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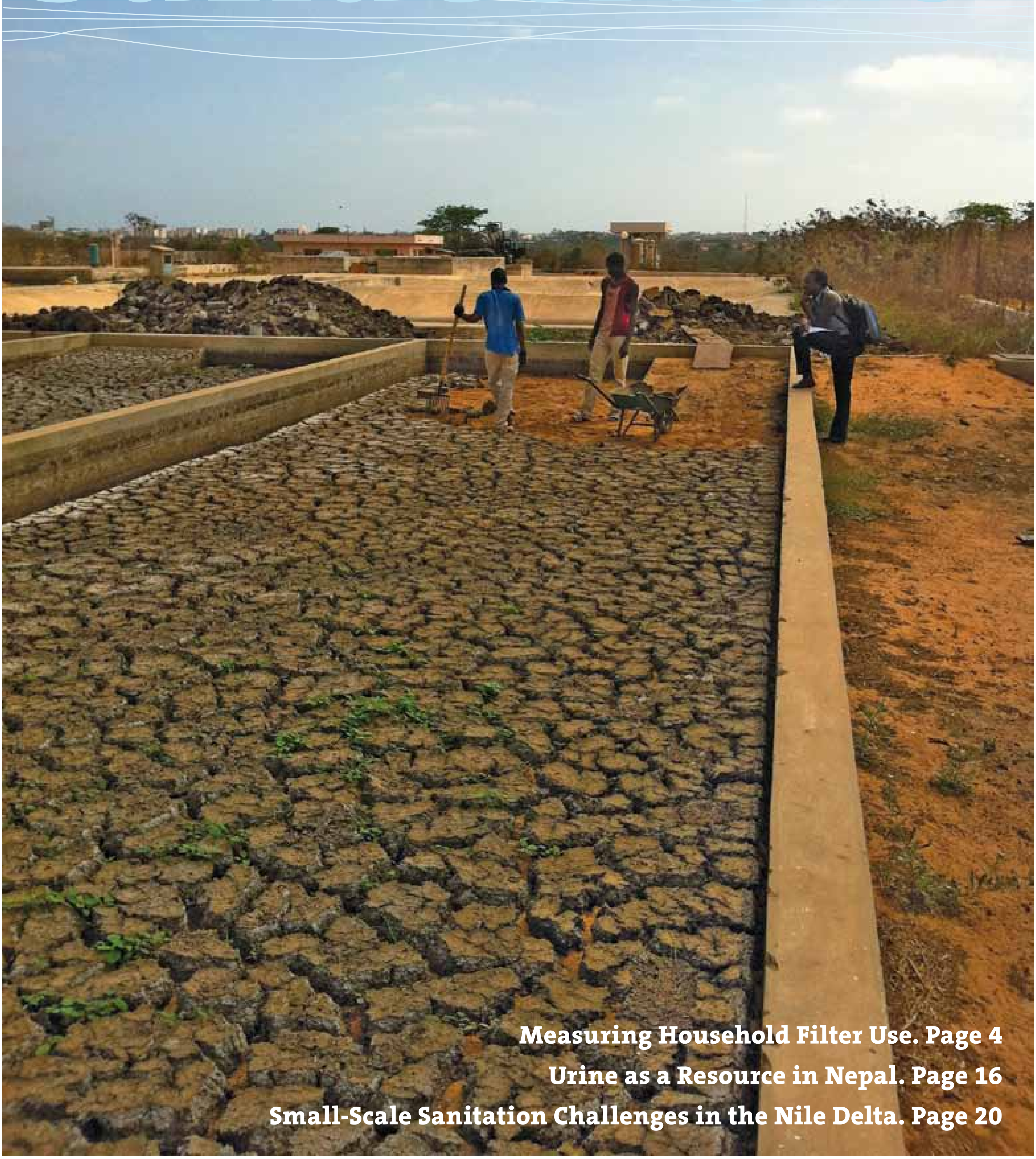
Sandec: Department of Water and Sanitation in Developing Countries
July 2011, No. 12

# Sandec News



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# Best Practices – Learning for Replication

**"Key for replication is understanding WHY projects are successful"**

Decision-makers in low- and middle-income countries face serious challenges since facilities and services in water supply, sanitation, hygiene, and solid waste management are often deficient and need upgrading. Broad field experience and "best practices" are available, so the wheel does not have to be reinvented, but the lessons learned from others adapted to the existing conditions. Gaining access to unbiased, analysed, clearly structured, and synthesised information remains a major challenge. Decision-makers in developing countries are still at high risk of being blinded by "sales representatives", be it from the private sector or even development agencies. Without a solid technical background or state-of-the-art knowledge and information, they often have difficulties in distinguishing project feasibility and the associated risks of a choice. Even NGOs, driven by their philanthropic motives, face the same challenges and repeat the same mistakes, as they are often unaware of past experiences elsewhere and tend to replicate a similar learning process.

Knowledge sharing and the concept of knowledge brokerage have become an increasing trend in current sustainability discourse. A wide range of literature promotes the importance of knowledge sharing and transfer as a way of breaking down barriers impeding sustainable development. Nevertheless, the question remains on how this information can be assessed, analysed and presented in a concise way to allow respective stakeholders to make an informed decision on the way to push forward in their improvement objectives. Documenting successful projects is, alas, insufficient. Proof of "why" projects are successful is mandatory and entails a structured analysis of the favourable enabling environment, process steps and human factors required for successful project implementation. Aside from Sandec's research portfolio, this task will continue to be on our agenda.

Dissemination, training, education, and provision of tools for decision support form part of Sandec's main objectives. We act as knowledge brokers, as intermediary to provide links, knowledge sources and, in some cases, knowledge itself (i.e. generated through research projects) to other organisations. As knowledge brokers, we structure knowledge and facilitate the transfer from where it is available to where it is needed, thereby improving the innovative capability of other organisations.

The "Compendium of Sanitation Systems and Technologies" is an excellent illustration of this role. None of the technologies described in this document are new, yet, we find it necessary to improve the way knowledge is presented and accord priority to increasing a *cradle to grave system approach*. However, we are well aware that the book has some limitations as decision support tool. To this effect, Sandec and the Swiss Agency for Development and Cooperation (SDC) jointly conducted workshops for trainers in Nicaragua and Peru on how to best use the Compendium in the planning process and in choosing sanitation systems and respective technologies. The skilled trainers will then be able to replicate similar training events for their local stakeholders.

The *Water Resource Quality* project, led by Annette Johnson of Eawag, also assists decision-makers in developing a mitigation framework for regional assessment of geogenic contaminants, and provides innovative and low-cost measures to reduce arsenic and fluoride contamination in drinking water. A handbook shall act as a step-by-step guideline to help NGOs, consultants and local governments make informed decisions when faced by geogenic contamination.

Two exciting new research projects are funded by the SPLASH Sanitation Programme. FaME (Faecal Management Enterprise) explores value chain management of faecal sludge in partnership with Hydrophil (Austria), the University of Dakar, the Office National de l'Assainissement ONAS (Senegal), Waste Enterprisers (Ghana), and Makerere University (Uganda). The second project focuses on economic constraints and demand-led solutions for sustainable sanitations services in poor urban settlements of Kampala, Uganda.

This newsletter provides a broad overview of our wide range of activities. If you feel disappointed by the lack of detail, do not hesitate to contact the respective authors by e-mail or access our webpage www.sandec.ch containing all the relevant documents for free download.

I hope you enjoy reading our present issue.

Chris Zurbrügg
Director Sandec

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**Sandec**
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**Publisher:** Eawag, P.O. Box 611, 8600 Dübendorf, Switzerland
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**Editors:** Sylvie Peter and Christian Zurbrügg, Eawag





**Publication:** Sandec News appears once a year and is free of charge. Our newsletter is available as printed copy, as email attachment or it can be downloaded as pdf file from our homepage www.sandec.ch

**Cover:** Removal of faecal sludge from drying beds in Dakar, Senegal (Photo: Stefan Diener)

**Layout and figures:** Yvonne Lehnhard, Eawag

**Photos:** All from Sandec if not mentioned otherwise

**Printer:** Mattenbach AG, Winterthur, Switzerland

**Circulation:** 3500 copies printed on original recycled paper

**New subscribers:** Should contact Caterina.DallaTorre@eawag.ch

ISSN 1420-5572

Eawag: Swiss Federal Institute of Aquatic Science and Technology

# Measuring Household Filter Use

**Household water treatment is gaining popularity globally, yet it is difficult to assess how much water is actually treated by households. Submersible dataloggers provide insight into actual use of defluoridation filters in rural Ethiopia.** Rick Johnston[1], Lars Osterwalder[2], Tesfaye Edosa[3]

More than 100 million people worldwide are exposed to high levels of fluoride or arsenic in drinking water, which most often originates from natural sources [1], [2]. Ideally, both chemically and microbiologically safe alternate drinking water sources should be identified. However, developing new supplies is a long-term endeavour, and in some water-scarce areas there is simply no alternative to chemically contaminated water. In such cases, removing chemicals from drinking water is the best option, at least in the short term. Many technologies have been proven effective for removal of arsenic and fluoride, including adsorption filters that are easy to operate and tend to be relatively inexpensive.

The capacity of removal filters depends principally upon the water chemistry: the concentration of the contaminant to be removed is obviously important, but pH and competing ions may also have significant effects. Compared to laboratory settings, filters typically display lower removal capacity under field conditions. For example, contact precipitation filters in Eawag laboratories have removed up to 6.5 g of fluoride per kilogram of filter material before treated water exceeds 1.5 mg/L, but more commonly about 3 g/kg removal is seen in Ethiopian household filters (cf. Annette Johnson's article on page 10).

Aside from the water quality, the treated water volume is the main parameter determining when the contaminant will 'break through' the filter (exceeding 1.5 mg/L fluoride in the treated water). A household defluoridation filter with 10 kg contact precipitation media should be able to remove 30 g of fluoride before breakthrough. However, it is not easy to convert this figure into a number of months even when the raw water fluoride level is known. Meters cannot measure the slow and intermittent flows in such filters, while self-reported consumption is imprecise and may be biased.

## Submersible dataloggers

As part of the ongoing fluorosis mitigation work in Ethiopia, 200 household defluoridation filters were distributed in April 2010 by the Oromo Self-Help Organization (OSHO) to several rural communities in the Ethiopian Rift Valley. In eight of these household filters, small submersible dataloggers, recording pressure and temperature at regular intervals, were placed in the treated water reservoir. A ninth logger recorded atmospheric pressure. By subtracting atmospheric pressure from pressure readings in filters, the height of the water column (and thus the volume of stored water) could be calculated at five-minute intervals [3]. In these households, an almost continuous record of about 50 000 readings was collected.

In household interviews, respondents reported filling their filters on average 2.1 times a day, which matched well the average of 1.8 recorded by the dataloggers. However, dataloggers indicated that daily consumption was on average 12.5 litres, compared to self-reports of 19.4 litres. When normalised by the number of household residents, the measured consumption averages 2.0 litres per capita per day, which is probably adequate for meeting drinking water needs, but not for providing cooking water. Survey respondents also reported that they mainly used the filters for drinking water rather than for cooking water.

Dataloggers allow calculation of short and long-range dynamics of water use. Fig. 1 shows longer-term trends in filter use in one typical household. Use steadily increased while the filter was new, peaking at approximately 20 litres per day. Use then declined for several months, reaching a low in late August, before increasing and holding fairly steady in September and October. Records from the other filters show similar trends. Part of this trend can be explained by heavy rainfall in the summer season – people traditionally collect and drink rainwater when available.

## Outlook

Dataloggers yield objective measurements of overall water consumption, but more importantly provide insights into the short and long-term temporal trends of filter use. While such data collection would be prohibitively expensive for routine use, this method can provide valuable data for research studies.

Though the number of households surveyed is small, this research suggests that defluoridation filters are more or less consistently used in rural communities where they have been distributed, but that households use filters only for some of their consumptive needs. Future promotion efforts are planned to increase use of filtered water for cooking and for drinking.

[1] Amini, M. et al. (2008): Statistical modeling of global geogenic arsenic contamination in groundwater. Environ. Sci. Technol., 42(10), 3669–3675.

[2] Amini, M. et al. (2008): Statistical modeling of global geogenic fluoride contamination in groundwaters. Environ. Sci. Technol., 42(10), 3662–3668.

[3] Johnston, R.B. et al. (2011): Measuring use of household drinking water filters: field experiences from Ethiopia. 35th WEDC International Conference, WEDC, Loughborough, UK.

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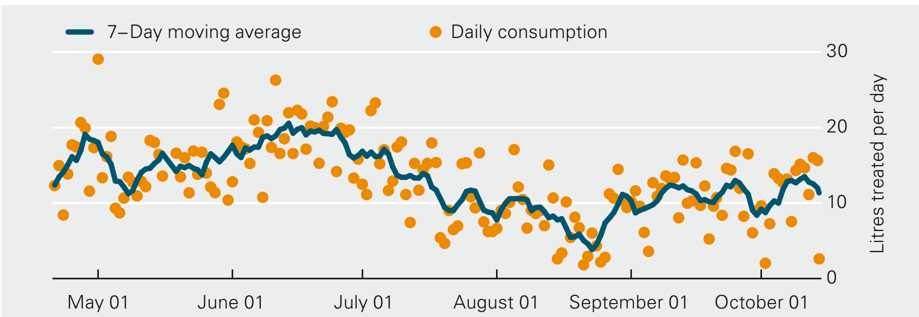


Figure 1: Consumption of treated water in a typical household.

# GDM Technology for Household Water Disinfection

**The Gravity-driven Membrane (GDM) technology reveals a high implementation potential for efficient, robust, durable, low cost, and virtually maintenance-free household water filters. A project was recently launched in Kenya to establish filter efficiency in the field and develop a market-based approach for their sustainable use.** Maryna Peter-Varbanets[1], Rick Johnston[1], Regula Meierhofer[1], Wouter Pronk[2]

## Household water filters

Household water treatment and safe storage (HWTS) systems have been associated with marked drinking water quality improvement and disease reduction. However, time-consuming operation and maintenance, aesthetic concerns, limited effectiveness, high costs of existing technologies, and lack of consideration of consumer preferences have limited the scale-up of HWTS systems.

Some studies on consumer preferences and efficiency of HWTS systems reveal that consumers favour filters rather than other HWTS technologies for their potential durability and ease of use [1]. Ceramic pot or candle filters, with a limited long-term efficiency, are the most widespread and marketed filters in developing countries. Aside from ceramic filtration, the choice of available HWTS filters is rather limited. Some filters are available for middle-income populations in emerging markets (i. e. Tata-Swatch, PureIt in India). However, since these filters require regular replacement of cartridges, they are associated with high operating costs. The potential of alternative filtration technologies should therefore be considered for HWTS applications.

## Ultrafiltration

Ultrafiltration (UF) has proved very effective in removing particles, colloids and microorganisms from the water. Conventional, large-scale ultrafiltration systems require pumps and control equipment for operation, backflushing and cleaning. Decentralised systems, designed in a similar manner, are usually complex and expensive. Only few gravity-driven ultrafiltration systems for decentralised application are currently available (e. g. SkyJuice for community water supply and LifeStraw Family for household water treatment). Yet, they also require regular manual chemical cleaning (Skyjuice) or manual backflushing (Lifestraw).

## GDM disinfection technology

With the gravity-driven membrane (GDM) disinfection technology, developed at Eawag, ultrafiltration operates for more than 24 months at a stable membrane flux of 4–10 $L.h^{-1}m^{-2}$ without backflushing, chemical cleaning or external energy supply. The transmembrane pressure of about 20–65 cm of the water column can be easily achieved in household systems. Natural water without pre- or post-treatment can be used as a feed. This phenomenon of a stable membrane flux was first documented in our previous study [2].

A layer of retained particles, colloids and microorganisms rapidly develops on the surface of the new membrane and leads to an initial decline in flux. However, after about one week, channels and cavities form in the fouling layer, allowing passage of water through the layer and resulting in stabilisation of the flux. These channels are caused by biological processes occurring within the accumulated organic matter and by microorganisms.

GDM systems can be operated with turbid water (up to 100 NTU) or high organic matter content (including diluted wastewater with a TOC of about 12 mg/L). Membranes used in GDM systems entirely remove protozoa and bacteria, and preliminary data shows 99.99 % retention of viruses. Membranes of even smaller pore sizes and intermittently operating filters will increase filter flow rate. This novel approach of operating UF systems at stable flux conditions allows development of a robust, maintenance-free and user-friendly household water treatment system.

Photo 1: Prototype of the GDM filter.

## GDM disinfection of household water in Kenya

A new project was launched at Eawag in July 2010 with the aim to develop a novel household water treatment system based on the GDM disinfection technology. Assessment of the 40 GDM filter prototypes, using different raw water qualities, started in Kenya in May 2011. The first phase of the project will focuses on a technical evaluation of the prototypes with user feedback on filter design and operation. Field testing will be conducted in partnership with the Kenya Water for Health Organisation (KWAHO).

Production costs of a household GDM system are estimated at about 30 Euro. Assuming a system lifetime of several years, the annual costs for water treatment using a GDM system will be within reach of an average slum dweller. For sustainable implementation of the system, this project also includes an evaluation of potential sales distribution mechanisms, supply chains, long-term support, and development of marketing strategies. Interventions are planned to create demand, including commercial marketing, behavioural change through household promotion and ongoing interventions to maintain new behaviour.

[1] Albert, J. et al. (2010): End-user preferences for and performance of competing POU water treatment technologies among the rural poor of Kenya. Environ. Sci. Technol. 44, 4426–4432.

[2] Peter-Varbanets et al. (2010): Stabilization of flux during dead-end ultra-low pressure ultrafiltration, Water Res. 44, 3607–3616.

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# Increasing Safe Water Consumption in Bangladesh and Ethiopia

**Behaviour change interventions that best support people in collecting safe water are a burning issue among practitioners and researchers in developing countries. This article provides a systematic approach to changing water collection behaviour in Bangladesh and Ethiopia.** Alexandra Huber[1], Jennifer Inauen[1], Hans-Joachim Mosler[1]

To mitigate water-borne diseases, safe water options for households and communities are currently being implemented in developing countries. However, most research is conducted on technical performance of mitigation options and little attention is paid to continuous use of safe drinking water by the risk-prone populations. To successfully promote safe drinking water options, it is important to investigate psychological determinants influencing their use.

## Systematic behaviour change approach

Our research group is developing a methodological approach to allow purposive behaviour change. We first present a conceptual behaviour model based on sound psychological evidence and theory, as well as behaviour change interventions targeted at changing the described behavioural determinants. An analytical tool is then depicted that quantitatively identifies the key behavioural determinants to be changed.

## Conceptual behaviour change model

The model is divided into three distinctive components: the targeted behaviours (new behaviour and alternative behaviour), the behavioural determinants and the corresponding behaviour change interventions. The behavioural determinants are derived from the **Theory of Planned Behaviour** [1], the **Health Action Process Approach** [2] and research on habit development [3].

To form habitual behaviour, five groups of determinants – risk beliefs, attitudinal beliefs, normative beliefs, ability beliefs, and self-regulation factors – have to become favourable towards the new behaviour:

- Risk beliefs entail perceived vulnerability and severity of contracting an illness, and factual knowledge on the possibility of being affected by potential contamination. Information interventions increase people's risk beliefs (i. e. educational interventions).
- Attitudinal beliefs comprise instrumental beliefs about costs and benefits of the behaviour, as well as affective beliefs, i.e. feelings arising when thinking about the behaviour. Positive attitudes can be induced by persuasive interventions (e. g. highlighting benefits of the behaviour).
- Normative beliefs include descriptive norms (behaviours typically performed by others), injunctive norms (behaviours typically approved or disapproved by others) and personal norms (personal standards, what should be done). Norms can be changed by normative interventions (e. g. opinion leaders, enhancing performed behaviours).
- Ability beliefs indicate a person's knowledge to perform a behaviour, the confidence in one's ability to organise and manage the behaviour (self-efficacy), and to deal with possible barriers (maintenance self-efficacy, recovery self-efficacy). Infrastructure and ability interventions help people gain confidence in their own abilities (e. g. adjusting the time of water collection to the daily schedule).
- Self-regulation factors help to manage conflicting goals and distracting cues when intending to implement and maintain the behaviour. Important determinants are commitment and remembering the behaviour. Planning interventions help to translate goals into actions (e.g. make plans to overcome barriers).

Photo 1: Promoter installing a prompt on an arsenic-contaminated tubewell.

All these factors may potentially influence behaviour. Aside from the target behaviour (e. g. drinking safe water), the alternative is also considered (e.g. drinking contaminated water). The aforementioned factors may also influence other outcomes, such as use of a new technology, behavioural intention and habit.

## Developing behaviour change interventions

The first step in developing successful behaviour change interventions is to identify key behavioural determinants from the pool of potentially influencing determinants depicted in the behaviour change model. Key factors may differ between behaviours (e. g. water collection behaviour versus hygiene behaviour) and target populations. Our approach therefore includes a structured survey to assess the status quo of behavioural determinants in the target population. Behavioural determinants can be measured by face-to-face interviews with a sample population using a structured questionnaire. Interviews are conducted in each household with the person responsible for water collection. Questions asked to assess the injunctive norm are for example: "Do people of your community rather approve or disapprove that you collect water from the arsenic-safe well?" Respondents are offered a nine-point rating scale ranging from "They strongly disapprove" to "They strongly approve". More examples are given in [4].

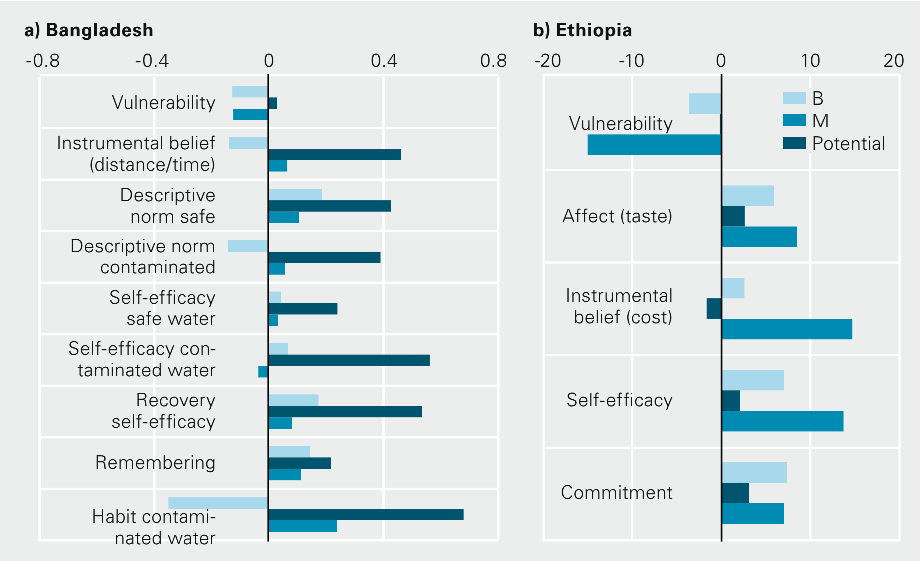

Figure 1: Intervention potentials of determinants for safe water consumption (regression weights (B), means (M) and intervention potentials ((Target-M)*B)).

To derive determinants with highest behaviour change potentials, the collected interview data is statistically analysed using a method proposed by Tobias [5]. Means and standard deviations are computed to estimate the level of determinants in the target population. Multiple regression analysis on behaviour, in this case water consumption, is then used to identify key behavioural determinants. For each determinant, the sample's mean is subtracted from the targeted value of the determinant. This value is then multiplied by the regression weight of the determinant (B, representing the strength of association between determinant and behaviour). The higher the resulting value for the determinant, the greater the potential impact of a behaviour change intervention targeted at changing this determinant.

The systematic behaviour change procedure is exemplified to increase safe water collection in Bangladesh and Ethiopia.

## Interventions in Bangladesh and Ethiopia

Bangladesh is the most arsenic-affected country in the world. Chronic consumption of arsenic-rich water can lead to severe health consequences, such as cancer. One mitigation option is collecting water from neighbouring arsenic-safe wells.

Structured face-to-face interviews were conducted with 362 households in 16 villages of Manikganj district.

Multiple linear regression revealed stronger habits to use neighbouring arsenic-safe wells for people with higher self-efficacies, higher descriptive norms, who reported using memory aids to remind them to collect safe water, who felt less vulnerable to developing arsenicosis, who found it less difficult to find time and handle the distance to the well, and who had weaker habits to collect water from contaminated wells.

Intervention potentials were computed as described above (Fig. 1a).

Based on these results, several behaviour change interventions were designed and two examples are given below:

- **Prompt on arsenic-contaminated well**
  - Goal: break habits of using contaminated wells.
  - Content: prompts attached to contaminated wells pointing to harmful water uses (Photo 1).
- **Community commitment**
  - Goal: prominently display that other community members also collect safe water.
  - Content: people are asked to publicly commit to collecting safe water.

In the Ethiopian Rift Valley, high fluoride concentrations in groundwater and surface water involve potential risks of developing dental and skeletal fluorosis. A fluoride removal community filter using the Nakuru technique (bone char and calcium phosphate pellets) was thus implemented in a rural village in the Rift Valley.

A cross-sectional survey of 180 households was conducted to investigate enhancing and hindering factors of community filter use. Results of the survey revealed that five factors of the behaviour change model significantly influence the consumption of fluoride-free water: perceived vulnerability, taste, perceived costs of filtered water, self-efficacy to fetch water at the community filter, and commitment to consuming filtered water. Intervention potentials were calculated (Fig. 1b) for these five factors. Perceived vulnerability and costs were targeted to achieve change. A persuasion campaign with two types of tailored interventions was conceptualised:

- **Perceived costs persuasion**
  - Goal: lower people's concern about the treated water costs.
  - Content: personal water budget calculation and quality persuasion.
- **Children's vulnerability persuasion**
  - Goal: increase people's awareness of the adverse impact of fluoride-contaminated water, especially on children's health.
  - Content: personal risk information for each child and consequences for their lives.

In both studies, the interventions described have already been implemented and are currently being evaluated.

[1] Fishbein, M., and Ajzen, I. (2010): Predicting and changing behavior: The reasoned action approach. New York: Psychology Press (Taylor & Francis).

[2] Schwarzer, R. (2008): Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. Applied Psychology: An International Review, 57(1), 1–29.

[3] Mosler, H.-J. et al. (2010): Personal, social, and situational factors influencing the consumption of drinking water from arsenic-safe deep tubewells in Bangladesh. Journal of Environmental Management, 91, 1316–1323.

[4] Inauen, J. et al. (2010): Acceptance, use, and promotion of arsenic-safe water options in Bangladesh. First results, implications and outlook. Oral presentation at the WRQ Meeting 30.9.2010 at Eawag, Dübendorf, Switzerland.

[5] Tobias, R. (2009): Changing behavior by memory aids: a social psychological model of prospective memory and habit development tested with dynamic field data. Psychological Review, 116, 408–438.

[1] Eawag/Siam, Switzerland

These studies form part of the Water Resource Quality (WRQ) project at Eawag.
The authors acknowledge the support received from HEKS (Swiss Interchurch Aid), OSHO (Oromia Self-Help Organization), CDN (Catholic Diocese of Nakuru), Addis Ababa University, the Swiss National Science Foundation (SNF), the Swiss Agency for Development and Cooperation (SDC), UNICEF Bangladesh, and the Christian Commission for Development in Bangladesh (CCDB).

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# Assessing Long-Term Sustainability of Former Eawag HWTS Projects

**Sandec's commitment to household water treatment projects has a long-standing tradition, especially the widely promoted solar water disinfection (SODIS) method. But what are the long-term benefits several years after project conclusion? A three-country comparison reveals that Household Water Treatment and Safe Storage (HWTS) use is quite widespread; yet, consumption of untreated water still persists.**

Andrea Tamas[1], Flavia Wehrle[2], Katharina Wojtalla[3], Regula Meierhofer[1]

Diarrhoeal diseases are still one of the main direct or indirect causes of child mortality. Water treatment at household level (HWTS) is an option to reducing transmission of water-borne, diarrhoea-causing diseases and thus child mortality [1].

Since 2000, Eawag has been actively supporting HWTS promotion projects mainly implemented by local partner organisations. A long-term partnership initiated with a number of these nationally operating NGOs has led to numerous small subprojects usually lasting 12 months.

The current study examines sustainability of a number of randomly selected subprojects in three key countries: Nepal, Indonesia and Bolivia. A large number of different subprojects were implemented in these countries by various government and non-governmental organisations during different time frames. The objective of the study is to compare the levels of HWTS use and identify hindering and facilitating factors in the three countries.

## Project assessment

We visited around ten different HWTS promotion projects in Nepal and Bolivia, and assessed two projects in Indonesia. Questionnaires were used to interview about 1000 households per country, and additional information was collected from previous promoters and project staff, as well as from sector professionals.

In **Nepal**, all the projects were implemented in the quite densely populated Kathmandu valley by different NGOs, municipalities and department health services. The projects were concluded between 2005 and 2009 over a project time frame of always one year. In **Indonesia**, the projects were implemented on two islands, Lombok and Flores. On Lombok, the project was conducted between 2004 and 2005 over a period of one year; on Flores, the project was implemented between 2005 and 2010 over two to four years. Implementation was always carried out by one NGO in cooperation with local health clinics. In **Bolivia**, most selected projects were conducted throughout the country's remote Andean highland regions by various NGOs, municipalities and one department health service. Implementation lasted between 2001 and 2008 over a period of one to three years. Except for Bolivia, where no urban projects were conducted, we examined rural, peri-urban and urban communities in all the studied countries.

## Overall water consumption pattern

The inhabitants of the three studied countries consume a variety of different water types, i.e. untreated and all types of treated water (filtered, SODIS-disinfected, boiled, chlorinated, and purchased) (Photo 1). A project is considered successful if a high percentage of the population consumes **only** treated water. In Indonesia, 73 % of the households treat all their drinking water, while in Nepal and Bolivia this number is significantly lower (53 % and 48 %). However, these percentages differ widely among the various communities within one country. In Nepal, success rates range from 16 % to 100 %, in Indonesia from 17 % to 96 % and in Bolivia from 14 % to 75 %.

Aside from households treating all their drinking water, some households use HWTS option(s), but still consume untreated water regularly. This number was far higher in Bolivia than in Nepal or Indonesia (31 % versus 14 % and 12 %). It seems that in the latter two countries the inhabitants have realised that consuming only treated water mitigates successfully water-borne diseases. The remainder of the population consumes only untreated water. This percentage is much higher in Nepal than in Indonesia or Bolivia (33 % versus 15 % and 21 %).

When examining the different HWTS options used in the three countries, we identified clear preferences (Fig. 1). While candle filters are used by 42 % of the households in Nepal, filters are neither used in Indonesia nor in Bolivia. Instead, Indonesians have a clear preference for

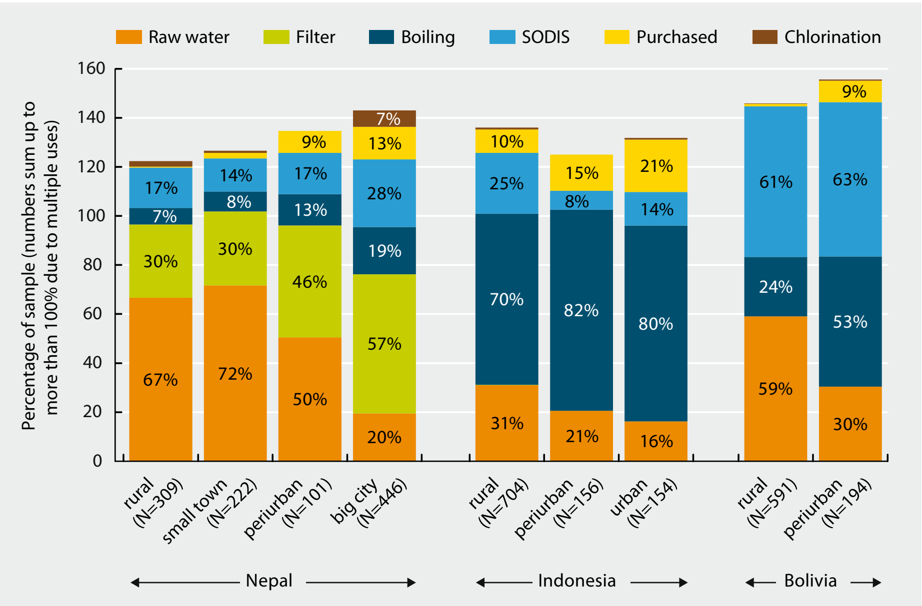


Figure 1: Water consumption of different populations in Nepal, Indonesia and Bolivia.

boiling water (73 %) and Bolivians favour the use of SODIS (62 %). The second preferred choice by the Nepalese and Indonesians is SODIS with 21 % of all households; in Bolivia, 31 % boil their water. Chlorination is not accepted in any of the evaluated areas mainly on account of the water taste.

## Different HWTS promotional aspects

In Nepal, **filters** are readily available and actively marketed. In urban and peri-urban Kathmandu, 55 % of the households use a filter, while in small towns and rural villages still 30 % use filters [2]. Filters are the preferred option over SODIS or boiling, possibly because they are more user-friendly. However, households often do not change the candle filter unit regularly – a prerequisite to obtain safe water. Users treat between 50 % and 100 % of their drinking water with the filter, the remainder is mostly boiled or treated with SODIS. In contrast to Nepal, filters are neither promoted nor available in Indonesia or Bolivia.

In Indonesia, **boiling** water has been promoted for decades by government health services. In most villages on Flores, boiling is practised by 75–100 % of the households; on Lombok 60 % of the people boil their water. This method is exclusively used by two thirds of the households. However, known drawbacks of boiling are its high cost and lack of safe storage after boiling. Though exclusive boiling is also practised by some households in Nepal, the population seems to have replaced boiling by filter use. In Bolivia, boiling is practised by 53 % of the peri-urban population, but only used by 24 % of the rural households for reasons of unavailable combustibles in rural areas.

**SODIS** is used by 62 % of the rural and peri-urban households in Bolivia [3]. This method has now been adopted by most NGOs promoting HWTS. Especially in sparsely populated rural areas, SODIS is often the only method used, as other alternatives are not available. Of the SODIS users, 74 % are regular and 26 % irregular users. In rural areas, SODIS has replaced untreated water consumption, while in peri-urban areas it has the potential to replace boiling, as gas bottles are often perceived as quite costly. SODIS is also used by 21 % of the households in Nepal and Indonesia. In Nepal, SODIS is more readily adopted in large urban areas, and more widespread among rural households in Indonesia. In all three countries, households using SODIS do not treat all their water with this method, but complement it with boiling, filter use (only in Nepal) or untreated water consumption.

Photo 1: Public water outlet in Patan, Nepal.

## Rural-urban differences and promotional influence

In **Nepal**, not only filters, but also SODIS and boiling are more widespread in large urban areas. Almost none of the households consume untreated water in large urban communities (0–20 % of households) as opposed to peri-urban, rural and small town communities (up to 72 % of households). Rural spring sources and treated tap water in small towns are often falsely perceived to be clean. No differences were found with regard to HWTS use between low- and high-income areas (only large cities) or government implementers and NGOs. However, in rural areas, government structures seem to be reaching further than NGOs. No correlation was found between HWTS use and year of promotion.

In **Indonesia**, fewer households use boiling and SODIS on Lombok, but more households consume untreated water than on Flores. However, the project on Flores was implemented in later years and lasted over a longer period. SODIS use varies strongly between villages on both islands (from 0 to 92 % of households) and is practised more in rural areas. High SODIS use was often associated with ongoing activities of local leaders. Since bottles had been provided for free during the projects, many inhabitants now refuse to pay for them and have therefore stopped using SODIS. In addition to boiling or SODIS use, 12 % buy water from small, non-branded drinking water refill depots selling water of varying quality.

While SODIS is equally popular in rural and peri-urban areas of **Bolivia**, boiling is twice as popular in peri-urban as in rural areas. However, even in peri-urban areas, 30 % of the households still consume untreated water at times; in rural areas this number is as high as 59 %. The combination of partly using SODIS and partly boiling water is very common. SODIS use is complemented with boiling by 42 % of the peri-urban households, and still by 22 % of the rural households. Compared to Nepal, HWTS promotion by government institutions in rural areas of Bolivia has been slightly more successful than by NGOs. Longer project duration yielded lower rates of households consuming untreated water.

## Conclusions

It is a real challenge to encourage all community members to entirely abstain from consuming untreated water. In Indonesia, with its lowest level of untreated water consumption, water boiling required decades of promotional activity. The improvement potential of HWTS use therefore prevails in most communities of the three countries. Since combined use of different HWTS methods is rather common, promotion of a mix of locally accepted HWTS methods is required to allow people to make informed choices. As promotion by government institutions can be highly successful, their involvement in ongoing projects is fundamental for sustainable and long-term HWTS promotional efforts.


[1] WHO (2007): Combating waterborne disease at the household level. Geneva: WHO.

[2] Tamas, A., and Meierhofer, R. (2010): How to achieve sustainable behavior change: Assessing the long-term effect of HWT promotion in Nepal. Paper presented at the Water and Health 2010, 25–26 October, Chapel Hill, USA.

[3] Tamas, A. (2011): Drivers of sustainable application of Solar Water Disinfection in Bolivia. Paper presented at the 35th WEDC International Conference, Loughborough, UK.



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We would like to thank the local NGOs ENPHO (Nepal), YDD (Indonesia) and the Fundación SODIS (Bolivia) for their support in data collection. Financial backing was provided by the Velux Foundation and by the SODIS Reference Centre at Eawag.



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# Introducing Fluoride Removal Filters to Ethiopia

**Bone char-based filters, developed by the Catholic Diocese of Nakuru, Kenya, are being tested in rural Ethiopia in a collaborative project between Eawag, Addis Ababa University and Kenyan, Ethiopian and Swiss NGOs.** Annette Johnson[1], Lars Osterwalder[1], Feleke Zewge[2], Raymond Rohner[3], Peter Maina Mutheki[4], Esayas Samuel[5]

According to estimates of the Ethiopian Ministry of Water and Energy, more than 14 million people in the Ethiopian Rift Valley region rely on fluoride-contaminated drinking water. The basaltic rocks in that region are the main sources of fluoride. Over 40 % of deep and shallow wells are contaminated with up to 26 mg/L of fluoride, a value significantly higher than the current WHO guideline of 1.5 mg/L [1]. Mitigation of this health problem has been hampered mainly by the lack of a suitable and inexpensive removal method. A switch to treated surface water for drinking is being discussed. Yet, fluoride removal systems in rural communities are necessary since successful implementation of such systems is still inexistent in Ethiopia.

A collaborative project between Eawag, technical and social scientists at Addis Ababa University, Oromo Self-Help Organization (OSHO), the Catholic Diocese of Nakuru Water Quality Section (CDN WQ), and Swiss Interchurch Aid (HEKS) mitigates fluorosis in rural Ethiopia. We are assessing technical performance, user acceptance and optimal institutional setting of bone char-based community and household filters for sustainable implementation. Two filters are being tested: the first contains bone char (BC), the second a mixture of BC and calcium-phosphate pellets (known as contact precipitation (CP) or the Nakuru Technique) [2]. The pellets prolong filter life by additionally precipitating insoluble fluorapatite. With the substantial support from the Ethiopian government's National Fluorosis Mitigation Project Office, we expect to reveal the potentials and limitations of fluoride removal technologies.

In April 2010, a CP community filter was built by OSHO in Wayo Gabriel, and 200 fluoride removal household filters (BC and CP) were distributed in three villages around Wayo Gabriel. The water price for the community filter was set with the local WASH committee, village and Woreda officials at 0.50 Birr per jerry can (current exchange rate: 18 Ethiopian Birr/USD). This water price should allow the water committee to cover around 50 % of the replacement costs of filter material, the caretaker's salary and raw water fee. The household filter price was set at 40 Birr, covering only 10 % of total filter cost. Weekly water measurements of fluoride, pH, turbidity, and arsenic were conducted at the community filter and at seven household filters. Dataloggers were used to monitor water consumption (cf. page 4). While the fluoride content of the treated water at the community filter is still below 1.5 mg/L, household filters containing BC have already been replaced with CP. In some household filters, filled with CP material, the media was replaced for 120 Birr (50 % of total filter material cost).

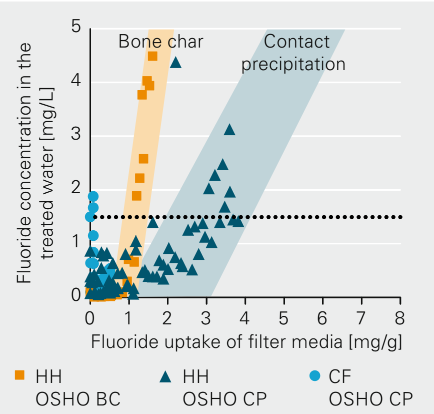


Figure 1: Fluoride uptake capacity from field tests in Ethiopia of one CP community filter (CF CP), seven CP household filters (HH CP) and three BC household filters (HH BC). Shaded areas show ranges for BC and CP obtained from previous tests in column, household and community filters at CDN WQ and Eawag [3].

## Filter performance

Uptake capacity of Ethiopian BC and CP household filters, and CP community filter correlates with average uptake capacities for BC and CP filters tested in laboratory columns and in the field in Kenyan household and community filters (Fig. 1). The high fluoride concentrations in the community filter at the beginning were caused by initial operational problems.

For BC and CP filters, the average uptake capacity is about 1.2 and 3 mg F/g, respectively, before treated water exceeds 1.5 mg F/L. The greater variability of the uptake capacities of CP filters is attributed to factors contributing to calcium and phosphate concentrations available for fluoride co-precipitation within the filters [3]. Fluoride uptake capacity is critical for the economic viability of filters. Higher fluoride uptake capacities of CP filters result in lower costs for treated water, though the price for pellets produced and sold by CDN WQ is higher than that for bone char.

## Outlook

Monitoring, filter material and construction costs appear to favour CP community filters. OSHO has constructed a furnace and started BC production with support from CDN WQ. OSHO plans to implement additional CP community filters and eventually produce pellets in Ethiopia. Our collaborative project will allow to support these activities. We hope that bone char-based technologies will soon turn into viable fluoride mitigation options in Ethiopia.

[1] Tekle-Haimanot, R. et al. (2006): The geographic distribution of fluoride in surface and groundwater in Ethiopia with an emphasis on the Rift Valley. Science of the Total Environment 367(1), 182–190.

[2] Müller, K. et al. (2008): Improving fluoride removal efficiency, Sandec News No. 9, p. 6.

[3] Mutheki, P.M. et al. (2011): Comparative performance of bone char-based filters for the removal of fluoride from drinking water. 35th WEDC Int. Conference, Loughborough, UK.

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This is an Eawag cross-cutting project on WRQ aiming to develop a framework to mitigate drinking water contaminated by arsenic and fluoride (www.wrq.eawag.ch)

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# Is Fluoride Only in Drinking Water?

**As a rule, when looking at fluoride uptake, only the ingestion through drinking water is considered. However, studies conducted in the Ethiopian Rift Valley revealed that the uptake with food becomes important through the water used for cooking.** Ruth Scheidegger[1], Meseret Desalegne[2], Marian K. Malde[3], Alexandra Huber[1], Lars Osterwalder[4], Hans-Peter Bader[1], Feyisa Lemma[5], Tesfaye Edosa[5]

Safe drinking water is often associated with water boiling. It is believed that once water has been boiled it poses no further health risk. This is correct if the contamination is microbiological. However, this is incorrect in the case of a geogenic contamination with fluoride or arsenic. A geogenic contamination can only be removed from water through filtering or other treatment options. To plan the most appropriate removal option, it is important to determine the amount of fluoride ingested by a person. An uptake analysis based on material/substance flow analysis (MFA/SFA) allows to distinguish between fluoride intake through food and beverage. The analysis will reveal whether treating only drinking water is sufficient, or if all water used has to be treated, and to what extent the ingredients themselves pose a problem.

## Uptake analysis

In three different villages in the Ethiopian Rift Valley, interviews were conducted with 20 families on their daily diet over the past seven days. In the same interviews, the persons responsible for preparation of meals were also asked about the recipes they use to prepare the dishes.

Based on these interviews, a master thesis was conducted in nine households. The women in charge of cooking were asked to prepare a selection of the most common dishes. This preparation was closely observed and all ingredients were weighted prior to their use, including the cooked dish. This allowed to determine more accurately the recipe of the dishes. Samples of all ingredients were collected, as well as part of all the dishes prepared and subsequently analysed for fluoride.

## Results

This combined field study resulted in an:

1. Assessment and description of an average daily diet in three villages in the Ethiopian Rift Valley.
2. Estimation of the average daily fluoride uptake by linking the dishes of the diet to the ingredients of the recipes.

A simple model [1], developed previously for a study on the daily diet of children living in the Rift Valley [2], was used to calculate fluoride uptake.

The calculations were conducted with water from the Chalaleki and Gura windmills and with piped water from Mesken Sefer (situated in Weyo Gabriel village) with a fluoride content of 17 mg/l, 10 mg/l and 3 mg/l. The average fluoride uptake through food and beverages amounted to 40 mg F/day/person (Chalaleki), 25 mg F/day/person (Gura) and 11 mg F/day/person (Mesken Sefer). The results revealed that food is an important source of fluoride uptake, as 40 %, 44 % and 59 % of the total uptake comes from food in the three villages (Fig. 1).

According to WHO guidelines, an uptake exceeding 6 mg F/day poses an increased risk of affecting the skeleton, 14 mg F/per day are a clear excess risk of skeletal adverse effects. The SCSEDRI (Standing Committee on the Scientific Evaluation of Dietary Reference Intakes) suggests an UL (tolerable upper intake level) of 10 mg/day for children older than eight years and adults. Considering SCSEDRI's UL and the stricter WHO guidelines, all the results obtained reach or exceed the threshold levels when using only untreated water.

By treating the drinking water (using the Nakuru Technique (cf. article on page 10) to an average concentration of 0.75 mg F/l fluoride uptake could be reduced by 57 %, 51 % and 29 %. If all the drinking and cooking water is treated by the Nakuru Technique to a concentration of 0.75 mg F/l, the uptake could be further reduced by 66 %, 52 % and 21 %. Only if both drinking water and water used for cooking are replaced by water filtered with the Nakuru technique, the daily uptake is reduced to 6 mg F/day/person. The remaining fluoride uptake of 6 mg/day/person comes from food ingredients. To reduce this uptake further, the contributions from the different ingredients have to be studied in more detail.

However, little is known about the bioavailability of fluoride, such as for example minerals in the diet that could reduce bioavailability. More studies are needed to determine the part of fluoride in drinks and food that is absorbed and poses a risk of developing fluorosis. The described analysis is a first assessment to further develop potential fluoride reduction options.

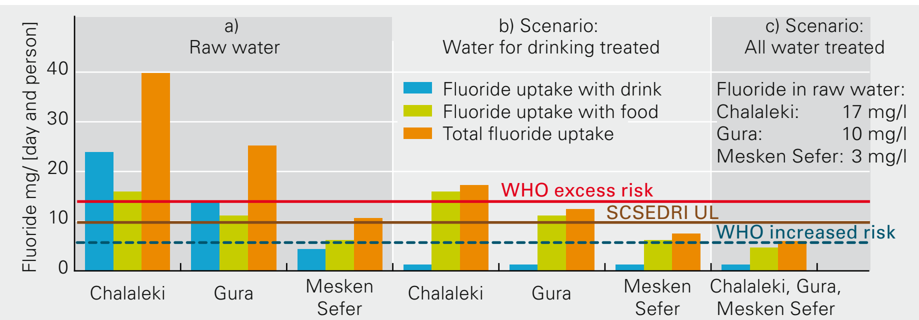


Figure 1: Calculation of uptake through average diet in three different villages (note that Mesken Sefer is situated in the Weyo Gabriel village). a) Raw water, b) Scenario with treated water for all drinks and c) Scenario with treated water for drinks and food.

[1] Malde, M.K., Scheidegger, R., Julshamn, K., Bader, H.-P. (2011): Substance Flow Analysis: A Case Study of Fluoride Exposure through Food and Beverages in Young Children Living in Ethiopia, Environmental Health Perspectives 119 (4); 579–584.

[2] Malde, M.K. (2002): Dietary Fluoride Sources in Areas with Endemic Fluorosis. PhD Thesis, Department of Odontology, University of Bergen, Norway.

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# Capacity Strengthening in Sanitation – Benefits of a Research – Operator Collaboration

**The National Utility of Water and Sanitation (ONEA) in Burkina Faso and the Department of Water and Sanitation in Developing Countries (Sandec) of the Swiss Federal Institute of Aquatic Science and Technology (Eawag) have struck a three-year collaboration to provide sustainable solutions and skills in the sanitation sector. The developed global approach evaluates existing infrastructure, identifies and fills gaps in operational capacity, local knowledge and institutional procedures for wastewater and faecal sludge management.** Magalie Bassan[1], Mbaye Mbéguéré[1,2], Linda Strande-Gaulke[1]

## Introduction

In 1996, the National Utility of Water and Sanitation (ONEA) in Burkina Faso was one of the first West African National Utilities to adopt a National Sanitation Strategy, including faecal sludge (FS) management. This led in 2004 to the construction and operation of a sewer network, three pumping stations and waste stabilisation ponds (WSPs) in Ouagadougou. However, ONEA has had operational difficulties due to limited financial and human resources for operation and maintenance (O&M), poor design decisions and lack of technical capacity. ONEA is also responsible for the challenging task of organising effective FS management of 88 % of the population in Ouagadougou served by on-site systems. The need to strengthen its capacities is therefore a major factor for future success of its sanitation infrastructure.

The French Agency for Development (AFD) provided funding to establish a three-year partnership between ONEA and the Department of Water and Sanitation in Developing Countries (Sandec). The scientific collaboration to strengthen technical capacity covers design, construction, operation, and monitoring of planned faecal sludge treatment plants (FSTPs), monitoring and optimisation of sewer networks, WSPs, and agricultural water reclamation. This is a unique collaborative partnership, as it is built on ongoing dialogue between these two stakeholders. The ultimate goal is to implement sustainable solutions for FS and wastewater (WW) management by joint research on new technologies and concepts, assessment of the performance of what has previously been implemented and by applying the lessons learned from Sandec's previous experience.

## Existing and planned collective sanitation infrastructure

WSPs in Ouagadougou were designed for 100 000 population equivalents [1], however, about 80 % of the influent is of industrial origin and the remainder from domestic sources. The treated effluent is used to irrigate a 10-ha agricultural area.

FS production in Ouagadougou is estimated at 500–1000 $m^3$/day [2]. ONEA plans to construct two FSTPs with unplanted vertical-flow drying beds designed to treat 125 $m^3$/day each. The effluent from the drying beds will be treated in the WSPs, and the dried sludge will be stored for six months following removal from the drying beds to ensure adequate pathogen reduction.

## Areas of research focus

The following three key research areas will focus on identifying weaknesses, stakeholders and appropriate solutions:

**1. Assessment of existing wastewater treatment options**

A study conducted to evaluate design, treatment performance and monitoring procedure of the WSPs revealed degradation of the infrastructure as a result of inadequate consideration given to the local context during design studies including poor maintenance. Since laboratory analysis showed high influent and effluent variability, monitoring of the industrial wastewater quality and researching optimal pretreatment methods will be essential to ensure smooth operation of the WSPs. Photo 1 illustrates the monitoring activity at the WSP in Ouagadougou.

Photo 1: ONEA's chemist taking samples in the second anaerobic basin at the WSP in Ouagadougou, Burkina Faso.

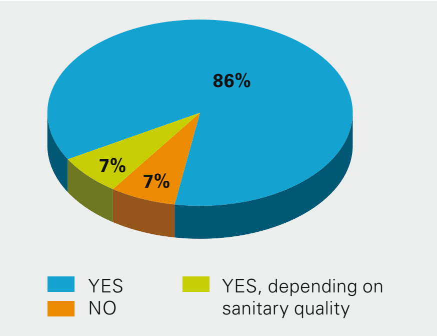


Figure 1: Willingness of cattle owners to use fodder plants cultivated on planted drying beds treating FS.

**2. Filling knowledge gaps to achieve adequate FSM**

Prior to designing the new FSTP, studies are currently being conducted to determine FS characteristics for the city of Ouagadougou. Analyses carried out during the dry season revealed limited FS production with a low solid matter content. Further studies are planned during the rainy season.

**3. Ensuring valorisation of by-products from FS treatment**

A study assessing farmers' working conditions and productivity was conducted on the agricultural area next to the WSPs. Interviews revealed that many farmers abandon the area due to poor water quality and very low production rates. This was confirmed by SAR (Sodium Absorption Ratio), which exceeded the maximum threshold value for irrigation [3].

Modification of the drying beds to planted drying beds is currently being evaluated. A study was conducted to assess optimal plants for FS planted drying beds and their market potential as fodder plants, which is highest during the dry season. Their acceptance as fodder plants by cattle owners is graphically depicted in Fig. 1. *Sporobolus pyramidalis* and *Echinochloa pyramidalis* are the two plant species selected for further evaluation in the planted drying beds.

## Strengthening collaborative capacity and optimisation measures

The stakeholders involved in the project include ONEA's staff, FS emptying and transport entrepreneurs, but also local universities, ministries, municipalities, the local press, AFD, and NGOs. Several workshops organised with ONEA address topics such as results obtained and recommendations pertaining to needs analyses, research studies and adequate institutional framework definition for FS management. The workshops and meetings with entrepreneurs led to official draft policies defining the tasks and responsibilities of the stakeholders.

The analyses identified a lack of human resources (HR), of specific knowledge on management projects and existing infrastructure, and measures to ensure institutional efficiency and capitalisation, including material and equipment for O&M and monitoring. To meet these needs, ONEA and Sandec are jointly collaborating to define quality assurance plans.

The uninterrupted flow of communication between ONEA and Sandec throughout project implementation has created a very strong collaborative exchange and trusting environment between ONEA, Sandec and the FS emptying entrepreneurs.

## Sustainable sanitation planning and management perspectives and issues

Important benefits and lessons learned from the collaborative partnership approach include:

- Concrete solutions and research results have enhanced Sandec's knowledge, dissemination strategies and future approaches.
- Acknowledgment and awareness of internal strengths and weaknesses of ONEA's sanitation approach and management.
- Development of sustainable plans and approaches for technical and institutional management of sanitation infrastructure.
- Increased lab capacity of ONEA to monitor WSPs, sewer networks and future FSTPs.
- Capitalisation of fundamental understanding of processes allowing ONEA to design, implement and operate the future sanitation infrastructure.
- Improvement of the financial balance of sanitation activities through valorisation potential of fodder and dried sludge.
- Global and holistic understanding of parameters and issues on FS and WW management relating to all stakeholders involved.
- Collaborative approach to sanitation solutions transferable to other locations and institutions.

Monitoring and optimising processes will be key components of the ongoing project activities to ensure ONEA's continued status as a sanitation leader in West Africa. The benefits of integrating ONEA and Sandec's collaboration into policy, technical procedures and development of quality plans confirm the need for holistic and collaborative approaches to finding sanitation solutions. Beyond the concrete solutions developed during the project, this type of collaborative approach can be readily transferred to other countries and sectors.

[1] Dodane, P.-H., Makboon, J., and Torrens, A. (2006): Assistance à la mise en place de l'exploitation du lagunage de la ville de Ouagadougou. CEMAGREF, p. 87.
[2] Koanda, H. (2006): Vers un assainissement urbain durable en Afrique subsaharienne: Approche innovante de planification de la gestion des boues de vidange. Ecole Polytechnique Fédérale de Lausanne: PhD Thesis, Lausanne, 351 p.
[3] Sou, Y.M. (2009): Recyclage des eaux usées en irrigation: potentiel fertilisant, risques sanitaires et impacts sur la qualité des sols. Ecole Polytechnique Fédérale de Lausanne: PhD Thesis, Lausanne, 178 p.

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The present activities and research programme are supported by the French Development Agency (AFD), the Swiss Agency for Development and Cooperation (SDC) and Eawag. The authors would like to thank ONEA and the FS emptying and transport entrepreneurs for an excellent collaboration. Commitment of the following students, who conducted research on this project, is gratefully acknowledged: Ousmane Ouédraogo, Shurstine Somé and Soumaïla Sodré. We are also grateful to Halidou Koanda and Tetouehaki Tchonda for their unparalled contribution to the project.
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# Planted Drying Beds for Faecal Sludge Treatment: Lessons Learned Through Scaling Up in Dakar, Senegal

**Experiments have revealed that planted drying beds are a promising technology for faecal sludge treatment in tropical climates. However, most of the current knowledge has been developed through lab-scale experiments. Full-scale planted drying beds have been in operation since 2008 at the Cambérène treatment facility in Dakar, Senegal. Monitoring and evaluation have resulted in important conclusions for scaling up and managing the critical start-up phase of this eco-technology.**

Pierre-Henri Dodane[1], Mbaye Mbéguéré[2,3], Ives M. Kengne[2,4], Linda Strande-Gaulke[2]

## Introduction

Planted drying beds for faecal sludge treatment in tropical climates are a promising technology thanks to their improved loading performance, resistance to clogging and resulting stabilised end product that can be used directly as a soil conditioner and fertiliser. The recommended loading rate for tropical climates is 200 kg/m$^2$/year of total solids (TS), applied in a loading cycle of one day per week, with six days for percolation and drying. This provides the plants with optimum moisture levels [1].

The start-up period for planted drying beds is critical in both temperate and tropical climates [2]. However, start-up guidelines for tropical climates are lacking or incomplete. Previous studies have only been conducted at the pilot-scale level in tropical climates with high rainfall, and were mainly focused on the treatment performance of the beds and not on overall plant health [3], [1]. The start-up period is especially important in drier tropical climates as it allows plants to acclimatise and ensures plant health and survival. Moisture stress, together with the high salt conditions, resulting from the application of faecal sludge, creates harsh conditions for plant growth.

## Methodology and objectives

The performance of pilot- and full-scale planted drying beds at the Cambérène treatment facility (Dakar, Senegal) has been monitored since 2008. The full-scale beds have a surface area of 130 m$^2$ and the pilot-scale 4 m$^2$.

Three species of plants and varying loading rates were monitored and evaluated, with a focus on general plant growth (colour, wilting, density, size), sludge layer accumulation rate and composition, similar to the study described by Nielsen [4].

The study resulted in recommendations for the scaling up of planted drying beds and progressive sludge loading during the start-up period to ensure plant acclimatisation, density development and improved operation.

## Planting

Based on pilot- and full-scale results, *Echinochloa pyramidalis* (Antelope grass) was selected for the planted drying beds, as it was more robust than *Typha australis* or *Phragmites vulgaris* during the start-up period. At the time of planting, the stems were 20 cm high and the roots had developed at least two nodes. The plants were planted at a depth of 5 cm with nine stems per m$^2$ to ensure rapid growth during start-up. The beds were fed supplemental water immediately prior to and following planting.

## Acclimatisation phase

During the start-up period, plants were watered daily with low-strength sludge (< 2 g TS/L) or wastewater (Photo 1). Preliminary tests with less frequent watering regimes resulted in a high plant mortality, as the sand beds dried out quickly without a layer of sludge on the bed surface. The sludge layer that accumulates helps to retain moisture. Use of higher-strength sludge led to significant plant wilting, which suggests the influence of salinity as previously observed by Kengne et al. [5]. Tests were also conducted with intermediate watering regimes with the outlet pipe blocked in order for ponding to occur at the surface. However, this required perfectly watertight beds. The water also needed to be flushed and replaced frequently to prevent salt concentrations from accumulating due to water evaporation.

During the dry season, the plants required a one-month acclimatisation period to ensure adequate moisture and to avoid salt stress. It is recommended that the start-up phase be implemented during the rainy season to reduce water stress and create an environment more similar to native growth conditions. The acclimatisation period should continue until the plants no longer show signs of stress (e.g. yellowish colour), and until a thin layer of sludge is observed on the bed surface.

## Gradual loading rate increase

A gradual increase in loading rates is required during transition from the plants' acclimatisation period to full loading rates. This is necessary to avoid plant stress and to develop adequate plant density.

Plant growth was monitored during a gradual increase in loading rates from 50 to 200 kg/m$^2$/year every two weeks over a period of 3–4 months with at least two applications per week.

Plant development was highly heterogeneous and seemed dependent on sludge distribution on the bed surface. The plants showed signs of wilting in areas that were lightly loaded and/or sometimes in areas that were heavily loaded (Photo 2).

## Faecal sludge distribution on the bed surface

Hydraulic distribution is critical during loading of the drying beds, as the faecal sludge needs to be spread evenly on the entire bed surface to allow good plant growth.

During the start-up trial period, two different methods were evaluated: the first pumped the sludge from a holding tank where trucks discharge sludge; the second directly applied the sludge from the trucks.

Direct discharge from the trucks worked well and was effective in achieving an

Photo 1: t = 0. Planting after sand watering.

Photo 2: Progressive increase in loading rate. Plant growth disparity.

Photo 3: t + 5 months. A robust development is achieved.

Photo 4: 10 cm sludge layer with 45 % DM content.

Photo 5: Manual and mobile screening grid.

even hydraulic distribution. However, it involved a more time-consuming management strategy to ensure that sludge was not loaded continually onto the same location. It also required a portable and mobile screening device (e. g. Photo 5). The sludge discharge points should be taken into consideration and planned in the initial bed design. Though this method is effective, it requires more time and managerial skill.

The results of the pumping tests revealed that multiple pipe outlets for each bed are necessary to ensure even hydraulic bed loading. This is also critical during the start-up period when the faecal sludge is less concentrated and infiltrates more rapidly. The uneven hydraulic distribution led to irreversible plant wilting after about ten days during the dry season.

A smooth and levelled bed surface is important to ensure even hydraulic loading and adequate moisture during the start-up phase.

## Summarised results

Twenty-one weeks following planting in the full-scale drying beds, average plant density totalled 1000 stems/m$^2$, and the plant stem had grown from 25 cm to 3 m (Photo 3).

At the end of the gradual loading phase, the average thickness of the sludge layer amounted to 10 cm. *Echinochloa* roots were growing throughout the sludge layer (Photo 4). Just prior to weekly loadings, the average sludge dryness amounted to 45 % dry matter (DM) content and varied according to layer thickness (less dry with thicker sludge).

During the five-month testing period, the average loading rate amounted to 80 kg/m$^2$/year.

Qualitative data revealed that mosquitoes develop more in planted than in unplanted drying beds, yet still much less than in the adjacent activated sludge wastewater treatment facility. This phenomenon may be attributed to the intermittent sludge loading rate leading to less frequent periods with higher moisture.

## Conclusions

Sludge loading frequency and TS concentration are two important factors to account for during acclimatisation. This poses a difficulty, as TS concentration of faecal sludge varies greatly from one truck to another and is not measured in advance under normal operating conditions.

This study reveals that planted drying beds are a viable faecal sludge treatment option that can be implemented on a large scale in dry climates. Constraints related to the starting phase (for instance low-strength sludge, even distribution) should be considered in bed design and integrated into operators' training and planning phase during the first year.

It can also be concluded that *Echinochloa pyramidalis* is a robust plant for use in planted drying beds, even during the critical acclimatisation phase in the start-up period.

Visual indicators, including plant stress (e. g. yellowish colour, slow growth rate), as well as sludge amount and dryness on the drying bed surface can be used to control application rates with the gradual loading method.

[1] Kengne, I.M., Dodane, P.-H., Amougou, A., Ngoutane, M.M., and Kone, D. (2009): Vertical Flow Constructed Wetlands as Sustainable Sanitation Approach for Faecal Sludge Dewatering in Developing Countries. Desalination, 1–8.

[2] Troesch, S., Lienard, A., Molle, P., Merlin, G., and Esser, D. (2009): Sludge drying reed beds: full- and pilot-scale study for activated sludge treatment. Water Science & Technology, 60.5.

[3] Koottatep, T., Polprasert, C., Oanh, N.T.K., Surinkul, N., Montangero, A., and Strauss, M. (2002): Constructed Wetlands for Septage Treatment – Towards Effective Faecal Sludge Management. Proceedings, 8th Int. Conference on Wetland Systems for Water Pollution Control (IWA/University of Dar es Salaam), Arusha, Tanzania: 16–19.

[4] Nielsen, S. (2005): Sludge reed beds facilities – Operation and problems. Water Science and Technology, 51(9), 99–107.

[5] Kengne, I.M., Akoa, A., Soha, E.K., Tsamaa, V., Ngoutane, M.M., Dodane, P.-H. et al. (2008): Effects of Faecal Sludge Application on Growth Characteristics and Chemical Composition of *Echinochloa Pyramidalis* (Lam.) Hitch. and Chase and *Cyperus Papyrus* L., Ecological Engineering 34, 233–242.

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# Urine as a Resource in Nepal

**Depleting fertiliser supplies call for alternative nutrient sources. Promising low-cost technologies to recover nutrients from urine were therefore field-tested in Nepal.** Bastian Etter[1], Elizabeth Tilley[1], Kai M. Udert[2]

## Quest for fertilisers

Over the last few years, Nepali farmers have struggled to meet their crops' quantitative and qualitative fertiliser requirements. While a rapidly growing population demands ever-increasing food production, only limited supplies of fertilisers have trickled into the country. To prevent a decrease in agricultural production and simultaneously reduce dependency on imports, landlocked Nepal is now trying to tap into domestic nutrient sources.

## Fertiliser from urine

Thanks to international projects and local initiatives working towards improving sanitation in the country, the number of urine diversion (UD) toilets is rapidly increasing and has allowed for separate urine collection. As urine contains a balanced mix of nutrients, such as nitrogen, phosphorus, potassium, and sulphur, it can be used as a fertiliser after treatment. Over the past three years, researchers from the STUN project have investigated various user-friendly and safe technologies to recover nutrients from urine. This article presents an overview of the tested technologies.

## A new bank: the urine bank

Though applying urine directly to crops may be an efficient method to recycle nutrients, UD toilet users without fields are forced to look for other alternatives. In a village near Kathmandu, Nepal, UD toilet users were invited to contribute towards the so-called "urine bank". Farmers could withdraw urine from the bank at a rate determined by the Urine Management Committee [1]. During the initial phase, the "pee-cycle" (a bicycle equipped with two 20-L jerry cans) collected urine from household UD toilets. Currently, the system has evolved and urine will be collected from two schools and transported by tractor to an extended urine bank.

## Struvite: concentrated urine

If distance hinders liquid urine transport from urban to agricultural areas, nutrients can be extracted and used in a more concentrated solid form. Up to 90 % of the phosphorus contained in urine can be precipitated in powder form (struvite: $MgNH_4PO_4 \cdot 6H_2O$) after magnesium is added to stored urine. In Kathmandu, a simple reactor was constructed to precipitate struvite and a rotating drum was used to convert the struvite powder into more user-friendly pellets [2]. STUN also explored different magnesium sources accessible in Nepal. Bittern, the waste brine remaining after sea salt production, is efficient but must be imported from India. Magnesite rock is available from a quarry near Kathmandu but must be calcined to form magnesium oxide suitable for struvite precipitation. A microbial risk assessment was conducted to guarantee safety during handling of stored urine and its derived products [3]. With regard to economics, large volumes of urine are required if struvite sales are to cover the production costs. In our case study [4], a struvite producer would have to process at least 7 $m^3$ of urine a day to be economically self-sufficient. This calculation does not include urine transport costs that may increase total costs markedly.

## Aquatic plants store nutrients

As an alternative to soil-based agriculture, STUN researchers used urine and struvite production effluent as a fertiliser in aquaculture, specifically using two species of aquatic plants native to Nepal, *azolla* and *spirodela* [5]. Both plants are rich in protein and can be used for biofuel production.

## Drip irrigation with urine

If urine is applied directly (e. g. with a bucket) to the field, a significant part of the nitrogen is lost through ammonium volatilisation.


Poster promoting the use of urine as a fertiliser in Nepal.

STUN showed that these losses can be prevented if urine or the effluent after struvite production is applied via drip irrigation [6]. However, long-term trials will have to prove that clogging does not occur over time.

## Anammox bacteria in Nepal

If agricultural use of the nitrogen-rich effluent of the struvite process poses a problem, then nitrogen removal should be envisaged to prevent water pollution. Together with local technicians, STUN researchers constructed a rotating biological contactor (RBC) to remove nitrogen via the nitritation-anammox process. This process is particularly suited for nitrogen removal from high-strength ammonia solutions, such as urine.

Further information on nutrient recovery from urine can be downloaded from www.eawag.ch/stun

[1] Kunz, M. (2011): Urine bank: community-based centralized urine collection. Eawag, Dübendorf, Switzerland.

[2] Etter, B. et al. (2011): Low-cost struvite production using source-separated urine in Nepal. Water Research 45-2, 852–862.

[3] Decrey, L. et al. (subm.): Fate of the pathogen indicators phage ΦX174 and Ascaris suum eggs during the production of struvite fertilizer from source-separated urine. Submitted to Water Research.

[4] Kunz, M. (2011): Economy of struvite production from source-separated urine in Nepal. Eawag, Dübendorf, Switzerland.

[5] Karli, M. (2010): Nutrient recovery from urine and struvite production effluent using aquatic plants in Nepal. Zurich University of Applied Science, Switzerland.

[6] Kashekya, J.E. (2009): Struvite production from source-separated urine in Nepal: The reuse potential of the effluent. MSc Thesis MWI-SE 2009/01. UNESCO-IHE, Institute for Water Education, Delft, Netherlands.

[1] Eawag/Sandec, Switzerland
[2] Eawag/Process Engineering, Switzerland

The authors would like to thank UN-HABITAT Nepal, the Univ. of Kathmandu, the Env. and Pub. Hlth. Org. (ENPHO), and the people of Siddhipur, Nepal, especially Jiban Maharjan, for their relentless support, and the Symphasis Foundation, Ingénieurs du Monde at the Swiss Federal Institute of Technology Lausanne (EPFL), the Swiss Agency for Dev. and Coop. (SDC), and Eawag discretionary funds for their financial support.

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# Providing Sanitation Solutions Through Value Chain Management

**A newly launched project in Sub-Saharan Africa will transpose faecal sludge from waste to a valuable product.** Stefan Diener[1], Mbaye Mbéguéré[1,2], Linda Strande-Gaulke[1]

## Introduction

The prevailing conditions for faecal sludge (FS) management across Sub-Saharan Africa are dysfunctional on-site sanitation systems, poorly maintained FS collection facilities and frequent dumping of untreated FS directly into the environment. One reason for the current situation is the lack of economic incentives for stakeholders throughout the FS service chain. In Dakar, for example, sludge emptying and transport companies are frequently not profitable and must rely on tax benefits and other sources of revenue to maintain their business.

The recently launched Faecal Management Enterprises (FaME) project consists of an international consortium of researchers, consultants and practitioners (cf. box). The FaME project is based on the concept that FS management can be transformed from a disposal problem to the recovery of valuable end-products, thus providing a profit motive and financial driver for the ongoing collection, treatment and recovery of FS. To this end, the FaME project will:

i) Conduct a market demand study in three countries (Senegal, Ghana and Uganda) to identify innovative industrial uses for FS end-products.
ii) Demonstrate the technical and financial viability of using FS as a fuel in cement manufacturing.
iii) Profile existing FS businesses and develop financial flow models to implement reuse-oriented FS management in Senegal, Ghana and Uganda.
iv) Disseminate actively the knowledge and findings of research in and outside Sub-Saharan Africa.

## Valorisation of FS end-products

An important focus of the FaME project is to evaluate the demand for profitable and beneficial end-uses of FS. A market demand study will identify stakeholders and functional groups of the value chain, appropriate technologies to ensure valorisation, adequate treatment and determination of the potential end-users willing to pay for end-products. In Dakar, most of the FS collected and treated in drying beds is currently sold for use as an inexpensive soil amendment. Use of dried FS as a fuel source in cement production is a very promising and hopefully lucrative alternative that will be evaluated during the project (Photo 1). Many cement factories already use alternative fuel materials in their kilns, be it for public relation purposes or due to the increasing oil costs. In addition to waste products, such as plastic waste, tires and peanut shells, use of sludge generated by municipal activated sludge systems (biosolids) is increasingly being implemented. The lower heating value (LHV) of coal is 26 GJ/dry tonne, while the LHV of biosolids varies from 10 to 29 GJ/dry tonne. These values suggest that FS can also be used as an alternative to coal. However, the physico-chemical characteristics of FS vary depending on technology (e. g. pit latrine, septic tank, drying technology). It is not known yet to what degree values based on biosolids can be transferred to FS. One of the key outcomes of the FaME project will therefore be determination of the calorific value and physical characteristics of FS from the different aforementioned sources in Senegal, Ghana and Uganda. These results will be used to determine optimum methods for use of FS as a fuel on a large scale pilot implementation at a cement factory in Senegal. The waste heat recovery potential to increase the drying efficiency of FS and raising its value as a fuel will also be evaluated.

## Value chain management

Even if a new technology is technically feasible and environmentally advantageous, it will not be adopted by industry unless it is financially viable. To successfully implement a new approach, its adjustment to existing policies and industrial practices must also be considered. Economic feasibility of new approaches in FS management will be assessed, as well as manner of integrating them into existing FS management and regulatory practice. A reuse-based financial flow model and methodology will be developed and implemented in Dakar and its applicability tested in Accra and Kampala. The project will also evaluate its potential as a standard model in Sub-Saharan Africa. It will identify the necessary managerial transactions in the value chain to establish a financially and economically viable market for FS reuse. The required incentives will be assessed, including non-financial barriers or incentives to trade (e.g. regulatory regime, administrative constraints, information sharing).

The overall goal of the FaME project is to offer innovative solutions to the entire FS management value chain to dramatically improve public and environmental health in urban areas of Sub-Saharan Africa by providing complete and reliable sanitation options.

Photo 1: Visiting a cement factory near Dakar, Senegal during project kick-off.

[1] Eawag/Sandec, Switzerland
[2] Office National de l'Assainissement du Sénégal, Dakar, Senegal

The FaME project is funded by a SPLASH grant (www.splash-era.net). The FaME consortium, headed by Eawag/Sandec, comprises the following research and consulting institutions:

- Eawag/Sandec (www.sandec.ch)
- Hydrophil iC GmbH, Vienna, Austria (www.hydrophil.at)
- Waste Enterprisers Ltd, Accra Ghana (www.waste-enterprisers.com)
- Université Cheikh Anta Diop, Dakar, Senegal (www.ucad.sn)
- National Sanitation Utility of Senegal (ONAS), Dakar, Senegal (www.onas.sn)
- Makerere University, Kampala, Uganda (www.mak.ac.ug)

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# Demonstration Plant for Dry Anaerobic Digestion in Kumasi, Ghana

**Dry anaerobic digestion could be an alternative to the wet digestion process currently used in developing countries. According to experts, this process has a high implementation potential in low- and middle-income countries; yet, its application will first have to be proven.** Yvonne Vögeli[1]

Different projects on anaerobic digestion of organic solid waste (kitchen waste, market waste) have been presented in previous Sandec News. All those projects centred on the continuous **wet fermentation** process requiring the organic waste to be cut into small pieces and mixed with water before being fed into the biogas digester. However, in the discontinuous **dry digestion** process, the organic solid waste is filled batch-wise into simple garage-like digester units without water mixing or size reduction. In Europe, such systems have recently been developed and implemented by German companies such as Bekon and Bioferm (cf. box).

Compared to the wet digester reactors, experts believe that the dry digestion process with its simpler design and lower costs has a high implementation potential in developing countries. Some of the main advantages of this technology are its waterless operation (water is often a scarce resource in numerous countries) and the easily and safely treated residues after digestion. Dry digestion is also less sensitive to a variety of substrates with regard to size or level of impurity. In contrast, diversity in feedstock size and composition lead to severe operational challenges with wet fermentation reactors. However, available or documented experience with this technology in a developing country context is currently still missing.

The so-called **dry fermentation** process allows methanisation of the stackable biomass (possibly with contaminating foreign substances such as sand, steel parts, stones, wood or fibrous components) both from agriculture and from practically unprocessed municipal biological waste. The fermentable materials do not have to be converted into a pumpable, liquid substrate. This process uses inoculation with already fermented material fed into a sealed container with a wheeled loader. This process does not foresee another stage of mixing or addition of material during fermentation (batch operation). The biomass filled into the digester remains there until the end of approx. 4–5 weeks the retention time. During the fermentation process, the substrate is solely tempered and percolated to allow ideal life conditions for the bacteria. The fermentation process usually occurs within a mesophilic temperature range of about 38 °C. At the end of retention time, the fermentation container is completely emptied and refilled. The fermented substrate can subsequently be sent for composting to yield high-quality compost for sale as a valuable organic fertiliser.

Box: Description of Bekon's dry fermentation technology. (www.bekon.eu)

Suitability of this approach for use in low- and middle-income countries can only be established by acquiring experience, and by developing and operating a pilot plant under locally prevailing conditions. Unfortunately, the systems implemented in Europe are operationally too complex and expensive and likely to fail if transferred to a developing country context. A dry fermentation digester should rather be developed on site with locally available materials and skills, as it would better meet the local, socio-economic, climatic, and technical requirements.

Within the frame of a preliminary study (December 2010 to May 2011), two Swiss students are currently working in the city of Kumasi, Ghana, in close collaboration with researchers from Kwama Nkrumah University of Science and Technology (KNUST). They are technically supported by the Zurich University of Applied Sciences (ZHAW). A first phase identified and evaluated different local materials potentially suitable for construction of a dry digestion biogas plant. Based on the findings obtained, a second-hand shipping container was purchased (Photo 1) and is currently converted into a biogas digester. Moreover, small-scale experiments with plastic drums are also ongoing to assess digestibility of feedstock and its gas production potential.

Swiss and local students from the University of Ghana will conduct a follow-up project (June to November 2011) to improve the prototype and carry out detailed studies on performance of the installation and its economic feasibility. Post-treatment of the digestate will also have to be examined in more detail. Furthermore, a second shipping container will be implemented to ensure that batch tests can be run in parallel and at regular intervals to maintain a permanently high gas production level. Finally, various scenarios will be developed to integrate dry digestion biogas plants into Kumasi's municipal waste management system.

Photo 1: Used shipping container currently converted into a biogas digester at KNUST, Kumasi, Ghana.

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# New Assessment Tool for Case Studies

**The ISSOWAMA Coordination Action project, funded by the European Commission under its Framework Programme 7, aims at raising awareness of the Integrated Sustainable Waste Management (ISWM) approach.** Yvonne Vögeli[1], Christian Zurbrügg[1]

ISSOWAMA (Integrated Sustainable Solid Waste Management in Asia) centres mainly on integrating sustainability aspects, (environmental impacts, economic considerations, legal and institutional aspects and social conditions in the target region) into existing assessment tools. The aim is to analyse and modify the common tools of Environmental Impact Assessment (EIA), Technology Assessment (TA), Risk Assessment (RA), and Life Cycle Assessment (LCA) by incorporating principles of Integrated Sustainable Waste Management (ISWM). This will eventually lead to an improved assessment of solid waste management systems and technologies in Asian developing countries.

Existing assessment methodologies for waste projects are rather complex and hardly suited for use by practitioners. Moreover, most methods emphasise environmental and health "impacts", which are only two aspects influencing sustainability of a waste management activity. Experience shows that financial, legal, social or institutional issues are often just as critical or even more important for the success of a waste management activity.

ISSOWAMA has therefore developed a structured tool to guide the user through the assessment and analysis phase of a specific waste management project. Due regard is given not only to environmental and health impacts, for which the described methods can be used, but rather to the measures taken or omitted that influence success or failure of an activity.

Starting point of the learning process is a clear analysis of the prevailing local conditions and factors, followed by an understanding of the full range of key aspects influencing success of any management project. It finally also includes the various impacts caused by the activity. This new assessment tool, developed by ISSOWAMA, uses a comprehensive questionnaire that includes all aspects of the ISWM model in order to evaluate relevant contexts. It examines the enabling environment, involvement of stakeholders and the project's health and environmental impacts. The tool uses both quantitative and qualitative parameters. Fig. 1 summarises the issues addressed in the questionnaire.

## For what purpose can the assessment tool be used?

This tool assists users in conducting a structured analysis of existing SWM systems. Ideally, this should help to identify challenges and lead to improvements in and beyond the system. Another goal is to foster the waste management learning process among stakeholders. Systematic documentation and analysis of the waste management activity is the basis for an in-depth understanding and, thereby, knowledge brokerage, dissemination as well as overall learning and replication of "best practices". By providing answers to a list of questions related to a specific SWM infrastructure or service, the user will become familiar with the strengths and weaknesses of the project and subsequently learn about the factors that enhance a project and allow it to become 'best practice'. The questions are specific, yet general enough to be applicable to different waste management systems and projects.

## What are its limitations?

The questionnaire is rather comprehensive and contains detailed questions on, for example, financial aspects, compliance with regulations and environmental standards. Depending on the context, access to this sometimes confidential data could prove difficult.

The questionnaire cannot be used to prioritise the issues in question. Defining and understanding the most important factors or comparing them is hardly possible with such a generic questionnaire, as the activities are heavily dependent on the relevant context. Future activities of the ISSOWAMA project will therefore identify and adapt more tools to overcome this shortcoming.

Since the questionnaire only assists in obtaining a snapshot of a particular point in time, it provides little insight into the dynamic development of an activity over time. Here, the user is requested to keep track of the changes over time. Since all activities undergo continuous development and change, the pathway and direction of change provide important clues to sustainability achievements.

**Main Functions and Characteristics**

**Technical Appropriateness**
- local skills to design, build, operate and maintain
- local availability of materials
- performance of technology
- flexibility & robustness of technology

**Policies & Legislation**
- supporting policies
- supporting legislation
- environmental laws, standards & regulations

**Social Aspects**
- training and education
- social benefits for community

**Health & Environment**
- workers safety and health
- community health
- emissions to air, water and soil
- visual/odour emissions and vectors
- resource recovery
- energy recovery
- efficient use of resources and energy

**Finance & Economics**
- cost efficiency
- cost recovery

**Organisations & Institutions**
- organisational status
- support by authorities

Figure 1: Various sustainability domains covered by the assessment tool.

[1] Eawag/Sandec, Switzerland
The questionnaire and full deliverable 5.5 "About Solid Waste Management" can be downloaded from www.issowama.net
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# Small-Scale Sanitation Challenges in the Nile Delta

**ESRISS – Egyptian-Swiss Research for Innovation in Sustainable Sanitation is a new SECO-funded research project at Sandec. It deals with the sanitation planning gap of Nile Delta villages facing challenges that are more organisational and institutional than technical. The five-year research project, in partnership with the Egyptian Holding Company for Water and Wastewater (HCWW), aims to connect local competence and experience in developing, implementing and monitoring an innovative decentralised sanitation system as a complement to the established centralised systems.**

Philippe Reymond[1], Christoph Lüthi[1], Rifaat Abdel Wahaab[2], Moustafa Moussa[3]

"Egypt is a gift from the Nile". What was true at the time of Herodotus is still true today. The gift is becoming more precious as the country's population grows: from 40 to 80 million people in 30 years, with one additional million every year. Pressure on water and land is enormous, and skilful management of both resources has become a burning national issue.

The Government of Egypt has taken a step forward towards future development by reforming the water and wastewater sector. In 2004, the Holding Company for Water and Wastewater (HCWW) with 23 subsidiary companies was founded to develop and implement a holistic policy, i. e. expansion of service delivery, introduction of the latest operation and maintenance technology and enhancement of private sector participation in activities other than its core fields.

In 2008, the World Bank launched the Integrated Sanitation and Sewerage Infrastructure Project (ISSIP) aiming at developing and implementing an integrated wastewater management approach for two canal command areas within the Nile Delta Governorates of Beheira, Gharbeya and Kafr El Sheikh (Photo 1). It introduced the "cluster approach" to maximise wastewater treatment coverage while minimising the cost per capita. Large wastewater treatment plants (WWTP) will be set up and gradually connect the main towns and villages situated at a distance of up to 5 km. These clusters can best be visualised as "stars" spread across the delta.

The Swiss State Secretariat for Economic Affairs (SECO) requested Eawag/Sandec to develop a parallel research component to ISSIP, which could provide coverage of villages and hamlets that cannot be connected to the clusters or to a traditional sewer and treatment system for the next few decades. This gave rise to the Egyptian-Swiss Research for Innovations in Sustainable Sanitation (ESRISS), whose aim is to develop, monitor and validate innovative sanitation systems that can be scaled up at the end of the third year of the project.

## Conditions prevailing in the villages of the Nile Delta

The Nile Delta is a flat, green, intensively cultivated area with thousands of densely populated villages of mainly urban character, as most buildings are three to four storeys high (Photo 2). The region's drinking water supply coverage is excellent and almost all households are supplied with tap water. Therefore, water consumption is relatively high, usually between 100 and 140 litres/capita/day. Yet, as worldwide experience shows, drinking water supply does not follow step with sanitation supply, i. e. most households still rely on traditional on-site sanitation systems, mainly infiltration pits locally called *bayaras* or *tranches*.

These on-site systems are often affected by a high water table, sometimes up to 1 m below ground, thereby causing infiltration of groundwater into the pits rather than infiltration of wastewater into the ground. As a consequence, these pits have to be emptied regularly (up to 2–4 times a month) and frequently overflow. The contents, pumped out of the pits and transported by vacuum tanker trucks, are generally dumped into the nearest drain or canal.

In any event, the environment, be it the soil, groundwater or surface water, is highly contaminated. This situation is particularly dangerous as groundwater – and sometimes drain and canal water (illegally) – is used and reused for irrigation in a context where the resource is scarce.

## Challenges of past and present initiatives

Most treatment technologies have been tried and tested in Egypt. Egyptian Universities and Research Centres have also conducted and are still carrying out numerous research studies.

Different initiatives have been adopted to solve these problems, however, they all had to face a series of obstacles, such as primarily the unavailability of land in the delta region. Since land is both expensive and precious, it is extremely difficult to

Photo 1: A typical Nile Delta village in the Governorate of Kafr El Sheikh.

Photo 3: Wastewater and sludge pumped out of the traditional on-site facilities are dumped into the nearest canals or drains.

acquire land for effective low-cost treatment, such as waste stabilisation ponds or constructed wetlands. At the same time, costs have to remain low and the required skills available locally. In such a setting, the communities would have to guarantee and cover most of the investment and daily O&M costs of the system.

Moreover, the common practice of dumping animal manure in the sewer systems has led to regular failures due to overloads in the treatment plants. Stormwater is also frequently drained into the existing sewers for lack of alternatives (Photo 3).

Yet, most challenges are institutional and organisational, as it is easier to build and manage a few large treatment plants than hundreds of small, decentralised facilities. There is a lack of innovative management interfaces linking the communities as beneficiaries to the water and wastewater companies in charge of O&M of the treatment plants. This leads to failure in the event of major breakdowns.

Laws and regulations also do not side with small-scale sanitation, as codes of practice leave little space for innovation, and the established effluent standards are as high for small as for large treatment units. In other words, it endorses a policy of "everything or nothing", although primary treatment for all would significantly alleviate the environmental burden. Besides, current water tariffs are very low and do not ensure cost-recovery for wastewater treatment, thereby hindering rapid expansion of the service. Work at the policy level is currently being conducted to improve this framework.

Legal and regulatory framework, institutional arrangements, skills and capacities, financial arrangements, socio-cultural acceptance, and government support are the main challenges faced by ESRISS in its quest to establish an enabling environment [1]. Therefore, improving a supporting and enabling environment is essential for future success.

## Connecting with the right people

ESRISS's key activity is to link up with local experts and establish a platform for small-scale sanitation to overcome institutional barriers. Many projects have failed because one of the components of the enabling environment was missing. Most of these projects could have succeeded with a better involvement of the potential stakeholders. In parallel, many projects remained at the pilot stage. In this case, ESRISS can contribute to insert and implement them into complete full-scale systems.

Photo 2: The Nile Delta – flat, green, intensively cultivated, with thousands of densely populated villages.

The project started with an inventory of small-scale sanitation initiatives in the country, identifying success and failure factors, gaps and missing data. Studies are planned to collect the latter, especially at village level: assessment of sanitation practices, characterisation of wastewater, sludge and manure, and analysis of their flows. Money fluxes within the sanitation business (on-site emptying infrastructure, transport, emptier charges, taxes) will be assessed to decide if and how they can be reorganised in a system where emptiers would bring their loads to determined treatment points.

The project will subsequently assemble pieces of the puzzle of the "Egyptian sanitation initiatives", combining competence and expertise from various institutions to set up a complete, compact, low-cost, as well as easy to operate and maintain treatment "system". "System" in this context comprises sustainable financial and institutional mechanisms, including roles and responsibilities, questions of ownership, contracts, rules and regulations, as well as procedures in the event of service default. The potential synergies with the existing centralised sewered systems will also be investigated and give rise to several scenarios, sewered or unsewered and compared in a cost-benefit analysis.

While working on organisational and institutional challenges, careful stakeholder analysis, involvement and collaboration with other projects currently conducted in the country will contribute to improving the enabling environment towards more favourable implementation conditions and, above all, to an "institutionalisation" of the approach.

One or two scenarios will be selected for implementation by the local partners at the end of the 1st year of the project. During the following two years, implementation and monitoring will be conducted at full-scale in one or two hamlets (locally called *ezbas*). Once validated, they will pave the way to a large-scale replication in the remaining thousands of settlements in the Nile Delta.

[1] Lüthi, C. et al. (2011): Sustainable Sanitation for Cities – A framework for action. Papiroz Publishing House, Rijswijk, The Netherlands, 164 p.

[1] Eawag/Sandec, Switzerland
[2] Holding Company for Water and Wastewater, Egypt
[3] UNESCO-IHE, Netherlands; Helwan University, Egypt

We would like to thank all our Egyptian partners and colleagues for their support and openness during the first months of the project.
The project is funded by the Swiss State Secretariat for Economic Affairs (SECO). (www.sandec.ch/esriss)

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# Presenting the Community-Led Urban Environmental Sanitation Guidelines

**After worldwide piloting and evaluation of the Household-Centred Environmental Sanitation approach, Eawag/Sandec, the Collaborative Council (WSSCC) and UN-HABITAT have published new guidelines for Community-Led Urban Environmental Sanitation (CLUES).** Christoph Lüthi[1], Lukas Ulrich[1]

Intensive field-testing and validation of the Household-Centred Environmental Sanitation (HCES) planning approach [1] was conducted between 2006 and 2010 in seven different urban and peri-urban settings in Africa, Asia and Latin America. The experience and lessons learned from these pilot projects were used to develop a revised set of planning guidelines called Community-Led Urban Environmental Sanitation (CLUES) (Photo. 1).

## From HCES to CLUES – What's new?

The name change from HCES to CLUES highlights the importance of broad community involvement (beyond the household level) in the planning and decision-making processes. Although the name changed, the main characteristics stay the same: a multi-sector and multi-actor approach emphasising participation of all stakeholders in the planning process from an early stage.

The revised guidelines differ in four ways from the former provisional version:

1. Simpler to use, featuring only seven planning steps (previously ten-step process).
2. Written in an easier and more accessible language for non-experts to understand.
3. They feature a complete toolbox with multiple "how-to-do-it" tools for each step of the process.
4. Special attention is paid to environmental sanitation at the community level, especially to low-income communities where service improvements are a complex task.

## Characteristics of the CLUES approach

The new publication presents a step-by-step procedure for planning and implementing environmental sanitation infrastructure and services in urban and peri-urban communities. Based on the Bellagio principles for sustainable sanitation [2], the planning approach builds on a framework, which balances the needs of people with those of the environment to restore human dignity and a healthy life. By involving all relevant stakeholders, particularly the targeted community, it aims to consider the entirety of perspectives and expectations, thereby helping to find and implement the best possible environmental sanitation solution in a common agreement.

Some of the strengths of the planning approach:

- CLUES adopts a flexible and neutral approach with regard to technology choice, taking into account economic factors (ability and willingness to pay) and social benefits such as privacy, dignity and convenience. Its objective is to link expression of needs at the community level with those resources available locally and those requiring additional inputs from external agencies.
- The approach combines expert knowledge at national and municipal level with local knowledge at community level.
- CLUES is primarily focused on solving sanitation problems in unserved (often informal) settlements. Its objective is to derive solutions requiring minimum external support and, at the same time, complementing citywide and strategic approaches such as "Sanitation 21".

## Structure and target audience of the new publication

The CLUES guidelines are organised in three parts: Part 1 elucidates the seven steps of the actual planning approach. Part 2 describes why an enabling environment (political, legal, institutional, financial, socio-cultural and knowledge framework) is needed as a precondition for the success of every planning process and how it can be nurtured. Part 3 provides 30 practical tools in digital form to support and streamline process implementation. An enclosed memory key containing the toolbox is also provided and will be accessible (in its latest version) on the Internet.

This document has been developed to provide guidance to experts and professionals working with peri-urban and urban neighbourhoods partially served or unserved in terms of environmental sanitation services. The structured seven-step process and accompanying toolbox should prove useful to local authorities, donor agencies, planners, and NGOs dealing with infrastructure programming and service delivery, as well as to non-experts, local NGOs and community-based organisations taking part in such a planning process.

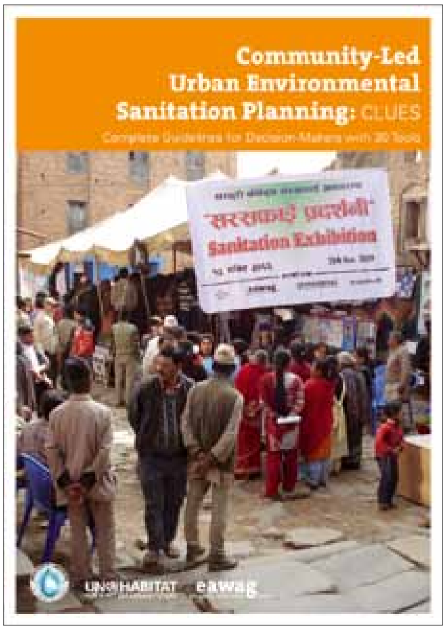


Photo 1: Cover page of the new planning guidelines for decision-makers.

[1] Eawag (2005): Household-Centred Environmental Sanitation: Implementing the Bellagio Principles in Urban Environmental Sanitation. Provisional Guideline for Decision-Makers.

[2] Eawag (2000): Bellagio Statement: Clean, Healthy and Productive Living: A New Approach to Environmental Sanitation.

[1] Eawag/Sandec, Switzerland

This open source document will be launched at the World Water Week 2011 in Stockholm and can be downloaded from the Sandec and WSSCC websites after the World Water Week. The development of CLUES was supported by the Swiss National Centre of Competence in Research (NCCR) North-South and SDC's Water Initiatives Division.

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### VUNA: Harvest in Zulu

An acronym, name and credo at the same time, VUNA stands for Valorisation of Urine Nutrients in Africa, and is the name of a new Eawag project. In isiZulu, the language of the project area in the municipality of eThekwini, South Africa, the word *vuna* means harvest. A healthy harvest follows a balanced nutrient application to the crops. And, in the case of the VUNA project, the necessary nutrients are harvested from urine.

By recovering nutrients from urine in decentralised reactors, VUNA aims to promote a dry sanitation system affordable to the poor, produce a valuable fertiliser, foster entrepreneurship, and reduce water pollution. In an interdisciplinary approach, eThekwini Water and Sanitation and the University of KwaZulu-Natal have paired up with Eawag to develop various nutrient recovery technologies, establish urine collection systems and identify social and economic implications of urine collection and treatment.

Find out more about nutrient harvesting in South Africa from www.eawag.ch/vuna

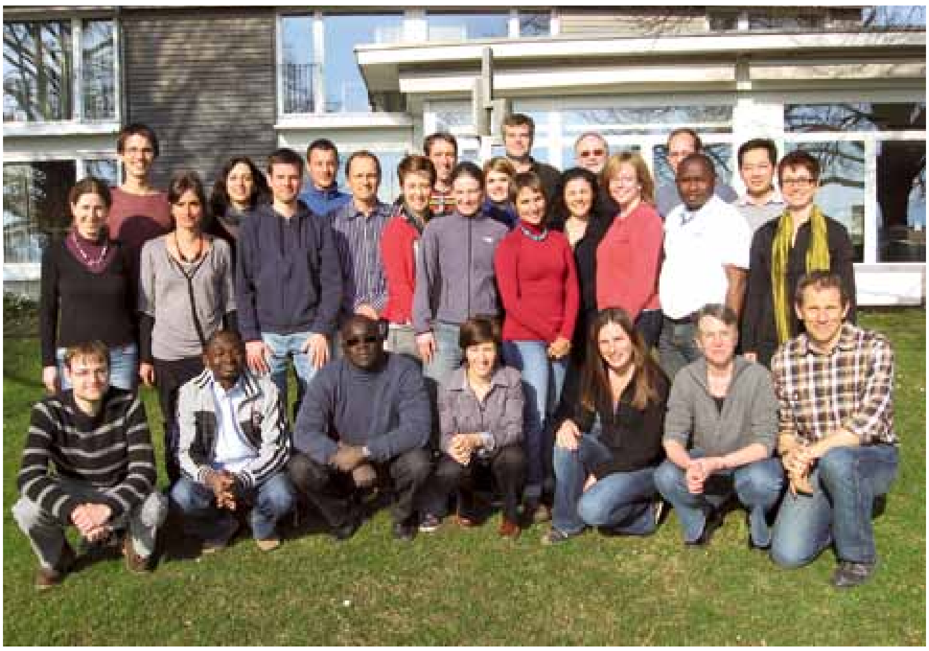
### New Faces

**Fabian Suter**, Master in Media and Communication, joined the SODIS team in November 2010. His main task is to develop and promote a new training manual for schools. This training manual forms part of the SODIS school programme aiming at evaluating the integration of drinking water treatment and hygiene in schools as an element for global HWTS promotion efforts. The manual will be applied primarily in schools in Kenya, Zambia and Bolivia. With his communication skills, he actively supports the SODIS team in raising the awareness of target populations for the SODIS method and its worldwide dissemination.

**Amalia Gallardo Llamas,** Civil Engineer from Spain, joined Sandec in October 2010. After working at Telemark Technological Research and Development Centre in Norway in the field of Wastewater Engineering and for several years in Structural and Construction Engineering in Spain.Her activities at Sandec will centre on biogas technology fed with municipal organic waste in urban areas with special focus on Latin America. Her tasks will also comprise developing materials (presentations, cases studies, tests) to be used in intensive workshops in Latin America. She is also in charge of reviewing the Spanish Compendium of Sanitation Systems and Technologies.

**Lukas Ulrich** completed his Masters in Environmental Engineering at the ETH Zurich in August 2010. He joined Sandec as a civil servant, working on the development of the new Community-Led Urban Environmental Sanitation (CLUES) Planning Guidelines. In August 2011 he starts as a Project Officer in the Strategic Environmental Sanitation Planning group. Lukas will be working on decentralised and reuse-oriented sanitation systems as well as on participatory sanitation planning for unserved urban and peri-urban areas. One of his tasks will be to develop a costing tool for different sanitation technologies.

## The Sandec Team



From left to right:
**Standing**: Monika Tobler, Philippe Reymond, Valérie Cavin, Amalia Gallardo Llamas, Sämi Luzi, Lars Osterwalder, Christoph Lüthi, Elizabeth Tilley, Rick Johnston, Andrea Tamas, Selina Müller, Stefan Diener, Malagie Bassan, Caterina Dalla Torre, Roland Schertenleib, Linda Strande-Gaulke, Matthias Saladin, Yves Kengne, Hung Nguyen Viet, Petra Kohler
**Kneeling**: Lukas Ulrich, Kouassi Dongo, Mbaye Mbéguéré, Yvonne Vögeli, Maryna Peter-Varbanets, Regula Meierhofer, Chris Zurbrügg
Missing on photo: Sylvie Peter
**Associated doctoral students**: Mingma Galzen Sherpa, Marie-Madeleine Ngoutane Pare, Jean Birane Gnin, Tu Vu Van, Ebenezer Soh Kengne, Parfait Kouame Koffi, Innocent Tumwebaze Kamara, Pham Duc Phuc, El Hadji Mamadou Sonko

# 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, community and household water systems, excreta and wastewater management as well as in the water and sanitation sectors.

## Solid Waste Management

**Collection of Municipal Solid Waste in Developing Countries**
This book is UN-HABITAT's response to the glaring need to improve urban waste collection systems. Since it seeks to encourage the designing of waste collection systems based on local information, the approach is valid in any developing country. The main focus is on municipal solid waste, which is taken to include waste from households, businesses and institutions, construction and demolition waste in small quantities, general solid waste from hospitals (excluding hazardous waste), waste from smaller industries that is not classified as hazardous, and waste from streets, public areas and open drains.
By UN-HABITAT, 2010, 200 pages, ISBN 978-92-1-132254-5. Available as hardback for $15.00 or as pdf download from
www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3072

**Waste and Climate Change: Global Trends and Strategy Framework**
The United Nations Environment Programme (UNEP) has directed its International Environmental Technology Centre (IETC) branch to take action in the area of waste management. There are substantial co-benefits of waste management in the context of climate change. As a first step to realize these co-benefits, this report seeks (a) to examine the potential of climate impacts and benefits of different waste management activities, and (b) to present a UNEP-lead framework strategy to assist member countries in prioritising their resources and efforts for waste management and climate change mitigation. The framework strategy is intended to align with the internationally recognised waste management hierarchy, in which waste prevention receives the highest priority, to optimise the co-benefits for climate change mitigation.
By UNEP DTIE, Int. Env. Tech. Centre (IETC), Osaka/Shiga, 2010, 79 pages. Available as pdf download from
www.unep.or.jp/ietc/Publications/spc/Waste&ClimateChange/index.asp

## Community and Household Water Systems

**Evaluating Household Water Treatment Options: *Health-based targets and microbiological performance specifications***
This document, for the first time, sets forth global criteria, which enables users to evaluate whether an HWT option reduces water-borne pathogens sufficiently to protect health. Through use of a risk-based framework and by emphasising the philosophy of incremental improvement, it is intended to provide implementers and policy-makers with an evidence-based and pragmatic approach to select options suited to local conditions.
It also provides a range of technical recommendations, including:
- A step-by-step overview of how to evaluate HWT microbiological performance.
- Elaboration of health-based water quality targets ranging from interim to highly protective, including establishment of default targets for use in data-scarce settings.
- Description of technology-specific laboratory testing protocols and guiding principles.
- Considerations relating to developing national technology evaluation programmes.

This publication is especially intended for resource-scarce settings where water quality laboratories may have limited capacity and incremental improvements of HWT performance could have a substantial, positive impact on public health.
By World Health Organisation, 2011, 68 pages. Available as pdf download from
www.who.int/water_sanitation_health/publications/2011/household_water/en/index.html

**Access and Behavioral Outcome Indicators for Water, Sanitation and Hygiene**
The HIP (Hygiene Improvement Project) developed this publication for USAID and other organisations to measure progress for handwashing, POU and sanitation activities, and provide guidance to implementers of WASH programmes on what indicators to use to measure their programmes' achievements. Most of the indicators presented here track output and outcomes at the household level. However, community-based indicators associated with community-led total sanitation (CLTS) are also included to help achieve the water and sanitation Millennium Development Goals (MDGs).
By USAID-HIP, February 2010, 80 pages. Available as pdf download from
www.hip.watsan.net/page/4148

**Household water treatment and storage (HWTS) guidelines**
PATH has created guidelines for designing and developing household devices for treating unsafe water and safely storing it for use. The guidelines provide evidence-based criteria for effective, commercially viable products that meet or exceed user expectations for long-term use. They take into account the unique needs of users in the developing world. These guidelines will help to advance development and use of household water treatment and storage (HWTS) devices by providing benchmarks for product attributes and performance.
By PATH, 2011. Available as pdf download from
www.path.org/hwts-design-guidelines/

## Excreta and Wastewater Management

**A Rapid Assessment of Septage Management in Asia**
This report documents the state of septage management for on-site sanitation systems, the main form of urban sanitation in many Asian cities. It provides a regional analysis of key challenges and existing good practices related to septage management, and highlights strategies through which governments, water and wastewater operators, and development assistance agencies can promote sustainable management practices. The key finding is that most countries neglect septage management, which results in significant urban water, environmental and public health damages. Nevertheless, a number of countries and cities in the region have established effective regulations, treatment facilities and supporting programmes that can be replicated across Asia through focused water partnerships.
By ECO-Asia International Development Inc. and Eawag/Sandec, January 2010, 144 pages. Available as pdf download from
www.waterlinks.org/septage-report

## Water and Sanitation

**Social Perspectives on the Sanitation Challenge**
This book presents a timely collection of scientific papers dealing with innovative sanitation concepts, perceptions and decision-making support. It comprises a valuable resource for political scientists, environmental engineers and urban planners whose work relates to meeting the ambitious Millennium Development Goal of halving the number of people without sustainable access to safe drinking water and basic sanitation by 2015.
By Bas van Vliet, Gert Spaargaren, Peter Oosterveer (eds), 1st Edition, 30 March 2010, 242 pages. Springer Netherlands, ISBN 978-90-481-3720-6. Available as hardcover for CHF 143.50 from
www.springer.com/social+sciences/book/978-90-481-3720-6

**Shit Matters – The potential of community-led total sanitation (CLTS)**
A comprehensive overview of one of the most promising approaches to improving hygiene and sanitation behaviours in rural contexts, 'Shit Matters' addresses both the potential and challenges of CLTS by drawing on research from South Asia, Indonesia and Africa. Besides in-depth case studies from Bangladesh, India and Indonesia, Part 4 of the book also looks at future CLTS prospects intended for scaling-up and sustained use over the long term. This book is essential reading for anyone interested in novel approaches to behavioural change and community-led initiatives. It includes a foreword by Kamal Kar.
By Mehta, L. and Movik, S. (eds), March 2011, 270 pages, ISBN 9781853396922. Available as hardback for $16.16 from
www.practicalactionpublishing.org