Sustainable Sanitation

As part of an integrated wastewater treatment strategy

By

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I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged

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III. List of Abbreviations

CLTS: Community-Led Total Sanitation

DEWATS: Decentralized Wastewater Treatment Solutions

P.E: Person Equivalent

UD: Urine Diversion

UDDT: Urine Diversion Dry Toilet

UDFT: Urine Diverted Flush Toilet

UWWT: Urban Wastewater Treatment

NGO: Non-Governmental Organization

1. Executive Summary

Sustainable Sanitation is a way of thinking and is not limited to one technology. Several technologies and components are involved within a system including: user interface, transport/ storage/ treatment, use and/or disposal. Technologies to be implemented can be urine-diversion dehydration (UDD) toilets, composting, rainwater harvesting, constructed wetlands, vacuum sewers, biogas reactors and many other low-cost to high-tech technologies.

The objective of this report is to describe the sustainable sanitation status quo worldwide and make people aware of its development opportunities and barriers.

The first part of this thesis will be dedicated to the background of sustainable sanitation. Several issues related to poor/ missing sanitation will be discussed such as health impacts (child mortality included), pollution of water bodies, socio-economic impacts… Sustainable Sanitation is often the concept presented as a potential solution to solve the incoming nutrient crisis. Details about the phosphorous peak and currently applied recovery possibilities will be presented. Then, in order to fully understand the concept, we have to go backward and realize what was done back then and what worked and did not work: this part will be dedicated to the history and present of wastewater reuse. Driving factors and barriers will also be described and last but no least the relation with the "Material Flow Management" concept will be explained.

In a second part, the sustainable sanitation planning will be observed from a spectator point of view. The first step being the definition of factors, it is important to embrace all criteria such as physical and environmental criteria, technological and legal factors, socio-cultural and economic factors; institutional and regulatory factors. These factors have to be understood and deeply analysed before starting a planning strategy. Since they are complex and really diverse, different approaches and concepts exist and are in constant evolution. The trend related with communicative planning and use of sustainability/ users criteria will be discussed.

The third part will concentrate on different systems (from dry to wet) and applicable technologies. Eight main templates will be presented as well as their advantages and drawbacks. A very low-tech sanitation system implemented in a peri-urban area in the Philippines will also be demonstrated before a general conclusion on the topic: Sustainable Sanitation.

2. Introduction

Today, scientific community mostly focus on clean air but living on our planet also requires clean water and therefore water, wastewater and resulting biosolids need to be treated in an appropriate manner to reduce water pollution on a global scale. Sustainable Sanitation is a part of a broader concept: integrated water resource management. This concept simply explains that all water resources are interdependent and that as a consequence they all have to be protected. For example, high irrigation demand and polluted drainage flows mean less freshwater for drinking but also for industrial use. Contaminated municipal and industrial wastewaters pollute water bodies and therefore threaten ecosystems. Sustainable Sanitation has a key role in protecting these water resources.

Water is a crucial topic nowadays because it is most of the time wasted/ not treated at all or in an adequate way. "No water supply without sanitation" was the statement of the German federal Ministry for Economic Cooperation and Development (BMZ) regarding the water sector strategy in 2007. This statement remains crucial regarding the development our world is facing.

World's population is growing faster than it never grew in the past centuries or millenniums. One of the main characteristic of this growth is the concentration of people, generating « mega-cities » and underserviced slums. Moreover, this population increase is mostly happening in low and middle-income countries. The situation creates real waste management issues but also wastewater management issues. The last ones, often being forgotten, need to be handled as precisely as possible to avoid water and soil pollution. But make sanitation sustainable is a long and difficult process that has not always been taken into account even in developed countries.[1] [2] The city of Barcelona is among the cities seriously lacking in wastewater treatment. It is therefore important to mention that sanitation is not a problem rising only in poor rural areas but also in big touristic cities in the developed world where centralized systems cannot treat all the wastewater generated during peak times.

Furthermore, almost everywhere in the industrialised world the current system is not sustainable because in the best case it wastes important quantities of energy to recover phosphorus from wastewater, and in the worst case nutrients are simply eliminated in centralised energy intensive wastewater treatment plants. Phosphorus is available in a concentrated form in our faeces and urine but people flush it away instead of collecting and recovering it. Knowing that tremendous quantities of chemical fertilizers rich in N (nitrogen), P (phosphorus) and K (potassium) are used to increase agricultural yields when nutrients are already available within our system make us also wonder about the sustainability of such chemical fertilizers use. The hot topic is: how long will these phosphorus resources last?

Moving towards sustainable sanitation is slowly reaching a global consensus but the supposedly sanitation improvements often lack in users involvement especially in really poor areas. Top-down decision making processes are often criticized and people expect more from planning than only the implementation of a new technology especially with the skyrocketing demographic rates of nowadays. Solutions need to be found but also used on a long-term basis.

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[1] According to the United Nations, 40% of the developing region's urban population still lacked adequate sanitation in 2008.

[2] According to the European Commissions 2007 report, only 61% of European cities with greater population than 150.000 inhabitants complied with the treatment requirements of the Urban Waste Water Treatment (UWWT) directive.

3. Background of the « Sustainable Sanitation » concept

3.1. Different impacts originating from poor/ missing sanitation

Common beliefs are that urbanisation is always correlated with a better sanitation cover due to the economic/ social advantages it offers (for example the presence of clean public toilets). But an increase in human density implies an increase in human waste and excessive waste accumulation leads to a quicker environmental degradation. Considering that a human produces around 1.5 litres of excreta per day, a city of one million people discharges approximately 1500 cubic meters of waste per day. The greywater production is at least 20 times higher and solid waste will accumulate in streets, drains and waterways. In most cities of the developing world, faeces end up in open drains, sewers or land outside the city centre. Most of the time, there is no appropriate treatment done on-site and people are satisfied with the “NYMB” (Not In My Backyard) disposal.

3.1.1. Health impacts

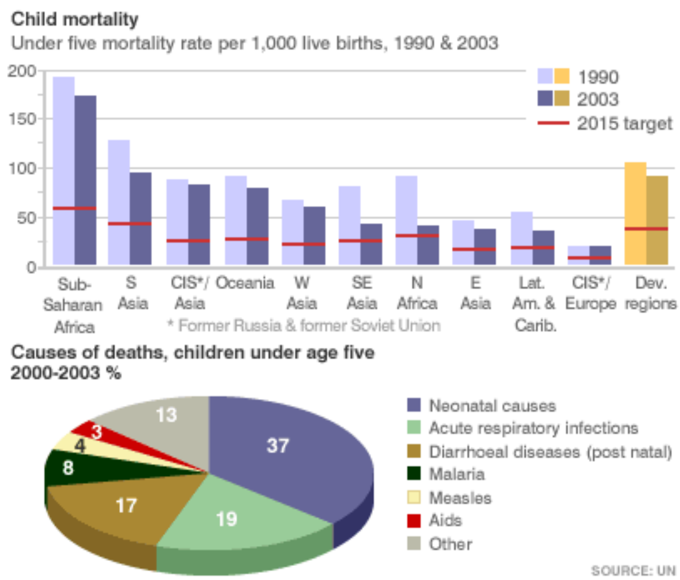

Figure 1: Causes of child mortality under 5 years old. Source: United Nations

Inadequate sanitation, water supply and poor hygiene are unknown plagues causing thousands of deaths everyday. Poor maintenance coupled with overuse of common latrines can often lead to the spread of diseases (especially diarrhoeal and infectious diseases) by faecal-oral route. Improving drinking water quality becomes useless when wastewater treatment is not adapted to the situation because pathogens and pollutants contained in the wastewater discharged improperly will anyway end up entering the drinking water chain. (Luethi, et al., 2010)

People die everyday from diarrhoeal diseases and this affects mostly children.[3] These deaths related to diarrhoeal diseases account for more than 40% of the total number of deaths related to unsafe water, poor hygiene behaviour and inadequate sanitation facilities. As it is shown by the graphic, diarrhoea remains the 3rd leading cause of deaths among young children. It is killing more children than AIDS, malaria and measles combined. Furthermore, the propagation of Malaria could also be reduced if there were less polluted standing water bodies attracting flies and mosquitoes. Cleaning and draining these water bodies is necessary to prevent this plague to spread in tropical and sub-tropical regions. Regarding the geography, Sub-Saharan Africa and South-Asia suffered most of the under age five mortality per 1.000 live births between 1990 and 2003. The situation is improving but these regions are also the ones suffering from children diarrhoeal diseases. (Luethi, et al., 2010)

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[3] Around 4000 deaths per day can be counted due to unexisting sanitation. (Wateraid 2009)

Figure 2: Child playing next to a water body in Uganda. Source: ECOSAN, GIZ

Other less famous diseases such as trachoma, schistosomiasis and chronic infestations by intestinal parasites (nematode worms) affect over one billion people worldwide. Diarrhoea is also exacerbating malnutrition that is directly related to children's growth. Furthermore, even if intestinal worms do not directly kill people, they are still responsible for substantial disability. Knowing that around two thirds of all schoolchildren are infected with intestinal worms in certain African countries, and that malnutrition causes 35% to 53% of children's deaths globally (half of this directly related to diarrhoeal diseases), poor sanitation has a direct impact on children's health. (Luethi, et al., 2010)

Poor sanitation does not only affect children but also women. According to the United Nations Water report 2006, around 1.3 billion women and girls in developing countries do not have access to a private, safe and sanitary toilet. The situation is so that women expose themselves to a high risk of rape or other types of violence in order to defecate. Furthermore, poor intimate hygiene, especially during menstruations can lead to diverse types of infections that can cause infertility. Urine retention is also not recommended by doctors and can be really painful if it evolves into an infection.

All these facts make us believe that people and governments should take action to improve the situation but this is not the case since sanitation has always been a social taboo. Worldwide leaders do not get enough involved in this sector because it is seen as a “dirty topic” and drinking water supply as well as wastewater treatment is sometimes delegated to private companies that build infrastructures in rich areas but not where it is mostly needed. According to the GIZ, there is also a lack of technicians and managers in sanitation authorities and utilities.

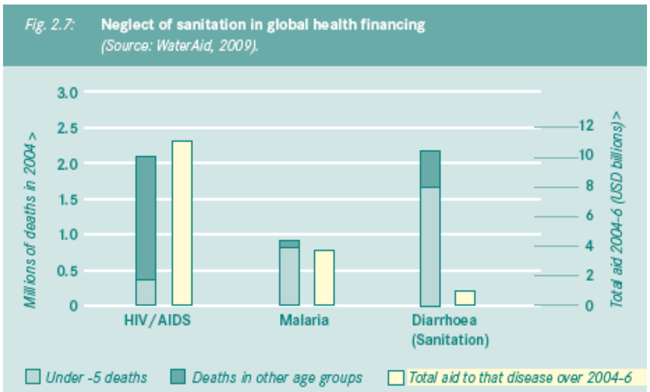

Figure 3: Neglected sanitation and sewer line in Free Town (Sierra Leone) represented by the black lines (business area). Source: Luethi et al.

The graphic and the map above show first that sanitation lacks in public interest. Poor sanitation conditions are not seen as crucial as AIDS to be urgently eradicated and sewers are only built in business areas where potential investors could visit and decide to invest in the country but not in peri-urban areas where people often defecate outside because of the lack of infrastructures. (Luethi, et al., 2010)

3.1.2. Pollution of water bodies

Water bodies are threatened everywhere: from overfertilization in most of the developed countries to inappropriate management of waste and wastewater in the developing world. Eutrophication is the result of this mismanagement taking the form of algal blooms in rivers and lakes because of the enrichment in phosphorous and nitrogen. Usually, the phosphorous content in fresh water bodies is really low so when the ecosystem is disturbed by wastewater discharge, the living conditions for all kind of organisms change as well. The oxygen level will decrease because of the algal bloom and fishes and vegetation will quickly die, increasing even more the eutrophication process.

According to estimations. 90% of all wastewater in the developing world is discharged in rivers and lakes without any treatment. In touristic areas, the situation is degrading quickly and sensitive species in the marine ecosystems start to disappear for a few decades. Within the developed countries, the situation is very heterogeneous even if it has been getting better since the 80's because of several E.U directives. But a lot of improvement can still be made and as shown on the graphic, only four countries are meeting the 100% wastewater treatment within the European Union. In south-eastern countries, only 40% of the population is connected to a wastewater treatment facility [4]

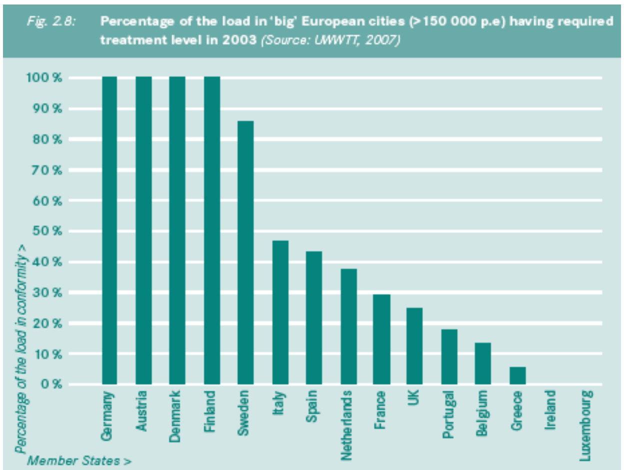

Figure 4: Percentage of the load in big cities, having required treatment level in 2003. Source: UWWT

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[4] According to the EU Commissions 2007 report on wastewater treatment, only 61% big cities in Europe (population greater than 150.000 p.e) complied with the treatment requirements of the Urban Waste Water Treatment (UWWT) Directive. 17 cities had no treatment at all.

3.1.3. Socio-economic impacts

Illness due to poor sanitation can have an important economic impact in developing countries when it leads to a loss in working days. When only one member of the family is working (for example physical jobs), it can affect the household very negatively. For children, sickness means fewer days at school or the impossibility to concentrate. The chronic infections due to bacteria transmission have effects on the household-savings, the lower learning ability, the reduced productivity and development objectives. (Luethi, et al., 2010)

Contamination of the natural ecosystems because of a lack of sanitation will affect tourism but also fishing practices because of eutrophication. The spreading of pollution will reduce local biodiversity and species will disappear.

3.2. The current nutrient crisis

3.2.1. The Phosphorous issue

What people usually do not realize is that the food they eat is dependent from the Phosphorus production. This resource is vital for all living matter (bacteria, plants, animal). Humans get phosphorus from their food, which itself comes from phosphate fertilizers/ organic fertilizers (for some of them) farmers are using. Phosphorus fertilizer is crucial for modern food production and can be a limiting factor in crop yields as water can be. But phosphorous is a critical global resource, along side water and energy resources. Around 90% of the phosphate rock extracted, is for food purposes; the remaining 10% are used in industrial applications like the production of detergents. (White & Cordell, 2009)

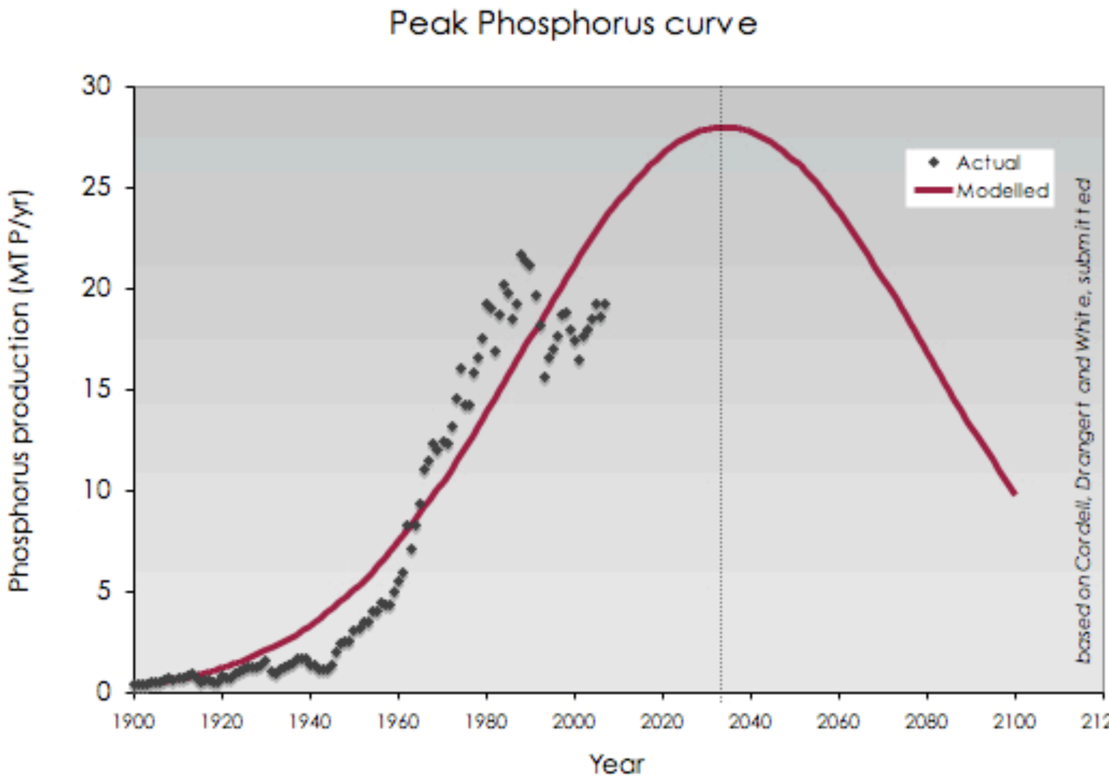

Figure 5: Peak Phosphorous. Source: Cordell, Drangert and White, 2009.

« The analysis of peak phosphorus is based on estimated P in current world phosphate rock reserves (approximately 2358 MT P) which are based on US Geological Survey data and cumulative production between 1900-2007 (totalling 854 MT P) based on US Geological Survey data (Buckingham and Jasinski, 2006; Jasinski, 2007, 2008) and European Fertilizer Manufacturers Association (2000). The area under the Hubbert curve must equal the depleted plus current reserves, totalling approximately 3,212 MT P. Units of phosphorus are presented as elemental P, rather than P2O5 (containing 44% P) or phosphate rock (containing 29-34% P2O5) as commonly used by industry. » (White & Cordell, 2009) The Hubbert Curve shows the Phosphorous peak expected approximately for the year 2030. Around that time, the production will reach its maximum and then start to decline. This situation is similar to the peak oil, which happened in the United-States in the beginning of the seventies.

Phosphorus is an essential non-renewable resource that the majority of today's agricultural fields depend on. This phosphate fertilizer comes mainly from phosphate rock that takes between 10 and 15 million years to form. This phosphate rock often contains toxic elements like cadmium and uranium. (BAM Federal Institute for material research, 2009) Furthermore, the production of each ton of phosphoric acid generates 5 tons of phosphogypsum. (Schnug & Eichler-Loebermann, 2009) This by-product of the fertilizer industry does not find applications and is most of the time stored outside (on unused/ contaminated lands) in stacks waiting to be pumped off to a disposal site. The problem with this material is its radioactivity, especially because the small particles can become airborne. But according to the U.S Environmental Protection Agency (EPA), the risks related with phosphogypsum are still acceptable. (Environmental Protection Agency)

Figure 6 : Phosphogypsum stack in Florida. Source : Wikipedia

Furthermore, phosphate reserves are mostly concentrated in a few countries such as the USA, China and Morocco who exploits illegally the Western Saharan reserves. The USA have approximately 25 years of reserves ahead in their mines while China built up a 135% export tariff to secure its own food supply. Importing Western Saharan phosphate rock via Moroccan authorities is condemned by the United-Nations and several Scandinavian firms are boycotting the trading of phosphate fertilizer with Morocco. Knowing that Western Europe but also India are completely dependent on phosphate imports and that prices have escalated by 700% since 2007, a solution is needed everywhere. Growing food demand and increase in biofuels use are two factors that could bring the resource to its depletion even quicker. (White & Cordell, 2009)

3.2.2. Wastewater treatment and phosphorous recovery: current practices

There are different types of wastewater: from the industrial to the domestic as well as rainwater, surface runoff and cooling water for example. In dense areas it became necessary to install centralized plants able to treat all kind of wastewaters instead of treating them separately (too costly). In these treatment plants, wastewater goes usually through a mechanical, biological and chemical cleaning with sometimes bio-filtration and additional methods. Today's situation of wastewater collection and treatment is characterized by:

- A mixed collection system (toilets, kitchen, bathroom and industry, stormwater, runoff...),
- Water intensive flushing toilets (from 5 to 10 litres per flush),
- Long transport distances in sewers via (gravity) pipes to centralised wastewater treatment plant (off-site treatment),
- Cost intensive removal of pollutants/nutrients from water before discharge or optional reuse,
- Sewage sludge production leading to a concentration of nutrients and pollutants. (Foellner, 2008)

The situation for wastewater treatment can be qualified as end of pipe since wastewater is seen here as "waste" and not as a valuable resource.

Phosphorus recovery from wastewater seems to be one of the easiest applicable solutions (no system change needed) but is rarely done because of social taboos. But human excreta are renewable and available resources. Urine is mostly sterile and contains nutrients: P for Phosphorus, N for nitrogen and K for potassium in a good crop assimilation ratio. Treatment and reuse are simple methods and the World Health Organization has even published guidelines for the safe use of wastewater, excreta and greywater.[5] All important nutrients: N, P, K are available in urine and faeces. (Cordell) Even if source separation seems to be the most logical way to recover nutrients in an efficient manner, current practices focus more on recovery at the centralized wastewater treatment plant since it is the major system in place.

[5] http://www.who.int/water_sanitation_health/wastewater/gsuw eg4/en/index.html

There are four different locations to recover nutrients in a wastewater treatment system:

- Effluent of wastewater treatment plant
- Process water/ sludge liquor
- Dewatered sewage sludge
- Sewage sludge ash

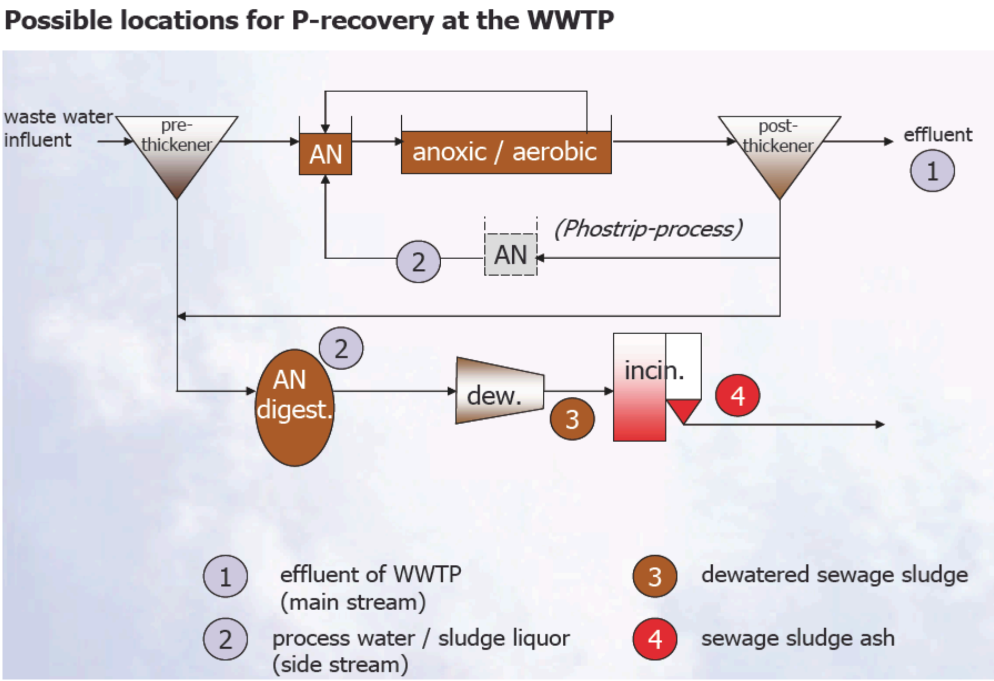

Figure 7: Different possible locations for P-recovery at the wastewater treatment plant. Source: BAM

Since wastewater treatment systems are mostly centralized, some projects such as the SUSAN project, carried out within the 6th framework of the European-Union sub-priority "Global Change and Ecosystems" and including the German Federal Institute for Materials Research and Testing, the European fertilizer producer Kemira Growhow (Finland), the German engineering company BAMAG and sludge incineration plant operator SNB based in the Netherlands, focused on the potential of phosphorus recovery by thermo-chemical treatment of sewage sludge ash. (the Australian Water Recycling Centre of Excellence, 2010) Currently, wastewater is the municipal waste flow with the highest potential for P-recovery: Germany has a potential of 60 000 Mg P/a. and in 2006 in Germany, 50.520 tons of Phosphorus were recovered from wastewater treatment plants and 30% of all sewage sludge applied on agricultural land. In 2007, 50% of all sewage sludge was incinerated in Germany. But there are other techniques currently tested or applied during different treatment phases. (BAM Federal Institute for material research, 2009)

Processes for P-recovery

Watery phase: wastewater (treated) or process water (e.g. sludge liquor)	
Crystallisation	DHV-Crystalactor® *(Giesen und De Boer, 2003)*
	Unitika PHOSNIX® *(Ueno und Fujii, 2001)*
	Ostara PEARL™ *(Esemag, 2006)*
	CSH-process Darmstadt *(Petzet, 2009)*, P-ROC-process *(Berg, 2005)*
Precipitation	Process of Berliner Wasserbetriebe / AirPrex *(Heinzmann, 2008)*
	PRISA-process *(Pinnekamp and Montag, 2007)*
Dewatered (or dried) sewage sludge	
Wet chemical	Seaborne-process or Gifhorn-process *(Versterager, 2003; Müller, 2005)*
Thermal	Mephrec-process, (dried sludge) *(Scheidig et al., 2009)*
Sewage sludge ash	
Wet chemical	BioCon-process *(Hultman et al., 2003)*
	SEPHOS-process *(Cornel and Schaum, 2005)*
	PASCH-process *(Montag et al., 2005; Pinnekamp et al., 2007)*
Thermal	BAM-/ASH DEC-process (EU-project SUSAN) *(Adam, 2009; Hermann, 2009)*
	Electro thermal P (Thermphos/SNB) *(Cornel, 2002; Korving and Schipper, 2009)*

Figure 8: Different technologies to recover phosphorous from and sewage sludge ash at wastewater treatment plants. Source: Foellner, 2008

Rates for recovery in laboratories can reach 60% for wastewater, 80 to 90% for sewage sludge. Techniques applied are calcium-phosphate route or struvite precipitation (Air-Prex and PRISA processes) for raw wastewater. For sewage sludge, sludge fractioning and biological nutrient removal are the 2 main recovery techniques. For sewage sludge ash, the wet-acid route (hydrochloric acid digestion), the sulphuric acid route (digestion +ion exchange) and thermo-chemical route are applied. (Hartard, 2010)

3.3. The wastewater reuse: history, present, future and main driving factors and barriers

3.3.1. Old times, when dry sanitation prevailed

Sanitation is evolving but also coming back to its origins. Lots of traditional societies used to practice excreta and urine reuse. In Japan, Korea and China, the reuse of excreta for agricultural purposes was well known during the ancient times. Various types of toilets were used from pot-toilets (excreta reuse for compost production), pig toilets (feed stocks for pigs) and ash toilets (compost) to temple toilets (dehydration on site). (Luethi, et al., 2010)

Figure 9 and Figure 10: Traditional pot toilet in Korea (Oh, 2010) and pig toilet on the Island of Jeju (South-Korea). Source: Schuetze, 2005

In South-east Asia, excreta were used for aquaculture (fish and aquatic plants). These organisms were not directly eaten but used as a second stage feedstock for the production of larger fishes and crustaceans proper for human consumption.

In ancient Arab cultures, the use of excreta was also incorporated in agricultural habits. Ibn al-Awam, an Arab living in southern Spain even wrote about composting techniques for excreta around the 12th/ 13th centuries.

One of the most interesting examples is the reuse of excreta for the production of "Terra Preta" (the most valuable soil farmers always dream of). It is now well-known that faeces were an important component of this black soil together with charcoal, organic waste, bones and so on... "Terra Preta" is famous for its ability to enhance and preserve soil fertility and allows a sustainable fertilization of forests and agricultural soils.

Urine was also used by the Celts for cleaning and dyeing of clothes but also for personal hygiene and for ritual. (Luethi, et al., 2010)

In ancient Greek and Roman cultures, excreta reuse for agriculture purposes was also a common practice but the Romans also reused greywater. As a result of the Roman bath culture, the daily water consumption of upper classes was around 600 litres. This water was then stored outside of the settlement and then reused for irrigation. (Luethi, et al., 2010)

But, literature also shows that different forms of water-based systems for urban sewage (discharge of stormwater and greywater) existed in ancient civilizations even if centralized systems are a quite new development. (Luethi, et al., 2010)

3.3.2. Contemporary times: the era of excreta reuse as fertilizers

Dry sanitation was still frequently practised during the 19th and 20th centuries. It is reported that countries like Japan had a well-organized use of excreta in agriculture and that public toilets were designed to respond specifically to these needs. Urine was collected separately and used as fertilizer as well. In China, this sanitation/ fertilizer combination became a real business, contractors had to pay a license fee in order to collect the excreta and sell it to farmers. (Luethi, et al., 2010)

In European cities, sanitation and waste management were both managed by the informal sector. Private workers were removing excreta from cities to deliver it to agricultural fields outside urban area. In Paris around 1850, the agricultural use of excreta could be done on site since 15% of the city area was dedicated to urban agriculture and Paris was exporting vegetables, compost and fertilisers derived from pits to the surrounding regions. The municipalities themselves or private businesses/ associations even often performed the agricultural utilisation of excreta. However, with the expansion of cities it became more and more difficult to utilise the excreta in the direct neighbourhood. In order to solve this problem, several cities in Germany and in the Netherlands developed the so-called "Liernur system", which consisted of a fertiliser powder based on dried excreta. Unfortunately, the process was requiring too much energy to be viable on the long term. Systems such as "soil" or "litter" toilets were widespread in Europe and some models were even equipped with a mechanical system to automatically drop ash (often a mix of burnt lime and charcoal) or other dry matter on the excreta in order to reduce odours. In the second-half of the nineteenth century, urine diversion systems started to appear in order to reduce further bad odours. (Luethi, et al., 2010)

3.3.3. Reasons behind the decline of excreta reuse and the rise of sewerage

Over time urban settlements grew to an extent where it became impossible to manage the logistical constraints of excreta collection for agricultural reuse. The traditional buckets and handcarts become too small to carry the important quantities of excreta generated in big cities. Furthermore, in the nineteenth century, the development of piped domestic water supplies and flush toilets did not allow the collection system to last longer. Traditional systems declined when demand for flush toilets increased really fast because of the opportunity to reduce bad odours and to have a toilet installed directly at home. (Luethi, et al., 2010)

The large scale and cheap production of chemical fertilizers also affected the recovery and reuse of nutrients from human excreta. The possibility to buy separately the different kinds of fertilizers (N, P and K) met the expectations of farmers, who were looking for easier management and flexible applications.

Political intervention is also a major factor for the demise of excreta reuse because decisions affected the perpetuation of agricultural or aquacultural use of excreta. In India for example, even if it still practised, the use of excreta for agricultural purposes was banned in the 1960's when chemical fertilizers appeared. The same situation has occurred in Thailand, Vietnam and China where the use of excreta for aquaculture is being made illegal by local governments. (Luethi, et al., 2010)

The combination of all these factors as well as a sanitation crisis contributed to the "end" of dry sanitation and other forms of excreta reuse. People thought that water flushed systems would improve this crisis but it actually just relocated the problem from city streets to nearby rivers leading to the pollution of downstream areas. Unfortunately, this water-based system also allowed the propagation of cholera in the city of Hamburg after a flood and killed 10 thousands people in 1892. Sewage contaminated with cholera pathogens was discharged in the Elbe and this contaminated drinking water. Discussions and critics regarding water-flushed systems started really early and some cities in the Netherlands, Luxembourg, Prague and St-Petersburg tried to implement the reuse of blackwater (other version of the Liernur system) in order to avoid important contamination/ pollution risks. (Luethi, et al., 2010)

3.3.4. Today's opportunities and barriers regarding excreta reuse

Today, sanitation is again becoming a hot topic and sustainable sanitation concepts are discussed all over the world. The drivers for this evolution are mainly the costs for water supply that are continuously increasing because of water scarcity in dry areas and rising prices of energy costs. There is also an increasing water demand for irrigation since population is growing everywhere and industries (mainly food and energy sector) use important amounts of fresh water. As previously debated, costs for mineral fertiliser keep on increasing since phosphate reserves are becoming scarce. Furthermore, the optimization of our water consumption becomes crucial as well as the reuse of already available nutrients.

But reuse implies several hygienic risks; therefore there are legal limitations for wastewater reuse (needs for standards and quality criteria). Organic matter, pathogens, organic and inorganic pollutants have to be removed before reuse. The last problem is the image deficit of crops irrigated with treated wastewater (Foellner, 2008)

3.3.5. Today's actors, main concepts and relation with Material Flow Management

Sustainable Sanitation is a broad concept with different systems and applications that is attracting more and more interest among the international community. Some famous actors of the "sustainable sanitation" way of thinking are the SuSanA (Sustainable Sanitation Alliance), which is a network of organisations, associations, private companies, governments, and research institutions interested in this topic and looking for the achievement of the Millennium Development Goals by promoting sustainable sanitation systems. This network counts around 150 partners such as the GIZ, the UNEF, the UN-Habitat and so on...

To be mentioned are also BORDA, which stands for Bremen Overseas Research and Development Association, Eawag-Sandec in Switzerland and many others. BORDA developed for example the famous DEWATS (Decentralised Wastewater Treatment Systems) applied also to Hotel and Hospitals (DEWATS HoSan). (See attached presentation in annexes). This system can be associated with a technical approach but not with a technological package since it is mostly proposing low maintenance and energy inputs solutions for a wider application. The main DEWATS components are: settler, anaerobic baffled reactor, anaerobic filter and planted gravel filter. (BORDA Bremen Overseas Research and Development Association)

It is difficult to define the exact goals of Sustainable Sanitation because it always depends on the people concerned by the problem. Where sanitation does not exist or in really bad

conditions, new sanitation has the ultimate purpose to protect and promote human health by allowing a cleaner environment to develop and by breaking the cycle of diseases related with poor sanitation. This will help for the achievement of the Millennium Development Goals. Sanitation systems in that regard shall be economically viable, socially acceptable and technically and institutionally appropriate but also protect the environment and natural resources. When sanitation already exists but has to be improved, reasons can be: less-water reliant systems, reuse of nutrients where needed... In fact, there are generally two issues with common wastewater treatment technology: high investment costs and high operation and maintenance costs. Natural resource-intensity is another important issue where water is used to flush, to convey, to dispose but also before and after treatment. But in every case, sustainable sanitation can be related with Material Flow management. This concept means "the goal-oriented, responsible, integrated and efficient influencing of material systems." [6]
Aims of Material Flow Management are:

- Increase of system efficiency: Sustainable Sanitation aims at improving the efficiency of energy intensive centralised wastewater treatment plant by moving towards decentralised solutions.
- Decrease operating costs: Maintenance of a centralised system is very costly, that is why decentralised solutions are more and more favoured.
- Create stakeholders networks: Sustainable Sanitation forces stakeholders to work together at the planning phase but also afterwards. For example waste management companies can be encouraged to cooperate with public authorities and sewage sludge treatment operators.

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[6] Enquete-Commission of the German Bundestag: "Protection of human-beings and environment", 1994, p.259

- Activate regional potentials: Moving towards Sustainable Sanitation also means moving towards the reuse of wastewater and therefore the reuse of nutrients. Closing the loop instead of importing expensive chemical fertilizers is a good example of Material Flow Management.
- Create and maintain jobs: In areas such as slums where the population density is too high to envisage private toilet in each household, the construction, operation and maintenance of common sanitation facilities proposing not only toilets but also showers at different points will create jobs. Furthermore, the operation of decentralised plants creates more jobs than centralised systems and small enterprises can start businesses in the collection, treatment or disposal sector.

The ultimate goal of Material Flow Management is to create a sustainable society and the relation with Sustainable Sanitation is quite clear from the "closing the loop" perspective. In fact, if we think about implementing a Circular Economy concept, the main point is to promote relations within the region or the community. Here, the situation has to be seen on a smaller scale but goals are similar. First, from the sustainability angle, the reuse of nutrients contained in faeces and urine can be compared to the use of organic fertilizer, thus avoiding the purchase of very concentrated chemical fertilizers polluting water bodies. This will be profitable from the economic point of view for farmers and from the environmental point of view: less mining of phosphate rock and less leaching of fertilizers in rivers. Furthermore, knowing that Morocco (one of the main provider of chemical fertilizers) is illegally exploiting Western Sahara's resources and that several global organizations asked for the boycott of these resources, it will also be profitable from a social perspective. But, this is just considering the reuse of products generated from sustainable sanitation. It also means that huge quantities of fertilizers coming from a few providers will not have to travel the world to be spread on fields.

Depending on the systems implemented, sustainable sanitation can be linked with biogas production that can be used for cooking and other purposes like electricity and heat generation on a bigger scale if the installation is coupled with a cogeneration plant. Implementing sustainable sanitation and especially decentralised solutions also creates jobs within the region for the collection, transport and treatment and disposal of the products. This is an important advantage in peri-urban and rural areas where people can create small businesses. Decentralised solutions are less cost intensive to implement but also to operate and that is why they are already preferred wherever possible. They are also perfect back-up solutions for households or new buildings with no connection to sewerage system. When centralised systems are already in use, water savings appliances as well as urine diversion systems and/ or dry sanitation systems will reduce the energy consumption to clean water but it is not always feasible. It can for example depend on the design of pipes. Sometimes, an important flow is necessary to prevent clogging.

Dry sanitation systems or urine diversion systems are not always well-accepted and therefore not always implemented. A new initiative happening in Luxembourg within the 7th Framework Programme of the European Commission is interesting from the disposal perspective. One of the main problems of centralised treatment plants is the tremendous quantity of sewage sludge produced, which is also really costly to eliminate. This interesting recent project selected for funding tries to solve the sludge issue by applying the gasification technology. The project takes place in Luxembourg on a platform where sewage sludge and organic waste from the community are usually composted. The new upgraded idea would be to use the gasification process (fluidised bed) to transform this new “fuel” made of sludge and organic waste into two valuable products: solid combustible pellets and fertilizers in order to reduce the disposal costs and environmental burden. Since, we are facing here a centralised wastewater system, options were limited and this project can find a way to make most of the current situation. ENERCOM is a good example of material flow management especially because it is enhancing the regional added value.

4. The planning process for Sustainable Sanitation

4.1. Understanding the factors surrounding Sustainable Sanitation Planning in urban/peri-urban areas

Planning sustainable sanitation can be really complicated especially in cities where socio-economic criteria can be really diverse. Urban areas cannot be categorized by one criteria only and have to be described according to spatial analysis but urban environments have to be seen from 3 different points of views: household, neighbourhood and city levels. In order to define opportunities for improvement, the following criteria have to be analysed: physical and environmental factors, social groups and institutional structures as well as the incentives for people to change their habits for better sanitation conditions. (Luethi, et al., 2010)

- Factors of urban complexity

Projects often fail because they do not take into accounts all necessary factors to design the best fitting system for a specific area. Engineers easily focus on the technological part, neglecting the social, institutional and organisational ones. (Luethi, et al., 2010)

- Physical and environmental criteria

Geographic and topographic criteria are important when planning a sanitation system because it is crucial to know the ground slope and groundwater level for example, already existing sanitation facilities and other urban infrastructure such as housing... To decide whether a centralised or decentralised system would be more appropriate, data such as population density and expected demographic growth are also important factors to be taken into account. Furthermore, local climate and precipitation determine if water scarcity or floods are threatening factors. (Luethi, et al., 2010)

- Technological and legal factors

Technological and legal factors are strongly influencing the sanitation system and especially its performance and feasibility. Norms and standards for sanitation are important criteria to consider when designing sanitation facilities. Sometimes, norms are official but there are also unwritten ones that became important because used in practice. Part of these standards can influence the cost of delivering as well as the consideration to improve sanitation. Both these factors matter a lot for investment decisions. (Luethi, et al., 2010)

- Socio-cultural and economic factors

They include a wide diversity of cultural and economical values, religious conventions, users preferences and established practices. Adapting sanitation to meet local needs is an important challenge. Economics matter because it represents the amount of money people can invest at different levels for sanitation. Purchasing power of potential users will determine which technology can be envisaged because most of the time people care about the price of the installation and not its environmental benefits. (Luethi, et al., 2010)

- Institutional and regulatory factors

Public institutions as well as private actors participate in sustainable sanitation projects and must be therefore considered in the planning. Diverse institutional issues can influence the delivery of sanitation services: from organisational competencies to human resources, knowledge and skills as well as financial capital. (Luethi, et al., 2010)

4.2. Analysis of these factors

As previously shown, there is a large variety of contextual factors to take into account before thinking about designing a sanitation system. But what makes the situation more complicated is that these diverse contextual factors are located in different sectors: from the water supply, to health regulation and waste management as well as different domains: households, neighbourhood, city and external to the city. Sometimes, these factors are not coherent and conflicting demands or conditions can occur. It is important to consider all factors in all sectors and all domains to reach a higher level of sustainability. It will also help to determine critical issues and their potential impacts. (Luethi, et al., 2010)

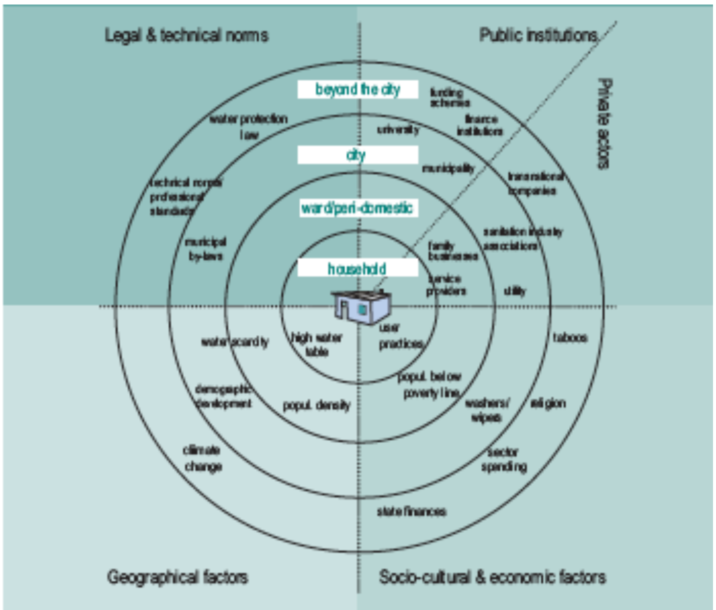

Figure 11: Multi-level map for identifying institutional, organizational and content factors. Source: Luethi et al. 2010

- Analysing the situation from a physical and technological perspective

First, a categorization of land use and settlement types is a necessary base for the planning framework and for easier decision-making. This will imply the set up of boundaries of the various settlement types within the urban area according to criteria such as land use, physical settlement characteristics and socio-economic status. The different neighbourhoods may need different sanitation solutions according to local conditions. Data can be difficult to find regarding local situation and undertake sites visits can be necessary to have a complete overview of the status quo. Discussions with local residents are also important to crosscheck information contained in the documents and have an idea about the efficiency of current infrastructures. Infrastructures and facilities should be mapped according to the domains in order to identify crucial information:

- Coverage and quality of household latrines and on-site sanitation
- Extension and quality of drainage and sewerage networks
- Locations of water bodies, which are recipients of wastewater and faecal sludge discharges (formal and informal sites)
- Areas where wastewater is used for irrigation purposes

In order to determine which areas are under "stress", it is necessary to analyse where the demand of sanitation services is higher than the supply. The level of stress is defined by the gap between demand and supply. The result of this assessment will show areas in need of priority attention. Assessing the quality and not only the quantity of sanitation services is also important because sometimes services are provided but they are poorly operated and maintained. Community members and other stakeholders can also be consulted to determine where problems are situated. (Luethi, et al., 2010)

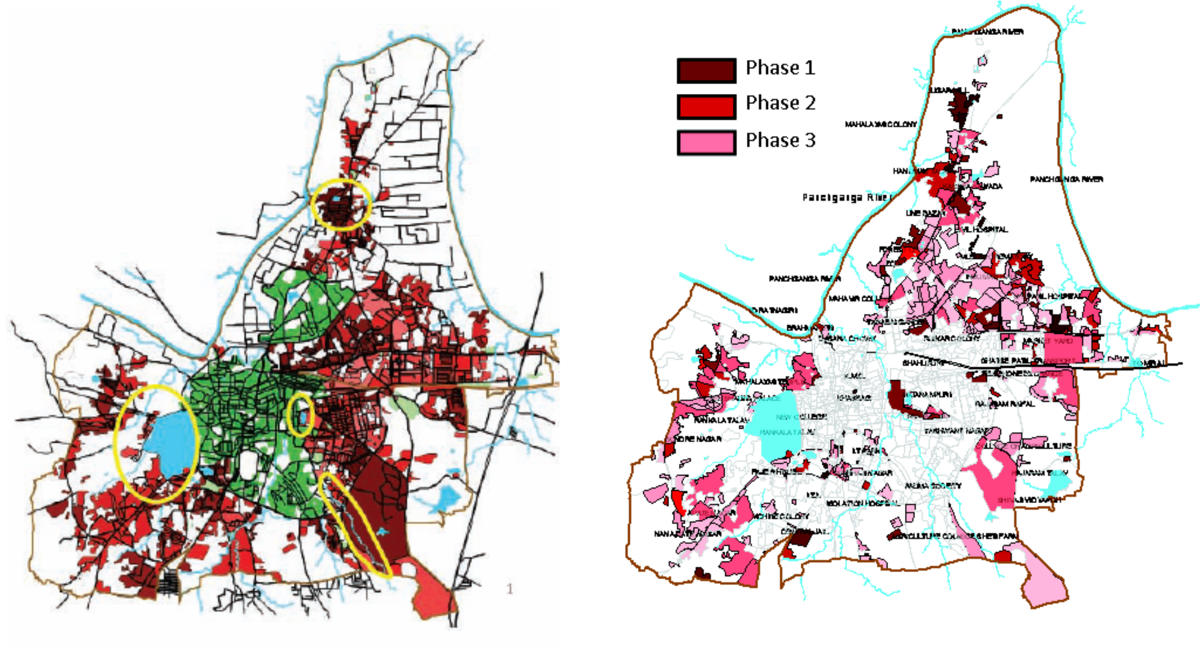

Figure 12: Mapped sanitation stress areas of Kolhapur, India ; red (darker=higher stress) to green (non-stress) and priority of action (from phase 1 to phase 3). Source: Balachandran et al, 2009

4.3. Analysis from a social and institutional point of view

Similarly to the physical and technological assessment above, this assessment also uses the different domains (from households to city levels) in order to identify all existing service providers such as NGOs or community-based organisations before analysing stakeholder's interests or drivers at each level. The process is conducted according to the following steps:

- Identify key actors in each domain and assess their interests, motivations and incentives
- Understand what external factors drive decisions in each domain
- Identify and assess capacities in each domain for implementation and long-term management

The analysis of these 3 different levels is useful to assess the context within which local sanitation systems are operating and a reference point for prioritisation of interventions. (Luethi, et al., 2010)

4.4. Identification of the interests of key actors

Regarding institutional assessment, the first step is to identify relevant stakeholders, actors and service providers that have direct or indirect involvement for each of the different components of the system. Public authorities range from ministries to governmental agencies such as regulatory bodies, municipalities and local authorities or public utilities to professional associations, universities and research institutes. In general, the main stakeholders involved in sanitation are municipal authorities, utilities and sometimes governmental agencies but there is also often a multitude of small-scale operators involved in the provision of sanitation. (Luethi, et al., 2010)

Private actors include all sorts of firms: small engineering companies, responsible for installation and operation of sanitation facilities to large multinational firms in the field of technology development or full service provision. Informal operators are found in the areas where official service is lacking or unable to operate. When planning an urban sanitation system, diverse interests and objectives may come into play such as health, environmental protection, economic development, poverty reduction, improved urban planning or reduced operational costs depending on which stakeholder is concerned. (Luethi, et al., 2010)

The following example from the sanitation 21 frameworks summarises how interests and stakeholder priorities may vary between different domains:

- Household level

The living conditions and immediate local environment improvements are the first objective of households. Health is rarely mentioned as a priority but people are aware of the risks associated with poor sanitation. Last but not least, an important motivation for households is privacy and safety improvements for all family members. (Luethi, et al., 2010)

- Neighbourhood level

The interests at the neighbourhood level concern mostly cleanliness but also health. NGOs are closely involved with community development activities and the important issue that is sanitation. They often see the improvement of collective service as way to strengthen social cohesion. (Luethi, et al., 2010)

- City level

The focus here tends to go for protection of the economy and environment of the city along with meeting externally-established targets. Health is also a major factor since outbreaks of diseases (due to poor sanitation or poor waste management) can directly impact the political credibility as well as economic attractiveness of the city. For financially independent utilities, financial considerations will be seriously taken into account when planning new sanitation facilities. City authorities objectives are also strongly influenced by higher levels of government (incentives can be from different nature: financial flows, penalties, electoral relationships and law) and elected municipal government, which want to stay in place, have an important interest in cleaning the city and preventing outbreaks of disease. (Luethi, et al., 2010)

- Beyond the city

At this level, objectives are directed to the impact exerted by the city on wider society. Health and access to sanitation remains important parameters since national governments are committed to reach improvements in health status and in meeting the Millennium Development Goals. This is the only level where such international goals come to mind. Considerations about the management of water and food resources, protection of the environment and economic development are well developed at this level. (IWA, International Water Association)

4.4.1. Definition of external factors and their influence as well as power relations

Interests among people greatly vary and depend to a large extent on power relations and incentives between actors in different domains and positions. The interest of a design consultant will focus on minimising the risks for the reputation of his company and this can lead him to recommend a conventional solution involving networked sewerage with a limited technical innovation. But, for a random household, minimising investment costs while gaining in privacy and dignity would be the main objective. Furthermore, connection to sewerage network is often unaffordable for households. It is therefore important to recognize that interests can be completely at the opposite between the consultant and the household or even neighbourhood. Poverty, tenure security or insecurity will really influence household's decision-making even if their objectives were clear. (Luethi, et al., 2010) In lots of countries, women and children do not feel safe going to communal toilets at night for their defecation needs. Their main need is therefore based on a private (even really low-tech) toilet.

In order to support effective planning decision suiting the majority, tools such as stakeholder assessments, institutional mapping or regulatory review can be interesting to analyse existing power relationships and vested interests. The analysis should be global and include formal and informal institutional arrangements, public, private, civil society institutions and focus on groups or individuals whose interests are likely to diverge. Understanding dynamics and regulatory environment in place in an urban settlement is crucial to provide suitable planning solutions. These tools can even help to address many other factors influencing decision-making such as religious, ethnic, social class, caste or gender. (Luethi, et al., 2010)

4.4.2. Assessment of capacities in each domain

Technical problems are not always originating from a lack of sufficient equipment or transportation possibilities but also management and institutional inadequacies. It is a common belief that problems are mostly generated by technical failures but sometimes institutional performance can be the source of the problem especially if the staff does not receive enough incentives to perform. Each position needs to be rewarded even the lower level of workforce in order to provide a quality service. (Luethi, et al., 2010)

4.4.3. Identification of entry points for action in different urban contexts

According to Luethi, et al. trying to improve sanitation over the whole city can be a hassle of work. A more realistic approach is to focus on key areas: “under stress areas” for a more effective planning. The approach has already been tested in Indonesia and seems to work pretty well. A participatory decision-making process to define these special areas is well adapted to avoid disagreement. De facto, it is better to focus on greatest impacts in particularly stressed areas and where certain contextual factors provide an opportunity for change. Communities where sanitation is poor or almost inexistent are priority areas. Sometimes, conditions are not favourable to a change, for example when people are squatting illegally on land and the situation has to be improved before proceeding. The city has to be seen as a patchwork of different domains and physical environments. By breaking the city into patches, it is easier to solve the puzzle it represents. (Luethi, et al., 2010)

There are 5 different typical urban contexts and they illustrate how the dynamics between physical, spatial, demographic and socio-economic factors within each of these settings present different challenges and opportunities for the provision of sustainable sanitation services. Even when considering a small town or an urban center, there is a need for many different sanitation technologies to serve a wide range of socio-economic residential areas but also to provide sanitation to institutions such as schools, hospitals and public places (bus, railway stations...). (Luethi, et al., 2010)

The 5 types of urban contexts are:

- Informal settlement

In these areas, the demand is really high whereas the income is mostly low. The constraints here are high density of population and marginal environment with no clear governance, especially in slums. But in this context, small investments can be really beneficial for a whole community and since sanitation systems are mostly inexistent, there is the possibility to implement new technologies and systems. Important assets are labour-force for construction of the system and community management structure. In slums, there is a great opportunity to build common sanitation blocks combined with washing facilities. This is a way to create a community action to strengthen links between people. People can be very willing to work in common to improve the direct environment and small business. Public toilets can be run through community-based organisations and collect user fees. If the community manages these toilets, it can improve their enthusiasm to improve drainage and clean streets to make their living conditions better. (Luethi, et al., 2010)

- Peri-urban interface

The peri-urban context is full of opportunity thanks to its situation: not directly in the city but not completely out of it. These areas have usually a low density of population and more space, which allows them to have agricultural activities. The connection to the city sanitation services is less likely to exist for these communities that have to find alternative solutions. Since agriculture is possible on these territories, it is interesting to think about decentralised technologies with reuse of the effluents. Peri-urban areas are essentially "transition areas" that will one day become fully urban therefore replicable innovations should be implemented there in order to spread the “urban technology of the future”. (Luethi, et al., 2010)

- Planned urban development areas

These areas, fully planned and not retrofitted offer great potential for innovative sustainable sanitation because of the lack of infrastructure. Integration of rainwater harvesting, greywater separation and reuse, solid waste management, irrigation of public spaces and recreational areas as well as urban agriculture and biogas production are the main sustainable solutions experienced in these areas. (Luethi, et al., 2010)

- Non-residential buildings

Non-residential buildings also allow opportunity for innovative technologies because they can be used as test-buildings before bringing some technologies to the market. The large numbers of users make it quicker to see if sanitation solutions are appropriate, feasible in the long run and effective. Non residential-buildings such as schools are also of a great importance to convey hygiene and behaviour change for health improvements. Last but not least, they also offer the opportunity to test innovative management and financial scheme. Solutions such as a biogas plant for example can be linked to the energy sector for the biogas to be sold (to cover operation costs of the new sanitation system) or to be used on-site. (Luethi, et al., 2010)

- Inner-city middle- and high-income settlements

In these settlements, sanitation already exists but often needs to be upgraded. Replacing sanitation to move towards water-saving toilets, waterless urinals, separated system for greywater is easily put in place but can already improve the system a lot. More money is available for investment in these areas, which makes the planning easier. (Luethi, et al., 2010)

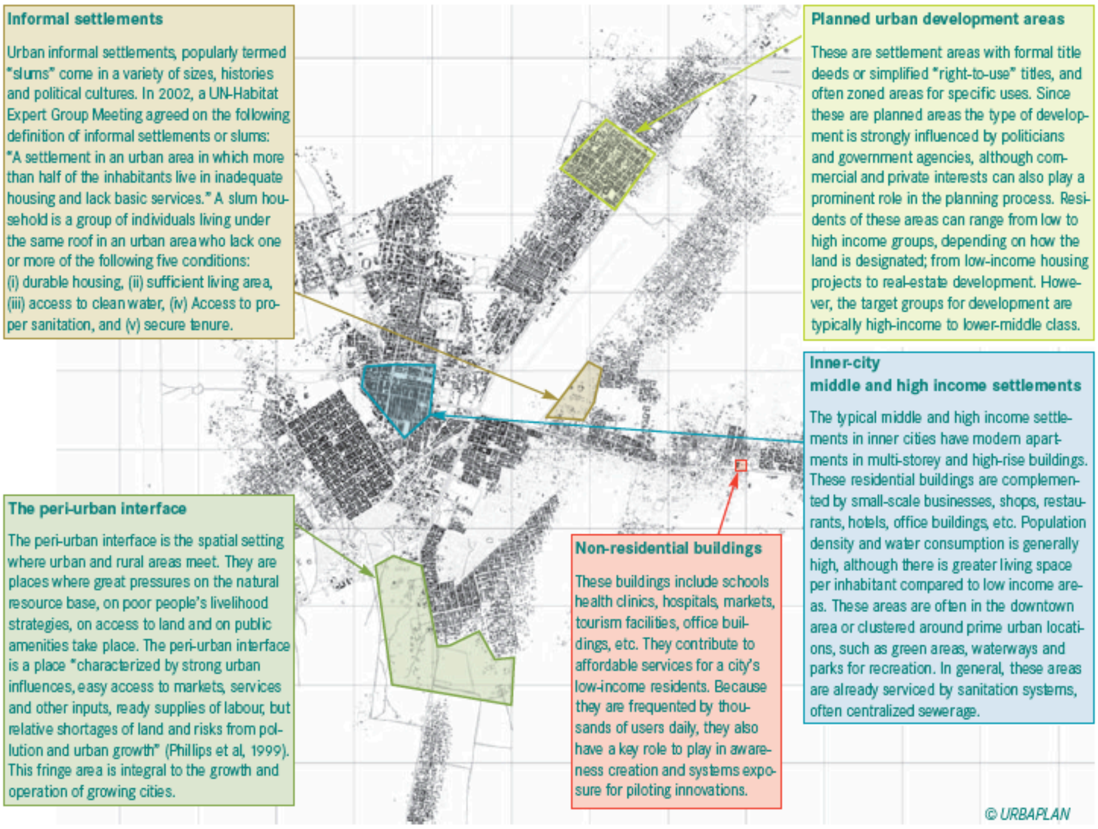

Figure 13: Entry points for sanitation in the urban context. Source: Luethi et al. 2010

4.5. Planning sustainable sanitation: approaches and concepts

New trends in planning focus on tools for improving sanitation solutions with sustainable criteria and participative communication between stakeholders. This is the end of general planning (top-down approach) and the beginning of an era for locally adapted solutions.

4.5.1. Challenges linked with sustainable sanitation planning

Planning for urban environments started approximately 5000 years ago with the beginning of urban civilization. Since the 19th century, this urban planning is left to specialists and experts using policies, plans and projects in order to build city areas. They usually assess needs in an area and then implement the type of service they see as appropriate. Connections to the existing system in peri-urban areas or implementation of new treatment steps are also part of the planning. Often, sanitation planning focuses on a specific neighbourhood because it is too complicated to introduce city-wide solutions. Nowadays sanitation planning consists in putting together sanitation systems vertically and horizontally instead of trying to develop a homogeneous system that could suit the whole city. The problem is that large parts of cities are neglected because of the rapid population growth. This population live either in really poor areas or even in illegal settlements. The situation also undermines local governments efforts to plan urban development and sanitation. Furthermore, developments are often project-based because strictly conducted by donor agencies and/or governments. These solutions are just partially suitable because not adapted to local needs. (Luethi, et al., 2010)

A common other mistake is that sanitation is not adapted to peoples needs in general. These people are users but also landowners, politicians, financial institutions as well as users of the reused wastewater for example. Supply-driven approaches have been also applied in several developing countries where one technology was favoured without taking into account people's needs. These approaches also lead to cost issues (high initial investment) as well as technocratic issues (large scale operators are favoured instead of small local companies).

Furthermore, institutional capacity of these systems is weak and no mechanism is in place to recover investment, operation and management costs, which is limiting service extensions but also degrading service provision and maintenance. Finally, public investments in poor areas is also really limited and improvement of sanitation coverage (even subsidised) is concerning areas where the population can afford higher levels of services (sewer, septic tanks and households connection). This “old time” thinking is no more operational and criteria such as institutional capacity, cultural issues and public participation are now being taken into account. (McConville, 2011)

4.5.2. Description of the trend in planning theory

When looking at different studies concerning sanitation, it is recurrent to find recommendations concerning more communicative and participatory planning styles and especially the inclusion of users in the planning process. As previously debated, planning should not be technocratic involving only engineers. But according to McConville, theoretical tendencies vary during the planning process and even if local residents are asked at the beginning of the planning, they may not actually have a word to say regarding the implementation of sanitation systems, This is what experienced the small town of Tougan, northwest Burkina Faso where the use rate of installations is very low. (McConville, 2011)

- Communicative Planning

Literatures usually agree on the fact that communicative planning should be necessarily conducted after the failure of top-down and supply-driven approaches. Giving all involved stakeholders a say in the process through open dialogue and exchange can be crucial for its success. (Luethi, et al., 2010) As presented by Jennifer McConville, participation is often promoted as a tool for “overcoming some of the major challenges to improve access to sanitation, such as low demand for sanitation infrastructure, poor hygiene habits, weak institutional structures and low capacity for operation and maintenance of built systems." (McConville, 2011) Here the point is to mediate the community rather than providing a strict plan to follow. Participatory tools are recommended in theory and several success stories and award-winning projects used such methods. One of them was started by the Sulabh International Social Service Organisation (India), whose actions are "sustainability oriented". They implemented for example the movement to liberate scavengers by implementing a low-cost safe sanitation system. One of their method is the Community-Led Total Sanitation (CLTS), which purpose is to eliminate open defecation by proposing to communities the opportunity to conduct their own appraisal and analysis of open defecation (OD) and take their own action to become a new community open defecation free (ODF). This method is focusing on behaviour change to realize real hygiene improvements. These tools are often based on Participatory Rural Appraisal (PRA) and SARAR for Self-esteem, Associative strengths, Resourcefulness, Action-planning and Responsibility) techniques. The general goal of this method is to push communities to face their own problems and find themselves solutions to remediate. Another tool called PHAST (Participatory Hygiene and Sanitation Transformation) aims to overcome community resistance towards behaviour change by pushing people to have open dialogues and raising awareness of the consequences of poor sanitation. These methods are shown to be effective for population to realize that an improvement in sanitation is necessary. Informed people have better chance to make good choices than the others and these methods will help people to understand that sanitation services will lead to less sickness for example. But following the communicative planning model implies also a change of role for engineers that are no longer only planners but also mediators in conflicts resolution and negotiation. (Luethi, et al., 2010)

On the other hand, participation also has drawbacks and it seems like participation is favoured in theory but not in practice. A study, conducted by Jennifer McConville et al. showed that actually participation appears to be occurring less frequently than recommended in the literature and that it is anyway a new trend in planning that will need time to develop. According to her, the situation remains controversial and it may be a sign that participatory planning presents less benefits than it is supposed to bring. The participation case in "Ouagadougou Strategic Sanitation plans" shows that households barely look at the whole sustainability of a project but only at the economic part. They will anyway choose the least expensive solution while being aware that it is not the most appropriate for their needs. Sometimes, they may also not be well informed about the different possibilities by the field workers. It is therefore recommended to adopt a mixed-methods approach (McConville, 2011)

- Use of sustainability criteria versus users criteria

According to Luethi et al, sustainability criteria should be the main focus when comparing and choosing sanitation systems. The criteria have to be defined during the planning, implementation and operation levels from the macro-to the micro level. By acting so, the sanitation designers will be closer to the users needs. (Luethi, et al., 2010) These needs are: (according to a study conducted by Jennifer McConville in small towns in Ghana) mainly convenience, hygiene and the availability of a subsidy. Significant improvements could be made according her through better linking of planning and implementation objectives in order to achieve functional and sustainability of all stakeholders. (McConville, 2011) According to the Sustainable Sanitation Alliance (SuSana) the sustainability criteria are very diverse and range from "health, hygiene, technology and operation, financial and economic issues, to socio-cultural and institutional aspects, as well as the environment and natural resources."

Well-designed sanitation systems can also become a failure when the focus of households and sanitation designers is different. The first ones, as explained in the Ghana case, will look for not expensive solutions solving their hygiene/ health problems in their own house (on-site treatment). The second one will look for environmental improvement and financing solutions. But, sometimes users can realize how beneficial it can be.

There was a case in Bolivia were villagers did not want to use the UDDTs (urine diverted dry toilets) because they were not really convenient. These people did not see improving their hygiene as main criteria for using the toilets. But, they slowly discovered that composting the dry faeces with organic waste could create valuable compost. This region was famous for its production of special mushrooms that would only grow under pine tree. A free fertilizer could allow them to plant more pine trees under which would grow more of these special valuable mushrooms. People come from all over Bolivia to purchase these mushrooms. The dry toilets are now fully used to reuse the nutrients contained in dry faeces. (EcoSan, 2010)

4.6. The planning process itself

It is easier to consider the planning process as a follow-up of different steps that will answer to three basic questions:

- Where are we now?
- Where do we want to go?
- How do you get there?

The process linked with answering these questions is not linear since situations can be really diverse but still happening at the same time and iterations if ideas or actions can happen all the time. But all different literatures describe the same key steps when defining planning.

Step 1: Problem identification

This step defines the status quo or the current context in which the sanitation designers will have to develop solutions. This step is somehow similar to a material flow analysis in the material flow management context: analysing the current sanitation, the stakeholders involved and institutional conditions. It is replying to the first question: “where are we now”? During this phase, different tools can be used such as “Political, Economic, Social and Technological” issues (PEST) and “Strengths, Weaknesses, Opportunities and Threats” (SWOT) analyses.

Step 2: Define objectives

Here, the purpose is to solve the second question, which is “where do we want to go?” This is the step where it is possible to include participatory approaches described previously. Potential conflicts and competing priorities have to be analysed and forecasted for prevention in the implementation process. The tools that can be used are: “Participatory Hygiene and

Sanitation Transformation" (PHAST) and "Community-Led Total Sanitation" (CLTS) and setting "Terms of Reference" (ToR).

Step 3: Design Options

Steps 3,4 and 5 answer to the third question: "how do we get there". The point here is to identify possible solutions by taking technical flexibility into account. Different kinds of systems: centralised or decentralised as well as technologies (from low-cost to high-tech) should be considered to meet all users needs in different areas. Different waste flows can also be considered for reuse.

Step 4: Selection Process

This process includes feasibility studies and critical comparison of the potential solutions. These solutions can then be ranked according to technical objectives, affordability and managerial capacities. "Life Cycle Assessment" (LCA) and "Environmental Impacts Assessment" (EIA) tools can be used as well as "Multi-Criteria Decision Support Systems" (MCDSS) in order to have a broader and transparent consideration of the potential solutions. Stakeholder inputs on potential design possibilities should be used for the selection of the most appropriate system.

Step 5: Action Plan for Implementation

The fifth step does not always appear in all planning processes but it is important to mention it since it is the direct result of the previous step. Only selecting a solution is not enough, planning its implementation with a timeframe for objectives and the roles of stakeholders will assure the implementation success.

This frame changes regarding design planners but a certain frame is starting to appear. New approaches also appear year after year and the latest known are for example the "Open

Wastewater Planning" (OWP) and "Household-centred Environmental Sanitation" (HCES). Stakeholder involvement is one of their first characteristics and they have to be implemented together with participatory sanitation tools as well as awareness-rising methods. (Luethi, et al., 2010)

5. The different sanitation systems

Sustainable Sanitation has to deal with all by-products of sanitation. The following graphic, from the GTZ (Gemeinschaft fuer Technische Zusammenarbeit) now called GIZ (Gemeinschaft für International Zusammenarbeit), shows most of the different flow streams that have to be collected, treated and when possible reused as well as different technologies.

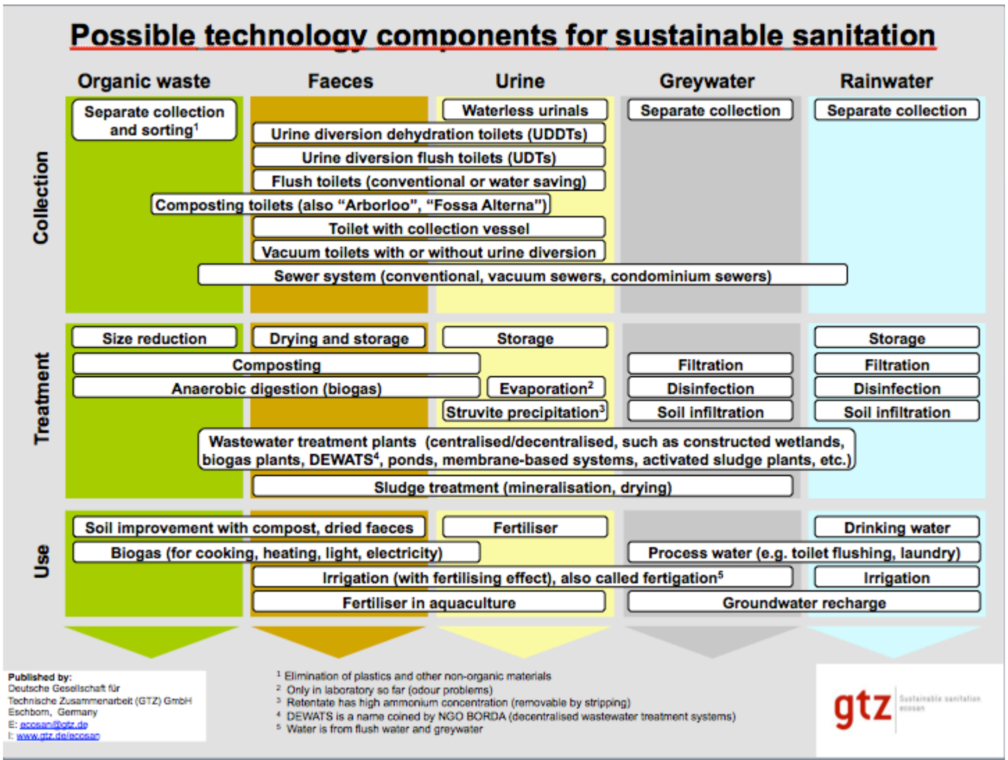

Figure 14: The different components of a sustainable sanitation strategy. Source: GIZ

A sanitation system consists of a combination of different stages in which human excreta and domestic sewerage are managed by different technologies from the point of generation to the point of reuse/ recycle or disposal. Two main systems are usually considered: the "wet" (water-reliant for the transport of excreta) and the "dry" system (non water-reliant), which relate to the use of flush water and/or anal cleansing water. Wet systems generate faecal sludge (mixture of faeces, flush water and sometimes anal cleansing water). Another distinction can be made between the separation of the incoming wastes: urine diverting sanitation will keep urine separate from faeces for example whereas in sewered sanitation, wastes are mixed and generate the general product called wastewater (mixture of yellow water, grey water, black water and cleaning material).

Different system templates are proposed in the literature, the following description is extracted from a compendium of technologies edited by Eawag-Sandec. It explains the different systems based on different criteria:

- User interface
- Collection and storage/ treatment
- Conveyance
- Semi-centralized treatment
- Use and/ or disposal

5.1. System 1: Single pit system

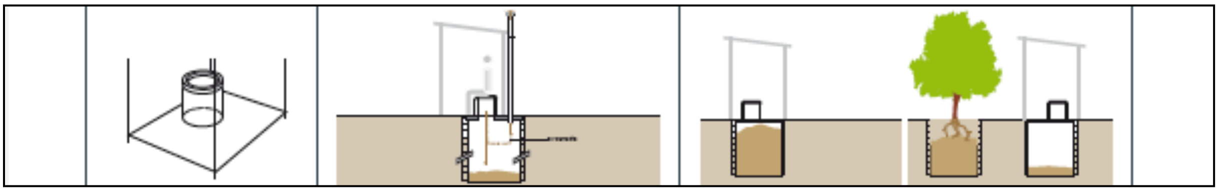

Figure 15 : Single pit system. Source : eawag

This system is based on a single pit using/ not using flushwater depending on the user interface, which can be either a dry toilet (does not need water, excreta are collected directly beneath the sit in a shallow pit, container or chamber) or a poor flush toilet. Inputs to the system are faeces, urine, flushwter and/ or anal cleansing water and dry cleansing materials. The user interface is linked with a storage/treatment technology such as a single pit or a single ventilated improved pit (with continuous airflow to avoid odours and proliferation of flies). When the pit reaches its maximum capacity, there are two different options:

The pit can be filled with soil and planted with a tree. Then a new pit will be built but this is only possible if the structure (of the pits) can be moved. The faecal sludge has to be removed and transported to a further treatment point. Since the faecal sludge is rich in pathogens, it should not be applied directly on the fields without treatment. It should be collected/ treated with one of these solutions (either directly or through a transfer station):

- Sedimentation/ thickening pond: simple settlings ponds where the sludge will thicken and dewater. The effluent can be removed and treated while the sludge can also be treated in a subsequent technology. The treatment will occur after this step that is only a way of collecting the sludge.
- Unplanted drying beds: simple bed with a drainage layer that collects percolated leachate and sludge can evaporate. Around 50-80% of the sludge volume drains off as liquid. Sludge is here also not treated nor stabilized.

- Planted drying beds: they have an advantage over the unplanted ones that is allowing an increased transpiration. In that way, filters do not need to be desludged after each feeding/drying cycle. The plants and their roots systems maintain the porosity of the filter.
- Co-composting: controlled aerobic decomposition of different organic materials such as organic waste (high organic carbon content and good bulking material) and faecal sludge (high moisture and nitrogen content).
- Biogas reactors: anaerobic degradation of organic materials that will lead to the production of a (stabilized) digested slurry and biogas, which is a mix of methane, carbon dioxide and other gases traces. (akvopedia, 2011)

If any of this treatment can be easily accessed, then faecal sludge can be discharged in a sewer discharge station (transfer point) for co-treatment with blackwater by:

- WSP for Waste Stabilization Ponds: large manmade water bodies that are filled with wastewater. The wastewater will be treated by naturally occurring processes of degradation. There can be different designs but usually the system includes 3 ponds: 1) anaerobic treatment, 2) facultative shallow pond (oxygen supply through surface contact) and 3) aerobic maturation.
- Activated sludge: multi-chamber reactor that makes use of mostly aerobic microorganisms (but also anaerobic, nitrifying and other organisms can be present) to degrade organics in wastewater and generate a clarified effluent. In order to keep the active biomass suspended, a constant supply of oxygen is required.
- Aerated ponds: large outdoor ponds with mechanical aerators (allows deeper ponds even in northern climates) to supply oxygen constantly and keep the appropriate aerobic conditions. This will lead to a better organic degradation and nutrient removal.

- Trickling filters: biological filter that is operating mostly under aerobic conditions. Pre-settled (pre-treated) wastewater will be trickled or sprayed over the filter to degrade its organic content (through the pores of the filter).
- Constructed wetlands: FWS (Free-Water-Surface) constructed wetland is a following of flooded channels (aiming to replicate natural processes of natural wetlands, marshes or swamps). Water is slowly flowing through the different layers of the wetland, particles will settle, pathogens destroyed and organisms and plants (cattails, reeds and/or rushes) will absorb nutrients. It has the disadvantage to be a standing body attracting mosquitoes. VF (Vertical-Flow) constructed wetland is a filter bed planted with aquatic plants. Water is poured from above the wetland and will go through different layers (rhizomes, gravels, sands). HSF (Horizontal Subsurface Flow) constructed wetland is a large gravel and and-filled wetland that is planted with aquatic plants. Here, the water will flow horizontally through the channel where filter material filters the particles out and microorganisms degrade organics.
- UASB for Upflow Anaerobic Sludge Blanket Reactor: the process is happening in one tank where wastewater enters the reactor from the bottom and flows towards the top. Within the tank, a suspended sludge blanket (microbial granules) filters and treats the wastewater during its flow. The clarified effluent will be extracted from the top and biogas (from the organic compounds degradation) will be produced. (akvopedia, 2011)

When the pit cannot be fully emptied, a fruit or flowering tree is to be planted at the decommissioned pit because it will use the nutrient rich soil to grow.

All (semi-) centralized treatment technologies (aerated ponds, constructed wetlands, biogas reactor...) produce effluent and faecal sludge that need treatment before their use or disposal. Possible use or disposal solutions include irrigation, aquaculture, macrophyte pond (or floating plant pond), and discharge to a water body or recharge to groundwater. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Really flexible, can combine different technologies even low cost ones

Drawbacks of the system:

- Only suited for rural and peri-urban areas, where the soil is appropriate for digging and absorbing
- Large space required in case of the implementation of constructed wetlands or aerated ponds
- Not suitable for areas with heavy rains or flooding
- Maintenance costs can be expensive
- Solid cleansing materials should be disposed of separately

5.2. System 2: Waterless system with alternating pits

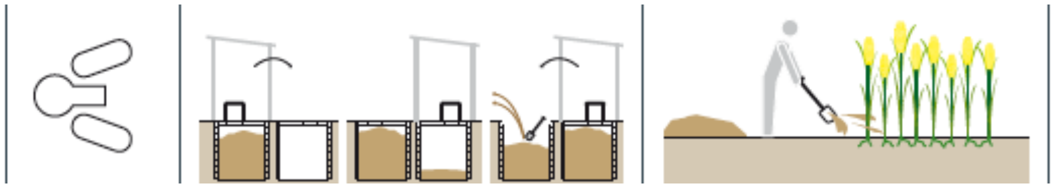

Figure 16 : Waterless system with alternating pits. Source : eawag

A bit more sophisticated, this system is designed to generate a dense material similar to compost with the use of alternating pits but without any Flushwater addition. Inputs materials for this system can be urine, faeces, organics, anal cleansing water and dry cleansing materials. As user interface technology, the only recommended one is the dry toilet (operates without water but has no urine diversion component). No flushwater can be added to the system and anal cleansing water should be avoided or at least minimized. The dry cleansing material can be added depending on the collection/treatment forecasted. The dry toilet is connected to a double ventilated improved pit (only containing excreta) or a Fossa Alterna (specially designed to produce eco-humus but requires a constant input of soil) or a composting chamber (conversion of organics and excreta into compost). Alternating pits give the opportunity to the material to decompose and transform in a humic material (with new characteristics: hygienically improved and nutrient-rich), which can be used or disposed of safely. When the first pit reaches its maximum capacity, the second one replaces it while the first one is covered and left unused (out of service) to allow the degradation process.

The produced compost/ eco-humus from the collection and storage/treatment technology will then be removed and transported to the disposal/ use point. The aerobic process leading to the degradation of the material allows it to be used in agriculture. In case of remaining pathogens, the material can be further composted at a specialised composting facility. The non-existence of faecal sludge makes the system much easier to handle. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Indefinite use
- Can be used where space is limited
- Can be applied in populated and water-scarce areas
- Dry cleansing materials can be added (even enhances the process)
- Dry toilet can be built and repaired with locally available materials and is suitable for all types of users
- Low capital and maintenance costs

Drawbacks of the system:

- Excreta pile under the toilet can be visible depending on the pit's depth
- Odours for the dry toilet are often noticeable
- Extended storage period to hygienize the material
- No humidity allowed
- Greywater must be treated separately
- Use for compost has to be found: agriculture/ gardening

5.3. System 3: Poor flush system with twin pits

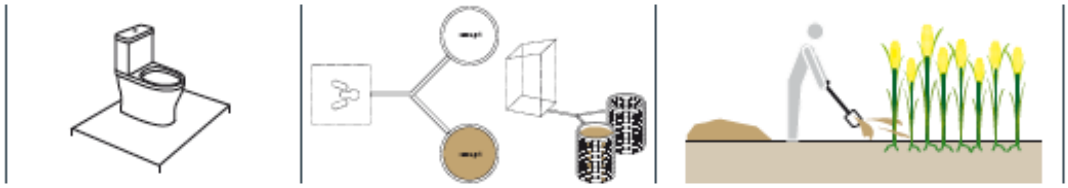

Figure 17 : Poor flush system with twin pits. Source : eawag

Unlike the previous system, the poor flush system with twin pits is water-based and generates a partially digested, humus-like product, which can be used as soil amendment. This system does not require the separate treatment of greywater. The inputs to the system can include faeces, urine, flushwater, anal cleansing water, dry cleansing materials (better if collected and treated separately) and greywater.

A poor flush toilet is indicated for this system even if an urinal can be used additionally. Twin pits for poor flush are among the technologies used for the collection and storage/ treatment of the blackwater originating from the user interface. The use of a porous material improves the effluent infiltration into the ground while solids accumulate and degrade at the bottom of the pit. Only one of the pits is working until it is full and then covered and left closed for the material to degrade. It takes approximately 2 years to fill a pit. A further treatment in a semi-centralized system is not necessary for the treated sludge; it can be either used or disposed of (surface disposal to prevent unmitigated disposal).

The blackwater from the pit can also be directed to a biogas plant where blackwater can be mixed with animal manure and organic waste to enhance the gas production. The gas can be used for cooking/ heating and treated sludge can be used as a soil amendment.

This system should not be implemented in areas with a low groundwater table to avoid contamination risks. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Low cost
- Generation of a safer material than raw blackwater and prevent from illegal dumping
- System can treat anal cleansing water
- Possible production of energy (biogas)

Drawbacks of the system:

- All types of soils are not appropriate like clayey or densely packed soils
- Maintenance for piping systems in case of the use of biogas
- Dry cleansing materials should be treated separately
- Odours may be noticeable depending on the pre-treatment
- Non-beneficial use of all resources

5.4. System 4: Waterless system with urine diversion

Figure 18 : Waterless system with urine diversion. Source : eawag

This system aims at separating urine and faeces to allow faeces to dry while urine is recovered for reuse as fertilizer. This system can be implemented in any geographical area but is especially recommended in rocky areas where digging is unfeasible, water is scarce or groundwater level is quite high. Inputs to the system can include faeces, urine, anal cleansing water and dry cleansing materials. Two sustainable user interface solutions can be used here: either urine diverting dry toilet (UDDT) or a Urinal. The UDD toilet operates without water and offers divided areas for the collection of urine, faeces and sometimes even anal cleansing water. Dry cleansing materials will not harm the system but a separate collection is still preferable.

For the collection and storage/treatment of faeces, double dehydration vaults can be used but anal cleansing water should be diverted to soak pits and never enter these vaults. Within the vaults, a constant supply of ash, lime or dry earth to cover faeces and minimize odours and flies spreading. The pH increase will also eliminate pathogens and hygienize the system.

Urine is nearly sterile and produced in smaller quantities; it can be used for land irrigation, land application or soil infiltration through a soak pit. Both dried faces and urine can be reused in agriculture/ gardening if respecting safe handling. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of this system:

- Easy recover and reuse of nutrients contained in urine and faeces
- No real odours problems if correctly handled
- Suitable for all kinds of users (sitters, squatters, wipers, washers)

Drawbacks of this system:

- Requires efficient separation of faeces and urine (can be complicated for young users)
- Is prone to clogging with faeces and misuse
- Use of suitable drying agent
- Preferable in dry hot climates
- Separate handling of cleansing materials/ greywater and anal cleansing water

5.5. System 5: Blackwater treatment system with infiltration

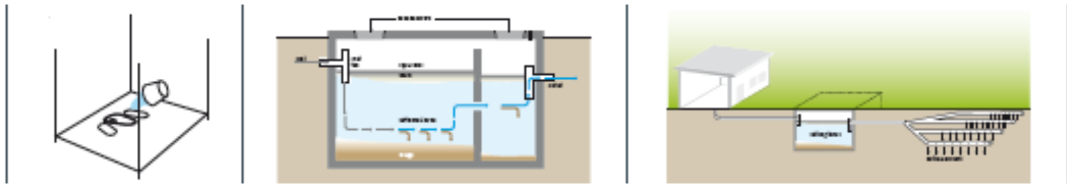

Figure 19 : Blackwater treatment system with infiltration. Source : eawag

This system is among the water-based ones using a flush toilet as user interface (either poor flush toilet or cistern flush toilet) directly in connection to a collection and storage/ treatment technology for blackwater such as:

- Septic tank: watertight chamber made of concrete, fibreglass, PVC or plastic for the storage and (pre-) treatment of greywater and blackwater. The settlement of solids parts plus the anaerobic process reducing the organic content treats the wastewater but only partially.
- Anaerobic baffled reactor (ABR): improved version of the septic tank where the wastewater flows through series of baffles. The upflow chambers provide additional removal and digestion of organic matter.
- Anaerobic filter: consists of a septic tank combined with one or more baffles and filters chambers. Wastewater flows through the system where particles are trapped and organic matter is degraded by the biomass that is attached to the filter material. (akvopedia, 2011)

The last solution really reduces the organic and pathogen content but the effluent still cannot be directly used, a further treatment is recommended. Greywater should be treated with blackwater except if water-recovery is necessary in case of water-scarcity.

Effluent produced at the collection and storage/treatment point can be diverted to the ground for disposal through:

- A soak pit (covered, porous- walled chamber where the soil matrix will help filtration of particles and digestion of organics by microorganisms)
- A leach field (network of perforated pipes, dissipating the effluent in underground gravel-filled trenches).

These applications require space and an appropriate soil to take in the effluent. If the absorption properties are low, the effluent can still be discharged in the stormwater drainage network (rainfalls) but only if the quality/ purity of the effluent is very high. Since the faecal sludge is still highly pathogenic, it should be further treated with one of these technologies: sedimentation/ thickening, (un-)planted drying beds, co-composting or biogas reactor. When not possible, it should be discharged in a sewer discharge station or a transfer station (co-treatment with blackwater) and treated with aerated ponds, constructed wetlands, activated sludge, trickling filters, UASB reactors...To improve the performance of semi-centralized systems, the faecal sludge can be introduced at timed intervals and if it is directly introduced in the sewers, the water amount shall be sufficient to dilute and transport the sludge. From the transfer station, faecal sludge can be treated thanks to sedimentation/ thickening, (un)/planted drying beds, co-composting or biogas reactor. The effluent can then be used for irrigation or aquaculture or disposed of in a macrophyte pond or discharged to a water body. Methods for the use and/ or disposal of treated faecal sludge consist of land application or surface disposal. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Flexible: can be used in cold climates
- Can be shared system for a certain number of households
- Anal cleansing water and dry cleansing materials can go through the system

Drawbacks of the system:

- Requires appropriate desludging and disposal methods for the sludge
- Requires constant supply of water
- Important capital investment depending on the chosen technology, the more sophisticated the tank, the more expenses.

5.6. System 6: Blackwater treatment with sewerage

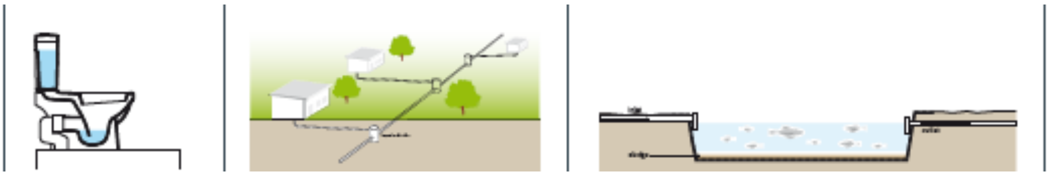

Figure 20 : Blackwater treatment with sewerage. Source: eawag

The system comprises the use of a household level technology to remove and digest settleable solids from the blackwater and a sewer system to transport the effluent to a (semi-) centralized treatment facility. The system can treat all kinds of inputs like the previous system: faeces, urine, flushwater, anal cleansing water, dry cleansing materials and greywater.

This system is somehow similar to the 5th one (same user interface: poor flush toilet or cistern flush toilet and same collection and storage/treatment (septic tank, anaerobic filter, biogas reactor...) except regarding the management and processing of the effluent generated during collection and storage/ treatment of the blackwater. The effluent can follow two paths:

- The not recommended one would be the discharge in the stormwater drainage network for use and/or disposal as groundwater recharge.
- The other possible path is the transport to a semi-centralized treatment plant via either a simplified sewer network (built using smaller diameter pipes laid at a shallower depth and at flatter gradient than conventional sewers) or a solids-free sewer network (network of small diameter pipes that transports solids-free or pre-treated wastewater).

Both systems are less expensive than conventional ones and allow a higher number of connected households to the network. Prior to the transport step, the effluent should flow through an interceptor tank in order to remove all possible clogging materials or the system can be used as a way of upgrading under-performing onsite technologies such as septic tanks by offering an improved (semi-) centralized treatment. In the (semi-) centralized treatment plant, the effluent can be treated with aerated ponds, constructed wetlands, thickening filters, activated sludge or (un-)planted drying beds, co-composting... These treatments generate both treated sludge and effluent, which can for the first one being used for land application or disposed in surface (stockpiling of sludge, faeces, biosolids and other materials) that cannot be used elsewhere. Although it is not recommended, it is preferred to dumping. The technologies for the use or disposal of the effluent include irrigation, aquaculture, macrophyte pond or discharge to a water body or recharge to groundwater. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of this system:

- Less expensive than conventional sewer systems
- Appropriate for dense urban settlements with a lot of connected households
- Even applicable for areas with high groundwater tables

Drawbacks of this system:

- Capital investment: moderate to considerable
- Success of the system depends on people’s behaviour
- Management/ Maintenance of the sewer system is crucial (avoid clogging)
- Durable materials (e.g leaves, rags) shall not be used (avoid clogging)

5.7. System 7: (Semi-) centralized treatment system

Figure 21 : (Semi-) centralized systems. Source: eawag

This water-based sewer system has no collection and/storage treatment step since blackwater is directly transported to a centralized treatment facility. The inputs to the system include faeces, urine, flushwater, anal cleansing water, dry cleansing materials, stormwater and greywater. The two used interface technologies are poor flush toilet or cistern flush toilet like for the previous water-based systems. Dry cleansing materials can be handled by the system or directly separated and transferred for surface disposal. Two kinds of sewer networks can be applied to the system:

- A simplified sewer network (described for the previous system).
- A gravity sewer network (conventional system using large diameter pipes to transport greywater, blackwater and stormwater to a centralized treatment facility using gravity and pumps where needed).

There is no wastewater separation and blackwater is mixed and co-treated with greywater. The collection of greywater together with blackwater avoids the sewer to be clogged with solids (necessary dilution). Stormwater collected within the stormwater drains can be input to the gravity sewer network, although stormwater overflows are required. Different treatments can be applied to the blackwater/ greywater mix such as anaerobic filters, anaerobic baffled reactors, aerated ponds, constructed wetlands, trickling filters, upflow anaerobic sludge blanket reactors, activated sludge or sedimentation/ thickening, (un-)planted drying beds, co-composting and biogas reactors.

The effluent can then be used for irrigation or aquaculture or be diposed in macrophyte ponds or for groundwater recharge. Treated sludge can be used for land application or surface disposal (together with dry cleansing materials). (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Flexible system: can be used for dense urban and peri-urban areas
- Users do not have to take part to the system at all

Drawbacks of the system:

- Costs can be really high
- Not well-suited for rural areas
- Necessary constant supply of water not to block the system
- Needs high willingness to pay for capital investment and maintenance

5.8. System 8: Sewerage system with urine diversion

Figure 22 : Sewerage system with urine diversion. Source : eawag

The last system is also a water-based system but linked with a Urine Diverting Flush Toilet (UDFT) or a urinal as user interface to allow the separation of faeces and urine. The inputs to the system can include faeces, urine, flushwater, anal cleansing water, dry cleaning materials, stormwater and greywater.

Brownwater and Urine are separated directly from the user interface and brownwater will bypass a collection and storage/ treatment plant and is then conveyed directly to a (semi-) centralized treatment facility using a simplified sewer network or a gravity sewer network. Greywater will follow the same path and is not treated separately. Stormwater drainage can be connected to the gravity sewer network. Although stormwater overflows are required. It will then be treated in a (semi-) centralized treatment facility using one of the technologies described in the previous system. Effluent and treated sludge will also be used or disposed off the same way as with a system without urine diversion: irrigation, aquaculture, macrophyte ponds or groundwater recharge for the effluent and land application or surface disposal for treated sludge.

Urine will go directly to a storage tank and will be transferred for urine application on agricultural lands. (Tilley, Luethi, Morel, Zurbruegg, & Schertenleib, 2008)

Advantages of the system:

- Can be used for both peri-urban and urban areas
- If the system is overloaded, it will help decongestion
- Closing the loop of nutrients

Drawbacks of the system:

- High costs for UDFTs
- Need for high-quality plumbing for the dual plumbing system
- Gravity sewers are expensive infrastructures
- Appropriate system only if urine can be reused (will to collect, transport and reuse urine)
- System needs a constant supply of water and used significantly more than a waterless system
- Not suited for rural areas
- If the plant got overdesigned (underloaded) that will make the problem worse

5.9. Review of the different systems

These 8 systems all have interesting characteristics but have to be adapted to every situation and to people's will. Some of them are developed especially for dense urban areas and others to more rural or peri-urban areas with a lot of space and the possibility to reuse the nutrients in agriculture. But it is restrictive to limit sanitation opportunities to these systems. They represent templates, which are general possibilities but reality can be different especially for poor areas. Some places need a case-by-case analysis to improve their sanitation especially when sanitation does not exist so far. The following case study shows opportunities to create a closed loop for 100 families in order to improve at the same time their sanitation and food habits by means of low cost materials.

6. Case study: sanitation system in a poor peri-urban area in Philippines

The project that took place in Cagayan de Oro in Philippines since 2005 is really interesting for its multiple components: biowaste, faeces, urine, greywater and rainwater are all collected and reused with or without treatment. The project concerns UDD (Urine Diversion Dry) Toilets with reuse in allotments gardens at Cagayan de Oro in Philippines and is part of a bigger achievement to improve living conditions of urban poor families of this city including an ecological sanitation. Cagayan de Oro is situated in the province of Misamis Oriental on the Northern coast of Mindanao (the most Southern island of the Philippine archipelago). This province is rapidly growing and Sustainable Sanitation solutions could really improve the living conditions of the local population. (Holmer, et al., 2010)

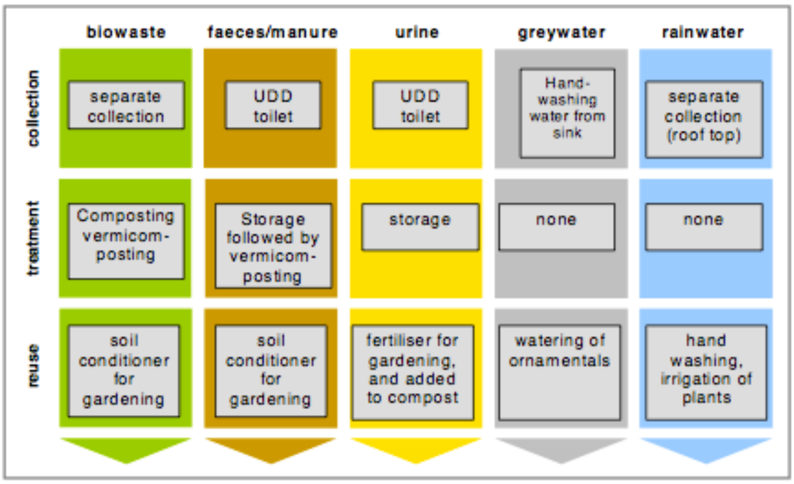

Figure 23 : Different components applied for this project. Source : ECOSAN

6.1. Actors

The first instigator of the project is the Xavier University in 1997 with its PUVeP for Peri-urban Vegetable Project with the help of different local governments units, the city government of Cagayan de Oro, the German Embassy of Manila and the Center for International Migration of Frankfurt (CIM) in Germany. The project concerns 100 urban poor families in 10 self-sustaining allotment gardens. The Project was then transferred under the authority of the newly created Research and Social Outreach Cluster (RSO) on July 2008. (Holmer, et al., 2010)

6.2. Objectives

The average vegetable consumption being really low in Philippines (around 36 kg/year), there is a high percentage of Filipinos suffering from hunger. One third of all children are also underweight and suffering from iron deficiency anaemia and very low vitamin A levels. Plus, two thirds of children have intestinal worms due to a lack of clean water and appropriate sanitation conditions. Furthermore, more than 90% of the untreated wastewater is going directly in water bodies. Unfortunately, all these facts are common plagues all around Philippines and therefore this project offers good replication possibilities.

The selected region is also very poor and people need access to food as well as good sanitation. Therefore the goal of this project was to create community-based allotment gardens to provide affordable and healthy food to these poor families. Allotment gardens were implemented in 2003 but quickly people started to complain about the lack of sanitary toilet facilities within these gardens. After several meetings and the attendance of one of the technicians to training courses on ecological sanitation at the Stockholm Environment Institute (SEI), stakeholders decided to implement UDD toilets. Research conducted by the PUVeP showed that urine application could increase yields of sweet corn by an average of 14%. An increase in flowering of different ornamental plants was also observed. The creation of a nutrient cycle for the production of vegetables could improve the living conditions of all these families.

Furthermore, promoting ecological sanitation was the second main goal since open defecation is common in Philippines. The project was upgraded during its implementation and other UDD toilets were also installed in public schools to improve learning conditions for students. On a long-term basis, the strategic goal of this project is to lead to the consideration of peri-urban food production and ecological sanitation into city planning in Philippines. (Holmer, et al., 2010)

Figure 24: Demonstration allotment with UDD Toilets, vermicomposting and biogas unit at Cagayan de Oro. Source : ECOSAN (GIZ)

6.3. Technologies

Double-vault urine-diversion dehydration toilets (UDDTs) are used to collect separately faeces and urine. Once, the first vault is full (after one year), the second-vault is used by transferring the UDD bowl. Covering faeces is important to hygienise them and therefore sawdust and lime are applied. Sawdust is actually easily available in Cagayan de oro and free of charge. Lime is important to raise the pH in order to destroy pathogens contained in faeces. If these products are not available, it is recommended to use ash, rice hulls and dried soil as substitutes. (Holmer, et al., 2010)

Figure 25: UDDT with anal washing. Source : ECOSAN (GIZ)

For men, waterless urinals using a modified plastic container (used normally for drinking water) are implemented. Rainwater is collected from the roof top of a neighbouring building and stored in a cistern. When needed, a piping system links the cistern and the UDDT for hand washing. The water will then be reused for irrigation of ornamentals in the allotments. After being used for hand washing, the greywater is also used for irrigation of flowers. A rubber balloon, which seals once the urine enters the container, prevents odour emissions. The collected urine is then stored in a plastic container exposed to sunlight for at least one month for pathogen removal. (Holmer, et al., 2010)

6.4. Reuse of the products

Urine is used as fertilizer after storage and (third step) after dilution: 1 part urine for 3-5 parts of water. It is necessary to have a higher dilution for plants that are at seeding stage. The urine shall be incorporated into the soil at a small distance (10 cm) from the plant and not be sprayed in order to reduce odour, nitrogen losses and foliar burns. Crops can be harvested after one month from last urine application. To ensure acceptance of the customers, urine application on vegetables that have to be eaten raw should be avoided. Urine can also be added to compost to enhance the nitrogen content in the C/N ratio. (Holmer, et al., 2010)

Figure 26: Application of urine 10 cm from the plant. Source : ECOSAN (GIZ)

For faeces, research studies at the Xavier University recommend a post treatment after the storage: either 60 days of vermicomposting or an aerobic composting at a temperature above 50 degrees C for at least a week in the compost heap. After treatment, dried faeces can be used as organic fertilizer. Here too, to ensure customers acceptance it is recommended to use this kind of fertilizer for fruits trees that have a certain distance from the ground. (Holmer, et al., 2010)

Figure 27 : Planting of an eggplant on top of the organic fertilizer. Source : ECOSAN (GIZ)

6.5. Review of this case study

This project received a basic assessment analysis to ensure its long-term impacts. Five criteria like health and hygiene, environmental and natural resources, technology and operation, finance and economics and sociocultural and institutional impacts have been considered and show the overall sustainability of the sanitation project.

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene		X		X			X		
• environmental and natural resources	X			X			X		
• technology and operation		X		X			X		
• finance and economics			X		X		X		
• sociocultural and institutional	X			X			X		

Figure 28 : Sustainability review of the project. Source : ECOSAN

It is an important improvement of living conditions of poor families (improvement of sanitation and food security). The participating families can grow fresh vegetables and the neighbouring ones can buy vegetables and give their biowaste to the gardeners for composting. Costs are around 410 Euros for a double-vault UDDT and 197 Euros for a single vault. These costs are nevertheless high because it is a demonstration project and cheaper components can be easily found. It also includes external costs. There are some operation and maintenance criteria that have to be respected in order to preserve the quality and safety of the toilets and generated fertilizers. Drawbacks would be the inconvenient anal washing area and the non-suitability for children's use according to the users. These facts have been taken into accounts and will be improved in the near future. New tests like a squatting pan from India are already in place. (Holmer, et al., 2010)

7. Conclusion

Waste and wastewater management will become major challenges in a near future with the estimated population growth. This growth is mainly expected in areas where sanitation is already poor or inexistent. The concept of Sustainable Sanitation also considers this future growth by planning flexible systems (decentralised systems) with possible upgrades in the near future. Implementing or improving sanitation is important to complete the Millennium Development Goals initiated by the United Nations, by 2015. Sustainable Sanitation aims at improving the health situation, especially for young children (propagation of diseases by faecal-oral route or by the presence of standing water bodies). This concept aims at avoiding the pollution of water bodies and preserving ecosystems such as rivers. Furthermore, it is also linked with socio-economic impacts since it can reduce the spread of diseases, it can reduce the number of missed work days/ school days because of sickness.

Sustainable Sanitation is also directly linked to the phosphorous issue and thus the hunger issue. Developing sanitation solutions with recovery and reuse possibilities will help to eradicate hunger worldwide. Since it is crucial to find a substitution to phosphate rock for several reasons such as:

- Environmental: Mining of phosphate rock is far from environmentally friendly.
- Economics: Chemical fertilizers are becoming more and more expensive due to special tariffs/ rules applied by the oligopoly of producers: China, USA and Western Morocco.
- Social: Morocco exploits illegal Western Saharan reserves of phosphate rocks and even if the international community condemns this, a lot of countries still get their phosphorous supply from Moroccan authorities.

Sustainable Sanitation can be seen as a "going back and forth" concept since dry sanitation already prevailed in the ancient times. But, it is difficult to compare what has been done back then with the possible future developments. Nevertheless, it is true that dry sanitation is becoming again of great importance as well as decentralised systems because of the unaffordable costs generated by the energy supply and maintenance of centralised treatment plants. Unfortunately, rethinking sanitation is always a complicated process because it is always seen as a taboo or a dirty topic. Waste generates also more attention from communities since visual impact is greater.

It is important to mention that Material Flow Management is always linked to Sustainable Sanitation because of the flows optimization of by-products such as urine and faeces, (chemical and organic) fertilizer, organic waste and energy but also for the jobs it can create and the regional added value it can generate.

Planning Sustainable Sanitation is the most important step because even the most environmentally friendly system can be a disaster from the users point of view. There have been cases where the technology implemented did not suit the potential users and remained unused until it has been dismantled or simply abandoned. The introduction of Sustainability criteria and communicative planning will help to achieve a successful planning.

Sustainable Sanitation technologies can be really diverse and different combinations are possible, their implementation will always depend on criteria such as groundwater table, climate types, and possible reuse of urine/ faeces/ greywater in the area… The different systems help to develop a clearer picture regarding opportunities but can be different in reality. There are anyway two main types of system: wet or dry. All advantages and drawbacks have to be considered by all actors during the planning phase. Maintenance and successful operation are the key actions to achieve a long- term sustainable strategy.

Furthermore, the sanitation strategy can be coupled with other objectives like presented in the Cagayan de Oro's project where improvement of food habits and sustainable sanitation are perfectly linked.

Sustainable Sanitation, as part of an Integrated Wastewater Management Strategy, has a key role to play for resources preservation and it is crucial for decision-makers to push its development. In developing countries, improving or acquiring a sanitation system could reduce drastically health problems in general. In the developed world, cities are sometimes privatizing their wastewater system because they cannot afford centralized treatment. This is a sign to move towards sustainable decentralized solutions.

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V. Annexes

Definitions

-Urine: liquid waste produced by the body in order to rid itself of urea and other waste products. Depending on diet, the usual human urine collected during one year reaches approximately 500 litres (2-4 kg nitrogen). Urine is also most of the time sterile.

-Faeces: semi-solid excreta without urine or water

-Biogas: mixture of gases released from anaerobic digestion. It is usually a mix of methane (50-75%), carbon dioxide (25-50%) and varying quantities of nitrogen, hydrogen sulphide and other components.

-Effluent: liquid that has been partially treated and/ or separated from solids.

-Excreta (nightsoil): urine and faeces not mixed with flushing water.

-Brown water: faeces and flushwater but in practise there is also always urine since urine diversion flush toilets only divert 70 to 85% of the urine.

-Blackwater: mixture of urine, faeces, flushwater, anal cleansing water (if used) and/or dry cleansing material like toilet paper.

-Faecal sludge: raw or partially digested slurry or solid that results from the storage of blackwater or excreta.

-Treated sludge: partially digested or fully stabilised faecal sludge.

-Flushwater: water used to transport excreta from the toilet (user interface) to the storage or treatment point. Freshwater, rainwater, recycled greywater or any combination of them can be used as flushwater.

-Organics: biodegradable organic material, also called biomass or green organic waste.

-Compost/EcoHumus: earth-like, brown/ black material that is the result of decomposed organic matter. In sanitation, it is often a mix of dry faeces, organic waste and sometimes dry cleansing materials.

-Dry cleansing materials: all kinds of materials used for anal cleansing (instead of water). These materials can be paper, corncobs, rags, and leaves...

-Anal cleansing water: Water collected after use for cleansing after urinating or defecating.

-Flushwater: water used to transport excreta from the toilet (user interface) to the storage or treatment point. Freshwater, rainwater, recycled greywater or any combination of them can be used as flushwater.

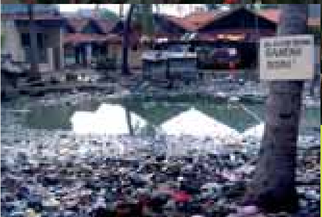
-Greywater: Total volume of water produced by activities such as washing food, clothes, dishes as well as from bathing or showering. It accounts for 60% of household's wastewater production and has a low pathogen load.

-Stormwater: general term for rainfall runoff from roofs, roads and other surfaces. This portion of the wastewater does not infiltrate into the soil.

-Forage: aquatic or other plants those grow in planted drying beds or constructed wetlands and can be harvested for feeding livestock. (akvopedia, 2011)

DEWATS
Decentralized Wastewater
Treatment Solutions

DEWATS | Decentralized Wastewater Treatment Solutions



Demand-based technical solutions to reduce water-pollution by small and medium enterprises and settlements in densely populated areas

BORDA

Treatment Systems |
DEWATS Service Package

Developed and disseminated by
BORDA & BORDA BNS Network

About DEWATS

DEWATS stands for "Decentralized Wastewater Treatment Solutions". DEWATS is rather a technical approach than merely a technology package.

DEWATS applications are based on the principle of low-maintenance since most important parts of the system work without technical energy inputs and cannot be switched off intentionally.
DEWATS applications provide state-of-the-art-technology at affordable prices because all of the materials used for construction are locally available.

- DEWATS applications provide treatment for both, domestic and industrial sources
- DEWATS applications provide treatment for organic wastewater flows from 1-1000 m^3 per day
- DEWATS applications are reliable, long lasting and tolerant towards inflow fluctuation
- DEWATS applications do not need sophisticated maintenance

Without considering facilities for necessary chemical pre-treatment of wastewater from industries, DEWATS applications are based on four basic technical treatment modules which are combined according to demand:

- Primary treatment: sedimentation and floatation
- Secondary anaerobic treatment in fixed-bed reactors: baffled upstream reactors or anaerobic filters
- Tertiary aerobic treatment in sub-surface flow filters
- Tertiary aerobic treatment in polishing ponds

DEWATS applications are designed and dimensioned in such a way that treated water meets requirements stipulated in environmental laws and regulations.

Appropriate Wastewater Treatment for SMEs

Advantages of DEWATS technology

- Providing treatment for domestic and industrial wastewater
- Low primary investment costs as no imports are needed
- Efficient treatment or daily wastewater flows up to 1000m^3
- Modular design of all components
- Tolerant towards inflow fluctuations
- Reliable and long-lasting construction design
- Expensive and sophisticated maintenance not required
- Low maintenance costs

Hence
DEWATS technology is an effective, efficient and affordable wastewater treatment solution for small and medium sized enterprises (SME).

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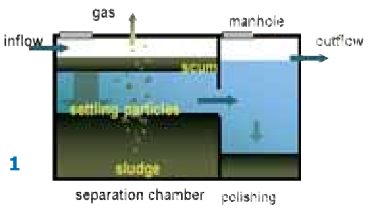

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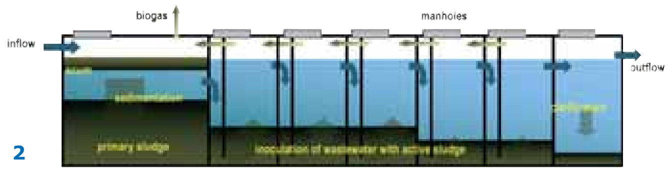

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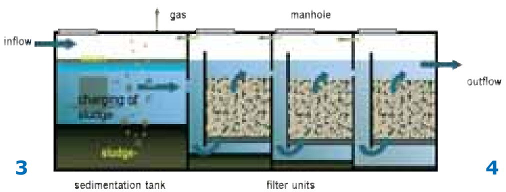

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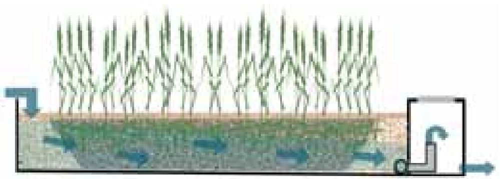


The Challenge

The demand for reliable, efficient and low-cost wastewater treatment systems is increasing world wide especially in densely populated urban regions where adequate wastewater treatment systems do not exist and uncontrolled discharge of wastewater endangers environmental health and water resources. Many Governments have passed new environmental regulations stipulating that dischargers of wastewater such as small and medium enterprises and housing estates will be held responsible for wastewater pollution and must therefore treat wastewater adequately on-site before it is discharged into the environment.

Main DEWATS-modules for physical and biological wastewater treatment:
1. Settler
2. Anaerobic Baf ed Reactor
3. Anaerobic Filter
4. Planted Gravel Filter

Common Wastewater Problems within Small and Medium Enterprises

Many SME are not able to pay high investment and maintenance costs required for sophisticated wastewater treatment system.

Maintenance of sophisticated wastewater treatment systems require high-skilled personnel.

Due to lack of investment capital and technical knowledge SME often adapt non-effective low-cost „solutions".

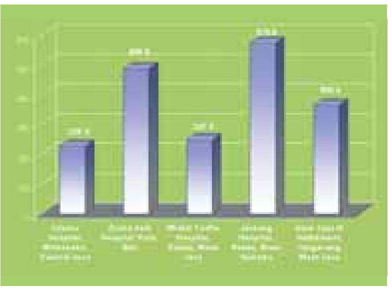
Wastewater discharged by SME often does not meet environmental standards.

Demand

For many small and medium enterprises and housing estates, conventional wastewater treatment systems are technically sophisticated and costly, often require high energy inputs for operation and rely on sophisticated maintenance services to ensure continuous operation.
In most cases, such requirements are unsuitable for SME.

For these potential clients, BORDA and its network of partner organisations started in 1994 to develop reliable and cost-efficient wastewater treatment systems which could efficiently treat non-toxic organic wastewater according to legal environmental standards.
Successful efforts to standardize main components of the DEWATS approach, such as multi-stakeholder approach, modular design of systems, project planning, implementation and quality control has resulted in a significant increase of implementation capacity and dissemination of technical know-how.

Today, more than 1000 stakeholders from the private sector, governments and NGOs have been trained by the BORDA-Network to facilitate dissemination, implementation and maintenance of DEWATS system resulting in the sustainable operation of more than 250 DEWATS plants. The success of DEWATS has fostered cooperations with numerous government departments, municipalities and international donor agencies to increase capacities and technical implementations.



DEWATS ensures state of the art treatment results at affordable cost, low maintenance and limited space requirements

Dissemination

To assure sustainable dissemination of appropriate wastewater treatment infrastructure in the long-term, a mere focus on technical aspects has proven insufficient.
The approach for implementation of DEWATS projects includes not simply the construction of hardware but a whole comprehensive set of integrated measures such as:

Information seminars and workshops to introduce DEWATS to key-stakeholders
Early information of key-stakeholders is vital to ensure continuous support for programme on macro-level.

Co-financing of demonstration projects
Financial support during the start-up phase of a demonstration project enhances the achievement of desired results and impacts.

Sector specific information-seminars
An early focus on specific priority-sectors supports an exchange of ideas between experts and potential clients that have similar professional experiences.

Technical training
Long-term DEWATS experts facilitate comprehensive training programmes for qualified staff of partner organisations and take on a supervisory role during first technical implementations.

Project planning
Project planning includes technical feasibility studies, detailed engineering designs and cost-estimates.

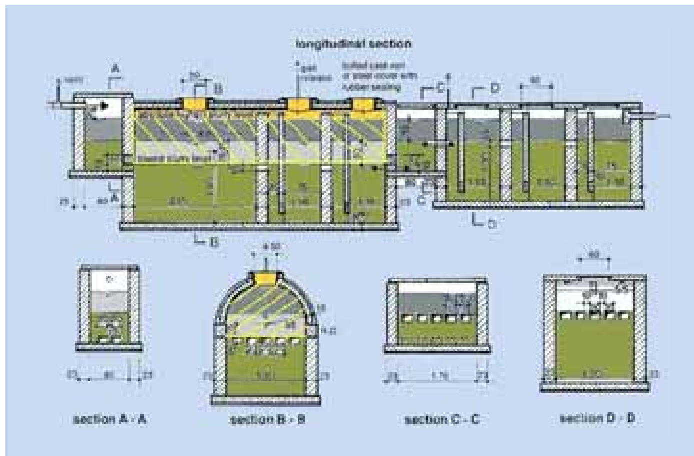
Project implementation
Service provision depends on preferences of clients and network-partners and may include supervision of construction, contractor services or turn-key operation. To ensure high quality standards, major tasks are always carried out by qualified experts.

Technical support and monitoring
Staff responsible for operation and maintenance of DEWATS plants are adequately trained by technical experts during the first year of operation.

Quality Control
All DEWATS systems constructed are designed and have a guarantee to fullfill specified discharge standards. Effluent tests are conducted at regular intervals.

Research & Development
Continuous efforts are made by members of the DEWATS partner-network to improve efficiency and effectiveness of treatment systems.

Dome shaped anaerobic baf ed reactor for biogas recovery



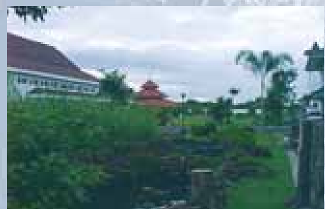
Good Practices

DEWATS for Hospitals

Characteristics:
- 250 beds with outpatient department
- untreated wastewater discharge into nearby stream
- complaints of neighboring communities
- limited funds
- limited technical skills of staff
- sufficient space

Technical Solution:
- Treatment system for 150 m^3 wastewater/day
- Sedimentation + anaerobic filter + horizontal sandfilter + purification pond
- Pumping chamber after anaerobic filter
- Total construction cost: $ 50.0000
- Training of maintenance staff and 1 year guarantee

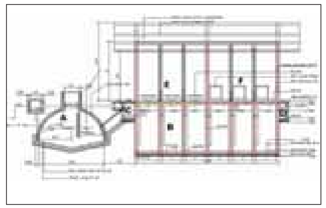




DEWATS for Communities

Characteristics:
- Open waste water lagoon within community
- 6 public toilets/6 bathrooms for 500 people
- Unwillingness of landlords to upgrade sanitation infrastructure
- Willingness to provide lagoon space
- Willingness of people to pay for use of proper sanitation infrastructure
- People willing to manage sanitation infrastructure
- Fully mixed digester (fixed-dome biogas plant)
- Baffled reactor
- Landscaping
- rehabilitation of WW ditches
- MOU between NGO and CBO regarding maintenance of Sanitation/DEWATS infrastructure



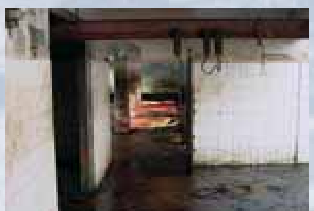
DEWATS for Agroindustries

Characteristics:
- More than 100 cattle slaughtered per day
- Extreme fluctuation of waste water composition
- extremely high organic load
- limited space for construction near stream
- unreliable responsibility and maintenance

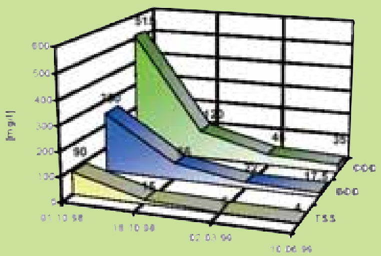
Technical Solution:

Separation of wastewater components:
- De-watering, sedimentation & floatation

Treatment system components:
- Screening
- Sedimentation
- Composting
- fully-mixed digestion in biogas reactor
- Anaerobic filter



Laboratory Test Results



Effluent Quality during first months of DEWATS operation

DEWATS Treatment Efficiency

No	Parameter	Unit	Anlytical-Results Inlet	Anlytical-Results Outlet	Reduction [%]
1	Temp.	°C	27	27	–
2	pH	–	7,6	7,3	4 %
3	BOD 5	mg/l	290	53,6	83 %
4	COD	mg/l	590	84	86 %
5	Phosphate	mg/l	18,33	3,67	80 %
6	TSS	mg/l	172	84	51 %
7	Ammonia	mg/l	0,19	0,07	63 %

Source: Graha Asih Hospital Bali,
Anaerobic Filter + Horizontal Sand lter + Puri cation Pond

Benefits of DEWATS

- Establishing of multi-stakeholder networks to combat water pollution
- Building up implementation capacity on various levels
- Providing treatment for both, domestic and industrial waste-water at affordable price
- Fulfillment of discharge standards and environmental laws
- Wastewater pollution reduced by up to 90%
- Providing treatment for waste-water flows up to 1000 m^3 / day
- Reliable and long lasting applications
- Tolerant towards inflow and load fluctuation
- Materials/ inputs used for construction are locally available
- Minimal maintenance and long de-sludging intervals
- Low operation and maintenance costs

- Resource efficiency and non dependence on energy
- Resource recovery through wastewater re-use and biogas generation

DEWATS Service Packages

- Treatment Systems
- Community Based Sanitation
- School Based Sanitation
- Sanitation for Hospitals & Hotels
- Wastewater Treatment for Agro-Industry
- Emergency Sanitation
- Sanitation for Prisons
- Sanitation for Real Estates
- Sanitation Mapping
- Municipal Sludge Treatment Plant
- Health Impact Assessment & Hygiene Education
- Capacity Development
- Standardisation
- Research & Development

DEWATS – Decentralized Wastewater Treatment Solutions

Developed & disseminated by BORDA and over 20 BORDA BNS Network Partners in South and South East Asia & Southern Africa

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