculating the minimum public toilet room fixtures:

- *Global Guideline for practical public toilet design* at the World Toilet Organization website
- Greed, C., (2003) *Inclusive Urban Design: Public toilets*, Architectural Press
- Hanson, J., Bichard, J., and Greed, C., (2007) *The Accessible Toilet Resource Manual*, University College of London
- The British Standards 6465 '*Sanitary Installations*' that give government standards on toilet provision, gender ratio, design and details.

Signage ~ how to find the place

5.2 - 6

Map showing public toilets

Photos courtesy of Clara Greed

People who are new to a city need to be able to easily find the public toilets. Some people may find it awkward to ask for the way to a public toilet. Others (mainly young men) may choose to pee in the open instead of asking. Some examples of how to guide users are given below.

Signs can depict commonly recognised female and male figures. The distinction between male and female toilets is not always obvious, and in some places, one really has to look twice in order to know which door to choose! Simplification can also go too far if artists are involved. Signs are culture-specific and the pictures (bottom right and slide 1) may be amusing to some but offensive to others!

Moreover, signs may be drowned in all the commercial ads that are on display in our cities. Separate signposts for important places seem to overcome this problem (left picture).

One may wonder why, in many communities, the public toilet issue is so poorly addressed by planners, other professionals and councils. Do planners assume that potential toilet users are shopping, eating out or drinking and that shops, restaurants, pubs and cinemas are therefore more appropriate providers of toilets? This is not always the case and planners should actively promote the allocation of space for toilet blocks, and make sure that town plans contain sufficient provision for public toilets. Decision-makers may underestimate the political gains of being champions of the public toilet issue. There is no taboo against addressing this need that we all have from time to time.

Some towns have taken the task seriously and issued maps of existing public toilets and urinals (top right). This is likely to happen only in towns with good-quality toilets. A map is helpful for tourists and other visitors, so why not show the public toilets in tourist brochures and maps? In some countries nowadays public toilet information is available by mobile phone, satellite navigator and the internet. For example the whole of Australia is now covered by downloadable toilet maps, and the centre of London is covered by ‘sat lav’ which enables tourists to find the nearest toilet on their mobile phone.

Access to the toilet and urinal

5.2 - 7

New urinal stands behind a toilet block. The urinal is being used for defecation during night hours when the main toilet block is closed

J-O Drangert, Linkoping university, Sweden

A toilet with accessories for many user groups

Courtesy of Clara Greed from Hanson et al. 2007

Once the overall toilet plan has been worked out, attention needs to be given to the specific design and operation of the individual toilet block. Before people can use a toilet they need to be able to gain access. Access relates to availability, opening hours and physical accessibility in respect of different toilet user groups (children, babies, teenagers, adults, elderly, disabled and so forth).

Availability is partially a question of resources, since a community can hardly afford to have a public toilet on every corner. It is also a question of what groups are being served by the available toilets. Long queues outside female toilets are too common to be acceptable. Research has shown that women, on average, take approximately twice as long as men to urinate, because of biological differences and clothing, and because at any one time around a quarter of all women of child-bearing age will be menstruating. Therefore, truly ‘equal’ provision will require a higher level of provision for women, In Japan, there are commonly twice as many public toilet facilities for women as there are for men. However, this must be adjusted to what proportion of men and women are present in the area served by a particular toilet block. Women comprise over 70% of toilet users in shopping centres and in social community settings, while men comprise over 80% of users in some sports, drinking, and leisure locations.

It is important to provide a range of toilet types within the block, to accommodate all types of people and to provide flexibility for changing demands. At least one disabled toilet should be provided wherever public toilets are installed. Baby-changing facilities may be provided within the women’s and men’s toilet block or provided as a separate facility between the two. If more than two urinals and washbasins are installed, one of them could be installed at a lower level to accommodate use by children and short people. Lack of provision of water inside the cubicles or beside the urinals for personal cleansing after using the toilet reduces access for some religious groups.

All users need to be able to get into the cubicle, turn around, and be able to sit on the seat, without their path being blocked by narrow doors, large toilet roll holders and sanitary disposal bins over-hanging the toilet seat. Many countries have inward opening doors in public toilets, and this immediately reduces the amount of space within the cubicle. In some cases the space between the edge of the door and the front of the toilet pan is so narrow that it is impossible to get in and sit down! Pregnant women have particular problems with getting into small cubicles and often seek to use the disabled toilet instead.

Some other people are not disabled but are too large to fit into or use a regular toilet cubicle. The growing proportion of citizens who are obese constitutes a new challenge for existing public toilets, but not for new ones since they can be built bigger. There is no excuse if members of the next generation find the door too narrow to enter or the cubicle too small for them to turn around! Poor design may also prevent people in wheelchairs from entering the toilet room, and the same goes for prams, and when you have shopping bags and other items that you cannot leave unattended outside the toilet or cubicle. Design rules need to be changed sooner rather than later to meet these needs adequately (as in the right picture).

Potential users may also be effectively deterred by untidiness, as shown in the left picture. This new urinal block is being used for defecation in the night, when the public toilet block is closed. Therefore it is important to provide at least one cubicle and urinal for night-time use when the rest of the toilet block is locked. In some localities there are no public toilets for women at all, or the facilities are so dirty and in such a state of disrepair that women decide to ‘hang on’ and not use them. Some women suppress the need to urinate for the whole day until they can use the toilet at home. This has health implications in terms of bladder strain and pelvic injury. Some women, especially the elderly, will not venture out at all without working out where the available toilets are likely to be found. They may decide not to travel out of their local area for fear of not being able to find a toilet.

Whilst these problems for women remain invisible and unheeded, male street urination is an obvious problem that local authorities have to deal with. In the evenings, porches and walls become urinals, and men do not seem to know that urine belongs to the soil, not to cement or stones! It would smell far less if men decided to pee on the soil under trees or bushes. Men have something to learn from dogs! In heavily built up areas, however, there may be no alternative, and the problem remains of the anti-social nature of urinating in public.

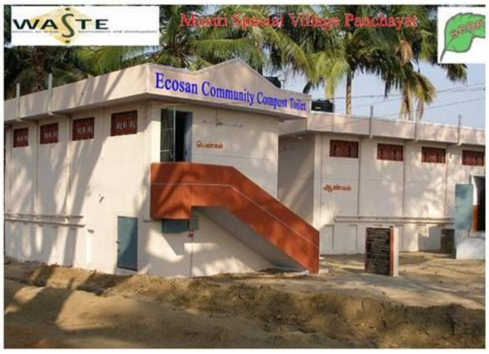
The toilet provider needs to weigh social, economic and design considerations when deciding what is the best option for a particular location. An existing substandard public toilet should not be closed down because it does not conform to modern access and design requirements, *unless* an alternative is made available. ‘*A second rate toilet is better than no toilet at all’*!

External appearance of the toilet or urinal

5.2 - 8

Excellent access to unisex street toilets in Waikato, New Zealand.

Courtesy of Clara Greed from Hanson et al. 2007



A block of urine-diverting toilets

Photo courtesy of Suburraman, Scope, India

The appearance of the toilet unit or urinal should be attractive to potential users. Architectural design could make the public toilet an interesting place. There is no limit to the aesthetic appeal of toilet blocks except conventional thinking. Why not become the town known to have the most fantastic public toilet blocks in the world? Toilet installations could be famous as public art and renowned architecture! Soft music could add value to the visitor’s experience. They can be combined with coffee kiosks (as in the Netherlands, for example the Groningen market square); with small shops selling souvenirs (such as in Beijing’s Tiananmen Square); with tourist information centres (as in Arizona, USA) or with local park facilities.

Toilet blocks should be open to light, clearly visible, with good circulation space around them to create a safe environment for users. Hiding public toilets down dark alleyways or behind bushes is asking for trouble! Some toilet providers plant low prickly bushes around toilets to prevent graffiti and vandalism. Trees can be also included, provided the branches do not overhang the toilet building, enabling vandals to climb on the roof. The two pictures above show good examples of an inviting, tidy entrance with clean floor and fair security. Some people do not like being seen entering a toilet, but this can be remedied more by public education than by design.

5.2 - 9

Toilets cost money. If the toilet block is kept clean and well maintained, users will appreciate it and be prepared to pay for the service, but the opposite is true if the unit is dirty and untidy. A public toilet is a service to the public. It is not an issue of human rights, but of human dignity. Thus, the quality of service is important.

An affordable direct or indirect fee for users requires that the costs for buildings, fixtures and staff are kept as low as possible while ensuring proper operation. We pay the cost for nice toilets in shopping centres as part of the bill when we purchase goods or services. We pay for access to off-street public toilets through local taxes. The council may pay for access to toilets in pubs, cafes, restaurants, fast-food places etc. through an annual fee (600 pounds per annum in the UK) to private operators if they make them available to the public. The famous Sulabh toilet complexes all over India charge 1 or 2 rupees to use the toilet. The income is used for upkeep of the block and to pay attendant salaries. In Durban, South Africa, slum dwellers pay a small monthly fee to support the janitor who takes care of their community toilet block. Overall, willingness to pay varies with the acuteness of the need. In many public toilets in Stockholm the franchiser charges US$1.50 even if you only want to pee. With such an exorbitant fee the needy user thinks twice – if there is time for it – before entering the facility. It is more economical to go to a café and have a cup of coffee for almost the same price – and gain access to a decent toilet.

Charging people for using the toilet is often seen as a means of deterring anti-social users, but at the same time payment barriers can reduce accessibility to bona fide users and cause particular problems for children, the poor, and the elderly. Controlled entrance by turnstiles causes major problems for people carrying luggage, pregnant women, larger people and anyone (especially foreign tourists) who has not got the right change (coins) to open the turnstile. Once money is involved the challenge of accountability for fee collection comes to the fore. We discuss this more in connection with the next slide.

Management inside the toilet block

5.2 - 10

Cleaning of toilets

Dutch toilet with slogan

J-O Drangert, Linkoping university, Sweden

Designing and building a public toilet block is only half the battle the other half is to manage, clean, repair and maintain it over many years. The municipality has the mandate to identify the need and decide on who is to provide or build the physical structure and how to manage and operate it. The block may be managed by an individual or a franchisee or municipal staff. Management issues are less of a problem when dealing with customer toilets in restaurants and pubs, since there is someone taking care of cleaning and surveillance for the whole building. In conventional public toilets, an attendant often does the same job, but nowadays many facilities are unsupervised with no staff on the premises.

A municipality may avoid a number of challenges by contracting the operation of an off-street toilet block to the highest bidder. A contract between the municipality and a franchisee may run for three years, during which the municipal can make inspections to check if the contract is being honoured. It becomes the contractor’s problem to ensure entrance fee collection. He or she may solve the problem by making it a family business or by installing a complicated entrance gate to count the number of visitors. A franchisee is in a better position than municipal staff to judge whether a customer should pay or not. He or she can negotiate with poor customers, drunkards and potential vandals on the conditions for using the toilet.

Public toilets do not need to be stand-alone single-function buildings hidden away from public view. The operator is working in a competitive market and better service means higher incomes – but also higher costs. Usually, the toilet block is profitable since customers are prepared to pay. The operator may also offer related services such as showers and washing facilities, chairs and benches outside, a coffee shop, a public telephone, free condoms, a newspaper stand, and even a bank teller machine attached to the toilet block. They may sell toilet-related necessities, especially for women, such as cosmetics, soap, tampons and the like.

Such a multi-functional block blurs the preconceived ideas of what a toilet block is and may make it more attractive and cost-effective. Also, the attendant could gain prestige in the community.

Janitors, attendants and staff need recognition to carry out their work diligently. In Singapore, janitors are trained in some maintenance procedures and duly certified (www.worldtoilet.org). In South Africa, franchisees are trained in providing information to the users (www.toiletshop.co.za.)

Management includes ensuring all components are kept clean at all times (top and bottom left). In some countries, records are kept concerning cleaning intervals, disinfection and maintenance and are available for inspection by supervisory staff. The dignity of attendants can be raised by building attractive and easy-to-clean toilet blocks. This has been proven for cleaners of toilets in shopping centres and well-known restaurants. Again, it is a management issue whether toilet cleaning and maintenance are given a high priority or not. The fact that a few users misbehave is no argument to let the toilet remain in a poor state to the disadvantage of well-behaved users.

Good public toilet management involves good maintenance and cleaning regimes, but also involves informing users about proper public toilet use. This could be built in with a printed flyer in the porcelain urinal that encourages men to pee on it. In this spirit are signs with a text that catches the interest of the visitor: “Use me well and keep me clean, I shall never tell what I’ve seen” (right) or “Please leave this toilet as you would expect to find it”. Another example is shown on picture on page 3. Public education through schools, television, and newspaper campaigns could raise the percentage of those who wash their hands after using the toilet above the present 30%. Many people do not flush, perhaps because the nob is dirty. A solution could be to have a flush operated by pushing the nob with the foot. A few people see public toilets as uncontrolled spaces which they vandalise. Therefore, we need to foster a new culture of care about what is happening while we are in the toilet block.

Some toilet providers tend to favour automatic toilet cleaning systems and high-tech solutions because they cut down on the costs of paying toilet cleaners, attendants and security staff. But this may be a false economy in the long run. The existing single unit public toilets that automatically clean themselves mechanically are hardly the answer to the management challenge for two reasons. They are very expensive and they require a constant and high-pressure supply of water. Moreover, many people are scared to use them, and wonder what would happen if the washing starts too early or if the door opened unexpectedly!

Five such toilets were installed in a borough in London at an annual running cost of 85 000 pounds, and it turned out that each visit to the toilet cost the municipality 8 pounds or US$12! Experience shows that it is often cost effective to hire an attendant, since vandalism is kept down and the number of visitors is higher when the place is kept clean and feels secure. Research has shown that attendants can reduce vandalism and anti-social behaviour by 60% (Greed and Daniels, 2002). Indeed high-tech solutions, especially automatic ones, frequently break down and then the whole unit is out of order and inaccessible. With traditional toilets, one malfunction does not shut down the whole facility and usually it is still possible to use the toilet until the plumber arrives.

Security and privacy

5.2 - 11

Ultra-blue light to prevent syringe injection

Courtesy of Clara Greed (from Hanson et al. 2007)

Less privacy may reduce vandalism & improve safety

J-O Drangert, Linkoping university, Sweden

A public toilet has to provide personal security and reduce the risk of psychological and physical attack. When it comes to physical security, the responsibility falls squarely on the operator. He or she provides the lighting, not only illuminated entrances and exits, but also walkways, paths, parking spaces and other areas where the public may require access to the toilets. Lighting should be sufficient to avoid trips or falls, to enable people to see what they are doing, and to discourage vandalism and the creation of areas for hiding. Walls, partitions and decorations of trees and plants should be selected so as to prevent the creation of areas of concealment. Prickly bushes planted alongside the outer walls can deter vandals and graffitists, and provided they are low they will not restrict visibility.

As for cubicle design, people like to know they can shut the door properly and feel secure, but at the same time they do not want to feel they will not be able to open the bolt from the inside. Therefore good design of locks, bolts, levers and handles is very important. On locking the door an indicator should change from ‘green’ to ‘red’ which is the internationally accepted sign to show if the cubicle is ‘vacant’ or ‘engaged’.

The gap under the door should not be so large that people can see what is going on inside, but a small gap is acceptable for cleaning purposes. Simple louvers (bottom right) allow daylight and air to pass through the cubicle. The user can see out to some extent but outsiders cannot see inside unless they lie on the floor or street. Such louvers can be made of metal, wood or cement.

The presence of a vigilant attendant contributes a lot to how safe users feel and reduces the opportunity for vandalism and antisocial behaviour. However many people have difficulty urinating if the toilet attendant is too near or if the attendant is of the opposite sex. Some men suffer from paruresis (piss-shyness) and prefer to use an enclosed cubicle where no-one is watching them, whereas many women are happy to have a woman attendant in the toilet block as she can also keep an eye on children or push chairs whilst the mother is using the toilet.

Cubicles, urinals and mirrors should be sited away from the line of sight of people especially if there is a separate waiting area. It should not be possible to look directly into the toilet, or at the urinals when passing the door, and so the door needs to be located in a position that prevents this or a screening wall may need to be installed. It is particularly important to keep facilities for women and men separate in public, on-street locations where users are complete strangers.

There are different requirements for men and women. In many societies men are “allowed” to be seen in a peeing posture (left picture) or squatting behind a long robe. This would not be possible for women. Ideally all toilets should provide secure levels of internal privacy and separation between facilities for women and men. Social, cultural and religious factors, including modesty need to be taken into account. For example, in tropical locations, in order to increase ventilation it used to be commonplace to leave a space at ground level around the toilet so the outer wall did not reach the ground. However this deterred many women from squatting down and using the toilets as they feared they would be seen by men passing by outside. This problem could easily be solved with louvers. It is also not advisable, particularly in traditional societies, to locate the women’s toilet directly next to the men’s or to have a situation in which women have to go past the entrance to the men’s toilets to reach their own toilets. The reasons are women’s concerns about personal safety, about having their path blocked, and about being accused of mixing with males who are not family members.

A special challenge may relate to drug taking and sex in public toilets, activities which have a strong impact on normal users. Visibility and exposure may counter such behaviours and make them less likely to occur – for example in the urinals shown in the left picture and in busy shopping centres. Some toilets have ultra-blue lights, which make it impossible to find the veins for injecting drugs (top right). However, blue light also creates reduced visibility for common users checking on hygiene and safety conditions in the toilet. This is particularly problematic for those checking for blood and other discharges in the urine. Such lighting solutions are not recommended, and drug addicts have found that if they mark their veins with highlighter pens they can still see them under ultraviolet light. Ultraviolet lighting also reduces the sense of personal safety which is so important within the toilet.

Cleanliness

5.2 - 12

A brightly lit, easy to clean toilet in which all cracks are sealed to prevent stagnant urine and water

Courtesy of Clara Greed from Hanson et al. 2007

Water "tap" for washing hands using 0.1 litre per hand wash

J-O Drangert, Linkoping university, Sweden

Talking about cleanliness, people are put off by what they see. We find it disgusting if there are faecal stains left in the toilet bowl, or if the previous user did not flush. Urine left on the sitting ring or on the floor is quite disturbing, and even a clean piece of tissue paper left on the floor can be a problem. The ideal, therefore, is an attendant who checks such things between each use! But worse still are the invisible germs: the pathogens and bacteria that lurk in dirty toilets.

In many public toilets hygiene standards are far below acceptable safety levels, and therefore users often take special precautions. They use a piece of toilet paper to open the door to the cubicle, avoid sitting on the toilet seat or cover it with toilet paper, and also use paper to turn the water tap on and off. Users may bring their own toilet paper, because there is likely to be none available or it is stacked in a dirty container that only dispenses one sheet at a time. This is particularly important for women, as many 'blot' their most intimate parts after urination whereas men generally only use toilet paper after defecation. To dry their hands, toilet users may simply shake them in the open air, wipe them on their clothing or put them in their pockets. This is because the towel provided is too dirty, the paper towels have run out, or the electric hand-dryer does not work. Many public toilets lack paper or hand drying towels so people carry 'wet wipes' and nowadays also anti-bacterial cleansing gel with them.

Hand washing is probably the most important health-preserving measure, yet only about 30% of people wash their hands after using the toilet. Washing is made more hygienic with self-closing delayed taps or touchless electronically controlled taps. The same benefit could be achieved with the simple device shown in the picture to the right. The lower section of the container handle has been plugged and a small hole pierced just above the plug. When the container is tilted forward (with a push of the user's foot or hand) water enters the handle and when the user releases the container it moves back to its equilibrium position. Water pours out slowly from the hole in the handle until the handle is empty. The next user tilts the container and water enters the handle again. The container has to be filled with water regularly, but so little water is used for each hand wash that the container will last for 50–100 washes! Our perception of how much water is needed is often exaggerated. A striking example comes from Niger, where the widespread river blindness disease can be prevented by washing the eyes several times a day. When asked how much water one wash takes, affected villagers responded "*at least one litre and we cannot afford that*". Practical trials showed that they needed only 0.1 litres. This surprised them and they became convinced that they actually had enough water to wash their eyes frequently!

Toilets should be designed from the outset to facilitate the easy cleaning and maintenance of fixtures and fittings. Architects should consult with cleaning experts as to whether their design is easy to clean. There should always be a slight gradient of floors towards a central drain to prevent puddles of stagnant water. There should be no ‘gaps’ or cavities between pipes and the floor, to prevent standing urine or water and dirt. This will also reduce bad odours in the toilet block. Smooth and hardy surfaces on fixtures and floors make cleaning easy, but floors should not be too smooth or people may slip. Ideally, public toilets should match the standard that is common in toilets in shopping centres. These are often spacious and well lit, and are visited by a constant flow of customers, which in itself improves user behaviour. The facility is usually tiled and attended between each use. Whilst white or lightly coloured tiles give an airy feel to the building, they are more likely to be subject to graffiti than textured tiles in darker colours, but these, on the other hand are harder to clean. For people with visual impairment coloured tiles that help differentiate the walls from the door are helpful. There are good and bad results for every toilet design decision!

There is anecdotal evidence that men do not perform as well as women when it comes to ‘leaving the toilet as clean as when you entered’. In particular they may spray the seat, or leave the seat up after using the toilet. This indicates that there are too few urinals in relation to toilets, and that the toilet in the cubicle is being used as a urinal. Drunken men complicate cleanliness of public toilets and urinals by being sick and peeing all over the floor.

Fixtures in the cubicle and urinal – and vandalism

5.2 - 13

It is generally true that the cleaner a toilet is, the more careful the users are likely to be. In contrast, if the toilet cubicle is dirty there is great risk of misuse and vandalism. Again, the role of an attendant becomes crucial. If flush toilets are installed, there must be a constant supply of pressurised water, otherwise misuse is invited as seen in the pictures. The problem of dirty toilet seats may be solved by using squatting-type toilets. In fact, squat toilets are the most ergonomically effective and also the least likely to be vandalised, and they can be used by both men and women, who can choose to stand, hover or squat over them as they wish. Unfortunately they are not popular because they are seen as old-fashioned and backward. For example they are being phased out in France where 'Turkish toilets' used to be widespread. In developing countries, upright toilet bowls are seen as a sign of modernity. Still, many toilet blocks in the world contain both options, for example, in Japan modern high-tech toilet blocks are likely to include a predominance of squat toilets.

Space is needed for manoeuvring, turning, removing and replacing clothing, and for hanging bags, brief cases or baggage. Hooks, shelves or other such devices should be provided. Also, a can with a lid to dispose sanitary pads saves the users from throwing them in the toilet. A trash bin in the cubicle makes most users throw trash there instead of in the toilet or on the floor. In this way potential blockages are avoided. But care should be taken to ensure that disposal bins in cubicles are kept clear of the toilet itself, so that women in particular can sit on the toilet seat without rubbing against the bin, as is the case where sanitary waste bins are squeezed in between the wall and the toilet pan in women's toilets.

Vandalism in public toilets is widespread (pictures). The local authority usually responds by closing down the facilities altogether. A better alternative would be to have better surveillance and a toilet attendant. Also, all installations in the cubicle and urinal room have to be able to withstand misuse and vandalism, and therefore all fixtures, accessories, and surfaces should be constructed of durable materials resistant to heavy usage, excessive weight, and possible abuse such as spray painting. Estimates suggest that the initial construction cost is only 40% of the financial cost of providing a toilet over a 10 year period. Therefore, the extra expense of providing good fixtures will reduce the maintenance costs, and be cost-effective.

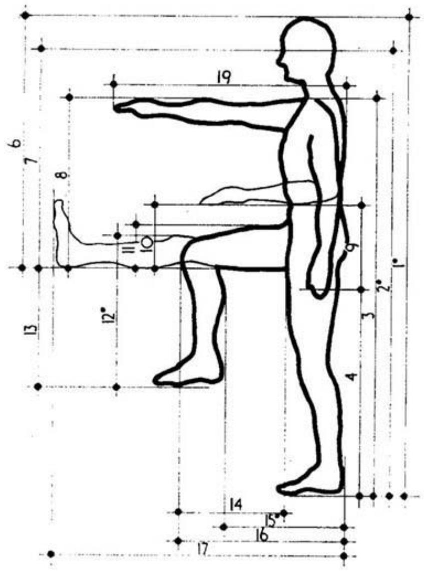
Careful thought should be given to the use of materials, as porcelain is the most likely to break and be vandalised, whereas aluminium, steel and other metals are more durable, and modern hardened plastic and polyurethane materials are lighter, cheaper and easier to install. Toilet bowl breakages often occur in countries where people have been accustomed to squat, so they squat on the toilet seat, causing the toilet pan to crack and collapse unless it is very sturdily built. Therefore, local habits and cultural traditions must always be taken into account when choosing fixtures.

One of the most important features is ventilation. Natural ventilation occurs through windows, doors, louvres or other openings to the outdoors. The risk of causing bad odours in the vicinity is present, and a vent pipe can send gases higher into the air where they are diffused before reaching anyone's nose. A vent pipe should reach at least two metres above the highest point of the roof(s). Winds and large differences in temperature between the indoors and outdoors improve the effectiveness of the vent pipe. If the temperature is low during the night or part of the year, the outside part of the vent pipe should be insulated (see slide 2.7-6).

If the cubicles are mechanically ventilated (using an electric fan), the rule of thumb is that air should be exchanged 15 times per hour, which means that one user per four minutes will be taken care of. But a conventional water-flush toilets do not prevent the smell from dropping faeces and released gases, and the odour will stay on for four minutes, even when the toilet cubicle is well ventilated. A dry toilet, on the other hand, is constructed so that a downward draft into the collection chamber will prevent the smell from spreading in the cubicle! (See slide 2.7-5).

Unisex and baby-friendly facilities

5.2 - 14



Women and men have quite different dimensions and ‘reach’ in terms of length of arms and legs (Goldsmith, 2000)

Baby friendly unit

Courtesy of Clara Greed from Hanson et al. 2007

People are shaped differently and their different requirements need to be considered in the design of toilets and urinals. In private modern homes, this is taken care of by having rather large toilet rooms which cater for most human sizes. The same should apply to public toilets. With an aging population and obesity increasing worldwide, we anticipate a trend towards larger cubicles for all. But it is a fact that most cubicles built in poor areas are very small. If public toilets are to become popular they have to have rather spacious cubicles making the visit comfortable.

Women are likely to be accompanied by babies and small children and they may have to bring in pushchairs and baby-changing bags when they go into public toilets. Ideally, disabled provisions should not be mixed with baby-changing facilities, and they should be separated out particularly in areas of heavy demand to avoid conflict and resentment between disabled users and young parents with babies. With rising expectations that men take more responsibility for children they will also require more space. In fact, new Swedish public toilets often have space for changing nappies in the male section as well as the female section.

Unisex toilets are often suggested as a means of reducing queues and creating greater flexibility. However, they do not increase overall capacity and if they reduce the queues, this could be because women are reluctant to use them. Unisex facilities can be unattractive to women because men are more likely to ‘spray the seat’ and have less hygienic toilet manners.

In some communities, people may feel awkward and out of place when they have entered the wrong toilet section. In other communities, sharing toilets with complete strangers of the opposite sex may result in the loss of a woman’s ‘reputation’ and have serious religious and moral implications. In locations where demand is heavy, unisex toilets are unlikely to reduce queuing and may lead to more frustration, particularly from men who are not used to queuing. They are simply not a practical solution for high-use locations. There are many sexual and social problems associated with situations where toilet cubicles and internal washing, drying and queuing space is shared by the sexes.

Another argument for introducing unisex public toilets is to keep the investment costs down. There is a trend towards toilets in workplaces becoming unisex, and this may eventually spread to general public toilets. Individual unisex toilet cubicles do have a place, for example in a local area where there is a low-level, but essential demand for toilet facilities (such as a workplace). But acceptance depends on how the toilets are designed. Because of privacy problems employees prefer to have self-contained separate compartments with integral washing facilities that open separately onto a corridor rather than a conventional set of toilets made ‘unisex’. In particular, women feel very uneasy if there are gaps above and below the cubicle walls and doors, and they experience embarrassment about toilet noises and smells and shared washing facilities.

However, unisex toilets which also include disabled facilities and baby-changing provisions are popular and appropriate in small coffee shops and other ‘off-street’ locations in small businesses. In the case of toilets for disabled people it is important to have unisex facilities in between the Ladies and Gents sections so that, for example, an elderly man can go into the toilet with his disabled wife to help her on the toilet. In contrast Automatic Public Toilets are a less popular form of unisex toilet, and only meet a limited level of on-street public toilet demand. They should not be seen as a substitute for traditional male and female public toilets in areas of high demand for reasons explained earlier. Therefore it is always important to consider the likely type of users and their needs before deciding if a unisex solution is appropriate.

Urinals

5.2 - 15

There are urinals for both men and women. Many attempts have been made to develop a suitable urinal for females (top and bottom left). The top one is a squatting type where the user faces the wall and keeps her feet on the blue-tile foot rests. The urine runs down the slanting groove to a collection tank. The bottom one is used for urinating standing up. The difference between the sexes is that men can direct the urine manually, while women cannot. Women need to be able to either sit or squat in a manner in which they can relax in order to completely empty their bladders. Whether men sit or not seems to be guided by tradition as evidenced by Muslim men using the squatting position while urinating

'Hovering' over the toilet seat, or 'flexing' over a female urinal causes muscular tension, and indeed it is only a viable option for those who are fit and healthy. Additionally, women's urinals have proved impractical in dealing with menstruation and also women need to decide whether they need the toilet for urination or defecation before choosing a urinal (which they are not accustomed to doing at present). Cultural traditions and biological facts make the design work more difficult.

It is well known that visitors to bars and pubs drink so much that they have a greater need to urinate in the evening and night hours. If no urinal is available they will probably relieve themselves indiscriminately. This is particularly the case with young men. As a result male street urinals have been introduced in many cities (top right and 5.2- 11), some of which retract back into the ground during the day time. There is rarely similar provision for women, and nowadays some young women will squat in alleyways out of desperation. This is still socially unacceptable, and it is dangerous in terms of personal safety and sexual harassment for them to urinate in public. Therefore a better solution is better provision for all.

In the daytime urinals are still the main kind of public toilet. They are not necessarily well-designed or environmentally sustainable. Two particular problems with water-flush urinals are the wastage of water and below zero temperatures. Previously, urinals with a constant flow of flushing water routinely used several cubic meters of water per day. Nowadays, urinals are fitted with devices to flush only after use. A general experience, though, is that they often leak. Even a small flow, slightly more than dropping, will waste hundreds of litres per day. The problem of water freezing requires some kind of heating – adding to investment as well as running costs – or a waterless urinal.

A waterless urinal with a smooth surface (porcelain, steel, or good paint) and sufficient slope for the drainage pipe is odour-free (bottom right). These are the two reasons why the authorities in the water-stressed Karnataka State in India made waterless urinals mandatory in five-star hotels and office buildings in Bangalore. Vacuum urinals are also odourless since the urine is not mixed with water and the drainage pipe is closed after use. However, their operation is more demanding and therefore less appropriate in many situations.

Differently abled persons

5.2 - 16

Photo Courtesy of M. Subburaman, Scope,. India

People are living longer, which increases the demand for facilities for disabled persons. There is also a greater emphasis on people with disabilities getting out and about, rather than being confined to care institutions or their homes. Society has moved from a medical view of disability, in which it is seen as the disabled individual's 'fault' that they cannot get around because of their disability, to an architectural view of disability in which it is seen as the fault of society that people cannot get around. Particular blame for the inaccessible nature of the built environment is put on the urban designers, town planners and architects. Therefore the emphasis nowadays in urban policy is upon creating accessible, equitable and comfortable cities and environments for everyone – and public toilets are seen as a key component in this process.

For quite some time, disabled persons have been catered for in town planning and toilet design. Now there is a trend to make provisions for less able persons, that is the dis-enabled (those who are restricted by limitations in the design of cities and buildings) both at the entrance and in the cubicle. The picture shows an affordable entrance with a ramp and railing facilitating access to the toilet. As we grow older the problem of sitting and rising increases, and the same goes for overweight persons. Some companies produce special gears such as handles, lifting devices and railing,to make it possible for disabled persons to perform inside the cubicle on their own (see 5.2- 7).

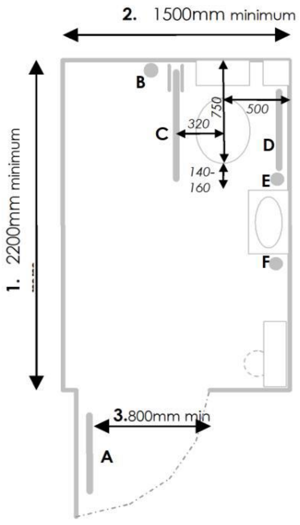
The VivaCity report, *The Accessible Toilet Resource Manual* (Hanson et al, 2007) contains useful information about technical standards and survey results (see 5.2- 4). The authors developed a toilet audit tool for technical standards for toilets (see below). Such a manual should be used when assessing drawings and designs of new toilets before they are built, in order to reduce mistakes.

The Accessible Toilet Resource Manual

Place:

Date:

Auditor name:



Dimensions:

1. Depth 2200mm min y/n? ______
2. Width 1500mm min y/n? ______
3. Door 800mm min y/n? ______
4. Grab rail heights:

A	(horiz. Door)	680mm	y/n? ______
B	(vertical)	800mm	y/n? ______
C	(drop down)	680mm	y/n? ______
D	(horizontal)	680mm	y/n? ______
E	(vertical)	800mm	y/n? ______
F	(vertical)	800mm	y/n? ______

5. Grab rail lengths:
A,B,D,E & F 600mm long y/n? ______
6. WC pan height (top of seat) 480mm y/n? ______
7. Basin height: 720 –740mm y/n? ______
8. WC pan from side wall? 500mm y/n? ______
9. WC pan from back wall? 750mm y/n? ______
10. Drop down to WC pan? 320mm y/n? ______
11. WC pan - basin 140-160mm y/n? ______
12. Height of basin mirror 1600mm min (to top) y/n? ______
13. Height of wall mirror 600mm – 1600mm y/n? ______

Observations:

14. Suitable access route to WC? Y/N
15. Suitable signage to WC? Y/N
16. Is WC near to male and female WCs? Y/N
17. Doors on route easy to open? Y/N
18. WC door easy to open? Y/N
19. Outward opening door? Y/N
20. Lever type door lock? Y/ N

21. Is there a colostomy shelf? Y/ N
22. Is there a General use shelf? Y/N

23. Backrest/cistern to lean on? Y/ N
24. Toilet paper single sheet dispenser? Y/ N
25. Lever tap to basin? Y/N Automatic tap Y/N
26. Soap facilities within reach? Y/ N
27. Paper towels within reach? Y/N
28. Grab rails appear grippable & sturdy? Y/N
29. Drop-down rail easy to use and sturdy Y/N

30. Alarm system? Y/N
Cord to floor? Y/N
Reset button within reach of WC? Y/N

31. Flush lever on the transfer side? Y/N
32. Is the transfer space clear of obstructions? Y/N
33. Left or right hand transfer? L /R /neither

34. Is there a waste bin? Y/N
35. Is there a sanitary disposal bin? Y/N
36. Is there an incontinence pad disposal bin or nappy bin? Y/N

37. Is there a coat hook at suitable height? Y/N

38. If there is a sanitary dispenser, easy to use and at good height? Y/N
39. If there is a hot air dryer, is it at good height and useable? Y/N

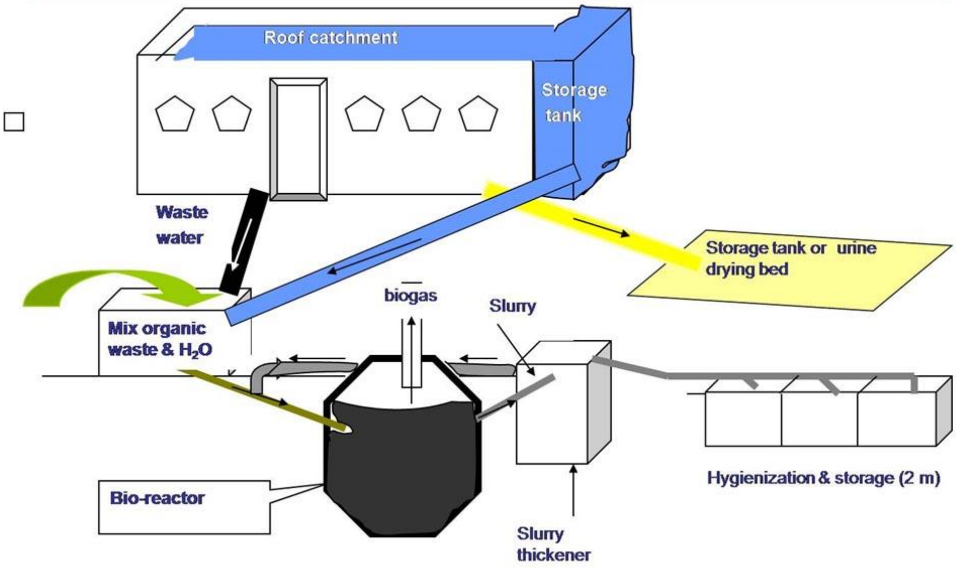
40. Is there a standing height basin to supplement hand-rinse basin? Y/N
41. Have Baby changing facilities been included in the WC? Y/N

42. Lighting good? Y/N
43. Good contrast in internal decoration? Y/N
44. In your opinion, is this an accessible toilet? Y/N

45. Further comments:

Where does urine and faecal matter end up?

5.2 - 17



J-O Drangert, Linkoping university, Sweden

Users rarely ask about where excreta end up – once defecation is done, they go back to other business. However, the toilet and urinal will not be sustainable unless the collected matter is disposed of in a safe and productive way. The amount of urine is huge, and faecal matter, if flushed away, is an even more voluminous discharge.

Instead of being utilised, excreta from toilets usually end up in overflowing septic tanks or in sewers which take it to a treatment plant. Designs need to view urine and faeces as resources rather than as waste. An NGO in Trichy in India (www.scope.org) has built public toilet blocks with dry urine-diverting toilets which use the urine as a fertiliser and the composted faeces as a soil conditioner. The Borda group (www.borda-sa.org) has done interesting work in Asia on a combination of biogas production and some treatment of the effluent, so that it can be safely disposed into drainage ditches or preferably agricultural fields. They also make use of all organic waste in the area to feed the biogas digester. We provide details about such toilet complexes in the biogas chapter (Chapter 5) and the greywater chapter (Chapter 4). .

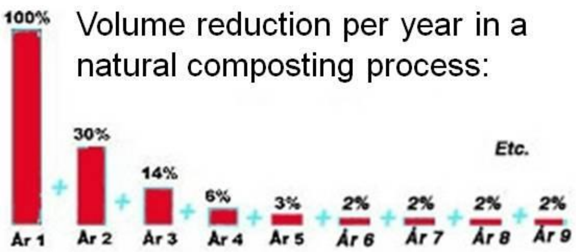
The picture above shows a self-sustained sanitation block where rainwater is collected for hand washing and ablution. If rainfall is low, well water may be a supplementary water source. The design of this toilet block allows for recirculation of valuable nutrients. Urine from the urine-diverting toilets and waterless urinals is collected and delivered as fertiliser to neighbouring farms. In this example wash water, ablution water and blackwater (if dry toilets are not being used) go into a biodigester together with organic waste. The treated slurry is also a good fertiliser (See Ch 5. on biogas). The toilet block is independent of piped water supply and sewerage, and can therefore be used in a variety of locations. It is self-contained, and requires minimal expenditure on infrastructure. Also, in some places there is a market for selling the urine.

To make toilet blocks more environmentally sustainable it is important to reduce electricity usage whilst balancing this with the provision of adequate lighting and ideally hot water for washing. Solar- and wind-powered electricity systems have been used in Australia and other countries.

The operation of such a toilet block requires trained staff, but we should not overstate this aspect since the technology is quite adaptable to changing conditions. Millions of Chinese farmers run such small biogas plants successfully.

Public toilets in remote locations

5.2 - 18



Courtesy of Compostera AB, Sweden

Public toilets in areas with no water supply or sewer connections represent a special case. No regular supervision is possible for toilets on walking trails, at roadside rest areas, and on small beaches (top-right). Such conditions require waterless toilets that seldom need to be emptied. These toilets have to be self-contained, odourless, and able to withstand some abuse.

The CompostEra company (www.compostera.se) has simplified the Clivus Multrum idea and developed a dry toilet with the following characteristics: the toilet room (top left) is tiled and easy to keep clean, the robust pedestal of wood with a plastic ring can resist some misuse, and the paper roll is difficult for visitors to take away.

Under the toilet room is a collection tank (bottom right). Prior to being used, the tank is half-filled with organic matter (filter bed) to facilitate vermi-composting of the faeces and paper. The urine drains off the faecal pile and into the starter/filter bed. As it very slowly seeps through the filterbed, urine is nitrified – that is, oxidised to nitrite (by Nitrosomonas) and nitrate (by Nitrobacter). These salts help kill the pathogens picked up from contact with faecal matter. The collected liquid ends up with a bacteria count defined as swimmable water. Within the first year, phosphorus and potassium have saturated the organic bed, and in the following years they remain in the liquid. Given that the pile receives some water from toilet cleaning and is moist, little nitrogen is lost as ammonia gas, while there is more loss from a dry faecal pile??. The liquid that accumulates is easy to empty. Odourless and virtually free of pathogens, it is a perfect fertiliser for gardens as it contains a broad spectrum of plant nutrients including micronutrients not found in chemical fertilisers.

The decomposition of the faeces and other organic material is slow but thorough – after six years the volume is only 2% of the original (bottom left). As new excreta are added, the total build-up is only 2–3% per year so it takes three to four decades for the tank to fill. Interestingly, medical residues (oestrogen, pharmaceuticals etc.) decompose during this prolonged 30–40 year storage/processing. By that time most of the accumulated material is mineralised. However, it also contains fresh waste so should be sanitised using a professional animal waste treatment process. Descriptions of Nitrosomonas and Nitrobacter can be found at http://en.wikipedia.org/wiki/Nitrosomonas and http://en.wikipedia.org/wiki/Nitrobacter

Summary of design and reuse options

5.2 - 19

Output	Option 1	Option 2
Water from hand washing	Soil bed	Sewer
Urine from urinal	Undiluted	Flushed
Faecal matter from diverting toilet	Mixed with ash or sawdust	Flushed
Excreta from toilet	Undiluted	Flushed
Ablution water	Soil bed	Sewer

J-O Drangert, Linköping university

'Nature's call' creates a demand for a physical toilet or urinal. Users' perceptions and societal values create demand for cleanliness, security, privacy, and comfort. If such demands are not met, the responses range from indiscriminate urination and vandalism to bladder strain and confinement to the home area.

A range of actors can provide public toilets: the municipality, shopping malls, pubs, restaurants and contractors/franchisees. There are also collaborations where the parties divide the tasks between them in various ways.

The required investment can be provided by councils, banks, or user groups. Running costs and maintenance are dominated by salaries, electric bills, water bills, and repairs. In the end the users will foot these costs through fees, municipal taxes or slightly increased prices for consumer goods and restaurant bills.

The greatest challenge for public toilets is their management. The solution is to create a locally functioning system in which the facility owner, franchisee, and janitors/attendants perform the required services to the satisfaction of the users.

The trend towards aiming at ecological sustainability means that authorities want to minimise resource inputs and maximise the re-circulating of outputs from toilet blocks. The selection of a sustainable public toilet design starts with establishing whether the water supply is reliable and whether the owner has the capacity to take good care of the wastewater. If there is little water available, or if the supply is irregular, water should firstly be reserved for hand washing. The disposal of the used water is then not a problem, as it can be infiltrated in the soil or discharged to a sewer. Cultural practices should be taken into account, but experience also tells us that customs may change when people move to town or migrate to new countries or for other reasons. Culture is being challenged and often revised!

The table above focuses on outputs from any toilet block, and these can be combined in whatever way the designer chooses. For instance, in the operation of conventional public flush toilet excreta and tap water from the hand-washing basin are flushed away in a sewer and discharged somewhere (as shown by the **blue boxes** in the table). It is difficult to safely reuse this output since the volume is large, and therefore expensive to treat. Sludge from a treatment plant for mixed waste streams commonly contains toxic ingredients and is not readily available for farm land.

The inputs and outputs from urine-diverting toilets are shown by the **green boxes**. Tap water from the hand-washing basin is discharged into a soil bed. Urine is collected and brought to a farm and used as fertiliser. The faecal matter can be hygienised by simple storage (WHO, 2006) or collected and co-composted with other organic material, and eventually used as a soil conditioner.

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5.3 School toilets

The school toilet is an essential component of a child's learning environment. It not only enables children to access a basic facility for good health and hygiene but also provides an example of how to manage waste and water resources in a scientific and responsible manner. A school toilet has many users, but they remain the same over several years, which is very different from public toilets. Therefore, there exists a potential for developing a good management system. The quality of school buildings may vary tremendously between urban and rural schools, and from country to country. There are countries where pupils in some schools may prefer to defecate in the open (see picture) or even stay away from school if sanitary conditions are too deplorable.

Many countries have strict regulations and designs for school buildings, including toilets. Protecting pupils' health and providing a clean, friendly, hygienic learning environment is a major concern, and consequently schools and kindergartens are viewed as ideal learning centres for developing and nurturing good practices in hygiene and health. Pupils are said to be able to play an effective role in creating a clean and healthy environment, not only in the school, but also in their homes (WHO, 2009).

In some cases, the reality may be close to these ideals but in others it may be very different – it depends on the standards in the country as a whole and whether the schools are rural or urban, public or private. It is not uncommon for schools, particularly those in rural areas, to lack drinking water and sanitation facilities, or for water and sanitation to be inadequate both in quality and quantity. For instance, the Department of Drinking Water Supply, Ministry of Rural Development in India writes: "*Coverage of school and kindergarten sanitation is abysmally low in rural areas. Sanitation facilities, wherever available, are generally unclean, poorly maintained and often not adapted to the needs of children, in particular girls. School sanitation and hygiene education have been given due importance in the Total Sanitation Campaign, and is now actively focusing on school sanitation in the light of the Government's goal to cover all the schools with toilet facilities by 2005-06. Meeting these goals will be critical for the improvement of health, education and all round development of children*." (Government of India, 2004).

Children spend a fairly large part of an average day in school. Schools with poor water, sanitation and hygiene conditions, and intense levels of person-to-person contact, are high-risk environments for children and staff. For instance, intestinal worms thrive in poor sanitary conditions. They infect close to 90 per cent of children in the developing world, and may cause malnutrition, anaemia and retarded growth (UNICEF, 2006). The need for safety standards is based on the fact that children are particularly susceptible to environmental health hazards. The World Health Organisation has prepared WASH (WAter, Sanitation and Hygiene) standards to address health issues for schools in low-cost settings (WHO, 2009).

Improved nutritional status helps to protect health. Sustainable sanitation contributes to improved nutrition in two ways: the re-use of human-derived nutrients as fertiliser will increase yields in food production (school gardens), and lowering the incidence of diarrhoea will promote healthy digestion.

It is often easier to imitate unquestioningly what others do, rather than to do something new and different. This path-dependency is commonplace in the sanitation sector, just as it is in other fields. An example from South Africa illustrates this. The idea of equity between racial groups, regions etc. was very strong after independence. Rural schools with no water were provided with flush WCs and a borehole to supply the required water for flushing. The problem of how to handle the resulting blackwater was neglected and consequently it was often discharged onto open ground. Only recently have rural councils begun installing DEWATS (decentralised wastewater treatment) or biogas reactors to treat the sewage even though a dry system would seem more appropriate under such conditions.

The widespread reluctance of authorities to do something different is also illustrated by the response to urine-diverting toilets (DUDT). The rules and authorising agencies readily accept conventional flush toilets, irrespective of how poorly they function, but they require perfect functioning under all conditions for any alternative option. Even if only two out of three flush toilets are functioning, the authorities will accept them but may refuse to give a permit to build urine-diverting toilets, a technology which is ecologically sound and outperforms dug latrines and often also WCs. However, authorities can sometimes be both farsighted and courageous. For instance, in the Odessa region in the Ukraine, authorities approved the building of DUDTs in some schools with no water supply. In 2009, after some years of positive experiences of these toilets, they made this technology an accepted one in such schools.

The ability to adapt is strong and human beings seem to accept poor sanitary conditions, unless they have seen better ones. Therefore, seeing good examples may help stimulate interest and demand for better options and ultimately break through the barrier which makes people accept unquestioningly the conditions they are accustomed to. The alternatives shown to individuals or groups need to be within their capacity to construct, and if possible they need to be adapted to the local culture. Otherwise, the idea is likely to be turned down with arguments such as “it is too expensive”, or because it is too different from the familiar, or because people are not convinced that it will work. School authorities and other decision-makers should be exposed to alternatives; they should be motivated and encouraged to consider a range of options and be made aware of what is currently available, what works well and what is liked by the users.

With the present international focus on sanitation as part of the Millennium Development Goals (2008 was the Year of Sanitation – remember?) more resources are available for the sector, and this increases our responsibility to use the investments in the best possible ways. We need to start from the fact that the global urban population will double in 40 years, while the rural population will remain constant (UN Statistics, 2008).

Variations in the quality of school toilets

5.3 - 2

Guidelines on sanitation and hygiene in schools are widely available, but standards differ. The four pictures above indicate that the quality of school toilets varies widely. They are from a semi-rural community in Ukraine with no water supply or sewerage. The old school toilet (top left) is still in place but has recently been almost deserted after the new white-coloured one was built (top right).

The old school toilet required minimal management and its main function was to store the excreta away from the pupils in a big pit in the ground. It was sited 50 meters from the classrooms and pupils had to walk there, sometimes through snow during cold winters. The new toilet unit (top right) is attached to the school building and users enter from a school corridor without leaving the school building. The unit is heated in the same way as the classrooms and is warm in the winter.

The inside of the old toilet unit (bottom left) is interesting in that urine is diverted to a groove in the floor next to the user's feet (circled) and eventually flows down into a pit underneath. The toilet was often misused and faecal matter was found on the seat or floor. The next user was forced to defecate a bit to the side and after a short time the whole floor became messy. Some pupils may have been discouraged from misusing the toilet if other users were present. The new toilet room (bottom right) is tiled and easy to clean – even in cases where users have used it carelessly. The squatting pan of hard plastic is waterless and urine-diverting. The urine is collected in plastic containers and used as a fertiliser in the school garden, while the faecal matter and used paper are stored in a chamber below the floor (circled) and either buried or composted together with organic waste and later used as a soil conditioner. The red doors to the chambers for storing faeces and paper are shown in the second picture (top right).

If funds are available, such investments are possible and they improve sanitary conditions tremendously. The pupils can easily visit the toilet. Girls specially appreciate the privacy and school attendance for girls increases. However, the school administration has to enforce a proper management system to maintain high standards of functionality, cleanliness and hygiene. In the case shown here, one school staff member has the responsibility of advising pupils on proper use and carries out regular cleaning of the toilet rooms. Other management options are discussed in connection with slides 17 to 19.

Hygienic conditions for pupils and school staff

5.3 - 3

Incinerator for sanitary pads

Water ”tap” for washing hands using 0.1 litre per hand wash

Courtesy of Maria Ines Matiz, Colombia and Subburaman, Scope, India

A toilet is not complete without a hand washing point with soap and adequate drainage. Given that washing hands after defecation is a major barrier against spreading diseases, new toilets must provide facilities for washing hands. Access to water is crucial, and in schools where tap water is not available rainwater can serve the same purpose for at least part of the year. A rainwater tank can also serve as a backup in cases where the tap water is erratic. There are simple ways to reduce the water consumption. A modified plastic vessel (bottom left) uses only 0.1 litres per wash as described in the chapter on public toilets, 5.2-12. In some situations water and soap may not be readily available, but hand washing can instead be done using ash or sand with good results.

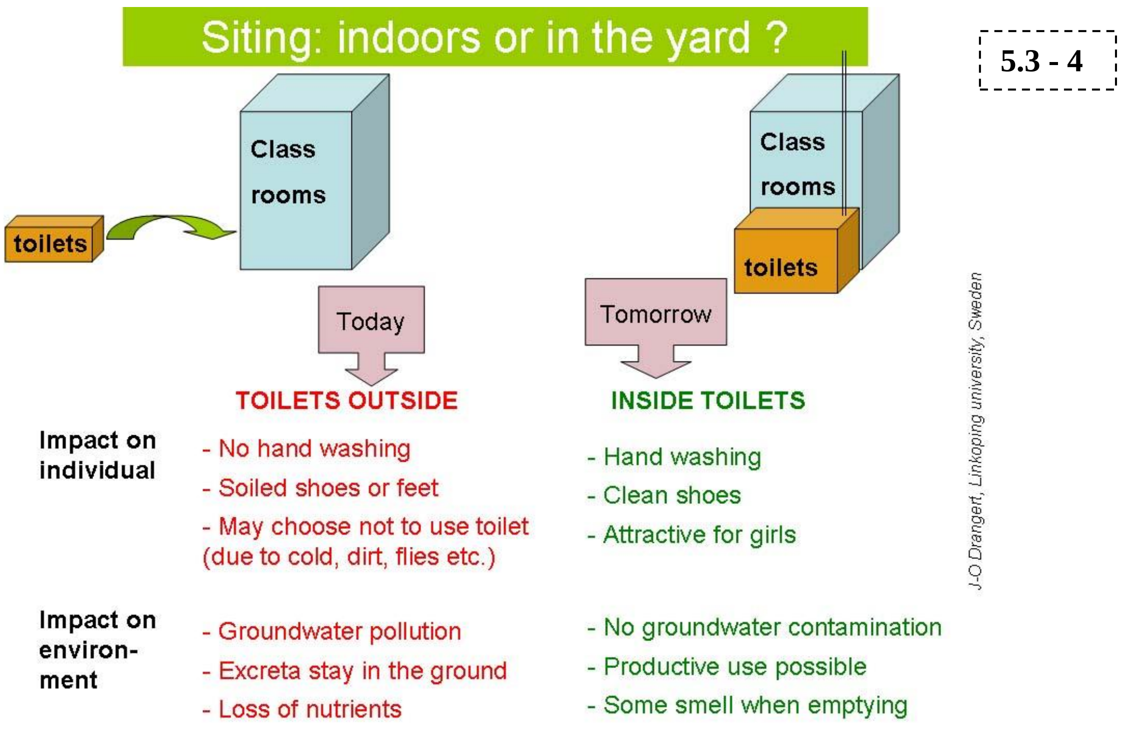
The use of soap in hand washing increases the removal of dirt and microorganisms – if the hands are rubbed together thoroughly. One question is how to make sure there is soap available all the time – and toilet paper whenever the situation demands. We can learn from societies practising anal cleansing with water. People bring water along when they go for defecation. In a similar vein, one could expect pupils to bring soap and toilet paper along to the school toilet. Another approach was used in a boarding school in Ethiopia, where students were given a piece of soap every month and they “paid” for it by not receiving a boiled egg for breakfast one day per month.

Hand washing may become more popular where there is a cold season if the water is lukewarm. This can be achieved by placing a cistern in the attic of the school building in order to bring the water to room temperature. The water flows by gravity to the washbasin. In sunny climates the water can be heated in a simple drum exposed to the sun.

A survey of hand washing in urban schools in Kenya reported: "*Of almost 1000 observed visits to a toilet, less than one-fourth was actually washing their hands afterwards. Access to soap was rare, and observation showed only 5 out of 100 schools had soap available for hand washing. Out of 491 girls observed, 14 used soap to wash their hands and only 7 out of 485 boys after using the toilet"* (Njuguna, 2009). There may be many reasons for the low usage of soap: there may be no soap or towel available, the soap, which is provided for common use may be considered dirty, or it may be swimming in water. Such obstacles could be overcome if pupils brought their own soap! Equally likely reasons are that pupils do not have the habit of washing hands, or they may lack knowledge or not be convinced that soap will improve the effectiveness of washing. Children need to be involved in discussions relating to the benefits of clean hands – the health benefits are the central theme. Such discussions can be associated with more appealing qualities such as "washed hands smell nice" or with the words of some local hero or celebrity who advocates washing of hands because that "protects from disease".

Often, school toilets have no appropriate place where girls can dispose of menstrual cloths and pads. This forces them to throw them in the toilet which in turn may block the WC or pour-flush toilet. A study in Kenya reported that "*The girls ask for permission to go home when menstruating"* (Njuguna, 2009). This response to the problem adversely affects the education of girl pupils. A simple technical solution to overcome this problem is to provide a place for the disposal of menstrual pads and cloths. The above picture (top left) shows an incineration unit attached to the toilet room for girls. They throw the pad down a hole in the wall into a chamber of cement with an iron mesh at the bottom. Lighting a fire underneath incinerates the pads (top left).

A well-functioning, clean school toilet will enable pupils to put into practice the hygiene knowledge that they have learned. Teachers and selected students can be used as role models and practical hygiene can become part of the syllabus. Ideally, pupils will bring these concepts and messages home and encourage their parents to improve the hygiene conditions there. The demonstration effect on visitors is also considerable if the toilets are clean and odourless (see slide 7)??.



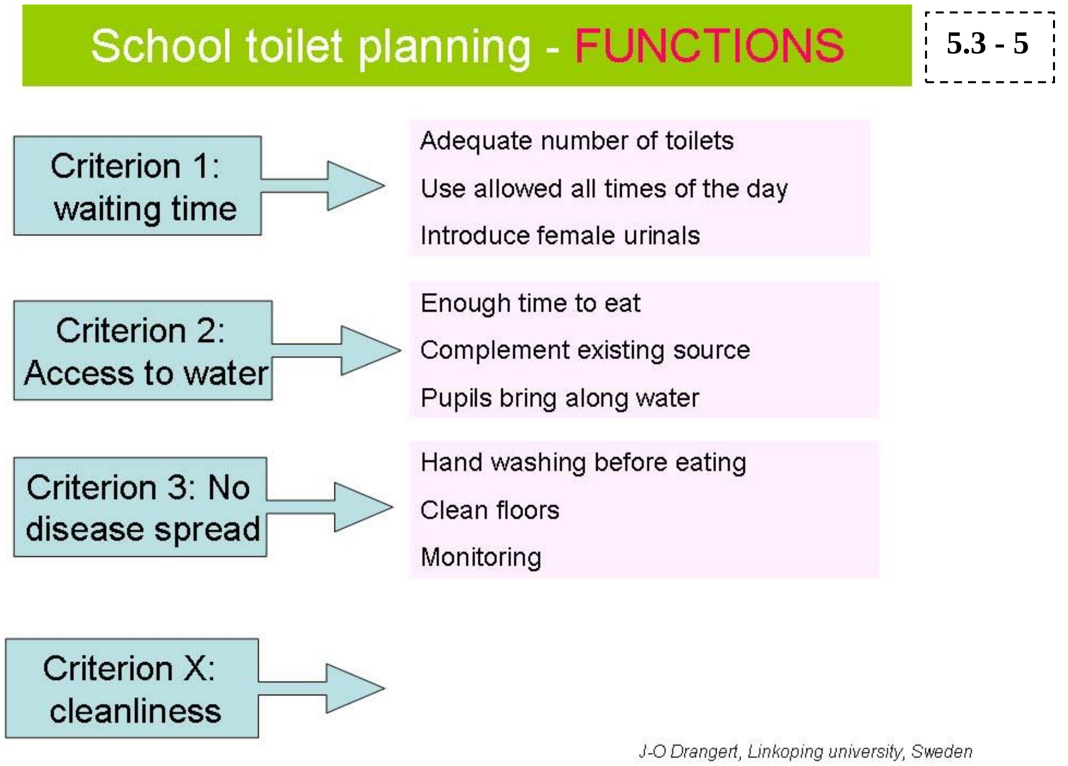
Having the toilet indoors rather than in the yard makes a vast difference. In rural schools toilets are often located away from the school buildings, especially if there is no running water. School building regulations may even require the toilet to be at a certain minimum distance, presumably to avoid odour complaints. From a pupil's point of view a yard toilet rarely provides a hand washing facility, and it may lack regular monitoring and cleaning. This encourages careless conduct and neglect of basic discipline, resulting in soiled floors which increase the risk of bringing dirt under one's shoes or feet to the classroom. Also, flies that sit on bits of faecal matter in a dirty toilet may carry microorganisms including pathogens to the classroom, books, play materials and exposed food and surfaces in the school kitchen.

An improved toilet attached to the school building reduces or avoids all these shortcomings and improves pupils' comfort, health and wellbeing. In addition, in cold climates pupils do not have to walk to the outdoor toilet in rain and snow, or sit in a freezing cubicle.

There is no excuse for waiting until tap water is installed in the school before improving dirty toilets. There are odourless dry toilet options that do not require water for flushing and they can bring about tangible improvements to sanitation in schools (slides 2 and 16).

From an environmental point of view latrine pits have certain disadvantages. Excreta get composted in the pit and fluids disperse into the surrounding soil through the honeycombed brick-wall lining of the pit. In situations where the water table is high, or there is a source of fresh water within a short distance of the latrine pit, the faecal pathogens can leak into the groundwater, unless the soil is impermeable. If the excreta is not emptied in a timely manner, the nutrients in it will be wasted. This represents a big loss of fertiliser. Sustainable toilet units, on the other hand make possible the recovery of urine and composted faecal matter under established safety standards. The nutrients are recycled back to plants to improve productivity in agriculture, horticulture and floriculture. Waterless urinals ease the pressure on pupils of having to queue up to use a small number of toilets. There are both male and female urinals (see slide9). The simplest option is to have two foot rests over a groove in the floor where urine is collected for reuse.

The conclusion is that an indoor toilet has important advantages that can improve health and comfort – and even improve food security by providing fertiliser for a productive school farm (Morgan and Shangwa, 2010).



Guidelines on water, sanitation and hygiene for schools are widely available. Design and building codes and norms give details about building requirements, and codes focus on physical dimensions rather than functions. However, one could say that dimensions are a response to (often hidden) functional criteria. Technical dimensions are often understood to be rigid and may prevent clever local solutions (path dependency). Dimensions are helpful, but it would be more enlightening if explicit functions make up the basis for the regulations which would allow thinking outside the box. Function-based regulations can enable the required outcomes to be achieved in a variety of ways, and schools can choose the combination of measures that is the most appropriate one for their particular circumstances.

For instance, the functional criterion that ***no one should have to wait more than one minute*** outside the toilet could be achieved – at high cost – by installing many toilets. But it could also be achieved with fewer toilets by allowing pupils to visit the toilet during lesson time. This shows that a functional criterion may involve several measures including simple management practices, not only one simplistic physical measure.

A general recommendation from WHO (2009) is to provide one toilet per 25 girls/female staff, and one toilet and one urinal per 50 boys. Girls tend to spend longer in toilets, and therefore introducing girls' urinals may be part of a low-cost solution which does not compromise access or comfort.

The function-based criterion that ***water is always available for washing hands*** after defecation and before eating could be achieved by installing piped water, supplemented by an emergency water tank in case the regular supply fails. The number of taps may limit access to water for washing before eating, so there needs to be a criterion that ***every pupil has enough time for washing hands before eating***.

Places without a reliable piped water supply may require that pupils bring water to school on certain days. This would be possible today, but not ten years ago, as plastic bottles are easy to access. Similarly, pupils could be made to bring along their own soap or ash for effective hand washing. Bringing water and soap are both activities that are easy for the teachers to monitor. This is no different from pupils bringing their school books and pencils. It would be worth investigating if this would make hygiene promotion more effective, since pupils are not likely to throw away water they have carried along to the school.

Good hygiene is not an option – it is a must. This function-based criterion can be achieved at very low cost, but not without strong engagement. It is well known that in places where many people congregate, the risk of spreading infection and disease is high. Schools are no exception. It has been estimated that 88% of diarrhoeal diseases are caused by inadequate sanitation and hygiene and unsafe water (UNICEF, 2006). Helminth infections affect millions of school-age children and can impair their learning ability. The Swedish Institute for Infectious Disease Control initiated a hygiene project in some kindergartens where staff and children wash their hands before eating and after defecation. The staff wash hands and the canvas on the table after changing nappies on toddlers. Sick children are sent home. Such simple measures almost eliminated stomach infections, and the number of sick days was reduced by half. Washing hands in school before eating and after going to the toilet is a must to reduce the spread of pathogens. General cleanliness of toilets is also essential. Only a combination of measures is effective in preventing the spread of disease. The final outcome depends on local conditions and management capacity.

All pupils are entitled to personal security and the key social criterion is that ***no harassment should take place in the school toilet.*** In the previously mentioned Kenyan study some 50 per cent of both boys and girls said they had been harassed in some way in the toilet. Some popular interventions to overcome this problem are: separate entrances for boys and girls, lights inside the toilets, lockable doors for the cubicles and minimising the space between the floor and the cubicle walls. The toilet should preferably be attached to the main school building. Other measures are to have a janitor around and to encourage reporting of harassment and dealing with those involved.

Additional functional criteria are brought up in the following slides.

5.3 - 6

The above pictures show toilets of varying sophistication, and there is a ***decent affordable option*** for every situation. Usually the ones which are less expensive to build require more work to operate. For instance, the grass-walled toilet shown above provides privacy and confinement of excreta, and soil bacteria take care of urine stains on the floor. But, hand washing is less straightforward since water has to be brought to the toilet. It is possible to identify some cost-reducing measures for any design. For instance, the basement (bottom-left) has thick walls which could be made thinner to save on material and labour. If there are no bends in ventilation pipes, natural ventilation will improve and there will also be cost savings. Having as few bends as possible on urine and wastewater pipes will improve flows and reduce costs (See Section 2.7). Urinals for girls can be constructed with tiles. They will result in savings on total cost and provide improved access.

The slightly higher investment cost of good construction and of the proper installation of durable devices will reduce long-term operational and maintenance expenses. The net result is likely to be that the initial extra investment is much less than the reduction in operations and maintenance costs. Moreover, there is a considerable opportunity cost due to the missed learning of schoolgirls who do not attend school due to unattractive and poorly maintained toilets. Therefore, time spent on fulfilling function criteria (see previous slides) pays off.

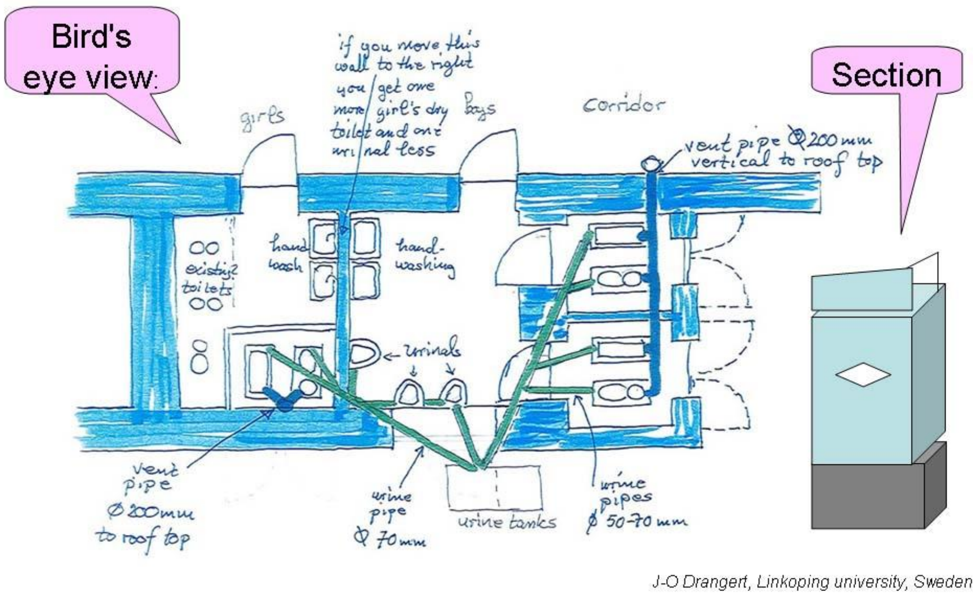
Good design and attractive finishing of surfaces, together with robust installations will ***prevent future problems and complaints***. Easy access to pipes and spots behind toilets and corners facilitates repair work as well as cleaning. However, a balance has to be reached between cost/affordability and physical sustainability. This applies to the selection of building materials, accessories, etc. But many installations, such as urinals and washing stands at different heights, involve no extra cost.

The school toilet unit should be built in a manner that enables all students to have ***equal access*** to facilities (CSIR, 2002). Children with special needs and those who are physically or mentally challenged should be able to use the facility with equal ease. Access for a wheelchair and hand rails on the wall or floor may need to be installed (see public toilets slides 5.2-7 and -16).

*The **toilet should be free from bad odours***. The most common origin of bad odours is from falling faeces before they reach the water in the WC or the collection chamber. Good ventilation is probably the only remedy. Even if there is an electric fan installed, the ventilation system should be designed for optimal natural ventilation, catching wind and using temperature gradients in case of a power cut (slide 2.7-6). Dry ventilated toilets leave no smell in the cubicle.

School toilet design

5.3 - 7



The design of school toilets is challenging for technical and cultural reasons. Most government regulations for school toilets are very rigid and, perhaps for cost reasons, provide only a few options. Still, there are very good reasons to take local conditions into account. An obvious condition is a lack of running water or an unreliable water supply. Where water supply is a perennial problem, a lasting solution is a dry toilet which has a vault or pit for faecal matter. However, a pit is not ecologically sustainable in cases where faecal pollution reaches the groundwater or where conditions are messy when collecting the nutrient content. A dry vault would reduce these problems.

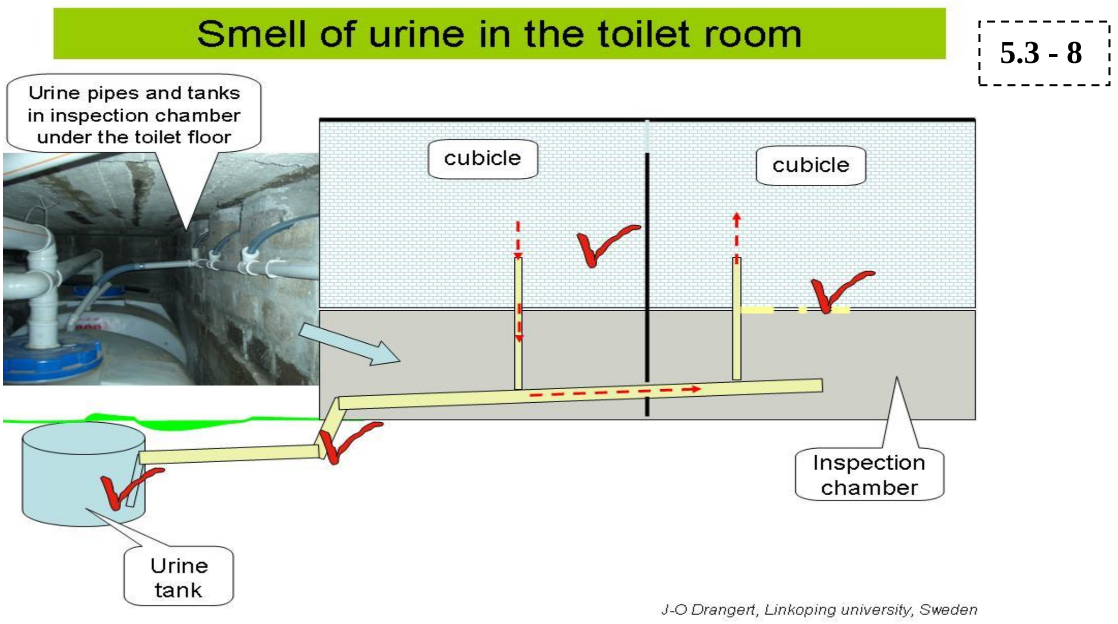
The slide shows a toilet unit with dry urine-diverting toilets and boys' urinals. Function-based criteria addressed in the slide include:

Enough space to allow easy inspection and repair of pipes. The slide indicates that there is a metre-high vault under the toilet floor (see Section: greyish part) for storage of faecal matter and urine, which at the same time serves as an inspection 'corridor behind the faecal chambers.

No blockages of the toilet, urine or sewer pipes. This can be ensured by having enough slope and no 90-degree bends. Incoming urine pipes should be higher than outgoing urine pipes. Ideally, they should be in a straight line to avoid flow-retarding bends (urine pipes are coloured green in the slide). If there are flush toilets, a disposal bin for sanitary pads has to be provided to prevent blockages

No bad odour in the cubicle. The ventilation (dark blue colour in the slide) must prevent back-flow of air, and facilitate through-flow. This is achieved by installing straight pipes with no 90-degree bends, the vent pipe extending 1.5 metres above the roof top, and no cooling of air towards the top of the pipe. The portion of the pipe outside the roof should therefore be insulated in areas with cold nights or cold seasons (slide 2.7-6). Also, in case of combined evacuation of air from more than one cubicle, backflow from one compartment to another must be prevented. A simple smoke test with a cigarette will reveal if the air flow goes in the wrong direction when cubicle doors are opened or closed. This can happen easily if the gap between the ceiling and the cubicle door is too small.

The next slide provides some instruction on how to trace and remedy foul urine odours in the cubicle.



There is a close relationship between movement of air and the design of urine piping. The drawing shows two cubicles with a joint urine pipe system leading into a collection tank. The picture shows the piping under the toilet floor. We assume that the ventilation of the block is properly designed (see previous slide). In the section below we give a *problem-solving guide* for dealing with bad smells in the cubicle on the right.

The smell may originate from one or more sources, indicated by the ticks ✓. The investigation starts with what is easy to check and remedy, and continues with more complicated problems.

Step 1. Look for urine spots on the floor, and clean if necessary.

Step 2. If the smell persists, sniff close to the floor, urinal and piping. This requires kneeling down and becoming another Sherlock Holmes. Otherwise, the source of the bad odour will be easy to miss. The investigator may find that the pipe fitting is loose and leaking urine. Fix the pipe and the bad smell will go if this is the only source.

Step 3. If the smell persists the investigation continues. While you are on your knees, someone else should open and close the cubicle or toilet door in order to catch the smell from the urinal when there is a change in pressure in the cubicle. A puff of bad air entering from the pipe (dotted arrows show this) indicates that there is an air-leak either in the second cubicle or further down the urine pipe.

If the back-flow comes from the other cubicle, a simple rubber (e.g. slit condom) can be attached to the connecting pipe from the urinal/squatting pan. The urine will slip though the two tight flaps, but there is no air going through, and thus no odour. A possible alternative measure is to shorten the doors to the cubicles so that air can flow more freely and the under-pressure is reduced.

Step 4. If the smell persists, check the connections between the pipe and the urine tank. If the pipe is dipping into the urine there is no air that can flow from there up through the pipe. But if the pipe is far above the surface of the urine in the tank, air can easily move up the pipe into the cubicle, particularly if air pressure in the cubicle is lower than the air pressure in the tank. Extend the pipe to 3 cm above the bottom of the urine tank.

Step 5. If the smell persists, it may be caused by a partial blockage of the pipe. In this case standing urine collects in the pipe and emits a bad odour that may enter the cubicle. The solution is to pour caustic soda into the pipe to dissolve the blockage. The appropriate/ideal pipe design is a straight line between the floor and the entrance to the tank to give the urine enough speed through the pipe (slide 2.7-2).

Girls´ school toilet

5.3 - 9

Girls´ urinals in a Musiri school, India with a water storage for washing

Girls´ school toilet, Indonesia with natural light and ventilation

Courtesy of Scope, India and Naning Adiwoso, Indonesia

School toilets in warm climates can use the luxury of building for good natural ventilation. In this case (right picture) there is no front door and privacy is achieved by an S-shaped entrance, which lets air flow freely through the building. At the same time the nuisance of broken entrance doors and dirty handles is avoided. The roof construction also allows daylight to enter.

With an open design like the one above, harassment and bullying becomes more exposed. A scream will be heard from afar.

One new feature that reduces queuing is urinals for girls. The simplest kind is shown in the left-had picture above. Each urinal has two foot rests (blue) and in between, a slanting V-shaped opening that prevents urine splashing onto the user’s feet. The whole area is tiled and the urine is diverted in a sloping drain leading to a collection tank. The urinals have significantly reduced the pressure on latrines, thus allowing girls adequate access to facilities for both needs. Due to congestion, pupils would otherwise spend many minutes waiting for their turn to use the cubicle. Often this creates a situation where younger pupils are pushed to the back of the queue by older children.

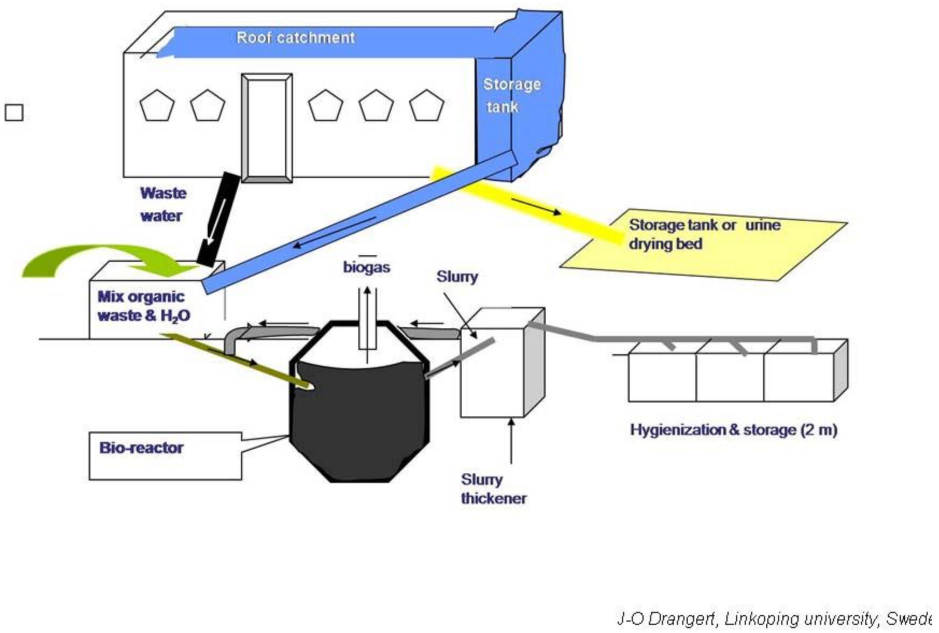
Such open urinals seem to be acceptable for younger pupils, but older girls prefer stand-alone urinals or a small partition between adjacent urinals, and at least units which are separate from the ones used by young pupils. This is partly explained by them having menstruation periods. The urinal should be located so that washing private parts becomes easy. Ideally, there should be a washbasin next to the urinals rather than an open tank (which is only possible if there is no problem with mosquitoes). Also, there is a need to have a place to dispose the sanitary pads (see slide 3) where these can be incinerated.

The urinals (above left) are easy to keep clean while the girls’ urinals on slide 6 are poorly built and will smell because the tiles are not slanting enough and urine stays and dries on the tiles and in the corners. The slope should be at least 5 cm per 20 cm of tile, and they should be V-shaped at the bottom.

Case studies on school toilets:

- “UDD toilets at a Girl’s secondary school Kalungu, Uganda” available at www.susana.org
- “Information Case: Girls_urinals_find (LeaPPS 090727) available at www.schools,watsan.net
- DeGabriels J, Keast G and Msukwa C (2004). Evaluation of the Strategic Sanitation and Hygiene Promotion for Schools Pilot Projects Nkhata Bay and Kasangu Districts, available at www.unicef.org/evaldatabase.

Where does urine and faecal matter end up? 5.3 - 10



Pupils and staff rarely ask about where their excreta end up – once defecation is done, they go back to other business. However, the toilet and urinal will not be sustainable unless the collected matter is disposed of in a safe and productive way. The amount of urine from a school is huge, and faecal matter, if flushed away, is an even more voluminous discharge.

Instead of being utilised, excreta from school toilets usually end up in overflowing septic tanks or in sewers which take it to a treatment plant. Designs need to view urine and faeces as resources rather than as waste. An NGO in Tiruchirappalli (Trichy) in the state of Tamilnadu in India (www.scope.org) has built dry urine-diverting toilets which use the urine as a fertiliser and the composted faeces as a soil conditioner. The Borda group (www.borda-sa.org) has done interesting work in Asia on a combination of biogas production and some treatment of the effluent, so that it can be safely disposed of into drainage ditches or preferably agricultural fields. They also make use of all organic waste in the area to feed a biogas digester. We provide details about such toilet complexes in the chapter on biogas, .

The slide shows a self-sustained sanitation block where rainwater is collected for hand washing and ablution. If rainfall is low or the dry season long, well water may be a supplementary water source. The design of this toilet block allows for recirculation of valuable nutrients. Urine from the urine-diverting toilets and waterless urinals is collected and delivered as fertiliser to neighbouring farms. In this example, wash water, ablution water and blackwater (if dry toilets are not being used) go into a biodigester together with organic waste. The treated slurry is a good fertiliser since only half of the organic material is converted to gas (See biogas chapter). Such a toilet block is independent of piped water supply and sewerage, and can therefore be used in a variety of locations and requires minimal infrastructure costs. A potential income may come from the sale of urine.

To make the toilet block more environmentally sustainable the gas can be used for lighting and cooking. Ideally, water for washing could be heated by the sun. Solar- and wind-powered electricity systems have been used in Australia and other countries.

The operation of such a toilet block requires trained staff, but we should not overstate this aspect since the technology is quite adaptable to changing conditions. Millions of farmers in the world run small biogas plants successfully.

Sustainable school sanitation contributes to better nutrition in two ways: the reuse of human-derived nutrients as fertiliser increases yields in school gardens, and the reduced incidence of diarrhoea allows the kids to keep and digest the food they eat. Intestinal worms – which thrive in poor sanitary conditions – infect close to 90 per cent of children in the developing world. They compete for the ingested food and may cause malnutrition, anaemia or retarded growth (UNICEF, 2006). A World Bank report comments on the interlinkages between sanitation, nutrition and water:

"*South Asia, where about one-fifth of the world population lives, still has both the highest rates and the largest numbers of malnourished children in the world. In Afghanistan, Bangladesh, India, and Pakistan, the prevalence rate varies from 38 to 51 percent and is only gradually declining, whereas in Sub-Saharan Africa, while the rate is lower at 26 percent, it is on the rise.*

"Although lack of food is obviously an important reason for malnutrition, recent reports and studies ever more consistently suggest that much of malnutrition is actually caused by bad sanitation and disease, especially in young children. Thus, contrary to popular perception, in many countries where malnutrition is widespread, insufficient food production is often not the determining factor of malnutrition. A recent collective expert opinion stated that about 50 percent of the consequences of malnutrition are in fact caused by inadequate water and sanitation provisions and poor hygienic practices, thus highlighting the need to mainstream environmental health into the development agenda." (World Bank, 2008:6-7)

School gardens can produce complimentary food for pupils and also give them useful experience in the cultivation of food products. Sustainable sanitation can add to this experience by reusing composted organic material and faeces and hygienized urine (slide). Many schools conduct experiments with doses of fertilisers and their effect on plant growth and size of fruits. The picture shows the positive effect on growth of adding human urine (bottom left).

From garden via kitchen to the pupils' plates

5.3 - 12

In Australia, 139 schools participate in a 'Kitchen Garden Program' which provides pleasurable food education through growing, harvesting, preparing and sharing fresh seasonal produce. The pupils are involved in growing vegetables and tending fruit trees. They harvest food and prepare meals which are served in the school.

The program links into all curriculum areas, supporting both health and educational outcomes. Pupils learn about the natural world, how to care for it, and how best to use resources. They also learn an appreciation of healthy and enjoyable food. They are exposed to nutritious food and are encouraged to eat less sugary, salty, fatty processed food and more fruit and vegetables. The meals they prepare consist of what is available in the season.

The pupils spend 45 minutes per week in a productive garden which they help design, build and maintain on the school grounds according to organic and permaculture gardening principles. They also spend one-and-a-half hours each week in a home-style kitchen classroom preparing and sharing a variety of meals created from their produce. The intrinsic link between the garden, the kitchen and the table enhances the learning about food and about eating it. The pupils work in groups and serve food to their peers. There is hardly ever anything left over and everyone feels proud of their work.

The Government funds the program to enhance diets and reduce obesity (which in Australia stands at 25%). A nationwide nutrient survey reports that 39% of 4–8 year-olds and 99% of 14–16 year-olds fail to consume the recommended 1–3 serves of fruit daily. For vegetables, almost 80% of 4–8 year-olds and 95% of 14–16 year-olds fail to consume the recommended 2–4 serves of vegetables per day. Children with no habit of eating vegetables and other real foods tend to retain poor habits into adult life.

Recent studies show that pupils in the Kitchen Garden Program are more willing to try new foods when they grow and prepare them themselves. An evaluation of the program shows a positive impact on health behaviour change (www.kitchengardenfoundation.org.au). The book *Kitchen Garden Cooking with Kids* provides over 100 recipes which have been tried and tested by children participating in the program.

Example 1: Urban and rural schools in Kenya

5.3 - 13

✓	Girls´ observed handwash	Boys´ observed handwash	Girls reported toilet use	Boys observed toilet use	Clean toilets	Water for handwash in toilet	No of children per tap
School has all three facilities	✓✓✓	✓✓✓				✓✓✓	
Water for washing hands in toilet	✓✓✓				✓✓		
Number of pupils per tap	✓✓✓	✓✓					
O&M carried out			✓✓		✓	✓	✓✓
Perceived toilet cleanliness			✓✓	✓✓			
Perceived privacy in toilet			✓✓	✓✓			
Girls´ school absences	✓		✓				

Source: V. Njuguna et al. 2009

A very informative study of 100 schools in Kenya in two urban areas (Nairobi and Mombasa) and a rural area (Kwale District) was reported in 2009 (Njuguna et al., 2009). The average number of pupils was over a thousand in the town schools and over 600 in the rural schools. The focus of the study is on the use of toilets, washing hands with soap and drinking sufficient safe water – three behaviours with known positive impacts on health.

In order for pupils to perform well, school toilets, washing facilities and water must be available. In this case all schools had toilets, but 12 out of a hundred had no water for drinking, and 48 had no hand washing areas or facilities.

The installations must also be in operation to be of any value as indicated in the following.

Water Supply: In urban areas the water supply is not reliable, and some of the schools in Nairobi and Mombasa face major water shortages. The selected supply technology of piped communal water is not reliable and schools cannot manage on this source alone. This is an interesting case in which decision-makers know that when the water supply fails the schools will be in trouble. Yet, they are reluctant to think out of the box and install reliable alternative supplies using rainwater collection or local wells.

Hand washing: On average each school had three working water taps with a mean of 203 pupils per tap, and 26 schools had more than 500 pupils per tap. If each hand wash takes 15 seconds, and if all students washed their hands, the last pupil would have to wait 50 minutes for his or her turn to wash their hands before eating! In schools with more taps, pupils washed more: 68% of the girls washed their hands if adequate facilities were available; if not, the figure was 17%. The low rates of hand washing (27% for girls and 19% for boys) mainly reflect the reality that only a few of the available taps were working. Only 2% of students were observed to wash their hands with soap.

Toilets: There were about 70 toilets for every 1000 pupils or one toilet per 15 pupils. The proportion of flush toilets actually working was 29% for girls' toilets and 23% for boys' toilets. The study identified some possible reasons for the very high proportion of failed flush toilets in schools:

- not very strong construction – flush mechanisms break as do the small pull wires
- a lack of understanding about how to use the flush toilets and the use of heavy anal cleansing papers (e.g. pieces of paper taken from school notebooks) that are not appropriate for the toilet design/technology and tend to block the toilet pipes
- a lack of water in the schools for flush toilets.

Sanitation: Observation and interview responses indicate that some 43% of the toilets were considered clean. The clean toilets were also more used than the fouled ones.

Teasing and bullying. Two-thirds of the pupils in Nairobi and a quarter of the pupils in rural schools expressed a fear of teasing and bullying. Boys and girls reported the same frequency. Boys can be rough to each other, shouting or shoving younger boys, while girls may shout at little girls to get out of the toilet quickly, but they also fear being teased or harassed by boys.

The analysis of the observations provides interesting findings and they are summarised in the slide. The links between various observations are shown, and the checkmark ✓shows the strength of the statistical association between the two variables.

✓✓✓ means a very strong statistical link (P< .001), ✓✓ means strong (p<.01), and ✓ means there is some association between the two variables (p<0.05). It reads as follows:

In schools with water supply, hand wash basins, and flush toilets, there was no evidence that the toilets were used more consistently or were cleaner than in the other schools. However, pupils washed their hands much more in these schools.

If water for hand washing was available in the toilet room there is very strong evidence that girls washed their hands, but no such correlation was seen for the boys. In this case there was also strong evidence that the toilet room is clean.

A higher number of taps influences strongly hand-washing habits among girls, but less among boys. There was no evidence that the number of taps affected the cleanliness of toilets.

If the toilets looked clean there was strong evidence of higher use by all pupils. However, no association with more hand washing was noticed.

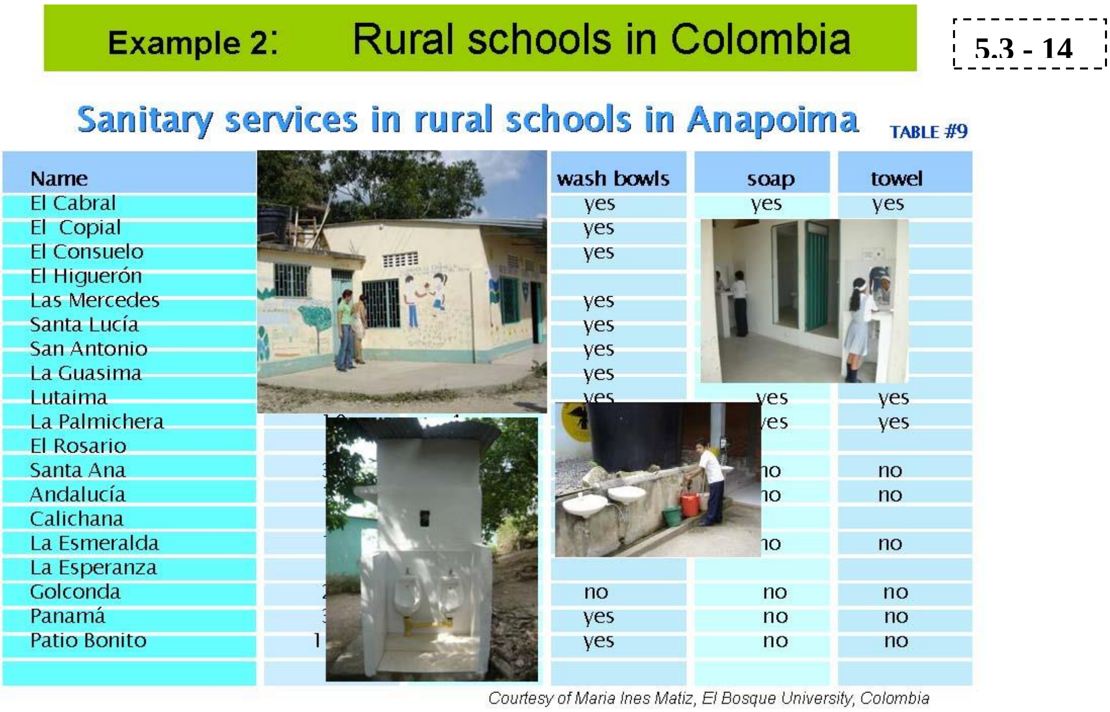
Perceived privacy in the toilet had a strong impact on toilet use.

As expected, maintenance and repair (O&M) enhanced the supply of water to the toilets, increased the number of working taps and improved the cleanliness of the toilet. In turn, these factors had a strong positive impact on girls' use of the toilets, but no impact on boys' use.

In 60% of schools the head teacher or another teacher was in charge of the O&M fund. In schools where teachers (and not the education department) controlled the fund, the supply of water was greatly improved, and more taps were available for the pupils. Boys in particular washed their hands much more frequently in these schools (Njuguna et al., 2009).

These interesting findings show that boys and girls are likely to use the toilet if it is perceived to be clean and to provide privacy. Thus, toilet use can be 'sold' with cleanliness and privacy. Clean toilets with hand washing facilities will help reduce school absenteeism. The frequency of hand washing was, as expected, strongly influenced by the provision of water in the toilet room (girls) and of enough taps (boys). There was no evidence that schools with active WASH clubs scored better on hand washing than schools without clubs.

Toilets with all facilities were not cleaner than other toilets. This is not surprising and relates more to how the toilet units were managed and maintained. Two out of three schools had janitors and in half of the schools pupils were involved in the cleaning activities. We come back to this issue in slide 5.3 - 17.



A school is not a unit isolated from the community, yet school issues do not appear often enough in community meetings or municipal planning. Monitoring of conditions at schools is often inadequate and is a neglected responsibility. Teachers may think that toilet conditions are the responsibility of the administration. There is often an abyss between the stakeholders, resulting in inactivity. A researcher at El Bosque university in Bogota in Colombia, Maria Ines Matiz, decided to raise the issue of school sanitation with decision-makers by sharing the results of an instructive monitoring template in which sanitary conditions in 34 rural schools with a total of 1,110 pupils were recorded. The objective was to establish management priorities and propose solutions that were socially, economically and environmentally sustainable.

The findings were as follows:

The rural schools in Anapoima and Apulo, in the east branch of the Andes mountains, have few pupils (usually 10 to 60 and only two schools had some 150 pupils), and therefore pupils of different ages (5–15 years) were mostly taught in the same classroom by one teacher. The pupils were responsible for cleaning and keeping the whole school well maintained. Toilets and taps did function, and was promptly repaired. For instance, extra drums of water were provided that could replace the piped water for a while if there were cuts to the usual supply.

The following limited set of indicators, which were easy to observe and record were used to assess the sanitation status. Monitoring these indicators was an effective way of identifying problems.

Water: Source of water, service level and treatment were recorded. Fourteen schools were connected to a communal water supply and received water five days per week, four schools were supplied three days a week and two schools were supplied two days a week. Two schools used rainwater and a water truck, while seven schools had no regular water supply. Eight schools provided pupils with treated water and the other 26 did not. The schools with a daily water service also had a storage tank in case of tap failure. However, these tanks were not routinely maintained.

Water treatment in the schools: 22 schools boiled the water for drinking, but children playing in the field drank untreated water from any nearby tap. Six schools had ozone filter or sand filter treatment, but mostly these were not well managed. The microbiological analysis performed on filtered water showed that out of 18 filters only two provided potable water.

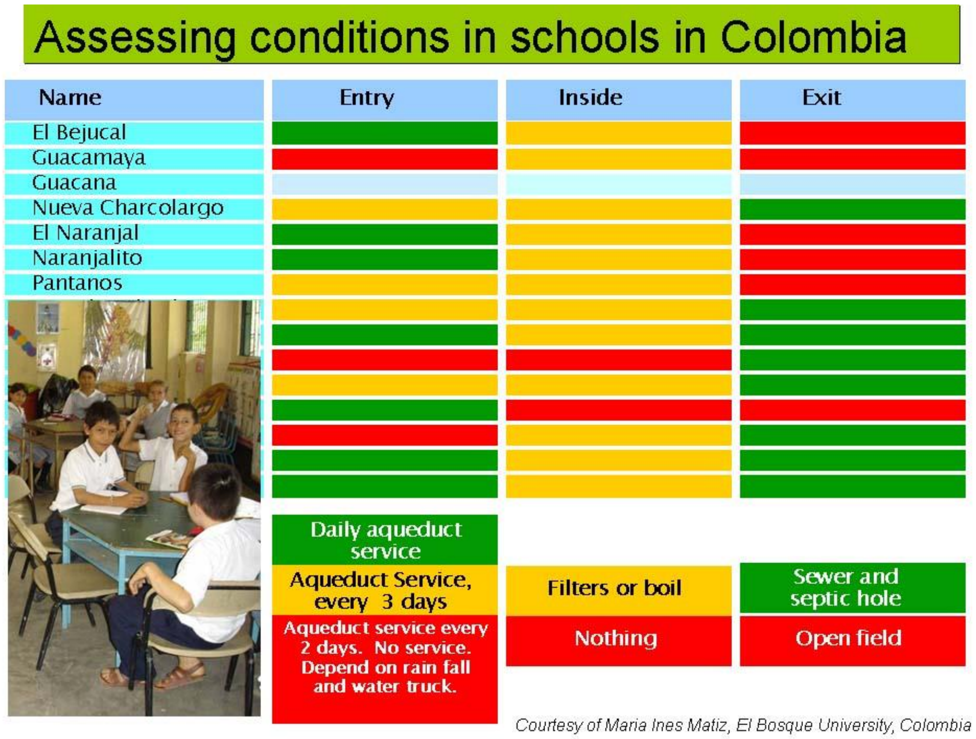
Discharge of used water: 16 schools used a septic “hole” in the ground (a pit with stones), 9 used open field discharge, and five were connected to a sewer service.

Sanitary service in schools: thanks to the small size of most schools, they had a favourable ratio of pupils per toilet. Five schools had less than five pupils per toilet, 9 had 5–10 pupils per toilet, 8 had 11–15, 2 had 30–35, and only one school had 60 pupils per toilet.

Hand washing: 26 schools provided washbasin s and 8 did not. All schools required the pupils to bring their own soap and towel.

Solid waste disposal: solid waste from kitchens, gardens and classrooms was picked up by a truck from seven schools, six schools buried the waste in a hole in the ground, 12 schools burned the waste (unlawful), and 7 dumped it in a field.

5.3 - 15



Quality concerns about school toilets and hygiene practices can be investigated with the help of a reliable and user-friendly survey of relevant parameters. In the above study of Colombian schools, in order to give decision makers and other stakeholders the sanitation messages and survey results in a pedagogical form, comparative charts were colour-coded for ease of understanding (see slide). The red colour indicates that the situation is already a problem that affects health or the environment or is unlawful. The green colour indicates that the parameter is satisfactory. The yellow colour indicates there is no problem now, but one may occur if nothing is done to improve the situation.

The charts were shown to relevant departments of education and health, and to community leaders. They were either proud of their achievements shown in this comparative way, or felt exposed by the fact that they lagged behind other schools. This comparison helped in raising the pressure on the "low achieving schools" to aim higher, and bring about improvements.

The process of analysing possible reasons for identified shortcomings included both technical and management aspects. This process was inclusive since most solutions required the participation of many stakeholders – pupils, teachers, directors, O&M staff, education managers and politicians.

The two mayors of the areas studied were informed about the sanitary conditions. Although both were shocked by the results of the survey, only one of them was willing to provide help and economic support to improve the situation. It was decided that the following areas, listed here in descending order of importance, should be addressed to improve the situation: (a) water quality within the schools, (b) water storage, (c) sanitary conditions, and (d) solid waste management.

After two years, the work in the 14 schools in Apulo led to the following improvements. Water tanks which were in poor condition were replaced with new tanks. Due to the agreeable climate, it was possible to place washbasins outdoors between the dining hall and the toilet rooms. Where new WCs were installed, separate rooms were created for boys and girls. In some cases the urinal was placed in the space where the washbasins had been located before. Cheap water filters of an easy-to-handle design (PAHO) were also installed. Recently, Oxfam water filters were installed in order to carry out a comparative study of the two models.

The Ukraine with its 46 million people (2006) has some 20,500 schools. Two hundred of the 7,400 urban schools have no water supply and rely on wells or water delivery by truck. Erratic water supply means that urban schools with flush toilets have intermittent problems with flushing. In rural areas 3,800 schools lack a water supply and most rely on pit latrines.

Rural schools face a serious problem with rapidly decreasing populations and shrinking pupil enrolments. Schools have very strained budgets, leading to poor maintenance and dilapidated toilets. Mama-86, a national environmental NGO, promotes improved school sanitation including dry toilets where water supply is a problem. They have managed to get approval to build seven school toilets. They negotiate with the local health authorities and refer to the WHO Guidelines (2006) to get approval from local hygienists and others.

The pictures show the dry urine-diverting toilet which was installed in the Gozhuly village education centre on the outskirts of the town of Poltava. It has 155 pupils, 20 children in a kindergarten and 30 staff. The erratic water supply, malfunctioning sanitation system and the poor reserve pit latrine in the yard necessitated a better dry system. A private contractor built three toilet cubicles and one urinal inside the school building. The block is heated, tiled and well maintained by a janitor. Each cubicle has a bin with wood chips and a brush. A washbasin is located outside the cubicles (bottom right).

The faecal matter and tissue paper drops into a chamber which is easy to empty from outside the building (bottom left). When full, an adjacent chamber is opened, and the matter in the first chamber rests for almost two years. Then it is emptied onto the organic compost. The urine is collected in an underground tank and after some storage it is used by a local farmer.

A recent survey showed that following the construction of the new toilet, water use fell drastically and the total school water bill went down 20%. The training/information on the use of the dry indoor toilets started before the block was built and is repeated every year. It has been successful. Three-quarters of the pupils are satisfied with the toilets and 90% of the staff. Half of the staff members are positive about the application of composted material.

The technical drawing (top right) shows a similar toilet block. The experience from Gozhuly is that visitors to the school can easily relate to what they see, because a similar cubicle could be located in the visitor's own home. Some villagers have invested in dry urine-diverting toilets in their homes. Thus, functioning, clean and well maintained school toilets can be an inspiration for individuals.

Management options

5.3 - 17

Item	Conditions (OK, fair, needs)	Measure to take (repair, replace)	Who is responsible	Cost estimate
Toilet room:				
Toilet floor	✓			
Pedestal or pan		✓	janitor	
Water seal	✓			
Ventilation				
Urine pipes		✓	janitor	
Water seal	✓		H/master	
Drainage pipe	✓			
Soak-away				
Door and hinges		✓	H/master	
Plaster on walls	✓			
Paint of urinal	✓			

J-O Drangert, Linkoping university, Sweden

The preceding three examples show some of the variations that occur in real situations. The general impression is that it is fairly easy to build good school toilet blocks, but it is difficult to maintain the quality of hundreds or thousands of school toilet blocks in a country. Often, facilities are not used or maintained as intended. They gradually become dirty and unappealing even for the needy, and fall into disuse (UNICEF, 2006). It seems to be more common to let the conditions deteriorate and await a total rehabilitation of the toilets, rather than to maintain them regularly. Many schools have seen several generations of toilet blocks over the years. An effective management system is crucial for continued proper use and operation. Therefore, management guidelines must be in place to take on the challenge of O&M, not the least as part of the large school-toilet programs that are being launched nowadays.

It is necessary to train teachers, elect a management committee or group of supportive adults and active pupils, include sanitation in the syllabus, etc. That is the easy part, but experience shows that this is far from sufficient. The deep challenge is to have an effective management system dealing with the operation and maintenance of the school toilet block day after day. The users need to be involved and they need to be responsible and accountable for the use and operation of their toilet block. But, cleaning of soiled toilets must never be used as a punishment for any offence other than for being the one soiling the toilet. The toilet and sanitation issues are integral parts of the school syllabus, and O&M activities are part of normal school activities.

The operation of a school toilet block comprises many activities: cleaning toilets and urinals, sweeping, emptying baskets, urine storage, filling up water tanks, checking light bulbs, locking the door after school hours, etc. Maintenance comprises a number of installations to be inspected and repaired if need be (some example on slide). Who is responsible for all these activities and their frequency has to be decided, and also who will monitor that the tasks are carried out satisfactorily.

A management blueprint to suit all situations is not possible. A big school is different from a small one, and a rural school is different from one in the city. A boarding school needs a different type of management system to a day school. A school in a country with rapid population increase has very different preconditions to a school in a country with low or no population increase. Therefore, different local conditions require different management solutions (slide 5.3 - 18).

Experiences of how O&M is organised and implemented vary a lot. The International Reference Centre IRC database in the Netherlands, provides many examples. Their website www.irc.nl gives 430 hits for schools! The Watsan website www.schools.watsan.net also provides extensive information.

5.3 - 18

Here we have highlighted a recent effort to use a contractor to carry out much of the O&M in schools. Such a model is not exactly new, and the method has been used in developed countries for some time. This example is from Butterworth Educational District in Eastern Cape, South Africa, where the department of education has signed a contract with a company (franchisor) to manage 400 school toilets in the district (*Financial Mail*, April 2, 2010). The reasons why the authorities embarked on this project were: loss of dignity for pupils and staff due to facilities being poorly maintained or not maintained at all, insufficient access to maintenance support due to geographical spread and internal system constraints, the low priority given to health and hygiene-related issues, issues related to solid waste management and disposal, and insufficient funds due to a higher priority being given to school construction rather than O&M activities.

The franchisor – in turn – has engaged local small and medium enterprises on a franchisee basis to do the work. The franchisor provided training for them and signed a detailed contract with them concerning the tasks, the required quality of work, and reporting. Under this arrangement, the trained local franchisee undertakes the following general tasks:

1. Clean inside and outside of the toilet block (top right picture)
2. Undertake basic maintenance of facilities
3. Remove solid wastes and dispose them safely at a designated waste site (bottom right)
4. Remove excess liquids and dispose them safely through irrigation nearby
5. Educate school-board members on water and sanitation
6. Make presentations to pupils about good health and hygiene practices (top left)
7. Report to district managers on activities and the state of facilities.

The franchisees – mostly women – take on a large part of the O&M tasks including providing hygiene-related information to the pupils. This effort to professionalise the franchisee staff is intended to boost their status. If successful, they will gain confidence and status in the school and in the community. An incentive for the franchisor is the possible scale-up of the approach to the remaining 22 educational districts if the pilot project is successful. A maintenance job is a job for life since it will always be there.

Below is a list of the types of problems encountered in the first year of the project. Many were due to the procedural requirements of the Department of Education (DoE:

- Payment delays due to "incomplete paperwork"
- Communication problems between the various DoE managers and the schools
- Logistical issues due to poor planning and the inexperience of franchisees
- Difficulties due to different stakeholder viewpoints, need for a common understanding
- Franchisee dropout.

Some of the observations made by the franchisor so far are as follows:

Franchisees are very enthusiastic and positive about their ability to succeed

DoE officials are cooperative, thanks to the leadership from the provincial managers and district directors

DoE officials are keen to ensure the success of the pilot

The school heads and teachers are generally happy with the concept. A number of letters have been received expressing gratitude for the initiative

The process of shared experience and learning needs to be managed.

The Water Research Commission is involved in this development project (bottom left) and will evaluate the process and progress and identify lessons learnt from the project (www.wrc.co.za).

Population increase as a challenge

5.3 - 19

Number of additional teachers and classrooms required to provide primary education for all new-born

Year	Popu-lation	Increase 000´ in Total	Increase 000´ in Newborn	Number of classes (000´) in Standard I	II	III	IV	V	VI	VII	New class-rooms
0	23.0	690	1.150	-	-	-	-	-	-	-	-
1	23.7	710	1.185	1	-	-	-	-	-	-	1,000
2	24.4	732	1.220	2	1	-	-	-	-	-	3,000
3	25.1	754	1.257	3.1	2	1	-	-	-	-	6,100
4	25.8	774	1.290	4.1	3.1	2	1	-	-	-	10.200
5	26.6	797	1.330	5.2	4.1	3.1	2	1	-	-	15,400
6	27.4	821	1.369	6.3	5.2	4.1	3.1	2	1	-	21,700
7	28.2	846	1.410	7.3	6.3	5.2	4.1	3.1	2	1	29,000

J-O Drangert, Linkoping university, Sweden

The main problem with high population growth lies with providing public services for all newcomers rather than finding housing and food for them. The school sector can illustrate what happens if all families send four children instead of two to school. There must be twice as many teachers and classrooms available. Let us assume that the total population of a country is 23 million, the growth rate is three per cent and the fertility rate is five per cent and that each class has 35 pupils and one teacher. The requirement for additional teachers and classrooms over a seven-year period is given in the red column in the table above.

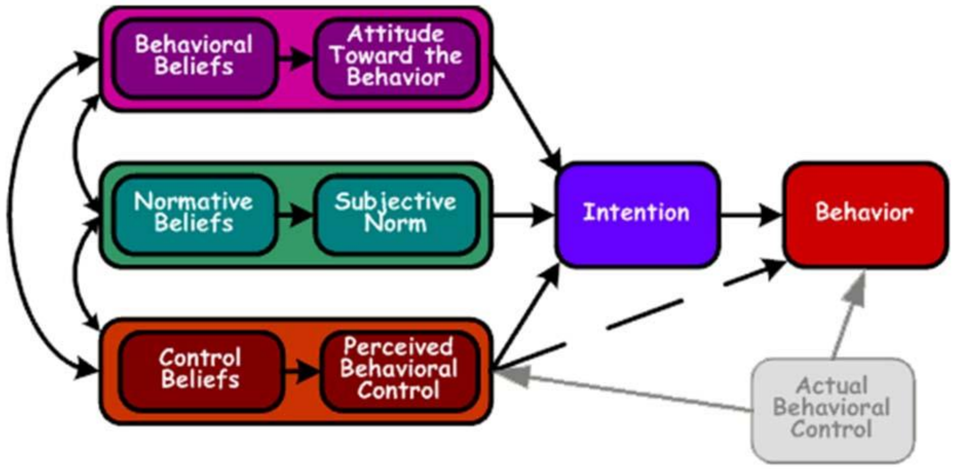
We may assume that in Year 0 there are sufficient facilities for all pupils and that there exists the capacity to train new teachers to replace retired staff. The number of new-born (blue column) increases by 35,000 in Year 1 and one thousand additional teachers and classrooms are needed in Standard I. These pupils will enter Standard II the following year (together with their teachers) while the intake to Standard I in Year 2 is 70,000 more than in Year 0. Another 2,000 new teachers and classrooms are required for those joining Standard I. Over the period of seven years the cumulative requirement will be about 28,900 teachers and classrooms. At least four new teacher training colleges are needed per year on average, each with a capacity to train 1,000 teachers annually. Additional institutions to train trainers of teachers will also be needed.

Governments cannot keep up with such rapid population growth and the situation is unmanageable, not because there is a lack of good planners, but because of the magnitude of the task. This applies to all communal services that require financing through taxes. Food and shelter, on the other hand, can always be managed by the individual family (see module 1.4). The result is that teachers are rarely adequately trained and classrooms are not adequately equipped. Lots of rural schools hire Standard VII leavers as teachers and classrooms lack desks, chairs, and school materials.

Worse still, pupils may think that they do not need to learn about traditional knowledge in the society, since they believe they have enough formal training and “book knowledge” as evidenced by their certificate. If the school functions poorly the pupils are likely to end up knowing too little about both the traditional and the modern world.

Awareness raising

5.3 - 20



From Ajzen (2002)

According to Ajzen (2002) human behaviour is guided by three kinds of beliefs about the likely outcomes of the behaviour and the evaluations of these outcomes (*behavioural beliefs*), beliefs about the normative expectations of others and motivation to comply with these expectations (*normative beliefs*), and beliefs about the presence of factors that may facilitate or impede performance of the behaviour (*control beliefs*). A weighted combination of the three considerations guides the individual to form a behavioural intention. As a general rule, the more favourable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question. Intention is assumed to be the immediate antecedent of behaviour or action.

We can apply this scheme to the use of school toilets and hand washing. Experience suggests that a pupil's behavioural beliefs rarely include health aspects as a major factor. This may be the reason why WASH projects emphasise information and education aspects to convince pupils about the close connection between good health and proper hygiene behaviour. As for normative beliefs, pupils in schools without proper sanitation facilities may conclude that there is no expectation or motivation for washing hands from the school staff or authorities. The lack of facilities also impacts on control beliefs, and actual conditions in the toilet block have been shown to be decisive in determining what pupils can do. The suggestion that pupils be required to bring along paper/water and soap is aimed at reducing this limitation.

A successful approach to improved school sanitation has to include all three interlinked beliefs. The South African effort (slide 5.3-18) to engage franchisees to remould reality as well as beliefs can be viewed as a way to strengthen the intention, and consequently action, to practice better hygiene.

An interesting finding brings out how difficult it is for individuals to revise basic perceptions through education. A training session was conducted for ten medical and anthropology students who were to do field observation of residents' behaviour around water wells and pit latrines in a poor, un-serviced periurban area in Eldoret in Kenya (Drangert, 2004). The students were asked "*What is safe water to you?*" The immediate response from one of the medical students was that water has to be boiled and chlorinated. Immediately a peer student disagreed, saying it would be enough to boil the water. Another maintained that chlorination would do. The other seven students contributed further diverse ideas on the topic. For example, one mentioned that he could drink any water without getting sick, while his room-mate had loose stools despite only drinking boiled water. His conclusion was that it all depends on how susceptible a person's body is to ingested microorganisms. Despite 12–15 years of formal training, these students entertained the full range of possible views that would be found among common residents.

This is not to say that successful education is impossible; only that the change agent has to understand what persons think about the issue at stake, and find persuasive arguments that take account of the person's preconceived views. One drastic example of this is used in the "No-open defecation" programs in Bangladesh where the crucial piece of information is that poor sanitation makes all people eat the others' faeces (see Module 2.3).

Another example is from a study in Ghana where 91% of the respondents who agreed to the statement *sanitised human excreta can be used as fertilizer* were willing to use sanitised human excreta for their crops, while only 1.8% of those who disagreed said they would apply it for their crops (Mariwah & Drangert, 2010). In the context of Ajzen's theory of planned behaviour, this finding is an example of how beliefs are likely to impact outcomes of the behaviour and the evaluations of these outcomes (behavioural beliefs). Thus, respondents who know about the likely positive outcomes (increased crop yield) of applying excreta-based fertiliser on the farm or garden, were significantly more willing to apply it than those who did not recognise this usage.

A treatise on norms and attitudes towards ecological sanitation systems with recirculation of human-derived nutrients in African countries provides examples of promoting as well as prohibiting factors (Drangert, 2004).

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