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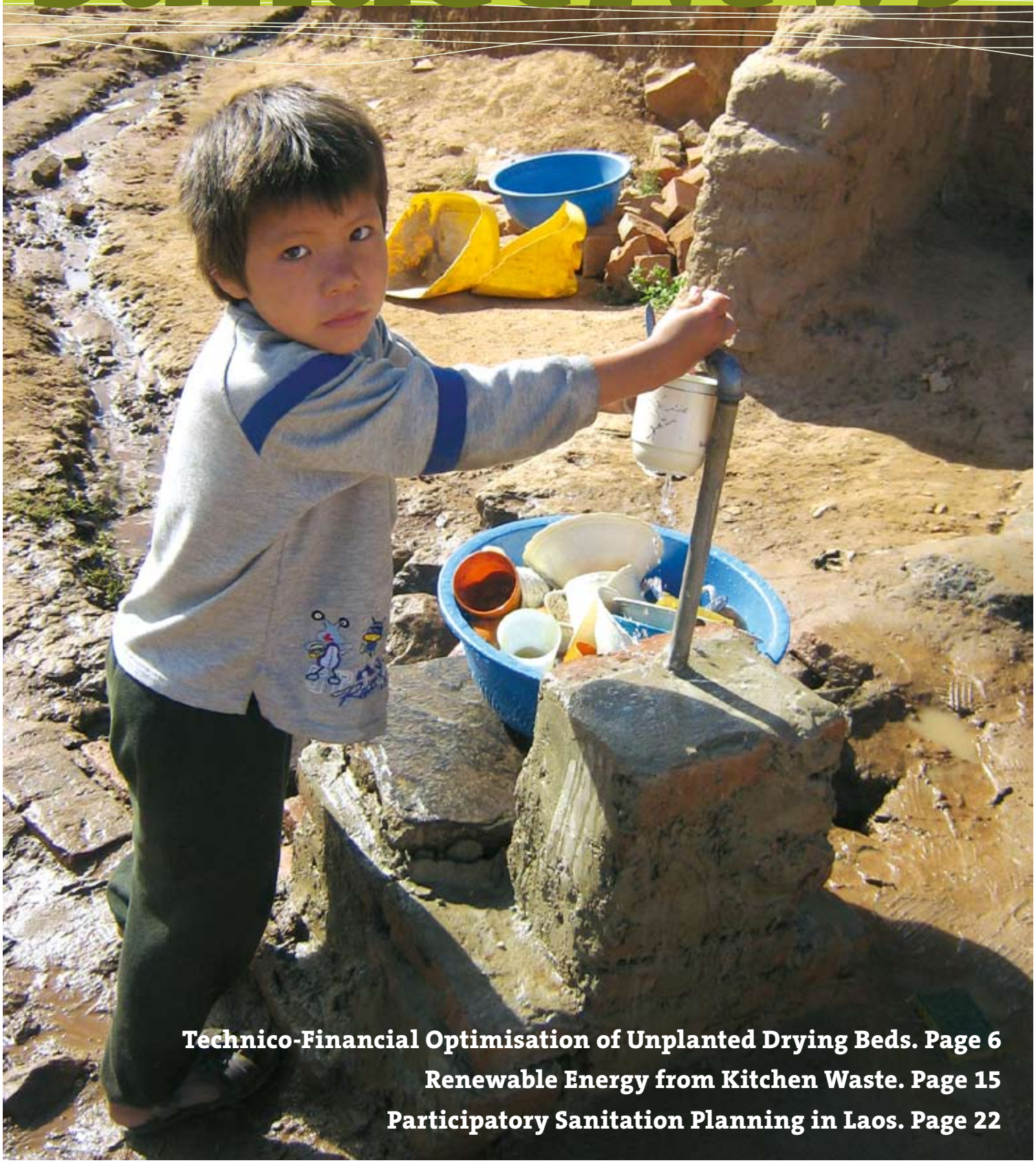

From Reference to Research Centre

> **“Eawag’s 40-year commitment to water and sanitation in developing countries”**

Focus on the developing world started at Eawag with the “International Reference Centre for Waste Disposal (IRCWD)” in 1968 on a suggestion by the World Health Organisation (WHO). IRCWD - later renamed Sandec: Department of Water and Sanitation in Developing Countries – originally acted only as a documentation centre. Early in the 1980s, when Roland Schertenleib was appointed head of the department, Sandec started to strengthen its research and dissemination activities. Close interaction with a large network of contacts allowed Sandec to identify the major research gaps in this field. Today the team, comprises a growing number of “south” research partners across the globe, as well as PhD students, Master students, interns, and civil servants as research is always conducted by involving local “south” partners in collaborative research projects. This also allows Sandec to fulfil its mandate of local capacity building in research and ensures its continuous close contact with local universities, research NGOs, development agencies, and local authorities in the specific country.

By intensifying its involvement in applied research and active participation in policy forums and international expert working groups, Sandec continues to expand its international network. Today, Sandec’s research activities centre both on mitigating acute problems of existing technological and organisational systems in the different sub-sectors and on promoting conceptual development, strategic planning, piloting, and advocacy of integrated approaches. The various articles in this News will give you a glimpse of these activities. Specific information is available from the individual authors or from our webpage www.sandec.ch.

Sandec’s selection of research subjects follows the concept of narrowing down to one or two specific subjects in a wider thematic domain and maintaining a wide geographical spread over as many countries and regions of the developing world as feasible. Using this approach means, however, that we may have to decline involvement in some exciting research brought forward by partners such as yourself, as the topic might not fit into our portfolio. We apologise for this but hope that you also value our concept of focusing and ensuring high-quality work with the existing human resources, rather than committing to too much we cannot handle.

Sandec is increasingly engaged in joint partnerships with social scientists to tackle non-engineering research gaps. The high practice and problem-solving oriented research focus is Sandec’s strength, which is also highly appreciated by engineers and development agencies facing such specific implementation problems in their projects.

We are confident that in the course of this year we shall be able to initiate new research and expand existing projects on: behavioural change, creating multi-stakeholder demand for sustainable improvements, gender appropriate technologies, as well as develop approaches in water, excreta, wastewater, and solid waste services to foster and create new exciting business opportunities for small and medium enterprises.

Major overarching thrusts of Sandec’s activities are: research into creating value and supply chains, providing scientifically sound evidence and a knowledge base on the wide variety of technologies to foster informed decision-making, and special focus on decentralised approaches to water and sanitation, where the household and/or community can play an important role in implementation, operation and maintenance.

Today, Sandec is not the only department of Eawag conducting research in developing countries. Other departments are involved in projects such as “Arsenic mitigation in Bangladesh and Vietnam”, “Occurrence and fate of perfluorinated chemicals in wastewater treatment plants and ambient waters of China”, “Adapt planning and operation of large dams to social needs and environmental constraints in Zambia”, and “Nutrient Cycling and Methane Production in Lake Kivu, Congo DR. These projects are proof of Eawag’s overall commitment to tackling the global water challenges in low and middle-income countries.

To enhance the impact of our research and capacity building we also rely on you – our partners. Whatever your specific role, i.e. researcher, teacher or transmitter of information, you are the key to “spreading the word” and we look forward to ongoing intense interaction in this regard.

Chris Zurbrügg
Director Sandec

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Department of Water and Sanitation in Developing Countries

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Struvite from Urine in Nepal (STUN)

A new project in Nepal examines whether the production of fertiliser from urine can inspire residents to take up improved sanitation, while reducing their dependency on imported chemicals. By harvesting urine and converting it to "struvite", the farmers of Siddhipur may better resist the coming years of fertiliser shortages. Elizabeth Tilley, Bastian Etter, Basil Gantenbein, Raju Khadka, and Kai M. Udert

Introduction

Chemical fertilisers, along with irrigation and improved seeds, were one of the main pillars of the "Green Revolution" that allowed the post-war world to support a booming population by ever increasing food output on ever scarcer and deteriorating land. However, phosphorus is a finite resource like oil and, as such, severely depleted and increasingly difficult to extract. The price of diammonium phosphate (DAP, a common fertiliser) increased over five times between 2007 and 2008 [1], meaning that many farmers who could not afford it saw their crops fail or fall short of an adequate price. Along with record oil prices, the price and availability of fertiliser led to the food riots of 2008.

Could improved sanitation be the answer to the global food and fertiliser crisis? The question is not as far-fetched as it may seem.

The average human excretes about 1 g of phosphorus and almost 10 g of nitrogen a day; the majority of which (about 60 % and 80 %, respectively) is excreted through urine [2]. In fact, urine is one of the only known renewable sources of phosphorus, as it has no sufficiently fast natural renewal cycle (like carbon or nitrogen). Urine can be used directly on fields as a liquid fertiliser, though it is heavy to transport, requires significant storage space, is unpleasant to work with, and is variable in composition, thus making it difficult to estimate the proper quantity. Moreover, application of urine as a fertiliser is further hampered by the volatilisation of ammonia.

The STUN (STruvite from Urine in Nepal) project is looking at the possibility of extracting a phosphorus-based fertiliser called "struvite" (magnesium ammonium phosphate hexahydrate, $MgNH_4PO_4 \cdot 6H_2O$) from the urine collected from the Urine-Diverting Dry Toilets (UDDTs) currently used in the Kathmandu valley. As of 2006, 73 % of the people in Nepal still lacked access to improved sanitation [3]. By creating a market for urine, we hope sustainable sanitation will spread and help the farmers to become more nutrient independent.

Struvite

Struvite is a bioavailable fertiliser, which can be stored indefinitely, transported easily and applied with sureness in its composition. Furthermore, it is easy to produce, as it only requires a high pH solution (which is naturally occurring in stored urine) and a soluble magnesium source. The magnesium binds with the phosphorus in solution and the struvite precipitates in less than ten minutes. Over 90 % of the phosphorus can be recovered with this simple method. Due to the low technological requirements, struvite precipitation is an ideal application in the developing world, especially where electricity is limited.

The resulting powder is odourless, dense, compact, and efficient to transport. It can be stored during winter or the dry season, used when needed and the nutrient quantity is consistent. Struvite from urine offers the simplicity and quality of chemical fertilisers without the high cost or technical requirements.

Study site

Siddhipur is a farming village located about 10 km south east of Kathmandu. Of the 6 000 residents, almost 90 % of them work in agriculture. Although there is a sewerage network in Kathmandu proper, Siddhipur is not connected. There are currently 100 family-owned UDDTs, i. e. toilets that collect urine and faeces separately in the absence of water. Siddhipur has a strong Water Supply and Sanitation User Committee (WSSUC) that was already active in the operation and management of the water supply, sanitation and solid waste programmes of the community. By working co-operatively with the WSSUC, the researchers were better able to understand the immediate needs for and limitations of a community-scale struvite reactor.

We would like to thank **UN-HABITAT Nepal**, specifically Dr Roshan Shrestha and Anjali Sherpa for their unending support. Furthermore, we deeply appreciated the enthusiasm and curiosity shown by Jiban Maharjan in supporting this work with his own land. We are also much obliged to the whole community of Siddhipur who has welcomed us so warmly. We acknowledge the assistance provided by the **Swiss National Centre of Competence in Research (NCCR) North–South**: Research Partnerships for Mitigating Syndromes of Global Change and **Eawag's Directorate** for supporting our project with discretionary funding.
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Photo 1: Bastian Etter at struvite headquarters.

Photo 2: Not quite the milkman: Raju Khadka proudly presents the "pee-cycle".

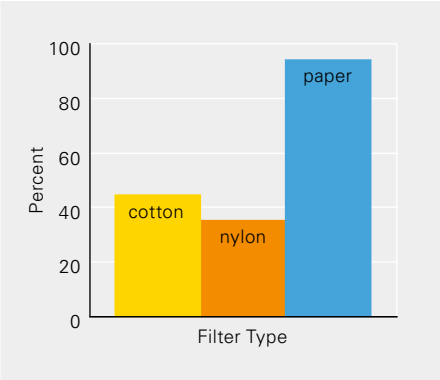

Figure 1: Percentage of struvite recovered from the reactor filter using either a nylon filter (pore size < 100 µm), cotton filter (pore size < 200 µm) or standard paper coffee filter.

Photo 3: Ideally, the struvite will have a uniform, pellet-like shape for easy application and spreading.

Results

The initial phase of the study focused on determining the quality, quantity and current uses of urine to calculate the potential production of struvite. Daily monitoring of household collection tanks revealed that approximately 360 L of urine could be produced per person per year, which would generate over 160 000 L of urine per year from the current UDDTs in use, and over ten times as much if everyone had a UDDT.

However, struvite production is not only related to the volume of urine, but also to the amount of phosphorus contained in the urine. Random samples were taken from 14 different urine tanks: ten were mixed into a composite sample and the remaining four were analysed individually. The results were surprising: the average phosphorus content was 260 mg/L with the lowest measurement being 123 mg/L. The most commonly reported values are somewhere between 600–800 mg/L [4]. Obviously, the concentration of phosphorus in the urine was unexpectedly low, so 14 samples of fresh urine were taken to determine if and by how much the urine was diluted with water. The results showed that in fact the urine was naturally very dilute and probably only diluted by around 15 % (based on a phosphorus balance).

Based on this data, we determined that about 327 kg of struvite could be produced annually in Siddhipur at current production levels, though significantly more could be envisaged if further toilets and therefore urine production were implemented.

Reactor design

Commercial struvite reactors are available but require significant energy and training to operate. For the purposes of the pilot project in Siddhipur, a hand-powered reactor was built using a 50-L polypropylene tank, which was modified with a welded stirring paddle and support casing (Photo 1).

Struvite was produced using the urine from some volunteer families. It was picked up from their home with the "pee-cycle" (a bicycle retrofitted to carry two 20-L jerry cans of urine) as illustrated in Photo 2. Bittern, a waste product from salt manufacturing that is rich in magnesium, was used as a magnesium source. To filter the precipitated and settled struvite, the bottom of the reactor was fitted with a wire mesh upon which either a nylon filter (pore size < 100 µm) or cotton filter (pore size < 200 µm) was laid. After approximately ten minutes of mixing and 24 hours of settling, the filter tray was removed and the struvite was left to dry in the sun (Photo 3).

Based on an analysis of the effluent produced, we determined that over 95 % of the phosphorus was removed in the form of struvite; however, the quantity (i. e. the mass) was significantly lower than expected. The cotton filter, though larger in pore size, retained a higher percentage of solids, although both filters performed poorly compared to a paper coffee filter, which was capable of removing over 90 % of the struvite produced. The results are summarised in Fig. 1.

Thus, the limiting factor to recovering large quantities of struvite is not the precipitation step but rather the solid-liquid separation. A Masters project is currently addressing this in further detail. Economic factors will ultimately determine the sustainability of this project and the feasibility of scaling it up. Some 500 L of urine are needed to produce 1 kg of struvite. The current price of a similar nitrogen-phosphorus fertiliser is available in Siddhipur for just about half a Euro (€ 0.5 or NRp 40–50). Therefore, to be profitable (or cost-recovering), the cost to produce struvite must be lower than this amount, which is currently not possible. However, with increased trade restrictions, reduced energy availability and lower fertiliser quality on the market, the possibility of producing high quality, renewable and affordable fertiliser – also promoting the use of sustainable sanitation – does not seem so far off.

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Technico-Financial Optimisation of Unplanted Drying Beds

Faecal sludge treatment is a key factor for controlling and reducing the impact of faecal matter from on-site sanitation systems used by more than 80 % of the African population. Yet, technical recommendations are still scarce and inaccurate. Since 2006, a treatment system using unplanted drying beds has been implemented and operated by ONAS (The National Sanitation Utility) in Dakar, Senegal. It offers a unique opportunity to formulate general recommendations for technical design and budgeting. Pierre-Henri Dodane, Mbaye Mbéguéré, Doulaye Koné

Faecal sludge treatment is considered an essential sanitation step in developing countries [1]. Its implementation requires, like any other sanitation infrastructure, appropriate design guidelines as well as a sound knowledge of investment and operating costs. The limited number of operational treatment plants certainly illustrates the current lack of these aspects.

With a capacity of 100 m^3/day and 700 kg TS/day, the faecal sludge treatment plant of Cambérène (Dakar, Senegal), combining settling/thickening tank and unplanted drying beds, is operational since 2006. This installation offers the opportunity to improve the state-of-the-art of unplanted drying beds under real-life conditions. Daily measurements of the pollutant fluxes were conducted at the inlet and outlets of the two-step treatment. Continuous monitoring of sludge characteristics (concentration, dry matter content) in the thickening tank and on the drying beds was conducted during several treatment cycles. Drying beds efficiency fed directly with raw sludge was also measured (bypassing the primary treatment tank).

Moreover, breakdown of the investment and operating costs has been established on the basis of bills of quantities of plant works and accounting figures for 2007. These elements allow to determine the conditions required for a balanced operating account. They are also used to assess the costs for the directly fed unplanted drying beds.

Lessons learned from plant performance

As regards the actually received sludge loads, plant performance (Fig. 1) reveals a hydraulic surcharge of 340 % and a loading surcharge of 240 %. This reveals an inaccuracy in previous studies that led to serious problems. The sludge volumes to be treated were underestimated and the sludge concentrations overestimated by 40 %.

Based on the previous raw sludge feeding experiments, the drying beds were conceived to receive 200 kg TS/m^2/year [2]. When feeding thickened sludge (60 g/L), the measured load amounts to 400 kg TS/m^2/year for a 50 % dry matter content after one-month drying period. However, the operator is currently running the plant at 300 kg TS/m^2/year, thus allowing for an additional bed-scrubbing period of about ten days. Moreover, since thickened sludge dewatering was observed to occur by evaporation, the drained free water is negligible.

Operating tasks and financial optimisation potential

Allocation of the operational tasks and their costs are assessed for a nominal condition. The accounting statement reveals (Fig. 2) that the administration costs (collecting disposal fees and organising subcontracting) and the overhead costs (cleaning of the facility and surrounding area, gardening) are more important than the technical tasks.

Based on the current state of technology, cleaning of the primary treatment step presents the main cost factor for the combined thickening tank and unplanted drying beds system. Moreover, the energy costs for sludge pumping onto the beds are insignificant compared to the other expenses.

The treatment plants also generate revenue. The treated sludge is in fact reused as soil amendment in urban landscaping. Its current sales price of 0.8 USD/m^3 biosolids (0.002 USD/kg) does not yield important revenues. The income generated could nonetheless have a significant motivating effect on the operator to increase sludge production and, thus, improve treatment efficiency. The actual sales price of 0.002 USD/kg, associated with an 80 % yield in relation to TS, allows,

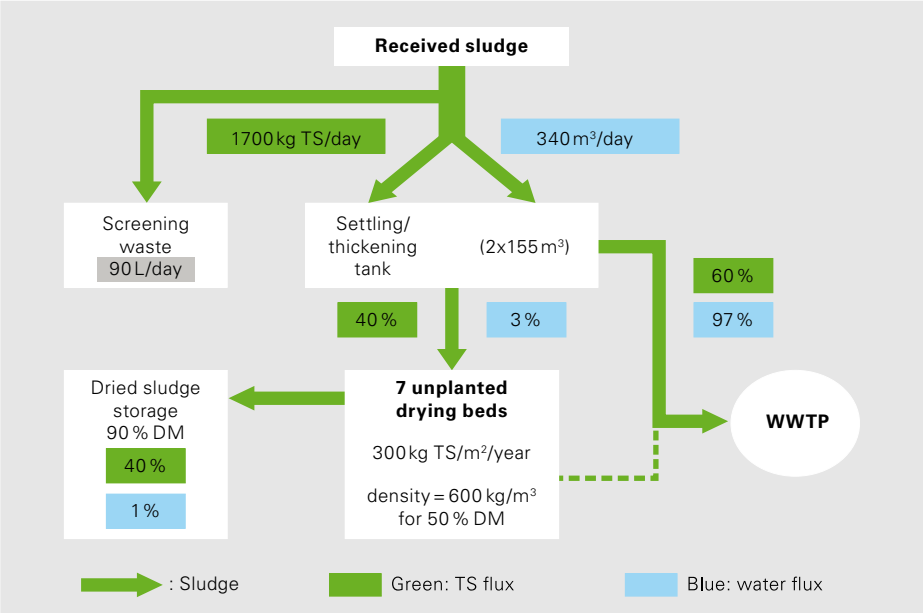

Figure 1: Material flux scheme at Cambérène (Dakar, Senegal), faecal sludge treatment plant in 2007.

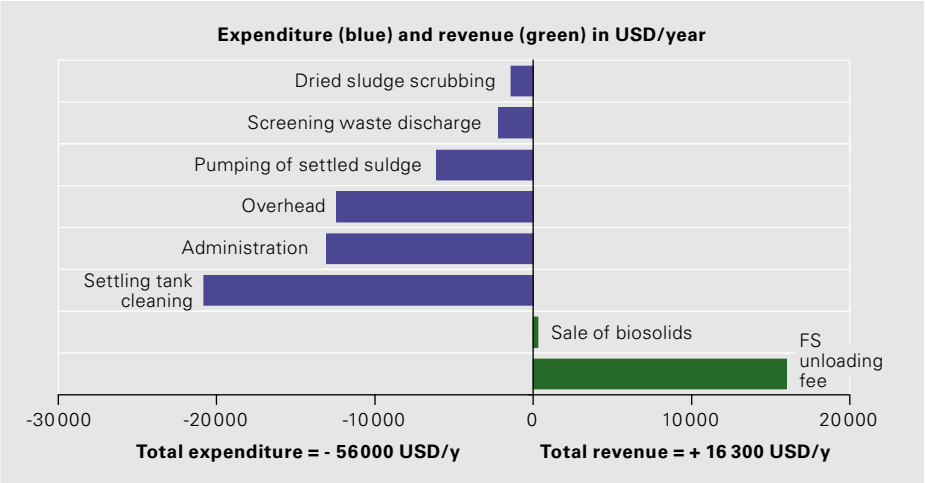

Figure 2: Management, operation and maintenance costs at nominal loading of the faecal sludge treatment plant combining settling/thickening tank and unplanted drying beds in Dakar.
Administration costs = Salaries and supplies
Overhead costs = Security, water & electricity, area cleaning
Settling tank cleaning = Scrubbing of settling tank using a high pressure truck

via the sale of biosolids, to offset the direct production costs of biosolids (pumping and scrubbing) and turn these into a source of income. Market research will soon be conducted in Dakar to optimise the sales strategy of the operator. According to Vodounhessi [3], a 50-kg compost bag is sold at 0.03 USD/kg in Kumasi (Ghana), a price 15 times higher than the one for biosolids in Dakar.

The unloading fee of 0.4 USD/m^3 sludge collected from the emptying companies generates important revenues. An increase of this fee to 1.4 USD/m^3 would allow to offset the operating costs of the treatment plant. This corresponds to a 20 % increase in the average household pit emptying fee (from USD 50 to 60) [4], as currently practised in the serviced area.

With an estimated investment cost of UDS 665 000, the net present value[1] of the treatment plant is offset by a 2.7 USD/m^3 unloading fee. This amount corresponds to an average household emptying fee of USD 73 or to a 50 % increase. This would seem daunting within the current social and economic context and lead to finding different pricing mechanisms.

Performance of raw sludge-fed drying beds

Measurements conducted on full-scale drying beds fed with raw sludge confirm the data reported by Heinss [5] in Thailand and Ghana, i.e. a 95 % efficiency as a function of the SS or 85 % as a function of the TS with loading rates between 100 and 200 kg TS/m^2/year. 50 % dewatering occurs by infiltration through the filter material. Improvement of the screening step and optimisation of the hydraulic distribution are recommended for a uniform feed over the entire surface of the beds.

With or without settling/ thickening tank?

As regards the necessary infrastructure, the thickened sludge feeding option requires a primary treatment step, but allows smaller drying areas, thus contributing to lower the investment costs (Fig. 3).

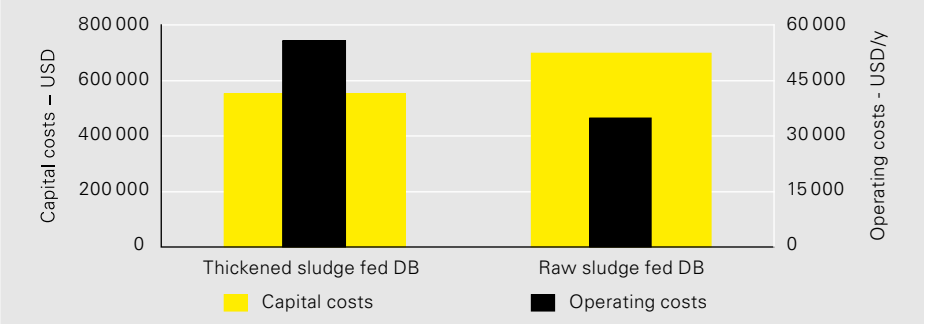

Figure 3: Capital and operating costs of the two feeding options (for a 100 m^3/d plant; raw sludge-fed drying beds (DB) designed for 100 kg TS/m^3/y; thickened sludge-fed drying beds designed for 300 kg TS/m^3/y).

However, based on the present state of technology, maintenance costs of the primary settling tank render operation of the thickened sludge option less attractive. Indeed, although the investment costs for the combined option are lower than for the raw faecal sludge-fed option (552 000 compared to 699 000 USD), its operating costs (56 000 USD/year) remain very high, about 38 % more expensive.

As regards the treatment quality level, the settling/thickening tank combination is less effective. An increased efficiency presupposes an improved hydraulic system with particular focus on the required storage volume of the thickened sludge.

At the operating level, cleaning operation of the primary treatment step proves to be a major constraint requiring systematic operation skills from the operator.

At the raw sludge feeding level, 50 % of the sludge is dewatered by infiltration of the free water through the sand filter material. This type of sludge feeding therefore requires use of a reasonably good sand quality, which will possibly have to be more frequently replaced than the thickened sludge option.

It can be concluded that state-of-the-art installation of a settling/thickening plant seems pertinent only if large surface drying beds pose problems, such as in places where the admissible direct feeding loads are low (low-strength raw sludge or in regions with considerable precipitation).

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Socio-Economic Profile of Domestic Faecal Sludge Emptying Companies

Since the development of on-site sanitation solutions, faecal sludge management has become a major challenge in developing countries. Control over sludge collection and transport to the disposal site is seen as a success factor for a good faecal sludge management policy. Definition of the socio-economic profile of domestic faecal sludge emptying companies forms part of the objective of this study.

Mbaye Mbéguéré[1-2], Jean Birane Gning[1-2], Pierre-Henri Dodane[1], Doulaye Koné[1]

Introduction

Developing countries are characterised by a rapid demographic growth mainly centred in urban areas where the economic activities are far more dynamic than in rural areas. This situation explains why the authorities find it difficult to satisfy the different basic service needs of their populations, particularly in the sanitation sector [1]. To offset this deficiency, the inhabitants have resorted to various survival strategies by developing several individual sanitation solutions (latrines, septic tanks, flush toilets etc.). These facilities are used by about one third of the world population or nearly 2.6 billion urban dwellers in developing countries [2].

However, on-site sanitation is characterised by a daily production of huge quantities of faecal sludge to be extracted from sanitation facilities and disposed of adequately to safeguard human health and the environment. In the city of Dakar alone, about 1500 m^3 of sludge is collected daily from on-site sanitation systems [3] and sometimes discharged directly into the natural environment.

It must be emphasised that faecal sludge management in developing countries is conducted by private entities and small-sized companies working independent of the public sector. Where public services are not always provided, these manual or mechanical emptying operators play a key role in on-site sanitation systems [4]. An improved faecal sludge management presupposes a sound knowledge of stakeholders, especially of mechanical emptiers who improve both the quality of emptying services and contribute to the generation of employment (Photo 1).

Materials and methods

Framework of the study

This study was conducted in Dakar, the capital of Senegal, a country located at the western tip of Africa with a surface area of 196 722 km^2 and a population of approximately 11 million inhabitants. Dakar and its suburbs, with over two million inhabitants, cover 0.3 % of the national territory but numbers 22 % of the total population.

With 30 % of its population living below the poverty line (less than two USD/day), Senegal is one of the least developed countries in the world. It is therefore a typical example of a country facing important difficulties regarding access to water and sanitation.

Definition of the emptying operator's profile

The profile of the emptying company was defined on the basis of interviews and by a review of official documents on the emptying companies over a period of one month (from 28 December 2006 to 30 January 2007).

Free and/or semi-structured interviews were conducted with 23 heads of the 52 companies identified in Dakar. Of these 52 private emptying operators, 40 work informally and only 12 are incorporated companies. Informal companies are entities not subject to the rules and regulations of private companies and without a legal status or declared revenue.

Results and discussion

Overview

Private stakeholders involved in mechanical emptying are divided into two categories: incorporated companies and individual operators.

As illustrated in Fig. 1, most companies (67.3 %) only own one truck and are generally managed by private entities operating their own truck in an informal way. Starting the business with one truck is a common strategy to acquire experience in the sector and learn the rules of management survival. Successful operators subsequently invest in additional trucks. Large operators holding only 6 % of the park or a fleet of 15 trucks are the best equipped service providers.

Photo 1: Faecal sludge discharge at Cambérène treatment plant, Dakar, Senegal.

Photo 2: View of an emptying truck.

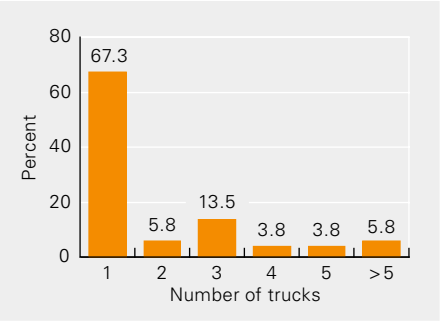

Figure 1: Number of emptying trucks per company.

The incorporated emptying companies are either Limited Liability Companies (LLC) or Economic Interest Groups (GIE). They own at least one truck, a head office and employ staff they manage in a more or less formal way.

An LLC comprises at least two associates, which may be natural or legal persons, whereas a GIE is a cooperation of existing companies aiming at facilitating or developing the economic activity of its members.

Moreover, it is important to note the wide range of activities conducted by the emptying companies. They do not work only in emptying domestic faecal sludge but are active in the disposal of wastewater and stormwater, in industrial emptying as well as in maintenance of the sewerage network.

Human resources

The emptying companies have two categories of staff: permanent employees and day labourers. The number of employees in these companies varies according to the company's size, number of trucks and nature of their business. Furthermore, the emptying companies visited are composed of teams with at least one director, who coordinates all the activities, one marketing specialist, one secretary-accountant, one mechanic, who ensures truck maintenance, drivers, and labourers – a typical organisational structure in West Africa [5], [6]. The organisation of the company is generally structured around the truck. Each truck requires a team of three persons:

- One driver, who is responsible for the truck and in charge of managing all mechanical parts, i.e. the truck engine and suction pump. He has to ensure proper functioning of the equipment before, during and after emptying or provide any other services requiring use of the truck.
- Two labourers, who provide technical assistance during emptying operations (opening of pits, joining of pipes, closing and cleaning of pits).

Material resources

Mechanical emptying activities in the city of Dakar require an important vehicle fleet of about 130 trucks; most of which are rundown. None of the identified trucks are less than ten years old. The emptying company surveyed has a fleet of 10 tankers but only three were operational at the time of the study (Photo 2). With a downtime rate of about 50 %, the number of tankers per household amounts to one truck for 2308 households. This explains the frequent demand for manual emptying – an extremely harmful activity to human health and the environment.

Currently, among the hundred trucks available in Dakar, only 3 % are hydrocuring, the remaining vehicles are pumping trucks and slurry tankers. This creates a problem in mobilising the full sludge capacity at pit level. Thus, after emptying, an important part of the settled sludge remains in the pit and only the supernatant is disposed of at the faecal sludge treatment plant. Aside from technical problems caused by this situation at the treatment plants, social problems are created between emptying service provider and the population, who considers the service unsatisfactory due to the rapid filling of pits after emptying.

The survey results reveal that the trucks are mostly imported second-hand vehicles from Europe. Rapid renewal of this fleet is difficult, as the import prices for second-hand tankers remain very high. They currently vary between USD 25 000 and 45 000, depending on whether it is a pumping or hydrocuring vehicle. To remain in the emptying sector and secure survival, truck owners are forced to extend almost indefinitely the life of their vehicles.

The interviews reveal that the operators agree unanimously on the rundown condition of the vehicles, however, their scarce resources limit renewal of the truck fleet. Donors and public entities should therefore impose regulations on types and service life of trucks operating in sludge emptying, create incentives for vehicle renewal and propose a blueprint for access to credits for this type of business.

Conclusion

The emptying companies have two categories of staff: permanent employees and day labourers. The number of employees in an emptying company varies according to its size, number of trucks and nature of its business.

The fleet of mechanical emptiers is outdated and leads to a high immobilisation rate of almost 50 %. This results in an important imbalance between supply and demand with a consequent increase in prices.

Since the emptying trucks are second-hand vehicles, their renewal costs are beyond the means of emptiers.

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Developing Strategies for Faecal Sludge Management

In Baan Klang municipality, Lamphoon province, Thailand, strategies have been developed to involve stakeholders in FS management. These strategies, adopted by the Thai Dept. of Health and UN-Habitat, have been integrated in their national or strategic plan for FSM. Thammarat Koottatep[1] and Supattra Jiawkok[1]

It is a well-known fact that in most developing countries faecal sludge management (FSM) remains unrecognised or is given low priority in community development practices compared to other sanitation practices, such as solid waste management, access to safe drinking water etc. To explore and learn from the possible causes, a research team of the Asian Institute of Technology (AIT), Thailand has undertaken a Partnership Action for Mitigating Syndromes (PAMS) project supported by the Swiss National Centre of Competence in Research (NCCR) North-South programme. Its aim is to develop strategies for effective FSM through stakeholder involvement processes. The project used a case study of a peri-urban community of Baan Klang municipality, Lamphoon province in northern Thailand, where only 3 % of the 36 000 m^3/year collected faecal sludge is treated by the constructed wetland system (Photos 1–6). Societal learning processes and analyses of stakeholder involvement will help determine the appropriate coping strategies for effective sanitation planning. The study has: (i) revisited technical performance of current treatment systems, (ii) analysed potential stakeholders, (iii) conducted stakeholder dialogues/workshops, and (iv) developed appropriate FSM strategies through national consultation seminar/workshops.

The field investigation revealed that indiscriminate dumping of 35 000 m^3 of untreated FS onto agricultural land, into aquacultural ponds or on bare land could be the prime cause for the high prevalence of diarrhoeal diseases in the community (Photo 7). The focus group discussions could highlight some main causes for inefficient FSM, i. e. inefficient operation/maintenance of on-site sanitation systems at household or commercial level, poor municipal management as regards the provision of appropriate FS emptying/collection services, inadequate capacity of FS treatment system, and lack of public participation and awareness. Even the questionnaire survey indicated that a majority of the interviewed persons regarded the health issue as a high-priority problem. Excreta-related diseases due to poor FSM are not well perceived compared to the health impacts by industrial emissions. SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the information collected from focus group discussions and the questionnaire survey revealed: (i) *Strength* from the active volunteer groups tackling health and environmental issues and high revenues secured

Photo 7: Indiscriminate FS dumping practices in Baan Klang municipality, Lamphoon province, Thailand.

by the municipal administration, (ii) *Weakness* as regards minimal recognition by policy-makers, inadequate legislative enforcement and less control of FS emptying service providers, (iii) *Opportunity* of financial support from central government for local development, and (iv) *Threat* from unavailability of national FSM guidance and regulatory measures.

Based on the aforementioned results, the consultative dialogues with stakeholders contributed to developing four main strategies for effective FSM: (1) capacity development of the local officers, (2) provisions of appropriate FSM practices, (3) enhancing societal learning processes on FSM, and (4) continuous monitoring of FS treatment systems. Details of such strategies are given in PAMS-SEA 2-2 Final Report [1]. The developed strategies have been adopted by the Thai Department of Health and UN-Habitat and integrated in their national or strategic plan for FSM.

1) Screening

2) Mixing

3) 1st Constructed wetland

4) Sump

5) 2nd Constructed wetland

6) Agricultural field

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Hydraulic Modelling of an Anaerobic Baffled Reactor (ABR)

Residence Time Distribution (RTD) studies conducted in Thailand allowed to describe and model the hydraulic behaviour of the ABR treating domestic wastewater. Yuttachai Sarathai[1] and Antoine Morel[2]

The ABR is successfully applied as treatment system for a variety of wastewaters. However, knowledge is restricted as regards its applicability to domestic wastewater exhibiting high qualitative and quantitative fluctuations. This PhD study investigates and models the hydraulic characteristics of the ABR treating domestic wastewater.

RTD studies

Residence time distribution (RTD) analyses (lithium chloride) were carried out in laboratory-scale ABR, comprising one sedimentation chamber and three upflow chambers in series (Fig. 1i). RTD curves were established using steady flow and non-steady flow tracer theories as described by [1]. These curves were used to quantify dead space, mean hydraulic retention time, short-circuiting effects, and mixing patterns in ABR operated at different peak flow factors (PFF 1–6), hydraulic retention times (HRT 24 h, 36 h, 48 h) and influent COD concentrations (379, 911 and 1 500 mg/L. RTD was further used to test the suitability of two non-ideal flow models (DPF and TIS) to characterise ABR's hydraulic behaviour.

Research findings

Dead space and short-circuits: RTD curves proved to be a good instrument to analyse the complex hydraulic patterns in ABR. Tracer response curves revealed rapid tracer breakthrough, indicative of prominent short-circuit channels and formation of circulation zones (dead zones). Highest short-circuit effects were observed at low nominal HRT (24 h and 36 h), with increased short-circuiting at increased peak flow factors. At a nominal HRT of 48 h, peak flows had little impact on short-circuits. No clear trend could be observed between dead space and nominal HRT or biomass concentration. A substantial increase in dead space (15–25 %) was observed at low nominal HRT (24 h and 36 h), when peak flows increased from 4 to 6 [2]. Dead space is assumed to increase mainly in the upflow chambers due to increased upflow velocities of the fluid.

Hydraulic modelling

Two non-ideal single parameter models (tanks-in-series), were applied to the experimental data.

DPF model: The dispersion calculated in the experiments (0.10–0.19), corresponds to a large dispersion in the reactor with flow patterns far from plug-flow. The DPF model also simulated higher grades of symmetry compared to the observed RTD curves, underestimating the longitudinal dispersion (mixing) occurring in the ABR.

TIS model: At steady flow and non-steady flow (PFF 2–4), ABR's hydraulic behaviour can reasonably well be compared to a four tanks-in-series (TIS) model.

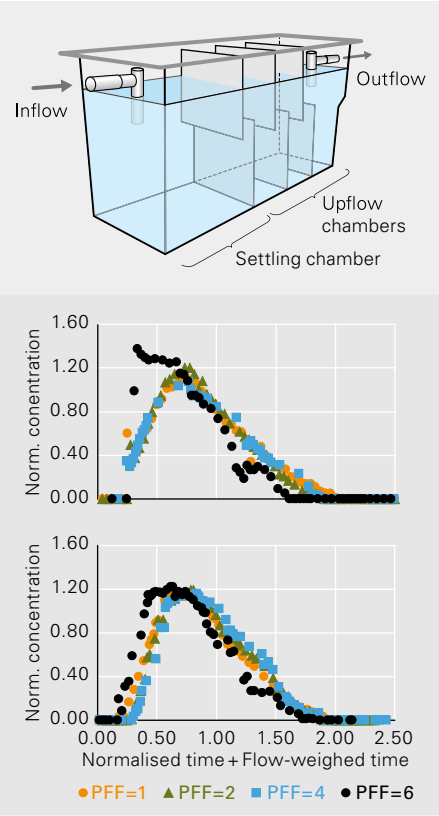

Figure 1i: Schematic diagram of the ABR model; ii and iii: RTD curves of the ABR operated at different peak flow factors (PFF) and HRT (ii: HRT = 12 h; iii: HRT = 48 h).

N was calculated based (1) on the variance of the RTD curve and (2) on the peak of the RTD curve. N values, calculated as a function of the variance of the RTD curve, were too high (N = 7–14). The second method provided more accurate results, with N close to 4 (3.6). This number is equal to the number of compartments in the ABR, thus indicating that the ABR behaves like four continuously stirred tank reactors (CSTRs) operated in series.

Conclusions

Based on the RTD curves, it is possible to analyse the complex hydraulic patterns in ABR. The method allows rapid identification and quantification of short-circuiting effects, dead space and hydraulic efficiency.

The ABR is hydraulically very efficient at 24 h–48 h HRT and dead space below 15 %. As high peak flow factors (PFF = 6) strongly affect hydraulic efficiency of the ABR at low nominal HRT (12 h–24 h), a nominal HRT of 48 h is recommended.

The TIS model with four tanks-in-series accurately reflects hydraulic behaviour of an ABR with one sedimentation and three upflow chambers operated at 12 h, 24 h and 48 h HRT for steady flow and non-steady flow up to 4 peak flow factors.

Local RTD curves (for each ABR compartment) would localise areas with insufficient mixing and channelling in the system and allow to establish a more accurate hydraulic model for ABR.

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Improvement of Faecal Sludge Management Strategy (FSM) in Thailand

Thai authorities, academia, the private sector, and citizens have contributed to the development of a national strategy to improve FSM in Thailand. Thammarat Koottatep[1], Supattra Jiawkok[1], Antoine Morel[2]

Introduction

The pollution control authorities in Thailand have until recently used a technical approach to solve the problems of faecal sludge management faced by the municipalities in the country. Since local knowledge, capacities and perceptions of local authorities, service providers and households were ignored; the strategies applied were not adapted to the local context and thus failed. The Department of Health (under the Ministry of Public Health) and the Asian Institute of Technology (AIT) recognised the problem and launched a project to identify the main limitations to more sustainable FSM in Thailand and to develop a strategy to overcome these limitations.

Objectives and activities

The project was conducted within the framework of the Partnership Actions for Mitigating Syndromes (PAMS) component of the NCCR North-South research programme (box). The main objectives of the project were to (i) review current sanitation and faecal sludge management practices, (ii) identify the main stakeholders affecting or affected by FSM, (iii) determine the factors affecting faecal sludge management, and (iv) define a strategy to increase the sustainability of FSM in Thailand [1].

A case study was conducted in the Baan Klang municipality, Lamphoon Province in northern Thailand (Photo 1). Current sanitation and FSM practices were determined based on a household survey and focus group discussions. Performance of FS treatment plants (constructed wetlands) was assessed on the basis of conventional performance indicators (organics, nutrients, pathogens). A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted in multi-stakeholder consultation workshops. The outcomes of this analysis were (i) discussed in a national workshop to define an action plan to improve FSM in Baan Klang and (ii) used as a basis to develop a national FSM improvement strategy.

Photo: AIT

Photo 1: Constructed wetlands for FS treatment in Baan Klang municipality, Thailand.

Barriers to sustainable FSM

A review of the current management practices in Baan Klang revealed that 97 % of the FS is currently discharged untreated onto agricultural land, into aquaculture ponds or surface water and only 3 % of the FS is treated. The following causes for ineffective management of FS were identified by the focus groups:

(i) FS treatment capacities are insufficient.
(ii) Treatment plant operators are not well trained.
(iii) FS emptying services perform poorly, illicit sludge dumping remains unpunished.
(iv) Current legislation is not enforced.
(v) Management capacities at municipal level are insufficient.
(vi) The lack of strategies, activity plans or budget to improve FSM are attributed to the fact that FSM is low on the priority list of municipalities.
(vii) There is a general lack of public awareness on the importance of FSM.

National FSM strategy

The multi-stakeholder dialogue resulted in the definition of a FSM improvement strategy comprising four main components:

1. Building FSM capacity al local authority level, including (i) implementation of an administration system, (ii) increasing human resources, (iii) allocating a budget for FSM, (iv) implementing a customer service system.
2. Promoting dissemination of the state-of-the-art FS collection and treatment technologies (e. g. improved sludge emptying trucks, vertical-flow constructed wetlands for FS treatment).
3. Raising awareness on the need to improve FSM by disseminating local and national information and national monitoring systems (cf. below).
4. Creating a national monitoring and evaluation system of municipal FS management (i. e. FS emptying, treatment and reuse). The evaluation will be based on Key Performance Indicators (KPIs).

Next steps

The strategy, developed within the framework of the PAMS project, was endorsed by national and provincial authorities under the Ministry of Public Health (MoPH). Though a clear concept on the implementation strategy is still missing, some components are currently being put into practice. AIT is, for example, currently supporting the MoPH in revising national regulations on faecal sludge management (including emptying, transport, treatment, and disposal, where the outcome of PAMS is introduced. MoPH has also invited NCCR researchers to conduct training courses on improved FSM and sustainable sanitation for local authorities in Southern, North-eastern and Central Thailand.

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This research was supported by the **Swiss National Centre of Competence in Research North-South (NCCR North-South).**

NCCR North-South PAMS component
This project was conducted within the framework of the PAMS component of the NCCR North-South research programme. PAMS are a vehicle for testing the applicability of developing research results. Each PAMS project is designed to implement strategies developed jointly by researchers and local stakeholders.
Further information www.north-south.unibe.ch

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Reuse of PET Bottles for SODIS – Blessing or Curse?

Allegations of health risks related to carcinogenic substances from PET bottle material in drinking water are circulating in the media of countries where such bottles are used for SODIS (solar water disinfection). A recent study shows that there is no reason for concern. Samuel Luzi

Solar water disinfection (SODIS) is an inexpensive and effective method to destroy pathogens in drinking water at household level. The disinfection mechanism is based on the biocidal effect of UV-A radiation in sunlight. Contaminated water is filled into colourless PET or glass bottles and exposed to direct sunlight for six hours (or two days during mostly cloudy weather).

Solar water disinfection is one of several technologies for household water treatment and safe storage (HWTS) recommended by the World Health Organisation. The application of SODIS significantly reduces the risk of infection by water-borne bacteria, viruses and protozoa, and decreases diarrhoea incidence in countries where access to safe drinking water is limited. An estimated two million people in more than 30 countries already apply SODIS for drinking water treatment.

Though PET (polyethylene terephthalate) is generally considered a very inert material suitable for food packaging, concern has been raised about the potential health risks related to the migration of chemical compounds from the bottle material into the drinks in PET bottles. As SODIS users rely on daily reuse of PET bottles, the SODIS Reference Centre at Eawag/Sandec has decided to assess the extent of migration of chemical compounds from PET bottles into water treated with SODIS, and quantify the associated potential health risks.

Earlier studies show that antimony – a catalyst in the PET production process – is indeed released into the bottled water during storage [1]. However, the antimony concentrations in the range of the WHO maximum levels for drinking water are only reached at very high temperatures (above 80 °C) and/or after very long exposure times (several weeks to months). These conditions are not typical for the SODIS process, as the water is kept in the bottles for only a couple of days and the water temperatures reached are well below 70 °C.

Other studies focused on the migration of phthalic acid and phthalate esters from PET and glass bottles into mineral water [2]. A recent article published by researchers from Empa (Swiss Federal Laboratories for Materials Testing and Research) and Eawag/Sandec illustrates the migration of organic compounds – with special focus on plasticisers – into the water contained in PET bottles under typical SODIS conditions [3]. For this study, colourless PET bottles of different origin were exposed for two consecutive days to sunlight at a geographic latitude of 47 °N (horizontal solar radiation varying between 194 and 845 W). Screening with GC/MS for organic compounds in the water after exposure revealed only food flavour constituents stemming from previous bottle contents – e. g. Coca Cola – at concentrations above the detection limit of 1 mg/L. Quantitative determination of the plasticisers di(2-ethylhexyl)adipate (DEHA) and di(2-ethylhexyl)phthalate (DEHP) revealed maximum concentrations of 0.046 and 0.71 µg/L, respectively. These concentrations are in the same range as the levels of plasticisers found in tap water or in commercially bottled water and range well below the WHO maximum concentration levels for drinking water (80 µg/L for DEHA; 8 µg/L for DEHP, Fig. 1). Only minor differences in plasticiser concentrations were observed in different experimental setups. The country of origin of the bottle was the most decisive factor, while the impact of storage conditions (sunlight exposure and temperature) was less evident.

According to the results of this study, the risk of negative health effects caused by reused PET bottles for SODIS treatment is negligible. These findings are contradictory to the allegations circulating in a number of print media in developing countries on the carcinogenic risk of (re-)using PET bottles. Such unfounded media reports potentially discourage SODIS users from applying this effective method for drinking water treatment and may instead expose them to a high risk of infection by diarrhoea-causing pathogens. The experiments conducted at Empa and Eawag/Sandec will be repeated in India to confirm the harmless nature of the technology in a country where media reports on the dangers of PET bottles are particularly widespread.

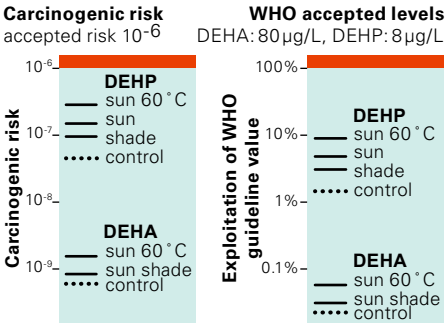

Figure 1: Carcinogenic risk and measured concentrations of DEHA and DEHP in PET-bottled water under different conditions relative to WHO guideline values.

Eawag/Sandec has been involved in SODIS (solar water disinfection) research and promotion since the 1990s. Today, the SODIS Reference Centre at Sandec provides support to SODIS projects in more than 20 developing countries.

Further information can be downloaded from www.sodis.ch

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Fluoride Removal in Ethiopia

To date, no appropriate fluoride removal technology has yet been successfully implemented in the Ethiopian Rift Valley. Filtration with bone char is known to be an efficient process in removing fluoride. However, is its use also compatible with religious beliefs in Ethiopia? Michael Jon Mattle, Kim Müller, Esayas Samuel, Feyisa Lemma, Annette Johnson

According to estimates by the Ethiopian Ministry of Water Resources [1], 14 million Ethiopians are potentially at risk of developing fluorosis; an illness caused by excess fluoride intake predominantly from drinking water. Fluorosis ranges from damaged teeth to crippling skeletal deformities in severe cases.

Though different defluoridation methods have been implemented in Ethiopia, a field visit in 2008 revealed that none of the defluoridation units were operational. Lack of maintenance, high costs and technical breakdowns were the main reasons for failure [2].

Bone char filtration is a relatively cheap and efficient method to remove fluoride from drinking water. However, Tekle-Haimanot et al. (2006) [4] reported that locally produced bone char was unacceptable to Ethiopian communities for religious reasons. According to a personal communication, bone char used in that study had caused taste and odour problems as a result of poor charring.

A collaborative team of researchers and practitioners (box) thus decided to re-evaluate the acceptability of bone char filters, using high-quality bone char produced by the Catholic Diocese of Nakuru (CDN) in Kenya.

First steps

A total of 121 households from two different communities took part in the pilot project. Several information and awareness raising campaigns and trainings on operation and maintenance preceded implementation of the household filter buckets (Photo 1). Each household contributed 10 % to cover the total filter costs.

Monitoring activities included interviews with the beneficiaries to assess user perception and acceptability of the treatment, together with regular sampling to quantify filter performance.

Success and challenges

One year after introduction of the filters, 90 % were still in use – a clear sign of high acceptability. Only one beneficiary refused to use the filter, the others readily accepted bone char as a filter material, as it was more important for them to see their children grow up in good health rather than strictly adhering to old religious beliefs. Interestingly, the village elders regarded bone char as a type of medicine to prevent the development of fluorosis. The interviews also revealed that the beneficiaries were well aware that bone char was not some kind of sand or other material but a processed animal product.

Fluoride removal efficiency was satisfactory, since fluoride concentrations as high as 23 mg/L could be reduced below the international WHO guideline of 1.5 g/L. However, the filters' lifespan was limited to a few months due to the high water demand and elevated fluoride concentration.

Development of odour in the treated water was one of the initial problems with the household buckets. According to field laboratory experiments, bad odour was mainly attributed to the use of highly turbid and organic-rich lake water combined with irregular filter usage. In refresher courses, the beneficiaries were told to use groundwater whenever possible. They were also instructed on how to best wash the filter material to avoid organic degradation with minimal disturbance of the material layers. Furthermore, a two-bucket filter-design with sand filtration followed by a defluoridation step reduced the problems, especially for households depending on water from shallow wells.

Photo 1: Training session in Weyo Gabriel, Ethiopia.

It can thus be concluded that bone char is a very promising fluoride removal option also for Ethiopian communities. Minimal maintenance, simple operation and efficient fluoride removal are the main advantages of this technology. However, bone char will only be accepted if it does not create bad odour and/or taste to the treated water, irrespective of religious or cultural aspects. This pilot study also revealed the need for a participatory approach, appropriate training and frequent monitoring to contribute to sustainable project development.

Future strategy

As the positive response of the community supports project upscaling, community-based filters will be tested jointly with the setting up of an Ethiopian production of high quality bone char and filter units. These implementation activities will be closely linked to a new research project of Eawag and Addis Ababa University on optimising fluoride removal treatment (page 25).

Project Manager and Implementor: Oromo Self-Help Organisation, Ethiopia (OSHO) and Swiss Interchurch Aid (HEKS).
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Renewable Energy from Kitchen Waste

Anaerobic digestion of organic household waste in developing countries is seen as a new treatment option to enhance waste management and provide households and institutions with biogas – a renewable, clean source of cooking energy. Yvonne Vögeli, Christian Lohri

As announced in the previous Sandec News No. 9, Sandec conducted a research study [1] on the performance of the ARTI compact biogas plant (Photo 1) in Dar es Salaam, Tanzania in 2008. It assessed the plant's suitability to treat kitchen waste at household level in urban areas of developing countries. In collaboration with the Ardhi University of Dar es Salaam, an ARTI biogas plant was installed, operated and monitored on the University campus for four months in 2008. The biogas plant was fed daily with 2 kg of food leftovers (TS:24 %) from the University canteen as well as vegetable and fruit waste (TS:10 %) from a nearby market. A daily quantity of 2 kg organic waste generated by a five-member Tanzanian household seems a realistic figure.

According to the results obtained, the system seems robust in terms of structural and biological stability and very effective in reducing the organic load (84 % COD removal). The digester effluent is an odourless, high-quality fertiliser valued in horticulture. The average daily gas production amounted to 290 L/d and 130 L/d when fed daily with 2 kg (wet weight) of food waste or market waste. Assuming that a Tanzanian household produces 1 kg of food leftovers and 1 kg of fruit and vegetable peelings, these 2 kg of kitchen waste generate 200 L of biogas (61 % CH_4) equivalent to a 45-min burning period. This represents about 1/3 of the average cooking time of 2.5 h per day and family (five-member household). An average household using annually 1008 kg of charcoal can therefore save one third of the charcoal (336 kg) or an equivalent of TZS 276 000 (Euro 168). As the ARTI system is sold for TZS 850 000 (Euro 507), its amortisation period amounts to roughly three years. However, since the investment costs are rather high, its widespread implementation is limited. Further experiments revealed that with some additional logistical and operational efforts, the daily feeding load could gradually be increased to 5 kg, and produce 670 L/d of gas or 150 min cooking time.

Though system performance in terms of gas production and removal of organic material is excellent, digester design has to be optimised. The most essential technical improvements concern digester and gasholder size. The current design leads to a gas loss of about 22 % of the total digester area as a result of the unfitting rim between digester and gasholder. An improved fit between these two elements would considerably reduce atmospheric loss of biogas.

Furthermore, a household survey indicates that most of the installed systems in Dar es Salaam are poorly operated and maintained. Operating instructions and follow-up service provided by ARTI-TZ were insufficient and need to be improved. Therefore, a follow-up service will have to be provided by ARTI-TZ after plant installation. Following this survey, ARTI-TZ has already made great efforts to improve its service and is currently distributing a customer manual in English and Kiswahili.

Although there is room for improvement, the ARTI biogas system proved technically and environmentally suitable. However, to render this system affordable to a wider public in Tanzania, the price would have to come down considerably.

ARTI is not the only household biogas system available on the market. A similar system has been developed by BIOTECH in India. However, unlike ARTI, it has its own manufacturing unit of digesters made of fibreglass reinforced plastic. The system is very widespread in South India, where 12 000 household digesters have already been implemented. By tightly fitting digester and gasholder, gas loss through the rim could be reduced. The latest biogas model is even equipped with a water jacket to prevent atmospheric biogas loss.

The experience gained in Tanzania and India reveals the great potential of anaerobic digestion of kitchen waste at household level. Since BIOTECH is already operating numerous biogas plants in schools, hotels and markets [2], this technology also seems very promising at institutional level. As the ARTI system can be scaled up, a follow-up project is now focusing on an ARTI biogas system with three 4 000-L digesters, already operating in a secondary school in Dar es Salaam since August 2008.

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Photo 1: ARTI household digester in Dar es Salaam, Tanzania.

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Assessing Peri-urban Land Use for Crop Production

Remote sensing techniques and geographic information systems are suitable tools to assess land use for crop production in peri-urban areas, thus valuing the contribution of peri-urban agriculture to urban food supply.

Dionys Forster[1,4], Tobias W. Kellenberger[2], Harald Menzi[3], Bernd Lennartz[4]

Rural-to-urban migration contributes to urban sprawl and uncontrolled peri-urban land development with complex structures marked by a predominantly horizontal expansion. However, peri-urban areas are important as they provide fresh agricultural products to cities. Land cover/land use (LCLU) analysis allows to assess crop production parameters and contribution of peri-urban agriculture to urban food supply.

Remote sensing can supply synoptic information on peri-urban LCLU. Very high spatial resolution satellite data (i.e. Ikonos or Quickbird) can be used for LCLU analysis of small-scale peri-urban agricultural systems.

Object-based classification, using high spatial resolution data, has been successfully applied to studies in agriculture [1] and is said to have considerable advantages over pixel-based approaches in highly diversified environments. In the object-based image analysis approach, homogeneous neighbouring pixels are grouped into objects or segments [2], which are subsequently assigned to different LCLU classes applying membership functions.

LCLU analysis of peri-urban Hanoi

An archived Quickbird image (acquisition date 8 Dec. 2004) with a panchromatic band of 0.6 m and four spectral bands of 2.4 m spatial resolution was ordered for the Dong Anh district (21°8´14´´N; 111°49´44´´ E). A field vector layer was prepared for the Bac Hong commune by drawing polygons of field parcels in ArcGIS®. This layer was subsequently used in the object-based segmentation and classification procedure Definiens Professional®. Based on membership functions, the field parcel objects were labelled into different LCLU classes, such as fallow, vegetable, maize, and orchard (Figure 1) and allowed assessment of areas covered by different crops for the specific cropping season.

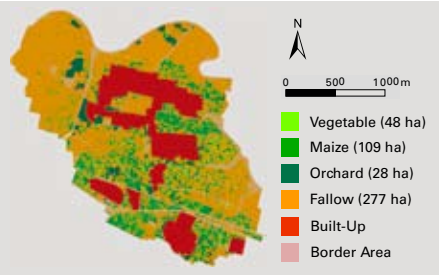

Figure 1: Object-based LCLU classification of the Bac Hong commune, Hanoi province, Vietnam, derived from Quickbird (high spatial resolution data).

Peri-urban agriculture and crop production

Based on spatially high resolution satellite data for a specific growing season, LCLU can be estimated for other cropping seasons. In the study area, up to four different crops were cultivated on a single field over one year. As satellite data (and deduced LCLU information) was only available for the third cropping season, LCLU of the first, second and fourth season was estimated based on data of the third season and on a field survey.

The field data collected during a survey for the Bac Hong commune (Oct. 2005 – Jan. 2006) allowed to identify patterns in the sequence of cropping seasons (i.e. succession of crops on the same plot over one year). Classification of crops into cash crops (e.g. vegetables or maize), staple crops (e.g. rice paddy) or fallow land allowed a proximate weighing of groups and fallow land for each cropping season (Table 1). During the first and second season, climatic conditions favoured staple crop production, whereas in the third and fourth season, cash crops such as maize and vegetables were cultivated on a fraction of the area, thus leaving much of the land to lie fallow. Summing up the areas weighted per crop group led to an annual estimate of cumulated cropping area. The cumulated cropping area of staple crops was somewhat larger than that given in the statistical yearbook, while the cumulated cash crops area was smaller than that in the reference data.

Object-based LCLU analysis derived from very high resolution satellite data proved to be a suitable tool to survey agricultural areas. Together with survey data on land distribution, it was possible to assess the cumulated annual cropping area. Since the results were close with the commune's official crop production statistics, object-based LCLU analysis can provide information on crop production where updated official statistics are missing.

	Cropping area per season [%]				Cumulated area (2004)	Statistical yearbook (2004)
	1st 2)	2nd 2)	3rd 1)	4th 2)	[ha]	[ha]
Staple crop	85	75	0	0	715	646
Cash crop	15	25	35	10	342	380
Fallow land	0	0	65	90	672	n.a.

Table 1: Land distribution between staple, cash crop and fallow land for four cropping seasons (one year) in Bac Hong commune, Hanoi province.

1) based on satellite image data and object-based LCLU classification
2) estimate based on 3rd season data and farming system survey

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[1] Buehler, Y., Kneubuehler, M., Bovet, S., Kellenberger T. (2007): Anwendung von ADS40 Daten im Agrarbereich. Von der Medizintechnik bis zur Planetenforschung – Photogrammetrie und Fernerkundung für das 21. Jahrhundert. Eckhardt Seyfert, 16, 381–390.

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Economic Impact of N-enriched Excreta-based Co-compost (*Comlizer*) on Maize Production in Ghana

Poor soil fertility is a key factor limiting crop production in many parts of the tropics. Nitrogen-enriched waste products have the potential to improve crop yield on depleted soils and provide high financial returns. Noah Adamtey[1], Olufunke Cofie[1], Godfred K. Ofosu-Budu[2], Dionys Forster[3]

Due to several decades of soil nutrient mining, African soils have become very poor. Though the combined use of organic (e. g. manure) and inorganic fertilisers has been widely advocated, their access and affordability can be limited. An alternative nutrient source, such as excreta based compost-fertiliser mixture (*Comlizer*) is seen as an option. Use of *Comlizer* has several advantages, including minimising heavy metal accumulation in soils and plants and leaching of NO_3^--N into groundwater. Moreover, it improves growth, yield, nutrient uptake, and water use efficiency of maize. However, farmers are concerned with costs and returns from farm investment and rather reluctant towards the adoption of new products. To provide a better basis for decision, the economics of mixing co-compost with inorganic N fertiliser and the impact of *Comlizer* on maize production in Ghana have to be assessed.

Production costs of *Comlizer*

Production of N-enriched excreta-based co-compost (*Comlizer*) is outlined by [1, 2]. Cost analysis of *Comlizer* production includes: fixed costs (i. e. land, construction of drying beds, shield for co-composting and storage rooms) and variable costs (i. e. solid waste or human excreta delivery, inorganic fertiliser (ammonium sulphate), pulverising and sieving, bagging N-enriched co-compost, wages, and transport to main distribution outlet). Compared to a 50-kg ammonium sulphate fertiliser bag sold at US$ 21, production costs of ammonium sulphate-based *Comlizer* amounted to US$ 9 in 2006. Production costs of 50 kg *Comlizer* are thus, three times as high as 50 kg co-compost.

Agronomic and economic impact

A field experiment with Randomised Complete Blocks Design was conducted at the University of Ghana. Maize (*Zea maize* L.) was sown at a distance of 40 × 80 cm in plots of 4 × 3 m size and replicated three times. Yield was evaluated on a sandy loam soil (*Ferric Lixisol*) under rain-fed and supplementary irrigation from March to June 2007. The treatments tested include ammonium sulphate (dry)-based *Comlizer* (COASD) at 91 kg N ha^{-1}, farmer practice (FP), i. e. NPK + $(NH_4)_2SO_4$ at 150 kg N ha^{-1}, co-compost (CO), and poultry droppings (PD) at 210 kg N ha^{-1}. Production costs were highest for CO (1052 GH¢ ha^{-1}), followed by FP (711 GH¢ ha^{-1}), COASD (634 GH¢ ha^{-1}) and PD with 498 GH¢ ha^{-1} (Table 1). Highest grain yield (6294 kg ha^{-1}) was recorded for COASD compared to FP (5631 kg ha^{-1}), CO (5071 kg ha^{-1}) and PD with 4884 kg ha^{-1} (Table 2). The net profit yielded by COASD (3772 GH¢ ha^{-1}) was 17 %, 29 % and 43 % higher than with FP, PD or Co alone.

The aforementioned tables reveal that urban organic waste products, such as *Comlizer*, offer farmers the opportunity to improve crop growth and yield on depleted soils, while achieving high financial returns.

Treatment	Recommendation (kg N ha^{-1})	Costs (GH¢ ha^{-1})					
		Fix	Seed	Fertiliser	Insecticide	Labour	Total
S + Co + $(NH_4)_2SO_4$ (COASD)	91	12.5	18	360	7.5	236	634
S + Co-compost (CO)	210	12.5	18	778	7.5	236	1052
S + Poultry droppings (PD)	210	12.5	18	224	7.5	236	496
S + NPK + $(NH_4)_2SO_4$ (FP)	150	12.5	18	381	7.5	292	711
Soil alone (S)	–	12.5	18	0	7.5	180	218

Table 1: Production costs of maize with application of *Comlizer*, compost, inorganic fertiliser, and poultry droppings at recommended rates.

Treatment	Yield (kg ha^{-1})	Gross return[1)] (GH¢ ha^{-1})	Production costs (GH¢ ha^{-1})	Net return[2)]		BCR[3)]
				(GH¢ ha^{-1})	(US$ ha^{-1})	
S + Co + $(NH_4)_2SO_4$ (COASD)	6294	4406	634	3772	4072	6.9:1
S + Co-compost (CO)	5071	3550	1052	2498	2698	3.4:1
S + Poultry droppings (PD)	4884	3419	498	2921	3155	6.9:1
S + NPK + $(NH_4)_2SO_4$ (FP)	5631	3941	711	3230	3489	5.5:1
Soil alone (S)	3337	2336	218	2118	2287	11:1

Table 2: Economic analysis of the effect of *Comlizer*, co-compost, inorganic fertiliser, and poultry droppings on maize production.
[1)] Gross return = Total yield × market price (av. retail price per 50 kg of maize = GH¢ 35); [2)] Net return = Gross return - production costs; [3)] BCR (Benefit:Cost Ratio) = Gross return / production costs.

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The research was supported by the **Swiss National Centre of Competence in Research North-South and IDRC Agropolis**.
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Quantifying Diarrhoea Infection Risks

Quantitative microbial risk assessment (QMRA) was used to determine the risks of diarrhoea caused by human interactions with untreated wastewater and contaminated surface water in a peri-urban area of Thailand. Aleix Ferrer Duch, Hung Nguyen Viet, Antoine Morel, and Jakob Zinsstag

This study assesses diarrhoea infection risks by wastewater use in Klong Luang municipality, northern Bangkok, Thailand. Bangkok numbers 1165 man-made drainage and irrigation canals of 2280 km total length and 45.6 million m^3 total water volume [1]. Use of this water for agricultural and recreational purposes has a very long tradition in peri-urban areas such as Klong Luang; however, the suitability of such practices is increasingly questioned. Indeed, as a result of rapid urbanisation and industrialisation, the quality of the canal water has deteriorated considerably over the last decade, mainly due to the discharge of untreated domestic and industrial wastewaters (Photo 1).

QMRA, Real-Time PCR

The Quantitative Microbial Risk Assessment (QMRA) method was used to determine the risks caused by human exposure to protozoa [2]. The QMRA methodology follows a four-step approach as described in Table 1.

Diarrhoea infection caused by the two protozoa *Entamoeba histolytica* and *Giardia lamblia* have been identified as relevant hazards in the study area (step 1). Dose-response models for the two protozoa were based on international literature (step 2). Population exposure to the hazards (step 3) was characterised and quantified by a household survey (i. e. frequency and intensity of exposure, reuse practices, eating habits, personal hygiene, behaviours etc.). Wastewater samples were collected in sewers, wastewater treatment plants, canals, and irrigation water. Samples of vegetables traditionally eaten raw (i.e. morning glory (*Ipomoea aquatica*), Thai basil (*Ocimum basilicum*) and Tulsi (*Ocimum tenuiflorum*) were collected from agricultural fields. Protozoa concentrations, at the most relevant exposure points in the environmental sanitation system, were quantified using *Real Time PCR* (totally 54 samples). Integration of steps 1 to 3 enabled to characterise the risks of infection in the study area (step 4). The risk of diarrhoea was calculated using estimated probability density functions, randomly sampled by Monte Carlo simulation. Finally, the quantified risks were converted into DALYs (disability adjusted life years). DALYs represent the time lost through disability or death caused by a disease as compared to a life free of disability in the absence of the disease.

Morning glory, hand washing

The results obtained reveal high concentrations of *G. lamblia* and *E. histolytica* in canal water and on vegetables (morning glory, Thai basil and Tulsi). The highest infection risks (*G. lamblia* = 1.00 & *E. histolytica* = 0.48) and highest load of *G. lamblia* = 2631 and *E. histolytica* = 37431 cysts/100 g^{-1} on vegetables were caused by consumption of morning glory; a highly appreciated vegetable growing in the canal and partly eaten raw. Among the human behaviour studied, current hand washing practices also resulted in high infection risks (*E. histolytica* = 5.2 E^{-2}). Other exposure routes studied here, like fishing or collecting vegetable in the canal, resulted in comparatively low risks. Calculated health risks and reported occurrence of diarrhoeal diseases in the project area were extrapolated to DALYs. According to this estimate, diarrhoea infection caused a loss of almost 1.5 years of healthy life in Klong Luang municipality in 2005 (total population: 49296).

Photo 1: Sampling morning glory in the canal.

Main observations

The methodology applied allows to identify the main transmission routes of protozoa-related diseases in an environmental sanitation system and to quantify the infection probability for main exposure scenarios. An improved understanding of the interrelation between hazard, exposure to hazard and resulting health risks enables to quantify the impact of potential interventions on public health and to assess their suitability in reaching (locally defined) acceptable risks. In the context of Klong Luang, we are convinced that awareness-raising among the population is the intervention with the highest potential in reducing health risks caused by direct or indirect exposure to untreated wastewater.

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Steps	Description
Hazard identification	Describe acute and chronic human health effects associated with any particular hazard.
Dose-response analysis	Characterise the relationship between various doses administered and incidence of the health effect.
Exposure assessment	Determine size and nature of the population exposed and route, amount and duration of exposure.
Risk characterisation	Integrate the information from the different identification steps to assess the magnitude of the public health problem, variability and uncertainty.

Table 1. Procedural steps in QMRA [3].

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Framework for Combined Assessment

A definite lack of integrated assessments exists in providing approaches to improve health and the environment more effectively. The newly developed framework aims at combining health, environment and socio-economic assessment to reach a comprehensive understanding of the relationship between these components that would lead to effective interventions. Hung Nguyen-Viet

Improving health systems, environmental sanitation and conserving natural resources for sustainable development form part of the UN's Millennium Development Goals. Since assessing ways of improving health and the environment have often been conducted in relative isolation or in a non-integrating manner, Eawag/Sandec and the Swiss Tropical Institute have developed a new conceptual framework to study this topic within the NCCR North-South programme. The framework uses an approach combining the assessment of various factors such as health, ecological, social, economic, and cultural.

Conceptual framework

The framework starts with a rapid analysis of both the status of health and the physical, social, cultural, and economic environment. This provides a basis for understanding the key issues to improve health and environmental aspects in a given area. Three main components are subsequently assessed: health status, physical environment, as well as the socio-economic and cultural environment. The physical environment comprises environmental sanitation, i. e. water supply, excreta, wastewater, solid waste management, and drainage infrastructure and services. Use of standard disciplinary methods provides information on each of these three components. An innovative combination of these methods is described hereafter.

The analyses lead to an in-depth understanding of health, ecological and social risks, while allowing critical control points (CCP) to be identified in relation to the following factors: epidemiological, ecological, socio-economic, and cultural. They complement the conventional CCP approach by including an actor perspective that considers vulnerability to risk and patterns of resilience. Interventions derived from the comprehensive analysis consider biomedical, engineering and social science perspectives or a combination of both. The framework thus jointly addresses health and environmental sanitation improvements as well as the recovery and reuse of natural resources. Moreover, interventions encompass also behavioural, social and institutional changes derived from the identified resilience patterns. The interventions are assessed with regard to reducing specific risk factors and vulnerability, enhancing health status and assuring equity [1].

Case studies

The framework is currently being tested in the peri-urban study site of Hanam – a northern Province of Vietnam (Photo 1). Human excreta and wastewater reuse in agriculture and aquaculture has been identified as an issue of environmental sanitation and agriculture, health and well-being. The material flow analysis (MFA) method has been used to analyse environmental sanitation and agricultural systems with emphasis on nutrient flow of nitrogen (N) and phosphorus (P) [2]. According to preliminary results, on-site sanitation and crop production discharge the largest flows of N and P into water bodies through drainage systems (CCPs). Remediation options are therefore expected to mitigate environmental impacts, for instance, by turning waste into fertilisers. A set of epidemiological and quantitative microbial risk assessment (QMRA) studies has been carried out on the health effects of wastewater and excreta reuse [3]. A cross-sectional study on the prevalence of diarrhoea, helminth and protozoan infections as a function of excreta and wastewater reuse has therefore been conducted to identify exposure to wastewater and excreta responsible for these health outcomes. A one-year follow-up study will be launched to further explore the link between diarrhoea and excreta as well as wastewater reuse. In parallel, QMRA is used to determine diarrhoea infection risks by wastewater and excreta reuse with focus on protozoa and bacteria, and a follow-up, one-year study is conducted on risk surveillance at different exposure points (CCPs). One study is examining the perceived health risks and ability of the population to prevent risks caused by wastewater and excreta reuse. The first survey on threat appraisal revealed that the population recognises the threat emanating from the black colour and bad smell of wastewater, the bad smell of excreta, inappropriate practices of excreta management, and suspected diseases caused by contact with excreta or wastewater.

Other case studies are also ongoing in other geographical sites. Wastewater health risk assessments were conducted in Pathumthani, Thailand and in Abidjan, Côte d'Ivoire. In Pathumthani, research revealed that activities such as consumption of vegetables grown in the wastewater canal and partly eaten raw, as well as current hand washing practices pose a far greater infection risk than the acceptable risk defined by WHO (cf. article on page 18).

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Photo 1: Farmers working with excreta and wastewater in a field in Hanam, Vietnam.

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Decision-Making for Sanitation Systems

This Eawag project addresses the various decision-making aspects in sanitation system and technology selection as a support tool for choosing the best available options to secure sustainable sanitation systems.

Chris Zurbrügg, Ahmed Bufardi, Elizabeth Tilley, Max Maurer, Bernhard Truffer

A sanitation system is a complex combination of technologies to treat human waste from its source of generation to its final reuse or disposal point. Selecting a sanitation system is not an easy task. In the past, the choice was tackled rather simplistically by using a top-down approach. Experts decided on the best sanitation system, the local authority was put in charge of its implementation and the target population was told how to use and what to pay. This type of supply-driven sanitation has led to frequent failures and is one of the reasons why the situation worldwide has not progressed as anticipated.

From a decision analysis viewpoint, selecting an appropriate and sustainable sanitation system and its corresponding technologies is a complex and multiple criteria group decision-making problem.

This brief article presents the activities of the WISDOM (Wastewater Infrastructure Systems DecisiOn Matrix) project involving: (i) collecting and structuring existing knowledge on Sanitation Systems (SanSys) and (ii) developing an approach that can be used to generate, evaluate and compare different SanSys alternatives. The method developed should:

- Use existing literature and expert knowledge on SanSys
- Evaluate the suitability of potential SanSys alternatives in a local context
- Consider the preferences of the different stakeholders, such as SanSys users and authorities
- Apply a multiple criteria approach to compare and rank the different feasible SanSys alternatives by assessing the different technical, economic, social, environmental, and institutional criteria
- Be flexible enough for application to various cases

The definition of SanSys alternatives relies on the classification of the SanSys into 'inputs & products', 'function groups' and 'technology options' (Fig. 1). Each system comprises different technologies capable of carrying out different functions for specific waste products. The products used in this work comprise human waste (urine, faeces) along with anal cleansing materials and the water to transport the waste. Depending on the technologies, greywater and stormwater may be co-treated along with the other aforementioned waste. The list of technology options in Fig. 1 is not necessarily exhaustive but is shown to illustrate the structural concept of SanSys.

Each SanSys alternative comprises one choice of technology at the "User Interface" and a maximum of one (i.e. one or none) technology option for each of the other SanSys functions and waste products. Thus, a first step in structuring alternatives is to determine all compatible combinations. These can then be depicted by a compatibility matrix to gain further knowledge on compatibility relationships between the different technology options.

The compatibility relationship between two technology options following each other must be understood as the possi-

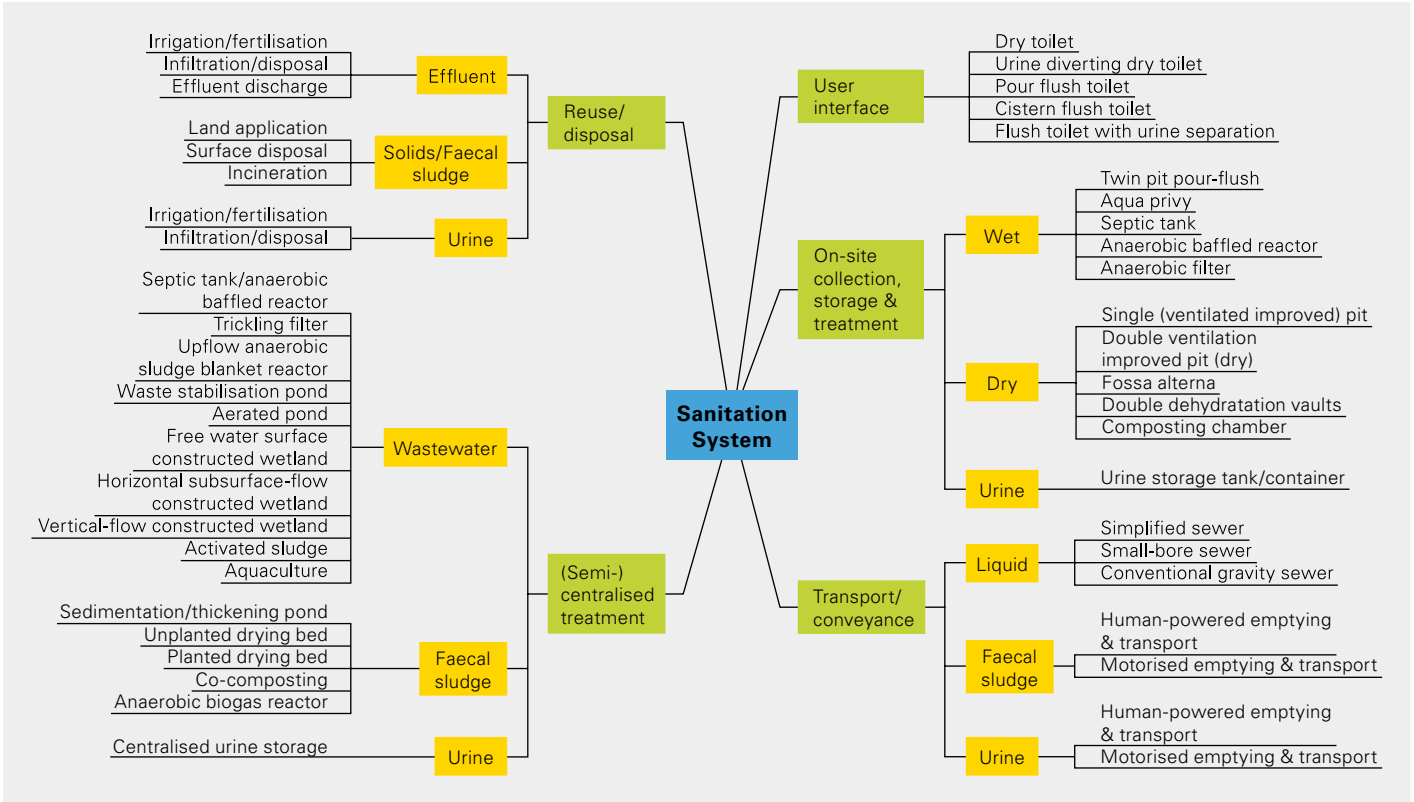

Figure 1: SanSys functions and technology options.

bility for the two options to coexist in the same SanSys. Two options are said to be compatible if at least one output from one of the two options can become an input of the other option. For example, the urine diverting dry toilet (User Interface Technology) is compatible with the urine tank/container (on-site collection, storage and treatment technology) as urine, which is an output of the urine diverting dry toilet, is also an input for the urine tank/storage container.

Once compatibility between technologies is established, the next step is to conduct a feasibility assessment based on case-independent attributes (e.g. land or amount of water required in order for this system to actually work), and set attributes as a function of the main characteristics of the application case (e.g. how much land or water is available in our specific application case).

Sustainability of SanSys alternatives is accounted for through consideration of the economic, environmental, social, technical, and institutional dimensions. To obtain predefined lists of criteria, the dimensions are classified into categories subsequently divided further into aspects, which are then broken down into criteria. For example, a dimension of the SanSys alternative selection problem is the environment. In the environmental dimension, a category can be natural resources. Within the category "natural resources", the energy consumption is an aspect and within this aspect "total non-renewable energy consumption" is identified as a criterion. The procedure for using these criteria is: (i) to select relevant criteria from the environmental, social, technical, institutional, and economic dimensions specific to an application case and (ii) weigh these selected criteria.

Seven main aspects are considered to represent a SanSys application case (Fig. 2).

The aspects can be categorised differently, however, their use in the feasibility assessment approach remains the same. In most cases, since the strategy of information gathering is not geared towards applying the feasibility assessment procedure as developed in WISDOM, a significant amount of necessary data is lacking.

By applying the procedure on, for the example, the Chang'ombe settlement in Tanzania, it was possible to generate the following four diverse generic SanSys alternatives with multiple options per selected generic alternative:

1. Single pit dry system with (semi-)centralised treatment of faecal sludge
2. On-site dry system with land application of compost/ecohumus
3. On-site urine diverting dry system
4. Hybrid pour-flush toilet system

If all potential technology combinations of the different generic alternatives are taken into account, the resulting SanSys alternatives total 198 according to the list of technology options in Fig. 1. None are very expensive or highly water-intensive.

Certain attributes can negatively impact the feasibility of some SanSys alternatives: depth of groundwater table, proneness to flooding, water availability, and availability of skilled personnel. However, the negative impacts can be overcome if additional measures are adopted. A high groundwater table and proneness to flooding may be surmounted if the pit latrine alternative is adapted by raising the mounds for pits. Also the lack of available water, which influences the choice for pour-flush toilets, may be offset provided additional investments are made to bring the water to Chang'ombe; a technically feasible solution. For SanSys alternatives requiring skilled staff, the problem of limited skilled personnel can be solved through education, training or by involving external specialists, particularly for design tasks. Consequently, since all 198 SanSys alternatives resulting from the four generic SanSys alternatives are regarded as either feasible or almost feasible, they can all be considered further in the decision-making process. However, analysing the required measures as preconditions for sustainability and their potential for implementation and success allows to reduce the 198 potential alternatives to about six to eight feasible SanSys options.

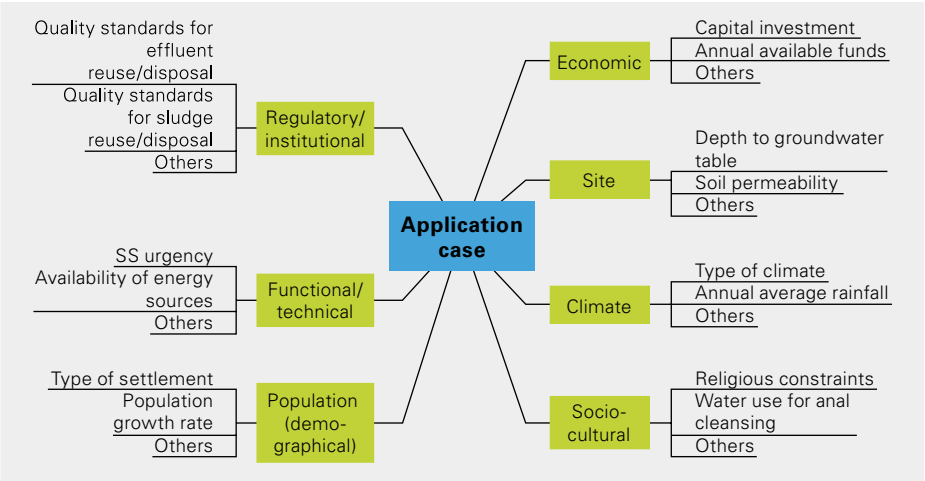

Figure 2: Application case aspects.

Conclusions

Despite its importance, the problem of generating appropriate alternatives is often neglected in the decision analysis literature. In WISDOM, this is achieved in three steps: (i) identification of all possible SanSys alternatives, (ii) determination of potential SanSys alternatives among all possible SanSys alternatives and (iii) determination of feasible SanSys alternatives among potential SanSys alternatives.

A lack of specific information often prevents planners from making a comprehensive feasibility assessment of the potential SanSys alternatives. The work conducted highlights the importance of developing assessment protocols and questionnaires for collection of information relevant to the evaluation of the different SanSys and attributes of the application case. Collection of data on different aspects of the application case needs to be planned properly. It is therefore advisable to develop questionnaires based on the relevant application case and SanSys attributes to allow collection of as much relevant information as possible for the feasibility assessment procedure.

WISDOM (Wastewater Infrastructure Systems Decision Matrix) is a collaborative project between three Eawag departments – Urban Water Management (SWW), Innovation Research in Utility Sectors (CIRUS) and Water and Sanitation in Developing Countries (Sandec). The project is financed by internal Eawag discretionary funds and the main author of the work is Dr Ahmed Bufardi.
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Participatory Sanitation Planning in Laos

The Household-Centred Environmental Sanitation (HCES) approach was applied to improve sanitation in a neighbourhood of Vientiane, Laos. Experience underlines the importance of a sound stakeholder analysis and involvement. Antoine Morel[1], Saykham Thammanosouth[2], Thongdom Chanthala[2]

This project, coordinated by the Public Works and Transport Institute (PTI) with the support of Sandec, adopted a demand-driven and participatory planning approach (HCES approach) to improve environmental sanitation services (ESS) in Hatsady Tai, a low-income village (*Ban*) in Vientiane. Other members of the project coordination committee (PCC) included the village head (*Naiban*) and a Village Environmental Unit (VEU) composed of community representatives, mass organisations and local authorities (Photo 1).

Project component

The three main project components included: (a) community-level capacity building, awareness raising in environmental management, (b) participatory planning of ESS (c) implementation of the developed ESS plans with private sector involvement.

The planning process

The planning process followed the 10 Steps of the HCES approach [1]. The local community was involved from the very early stages of the project through participation in:

- assessing the current ESS and hygiene practices (*HCES Step 3*)
- establishing their needs and priorities (*HCES Step 4*)
- developing a sound concept for improved ESS, including technical and managerial components (institutional setup, financial management, O&M) (*HCES Steps 5 to 8*)
- physical implementation of the interventions (*HCES Step 10*)
- management (O&M, financial management) of the improved ESS.

Main project outputs

Some 110 residents in the centre of the Ban benefitted as follows from the project:

Improved ESS infrastructure, including rehabilitation/construction of 20 private pour-flush latrines; installation of a wastewater collection and treatment system servicing 50 households, stormwater drainage (300 m) (Photo 2), and implementation of a solid waste collection system.

ESS management regulations and procedures, which define organisational structures and responsibilities, financing principles and mechanisms, reporting procedures and O&M equipment.

Adapted institutional organisation: A Village Environmental Unit (VEU), composed of representatives from the community, the local authorities and mass organisations, was created and played a key role in the planning process. The VEU was put in charge of implementing the ESS management regulations and procedures.

Increased capacities and awareness through: (a) training courses on solid waste management, on O&M of liquid waste and on gender sensitive planning for environmental management, and (b) awareness raising on improved ES management through participatory assessment of ESS and problem identification, village cleaning campaigns and involvement in construction activities.

Three important lessons

More guidance required: The HCES planning guideline [1] provides a useful theoretical framework with clear working principles easily understood by all parties involved. Additional training manuals and user guides, such as the Compendium of Sanitation Systems and Technologies [2], are necessary to facilitate application of the HCES framework.

Top-down vs bottom-up: Transition from a top-down to a demand-responsive, bottom-up approach is not trivial. The decision-making power of district authorities in Laos was clearly underestimated. This was felt especially during Step 8 (finalisation of ESS plans) and Step 10 (implementation), when decisions taken by the district (i. e. defining minimal road widths) significantly influenced the plans previously approved within the framework of a participatory process. The importance of a sound and comprehensive stakeholder analysis during the launching phase is thus re-emphasised here.

Participatory processes take time: The HCES planning process was perceived as (too) long by the community, which was reflected in a growing dissatisfaction with the project coordination team and scepticism of the project. This strained situation disappeared as soon as construction started. It is thus crucial that all involved stakeholders, especially the community, understand the rationale of such participatory processes to avoid frustrations and consultation marathons.

A comprehensive case study is currently conducted and will soon be available for download on www.sandec.ch.

Photos 1 and 2: Different project phases, from top to bottom: An intervention plan was developed in close collaboration with the community and different interest groups (here: Village Environmental Unit defining management regulations). Construction of the stormwater drainage network.

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[2] Public Works and Transport Institute (PTI), Vientiane, PDR of Laos
This research was supported by the **Swiss National Centre of Competence in Research North-South (NCCR North South).**
Contact: antoine.morel@eawag.ch

[1] Eawag and WSSCC (2005): Household Centred Environmental Sanitation. Provisional Guideline for Decision-Makers. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Available from www.sandec.ch
[2] Tilley, E. et al. (2008). Compendium of Sanitation Systems and Technologies. Swiss Federal Institute of Aquatic Science and Technology (Eawag). Available from www.sandec.ch

Research Partnerships at Eawag – The EPP Programme

In 2008, Eawag introduced a new fellowship programme for talented students from the developing world. The programme entitled "Eawag Partnership Programme" (EPP) strives to strengthen Eawag's research links with universities and research institutions in developing countries and to enable young promising researchers to actively benefit from an internationally renowned aquatic research institution. Christoph Lüthi

Research partnerships between North and South are paramount for enhancing developing country knowledge. Such partnerships contribute to academic and research competence as well as strengthen individual know-how and confidence. Many academic institutions, especially in less developed countries, are faced with academic isolation. Academic partnership programmes can assist young researchers in having their research results published in high-impact journals or visiting major conferences and symposia, thus making their research institutions more visible.

Last year, Eawag's Directorate therefore embarked on a new initiative to strengthen research in and with developing countries. At the centre of the EPP initiative is the "EPP Fellowship Programme", which currently supports six fellowships per financial year for motivated and talented PhD or MSc students from developing countries (Map). Selected students are awarded a 3–4-month research grant covering a monthly salary, travel and administration costs.

Applications can be submitted biannually on 1 March and 1 September. All candidates are subject to a competitive selection procedure.

The following two selection criteria are critical for successful application:

1. The research subject must be relevant to the developing country and address critical issues like water scarcity, environmental pollution, environmental sanitation, loss of biodiversity etc.
2. Scientific quality: this includes a clearly formulated research proposal outlining the candidate's objective to attain during his/her stay at Eawag.

According to all six EPP fellows selected for this Eawag initiative in 2008/2009, the main benefits were access to state-of-the-art libraries (Eawag and ETH), exchange of experience with other researchers and scientists in Switzerland and Europe and the possibility to work in an enjoyable and communicative environment. Eawag's multi-disciplinary research approach with its network of scientific partners and research centres in the developing world offers an ideal environment for these young professionals (Photo 1). So far, the successful fellowship candidates from China, Vietnam, the Democratic Republic of Congo, Ghana, Senegal, and Zambia have benefited from this programme as they were able to formulate their full PhD research proposals, write papers for peer-reviewed publications or receive training in lab testing, and become acquainted with new software and programmes.

Some typical research themes from previous EPP fellows include:.

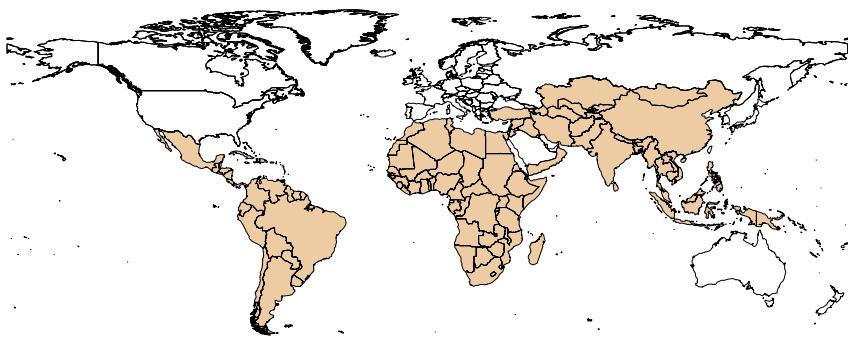
- Development of a chemical analytical method for detecting precursors of perfluorinated compounds.
- Nutrient cycling and methane production in Lake Kivu, D. R. of Congo.
- Use of enriched co-composting under irrigated urban agriculture: Effects on water use and transpiration efficiency, nutrient uptake and maize yield.
- Humification process in faecal sludge beds in Dakar, Senegal.

Photo 1: EPP summer fellows on Lake Lucerne, July 2008.

To further strengthen existing scientific partnerships between Eawag and universities in developing countries, applications are only accepted from universities and research centres that entertain an existing collaboration or agreement with Eawag. EPP is certainly open to any new scientific partnership that may develop in the years to come.

Moreover, Eawag offers annually three UNESCO-IHE MSc students the opportunity to complete their theses at Eawag in a so-called "sandwich programme", where students spend some weeks at Eawag before travelling to their home country to conduct field research, then come back to finalise their MSc thesis at Eawag.

More information on the EPP Programme and application forms for an Eawag fellowship are available from www.eawag.ch/programs/



Map: Candidates from highlighted countries are eligible for Eawag's EPP programme.

EPP at a glance:

- Six fellowships annually (3–4-month stay)
- 3 IHE MSc students annually (6-month stay)
- Application deadlines: 1 March and 1 Sept.
- Contact: epp@eawag.ch

Evaluation of Biogas Plants in Nepali Prisons

To improve the deficient sanitation conditions in Nepal's overpopulated jails and reduce wastewater pollution as well as provide renewable cooking energy, several biogas systems were installed in 2008.

Many people were detained during the armed conflict between Maoist rebels and government forces. The obsolete infrastructure in Nepali jails leads to poor water, sanitation and environmental conditions. Air pollution in the kitchen environment and high fuel wood consumption are also particular problem areas.

Photo 1: Biogas plant in a prison in Nepal.

In 2004, the Water and Habitat Service (WatHab) of the International Committee of the Red Cross (ICRC) therefore decided to assist the detention authorities by providing technical expertise and ensuring that detainees held in civilian jails get access to improved infrastructure, such as water supply and sanitation. In 2008, the local expert "Biogas Sector Partnership Nepal" (BSP-N) installed biogas systems in three district jails (Photo 1).

Rwanda's prisons, where the first biogas plants were installed in 2001, served as role model for the Nepali biogas plant project. Biogas plants are currently used in six prisons with totally 30 000 detainees. The Kigali Institute of Science and Technology (KIST), who developed and installed these large-scale biogas plants, won the Ashden Award for Sustainable Energy in 2005.

The smaller biogas plants conceived for Nepal's jails (for up to 300 detainees per prison) pursue the same goals, i. e. improve the sanitary conditions in the prison (safe treatment of human waste) and supply clean and renewable cooking energy. The treated effluent can subsequently be used as fertiliser. Now, one year after operation, an evaluation will determine whether these goals were reached.

On behalf of the WatHab Department of ICRC, Sandec is carrying out a study (from March to August 2009) on biogas plant performance in Nepal's prisons. The study includes an evaluation of plant design, measurement of gas production and composition, treatment efficiency as regards the organic loading rate and pathogen destruction during the anaerobic process. Aside from these technical aspects, an economic analysis will also be conducted of the system's cost efficiency.

Project team: Christian Lohri, Yvonne Vögeli, Chris Zurbrügg.

Integrated Sustainable Solid Waste Management in Asia (ISSOWAMA)

Within the Seventh Framework Programme of the European Commission, Eawag/Sandec together with 20 other research institutes from Europe and Asia aims to document and evaluate the current state of solid waste management in Asia. ISSOWAMA also intends to bring together experts and stakeholders in the field of solid waste management in Asian developing countries and Europe.

The project officially started in January 2009 and will last for 30 months. During the kick-off meeting in Bangkok from 11–12 February 2009, all partners met for the first time to discuss and define the next steps ahead. Basically, ISSOWAMA comprises the following work packages:

WP1: Mapping of solid waste management networks: Identification and mapping of current research activities and networks operating in solid waste management in the countries addressed.

WP2: Mapping and evaluation of solid waste management case studies: Based on a set of characterisation criteria, not only technical but also socio-economic parameters and appropriate case studies are selected to assess the performance of different technologies currently used for the major waste streams in Asian developing countries. The evaluation will be carried out along with the mapping of existing successful and unsuccessful stories in solid waste management, thus allowing improved decision-making.

WP3: Review and analysis of environmental impact assessment methods and impact categories: In WP3, the partners will firstly carry out a comprehensive analysis of the relevant impact categories, taking into account the special conditions of the countries addressed by the project. Subsequently, a critical assessment of the different Environmental Impact Assessment (EIA) methods will be conducted and lead to an improved EIA for developing Asian countries.

WP4: Analysis of representative local case studies: In this evaluation stage, the representative local case studies selected will be used to assess the performance of methodologies and impact categories proposed in WP3. The activities proposed in this work package aim at confirming the suitability of the methods used (and thus validating their current use) or proposing better approaches.

WP5: Dissemination and promotion of stakeholders' participation: The results of the first four coordinating work packages will be used to prepare appropriate dissemination tools. In thematic panel discussions with regional stakeholders, the scientific, economic, social, and cultural acceptance of the proposed assessment tools will be analysed. Regional workshops will be held to inform municipalities, SMEs, industry, and the informal sector about the importance and advantages of an improved Integrated Sustainable Waste Management (ISWM) and train the participants on the developed tools.

New Research Collaboration with Addis Ababa University

According to estimates by the Ethiopian Ministry of Water Resources, more than 14 million people in the Ethiopian Rift Valley rely on fluoride-contaminated drinking water. Over 40 % of the deep and shallow wells are contaminated by fluoride, whose concentration (up to 26 mg/L) is significantly higher than the international WHO guideline for drinking water of 1.5 mg/L. Over 80 % of the children suffer from different degrees of dental fluorosis; and skeletal fluorosis is increasing mostly among older people. Mitigation of these health problems has been hampered mainly by a lack of efficient and inexpensive removal technologies. A switch to treated surface water as a source of drinking water is being discussed. However, fluoride removal systems for rural communities are also required.

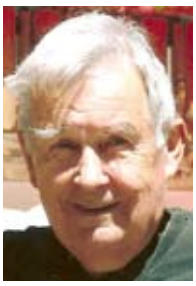
Since 2006, Eawag has been engaged in a pilot project to assess the acceptability and performance of bone char-based filters (cf. article on page 14). The study revealed that use of bone char as a filter material is acceptable and its filter efficiency high. Technical improvements to increase the lifespan of the filter material are, however, required. A research-based study of user behaviour and user perception is necessary to improve our understanding of the incentives and requirements of end users.

A new research collaboration between Eawag and Addis Ababa University (AAU) is therefore tackling these open questions with the aim to further develop and compare acceptability and technical performance of fluoride removal filters and explore sustainable implementation strategies in rural Ethiopia. The three-year project is funded by the Swiss National Science Foundation (SNSF) and the Swiss Agency for Development and Cooperation (SDC).

The project combines technical and social research both at Eawag and AAU, including field-testing in collaboration with NGOs to determine the best options of reducing fluoride concentration in drinking water. Apart from technical improvements, fluoride mitigation systems also have to be compatible with social, cultural, economic, and institutional settings. Capacity and human resources development in Ethiopia is a further aim of the collaboration project. The participation of NGOs will consolidate the ties between research and implementation.

More information on: www.wrq.eawag.ch

In Memory of John Kalbermatten



The Water and Sanitation Sector has lost an outstanding personality

John Kalbermatten, a real pioneer and visionary in the Water and Sanitation Sector over the last three decades, died on 26 February 2009 in Bethlehem, PA (USA) at the age of 77.

He was born in Lucerne, Switzerland, and had worked as a professional engineer in many parts of the world before he was appointed in the late 1970s as the Water Supply and Sanitation Advisor of the World Bank in Washington, DC. When John realised that World Bank-financed sanitation projects were often not reaching a large segment of the population, the poor, he initiated several research projects with the overall aim to determine the best level of service to be provided at a cost compatible with the family income of the population to be served and the most cost-effective technology in providing that level of service. One of the outcomes of these projects were some truly ground-breaking publications such as three books on Appropriate Sanitation Alternatives[1] and several reports published in the World Bank Series "Appropriate Technology for Water Supply and Sanitation". In 1978, John Kalbermatten obtained funds from UNDP for establishing the Technology Advisory Group (TAG) to put the lessons of the research project into practice. All these initiatives and projects came together in later years to become the World Bank-funded Water and Sanitation Programme.

After his early retirement from the World Bank in 1986, John continued as a private consultant for 14 years and followed developments in the sector with great interest and offered his professional advice to his many colleagues and friends until a few months ago.

John Kalbermatten was also instrumental in several global initiatives. He and a few other visionaries invented and promoted the International Drinking Water Supply and Sanitation Decade (IDWSSD) at the first UN-sponsored World Water Conference in Mar Del Plata, Argentina, in 1977. John always promoted within the UN family the idea of new international arrangements to keep sharp focus of WSS services for the poor. He and a few like-minded thinkers from multilateral and bilateral funding agencies first proposed a sectoral Collaborative Council at a conference in Interlaken in 1987. That idea also took root and was further developed to the Water and Sanitation Collaborative Council (WSSCC), which continues to be a model of sector collaboration between individuals and organisations concerned with water, sanitation and hygiene for poor people in developing countries.

Over the years, many people at Sandec, including myself, had the privilege to know John personally and to work with him on different occasions. It was always an extremely enriching and inspiring experience, both professionally and personally. John inspired me and the work of Sandec in many different ways and I will always remember him with gratitude for his outstanding and warm personality and for his enormous contribution and outstanding achievements for the benefit of the underprivileged.

[1] A Technical and Economic Appraisal; A Planning and Design Manual (both published in 1982 by John Hopkins University Press); Sanitation and Disease: Health Aspects of Excreta and Wastewater Management (John Wiley & Sons, 1983).

Roland Schertenleib

New Faces

Andrea Tamas, Social and Environmental Psychologist, joined the SODIS team in November 2008 after completing her PhD at Eawag's Department of Systems Analysis, Integrated Assessment and Modelling (Siam). Her PhD activities focused on determining the best SODIS promotion campaigns in Bolivia. She is now in charge of conducting a SODIS Sustainability Study on the sustained use of SODIS and other point of use (POU) options, as well as on the level of institutionalisation of Household Water Treatment and Safe Storage (HWTS) promotion in Nepal, Indonesia and Latin America.

El Hadji Mamadou Sonko, Master in Environmental Sciences, started his PhD thesis with Sandec in 2008 on "Humification performance and helminth eggs inactivation in faecal sludge dewatering beds". Mr Sonko is currently enrolled at the Doctoral School of Life, Health and Environmental Sciences, University Cheikh Anta Diop of Dakar, Senegal under the supervisor Dr Doulaye Koné, Sandec and Prof. Bienvenu Sambou, University Cheikh Anta Diop of Dakar, Senegal.

Patricia Corteel has a PhD in Pharmacy and a Master in Water Chemistry and Microbiology. After four years of reed bed experiments in Kenya and France, she joined Sandec in November 2008 to work on the AMSED project in Morocco. AMSED is the Moroccan-Swiss Association for Environment and Development whose members are also Eawag scientists. Its goal is to improve the environmental situation and promote sustainable development in Morocco through raising awareness and training. The project is conducted in the High Atlas Mountains and mainly aims at improving the living conditions in the Asselda village by an appropriate and sustainable wastewater treatment process, by raising awareness of the dangers of raw wastewater reuse, by informing on the disease transmission routes and best means of prevention. A further objective is to train a team of professionals to independently carry out this sustainable process in other villages.

Hung Nguyen Viet holds a PhD in Life and Environmental Sciences (2005) from the University of Franche-Comté, France. He joined the Swiss Tropical Institute (Basel) in November 2006 as a postdoctoral researcher in Microbiology, Health and Environment within the NCCR North-South programme. Main work of the postdoc project was to develop, in collaboration with Sandec, a conceptual framework on the combined assessment of health and environmental sanitation (Page 19) and test the concept in geographically different case areas. He will be joining Sandec in November 2009 to lead a research project within the framework of the NCCR North-South Phase 3. The new project will aim at developing a health and environmental risk-based approach coupled with a technical, economic and social assessment to foster identification and application of appropriate sanitation options for specific areas in developing countries.

The Sandec Team

From left to right:
Back: Roland Schertenleib, El Hadji Mamadou Sonko, Stefan Diener, Chris Zurbrügg, Christoph Lüthi, Antoine Morel, Kim Müller, Jürg Graf, Christian Lohri, Hung Nguyen Viet, Samuel Luzi
Middle: Caterina Dalla Torre, Patricia Corteel, Marie-Madeleine Ngoutane Pare, Monika Tobler, Magalie Bassan, Regula Meierhofer, Pritam Saliam, Valérie Cavin, Attitaya Panuvatvanich, Elizabeth Tilley, Yvonne Vögeli, Petra Kohler
Front: Yves Kengne, Pierre-Henri Dodane, Mbaye Mbéguéré, Doulaye Koné
Missing on photo: Andrea Tamas, Dionys Forster, Philippe Reymond, Susanne Koller, Sylvie Peter, Rick Johnston
Associated doctoral students: Noah Adamtey, Yuttachai Sarathai, Mingma Sherpa, Narong Surinkul

Water Supply and Treatment at Sandec

Sandec is pleased to welcome its newest staff member, **Rick Johnston**, to the position of Research Scientist, Water Supply and Treatment.

Rick holds degrees in Environmental Engineering from Johns Hopkins University and the University of North Carolina at Chapel Hill. Prior to joining Eawag in June 2009, Rick worked on water quality issues at UNICEF for more than ten years, where he was lead author of the *UNICEF Water Quality Handbook*. Most recently, he spent five years with UNICEF in Bangladesh working on arsenic mitigation, low-tech systems for water treatment, as well as designing and implementing impact assessments. His research there included household and community arsenic removal filters, in situ arsenic removal, iron and manganese removal, and household pasteurisation of drinking water.

At Eawag, he plans to contribute to the cross-cutting project Water Resource Quality (WRQ) by continuing his investigations on arsenic mitigation in Bangladesh and join Eawag's ongoing fluoride mitigation efforts in Kenya and Ethiopia. His current work mainly focuses on chemical water quality problems; however, he plans to become more involved in household water treatment technologies for microbiological contamination such as pasteurisation and gravity-driven membrane filtration.

WRQ - Water Resource Quality – A cross-cutting Eawag project
WRQ is an integrated project focusing on the identification of geogenic contamination in groundwater and development of water treatment techniques to mitigate the contamination effects. The project team comprises geochemical specialists, modellers, social scientists, and valuable global partners. Its main objectives are to:
i) develop GIS maps for the prediction of areas where geogenic contaminant may pose a problem; ii) develop expertise and technologies appropriate for low-income countries for treatment of waters contaminated by arsenic and fluoride; iii) develop dissemination and behaviour change strategies for adoption of water treatment technologies.
These elements will be part of a comprehensive risk mitigation framework toolbox for a wide range of stakeholders active in the drinking water sector.

Open Access for the Global Scientific Research Community

Access to scientific journals and research publications – a basic prerequisite for state-of-the-art research – has long been a major stumbling block for scientists in developing countries. However, this is changing! With increasing internet access and efforts undertaken by the global community along with leading publishers, open access journals are increasingly available online. This brief article provides an overview of some important websites allowing online access to water and sanitation relevant journals. The "Directory of Open Access Journals" www.doaj.org service covers free, full text, quality-controlled scientific and scholarly journals. Currently, 4 253 journals are listed in the directory and 1 574 journals are searchable at article level.

For all those interested in environmental engineering, we recommend to consult "Online Access to Research in the Environment (OARE)" www.oaresciences.org/en/index.html, an international public-private consortium coordinated by the United Nations Environment Programme (UNEP), the Yale University and leading science and technology publishers. This platform enables developing countries to gain access to one of the world's largest collections of environmental science research journals and publications. Countries with a per capita GNI below USD 1 250 (in OARE, Band 1) are entitled to free access to over 2 990 peer reviewed titles (as of 4/2009). You are eligible to join OARE if your institution is an academic, government or research institution located in one of the countries listed in "Band 1".

The following journals frequently publish interesting articles relevant to the water and sanitation sector of low and middle-income countries. Some of these journals also contain Sandec's research results.

Bioresource Technology -- (Elsevier)	**Journal of Environmental Management** -- (Elsevier)
Development in Practice -- (Taylor & Francis)	**Journal of Environmental Planning and Management** -- (Taylor & Francis)
Desalination -- (Elsevier)	**Waste Management** -- (Elsevier)
Cities -- (Elsevier)	**Waste Management and Research** -- (Blackwell Publishing)
EcoHealth -- (Springer)	**Water and Environment Journal** -- (Blackwell Publishing)
Ecological Engineering -- (Elsevier)	**Water Practice & Technology** -- (IWA Publishing)
Environment and Urbanization -- (Sage Publishing)	**Water Research** -- (Elsevier)
Environment, Development and Sustainability -- (Springer)	**Water Resources** -- (Springer)
Environmental Health -- (BioMed Central)	**Water Resources Management** -- (Springer)
European Journal of Development Research -- (Taylor & Francis)	**Water Science and Technology** -- (IWA Publishing)
Habitat International -- (Elsevier)	**Water Science and Technology: Water Supply** -- (IWA Publishing)
Journal of Environment & Development -- (Sage Publishing)	**Water, Air, & Soil Pollution** -- (Springer)
Journal of Environmental Engineering and Science -- (National Research)	**World Development** -- (Elsevier)

On the Bookshelf

Apart from the publications cited in the previous articles, we recommend the following new books and key readings in the solid waste management as well as in the water and sanitation sectors.

Solid Waste Management

Looking Back on Looking Forward: A Review of Evaluative Scenario Literature
The European Environment Agency (EEA) has issued this technical report, which addresses this lack of information, presenting a review of relevant academic and non-academic literature on the issue. The report points to ways that public agencies could be organised to make better use of scenarios and methods and render scenarios more relevant to policy-makers.
By the European Environment Agency (EEA), Denmark, 2009, 28 pp., ISBN 978-92-9167-992-8. Available from www.eea.europa.eu/publications/looking-back-on-looking-forward-a-review-of-evaluative-scenario-literature/at_download/file

Developing Integrated Solid Waste Management Plan – Training Manual Vol. 1–4
These are four volumes on developing Integrated Solid Waste Management plans. Volume 1 tackles waste characterisation and quantification. Volume 2 highlights assessing current waste management system. Volume 3 helps practitioners and policy-makers setting up targets for ISWM and identifying stakeholders' issues of concern. Volume 4 helps developing a comprehensive ISWM Plan.
By the United Nations Environmental Program, Division of Technology, Industry and Economics, International Environmental Technology Centre, Osaka/Shiga, Japan, June 2009. Available from www.unep.or.jp/letc/Publications/index_pub.asp

E-Waste – Inventory Assessment Manual and E-Waste Management Manual Vol. 1 & 2
These two volumes aim at building the capacity of practitioners and policy-makers for preparing WEEE/E-waste inventory and developing WEEE/E-waste management system.
By the United Nations Environmental Program, Division of Technology, Industry and Economics, International Environmental Technology Centre, Osaka/Shiga, Japan, December 2007. Available from www.unep.or.jp/letc/Publications/index_pub.asp

Water and Sanitation

UNICEF Handbook on Water Quality
This handbook is a comprehensive new tool to help UNICEF and its partners contribute to global efforts to mitigate water quality problems. It is primarily aimed at UNICEF WASH field professionals, but it will also be useful to other UNICEF staff and partners in government, other external support agencies, NGOs, and civil society. The handbook provides an introduction to all aspects of water quality, with a particular focus on the areas most relevant to professionals working in developing countries. It covers the effects of poor water quality, quality monitoring, protection of water supplies, methods for improving water quality, and building awareness and capacity related to water quality. Finally, the handbook provides an extensive set of links to key water quality references and resources.
By Keast, G. and Johnston, R., United Nations Children's Fund (UNICEF), New York, 2008, 191 pp. Available from www.unicef.org/search/search.php?q=G.+Keast&Go.x=11&Go.y=8

Arsenic Pollution: A Global Synthesis
This book compiles and summarises the most up-to-date research on the distribution and causes of arsenic pollution in nature, its impact on health and agriculture and the encouraging research that offers hope in mitigating this unfolding health crisis. Seamlessly integrating geochemistry, hydrology and agriculture, it offers the first truly global and interdisciplinary account of arsenic pollution. The book provides information on the geographical distribution of arsenic contamination of groundwater and surface water, the geochemical causes of high arsenic concentrations in aquifers and the health implications of prolonged arsenic ingestion. Finally, options are highlighted for developing alternative water sources and methods for arsenic testing and removal.
By Ravenscroft, P., Brammer, H., Richards, K., March 2009, 616 pp., Wiley-Blackwell, ISBN 978-1-4051-8601-8. Available from www.wiley.com/WileyCDA/WileyTitle/productCd-1405186011.html

Making Sustainable Sanitation Work for Women and Men: Integrating a Gender Perspective into Sanitation Initiatives
This publication is meant to give background information on the pressing need to integrate a gender perspective into the efforts to promote safe and sustainable sanitation. It provides guidance on how to mainstream gender into this sector.
By Dankelman, I., Muylwijk, J., Wendland, C., Samwel, M., WECF, Women in Europe for a Common Future: The Netherlands / Germany / France, February 2009, 10 pp. Available from www.wecf.eu

Change of Water and Sanitation Services Management Model in Small Towns with a Participatory Approach: A Summary of Guidelines
This document presents lessons learned from the process carried out in Peruvian small towns. It is a contribution to the development of the water and sanitation sector in small towns, and pursues the establishment of a social agreement as a mean to attain an efficient management of the water and sanitation services, and thus become the foundation of a Public-Private-Social Partnership.
By McGregor, J. L., Water and Sanitation Program, Latin America and Caribbean Region. Lima, May 2008, 36 pp. Available from www.wsp.org/UserFiles/file/527200810601_PPPLfin.pdf

A Guide to Decision-Making – Technology Options for Urban Sanitation in India
This guide aims to meet some of those needs by providing advice on the selection of technology options for urban sanitation, whether for new infrastructure or the upgrading of existing services.
By Parkinson, J., Tayler, K., Colin, J., and Nema, A., Water and Sanitation Program, South Asian Region. New Delhi, September 2008, 144 pp. Available from www.wsp.org/UserFiles/file/Urban_Sanitation.pdf

Identifying Constraints to Increasing Sanitation Coverage, Sanitation Demand and Supply in Cambodia
This field note summarises research from two studies undertaken in rural and peri-urban areas of Cambodia: one on the demand for latrines among consumers, and the other on the supply of latrines by the private sector. It provides discussion on the opportunity to increase latrine purchase and installation via market forces, and outlines the recommended interventions on both the demand and supply dimensions of the market in achieving this target.
By Water and Sanitation Program – East Asia and the Pacific (WSP-EAP), Field Note, October 2008, 24 pp. Available from www.wsp.org

Progress on Drinking Water and Sanitation: Special Focus on Sanitation
This report details global progress towards the Millennium Development Goal (MDG) target for drinking water and sanitation. The report has a special focus on sanitation.
By the World Health Organisation and United Nations Children's Fund Joint Monitoring Program for Water Supply and Sanitation (JMP). UNICEF, New York and WHO, Geneva, 2008, 56 pp., ISBN 978 92 806 4313 8. Available from www.who.int/water_sanitation_health/monitoring/jmp2008/en/index.html

Study for Financial and Economic Analysis of Ecological Sanitation in Sub-Saharan Africa – Final Synthesis Report
The aim of the study was to compare ecosan with conventional sanitation systems in terms of financial and economic costs and benefits in order to assist decision-makers and sponsors of development programmes to make better-informed decisions about the relative merits of different types of sanitation. The authors developed an analytical framework and a computer model to be able to assess and compare different technologies in terms of financial and economic NPV.
By Hydrophil and Atkins, Water and Sanitation Programme – East Africa, April 2009, 26 pp. Available from www.wsp.org/

Sanitation for Unserved Populations: Technologies, Implementation Challenges and Opportunities
This chapter reviews the wide range of technical options available for providing sanitation and discusses the technology options within the context in which sanitation projects are implemented. The review is intended to be as broad as possible to make the strengths, weaknesses and trade-offs of various technology choices apparent. The authors discuss the institutional, financial and social factors that impact technology decisions to provide those working on sanitation from multiple disciplines with common ground for understanding complex, myriad factors that must be addressed to successfully meet the sanitation challenge.
By Nelson, K. L. and Murray, A., Annual Review of Environment and Resources, 2009, Vol. 33, 119-151. Available from http://environ.annualreviews.org