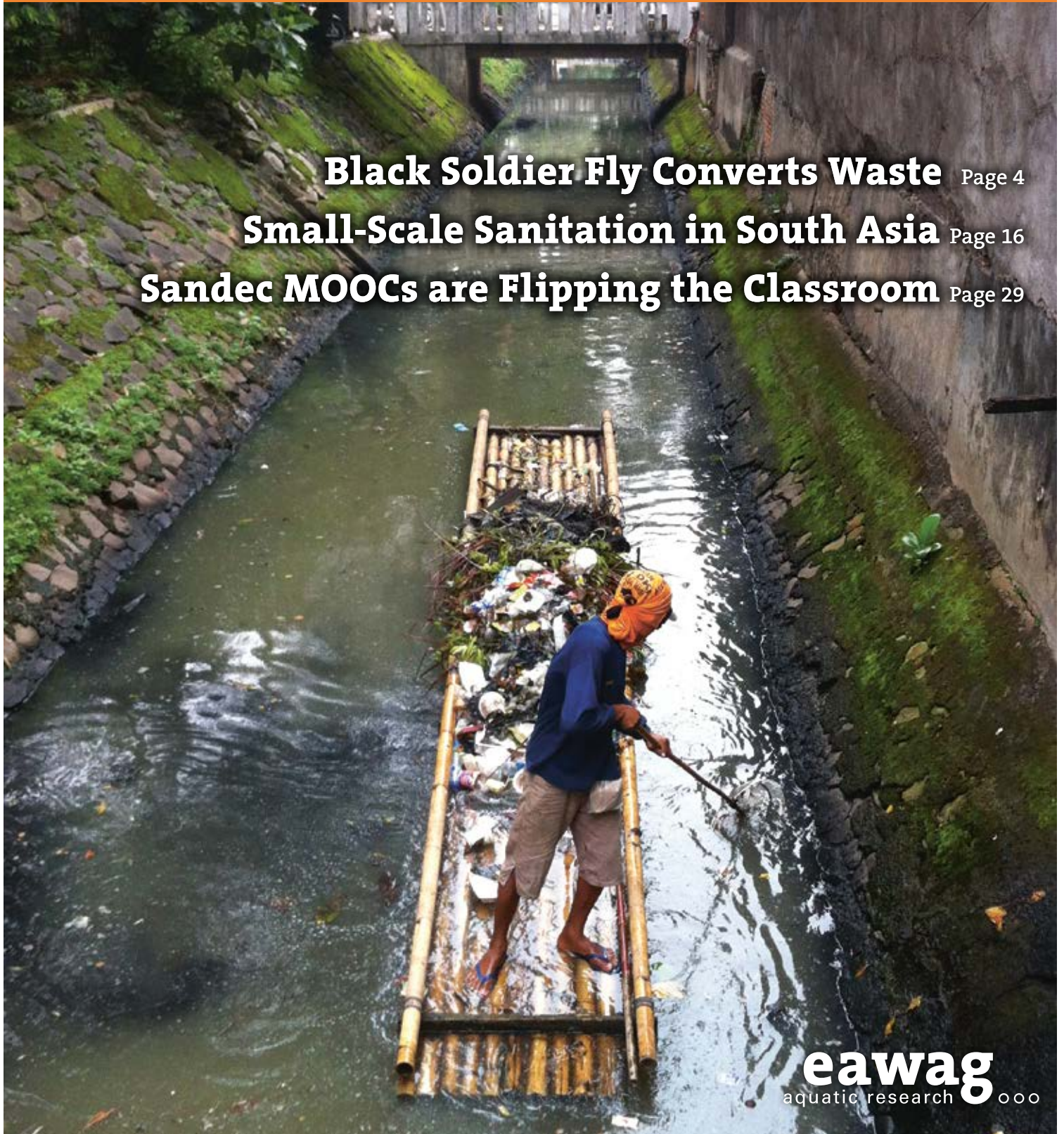


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### Sandec

#### Sanitation, Water and Solid Waste for Development

**Publisher:** Eawag, 8600 Dübendorf, Switzerland, Phone: +41 (0)58 765 52 86  
caterina.dallatorre@eawag.ch, www.sandec.ch

**Editors:** Paul Donahue and Christoph Lüthi, Eawag

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

**Cover:** Open Channel Cleaning and Maintenance in Jakarta, Indonesia (Photo: Chris Zurbrugg).

**Layout and figures:** Lydia Zweifel, Eawag

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

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

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

**New subscribers:** Please contact caterina.dallatorre@eawag.ch

ISSN 1420-5572

Eawag: Swiss Federal Institute of Aquatic Science and Technology

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# Make the SDGs a Reality



**“How to adapt the water indicators so that they provide value for the local context while still supplying disaggregate data for the SDGs will be a key challenge.”**

It was a unique milestone last September in New York City when the United Nations agreed on the new catalogue of Sustainable Development Goals (SDGs), which are part of the 2030 Agenda for Sustainable Development. This took months of global consultation and diplomatic arm-twisting. Unlike the Millennium Development Goals, the 2030 Agenda defines a holistic understanding of global sustainability that includes both developing and developed nations and defines 17 goals and 169 targets that are integrated and balanced across all levels of sustainability. Switzerland was an important player in defining the integrated water goal, while sanitation and water are well represented in targets 6.1 to 6.6 of the SDGs.

However, achieving these goals represents a significant challenge, not least in connecting them to existing decision-making processes. At the sub-national level, authorities see that the indicators add little or no value to on-going planning processes and it is feared that reporting will be an added administrative task. A key challenge is, thus, how to adapt the water indicators so as to provide value for the local context while still supplying the comparable and disaggregate data needed for international comparison.

At Sandec, we strive to contribute to tools and methods for the state-of-the-art collection and analysis of disaggregated data. For on-site urban sanitation, we have been involved in the validation of so-called Shit Flow Diagrams (or Excreta Flow Diagrams) which allow for the rapid assessment of waste flows in a city-wide context without requiring time-consuming detailed surveys and calculations (See pages 14–15 for details).

Our Water Supply and Treatment Group has been testing proposed indicators and developing field-robust procedures for measuring drinking water quality – to allow for the collection of the disaggregate data which forms the core of the new target 6.1 “...*achieve universal and equitable access to safe and affordable drinking water for all*”. This will enable mid-level staff at the district and municipal authority level to carry out water quality assessments and water system inspections even in remote areas (pages 24–25).

And finally, in our Genderised WASH in Health Care Facilities project (page 17), we are developing a mobile based monitoring tool for assessing WASH service quality in health care facilities. The application will permit the collection of gender segregated data for the monitoring of WASH in health care facilities.

We have also just completed our third massive open online course entitled “Municipal Solid Waste Management in Developing Countries” that had more than 20 000 participants from 166 countries. As with our two previous online courses, all course materials are available for download at [www.eawag.ch/mooc](http://www.eawag.ch/mooc).

If you have not yet noticed, we have a new name! Sandec now stands for Sanitation, Water and Solid Waste for Development, and indicates the perspective that the term “developing countries” no longer reflects contemporary development discourse.

For more details on any of the projects featured in this edition, please do not hesitate to contact the authors. We hope you enjoy this issue of Sandec News.

A handwritten signature in black ink, appearing to read 'Ch. Lüthi'.

Christoph Lüthi  
Director Sandec

# Market-driven Upcycling of Urban Organic Solid Waste in Indonesia

*FORWARD* is a research and development project in Sidoarjo, East Java, Indonesia. Driven by market opportunities for conversion products, Sandec is piloting the innovative Black Soldier Fly Larvae technology as the pivot of an integrated organic waste conversion system. B.M. Verstappen<sup>1</sup>, F.F. Pawa<sup>1</sup>, B. Dortmans<sup>1</sup>, A.Y. Bagastyo<sup>3</sup>, A.H. Pratono<sup>4</sup>, P. Rahmani<sup>5</sup>, Ch. Zurbrugg<sup>2</sup>

## The challenge

There is a dire need for location-specific municipal solid waste management (MSWM) solutions in rapidly developing small- and medium-sized cities where the authorities often cannot respond adequately to rapidly changing conditions. Indonesia, the fourth most populous nation in the world, is no exception. The island of Java has the highest average population density of all islands worldwide (1 000/km<sup>2</sup>) and the urban density approaches 10 000/km<sup>2</sup>. This has intensified the waste problem, and in many towns and cities, much of all generated waste is dumped, burned or discharged into rivers. Organic waste (OW) makes up around 60 % of the total generated municipal solid waste (MSW), and is thus by far the largest fraction of MSW. Sustained solutions for this large OW fraction are rare, mainly due to the low (often negative) market value to processing cost ratio of OW conversion products.

## Focus on market opportunities

The *From Organic Waste to Recycling for Development (FORWARD)* project evaluates how OW treatment can be driven by local market opportunities for waste conversion products. The aim is to foster a business approach to incentivise private or community OW treatment solutions. *FORWARD* explores and develops technological and managerial innovations for OW management to generate employment and simultaneously facilitate a more complete recycling of the inorganic MSW fraction.

## Current situation

The Indonesian law 18/2008 regulates waste management (WM) at the national level. The national government fulfils a supporting and coordinating role, while implementation is a decentralised responsibility of Regency and City authorities. Besides the “reduce, recovery and recycling” (3R) objectives, it describes the rights and obligations of all layers of society, and stipulates that all open dumpsites in the country should be closed or replaced by sanitary landfills before 2014. Today, sanitary landfills are still rare. Open dumpsites are reaching full capacity and local authorities face difficulties to establish new sites. The availability of suitable land, distances and cost of both waste collection and of properly operating sanitary landfills are the main reasons why this is the case.

The rapid filling of landfills can be avoided if they would only need to accommodate the fraction of MSW left after recycling. Keeping the large OW fraction out of landfills reduces waste transportation requirements, extends landfills’ lifetimes and reduces the costs of leachate treatment and methane control. Incineration of mixed MSW is economically and environmentally not feasible for small- and medium-sized cities of Indonesia given the high water content of the waste. Furthermore, controlling air emissions from incineration can only be ensured with sophisticated equipment, which is expensive to operate and maintain.

A sustainable solution lies in source segregation of OW (kitchen, market and garden



Photo 1: Harvested Black Soldier Fly larvae.

waste) to allow for appropriate decentralised treatment. This reduces the need for transport to landfills and also enhances the recycling of the inorganic fraction because source segregation increases the quality of recyclables. OW materials can be treated in different ways: they can be decomposed anaerobically into energy products (biogas or biochar), upcycled to animal protein as feed for a range of animals or decomposed aerobically into compost.

## Market potential of waste conversion products

*FORWARD* evaluated the market potential of different OW conversion products. This market research complemented the assessment of OW generation and of current MSW management practices in the Sidoarjo regency. The steadily growing population and economy indicate a clear need for energy, protein and soil amendment, i.e. compost. However, these requirements do not necessarily translate into viable market opportunities.

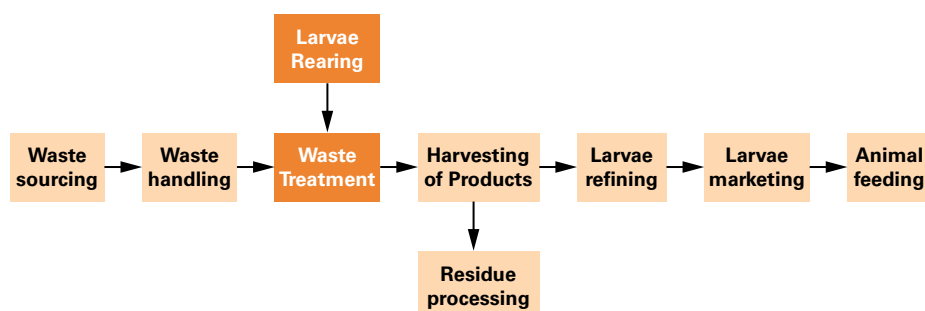


Figure 1: Process steps of an organic waste treatment facility utilising conversion by BSF larvae.



Photo 2: Adult Black Soldier Flies reproduce in “love cages” and the eggs develop into young larvae.

**Compost** production is relatively simple and can convert most OW fractions. Also, Javanese agricultural soils are low in organic matter due to the ongoing and decennia-long intense agricultural practices and the promotion and subsidising of chemical fertilizers. Thus, compost could play an important role to sustain soil fertility and structure. Yet, without governmental promotion and financing or preferential treatment in the marketplace, compost can barely compete with fertilisers and other soil amendments.

**Biogas and biochar** production is complex and restricted to specific OW types and mixtures. In the Indonesian consumer energy market, biogas and biochar cannot compete with convenient, clean and subsidized Liquefied Petroleum Gas. OW-derived energy products are feasible only in very specific and rather small on-site applications.

**Protein** production from organic refuse could meet the needs of the large Indonesian population. Currently, around 80 % of the total soybean and 55 % of the total fishmeal requirements are imported, which weighs on the Indonesian trade balance deficit and contributes to global environmental issues. Local meat production in Indonesia is well below consumption. Up to 80 % of the cost of meat or fish production is the cost of animal feed; thus, local animal production is restricted mainly by the availability of base protein. Indonesia cannot, for example, realise its huge aquaculture potential, which could also serve the export market. The government is eager to achieve

food self-sufficiency and often regulates food and feed imports to boost opportunities for local farmers. Growing demand for locally produced base protein to increase local animal production and the relatively high value of protein make OW-to-protein conversion very promising from a market perspective. Direct feeding of selected kitchen and market residues to cattle, goats, fish (especially catfish) and poultry (chicken and ducks) is already common, particularly during the dry season when foraging and grazing are limited. Feeding organic kitchen and market waste to insect larvae of the Black Soldier Fly (BSF) is an alternative solution, linking OW treatment to the production of base animal protein, namely the protein from nutritious insect larvae (Figure 1).

### FORWARD pilot operations

FORWARD has established an organic waste conversion site at the Puspa Agro vegetable market in Sidoarjo, where conversion by Black Soldier Fly Larvae (BSFL) has been developed as the core OW conversion technology. BSFL are fed dewatered fresh market waste, and the OW fraction not consumed by BSFL, i.e. the cellulose-rich “garden waste”, is composted. The biogas production potential of the liquid from waste dewatering and the residue after BSFL conversion are currently being explored. This on-site energy source could be used for post-harvest processing of larvae (Photo 1). The residue is also being tested for vermiculture.

### Ongoing research

FORWARD currently rears enough young BSFL to process 2 ton of fresh OW daily, and this can be flexibly scaled up (Photo 2). Our research now focuses on improving and streamlining the BSFL waste conversion operation, such as finding ways to remove excess water by dewatering and/or mixing different waste types. The goal is to have the final residue dry enough to allow for mechanical harvesting of larvae. Research with Indonesian universities involves evaluating the feeding of larvae to fish, poultry and baby goats, as well as the biogas potential of the liquid and residue fractions. FORWARD also interacts with communities to obtain segregated household organic waste and with agribusiness companies to test industrial organic waste streams. The project is also doing market development with potential end-users and commercial partners.

### Outlook

Although BSF technology is still in its infancy, stakeholder interest is steadily growing, providing an incentive to explore source segregation of waste, a yet rare practice in Indonesia. To respond to the market potential and to meaningfully impact waste management, more knowledge on OW conversion by BSFL at different scales is necessary, and technology and business models need to be developed and evaluated according to these scale requirements. FORWARD is successfully demonstrating to governmental, private, social and academic partners that widespread decentralised OW conversion is key to the overall MSWM challenge and that OW resource recovery can contribute considerably to social, economic and environmental welfare in many ways.

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This project is funded by SECO (Swiss State Secretary for Economic Affairs) and works in cooperation with the Indonesian Ministry of Public Works & Housing and local Sidoarjo Regency government departments. The research is implemented with contributions from lecturers and students associated with Institut Sepuluh Nopember Universitas Surabaya and Universitas Airlangga (both located in Surabaya), Universitas Indonesia (in Depok) and Institut Pertanian Bogor. The pilot site is provided by PT Puspa Agro, a company of the East Java Provincial Government.

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# Appropriate Biowaste Treatment Technology for Aquitania, Colombia

A Swiss student at a local NGO, Fundación Montecito, applied the organic waste treatment decision support tool (SOWATT) in Aquitania. In-vessel composting was found to be the most promising technology; yet, marketing the produced soil amendment would require special emphasis. Adeline Mertenat<sup>1</sup>, Imanol Zabaleta<sup>1</sup>, Chris Zurbrügg<sup>1</sup>



Photo 1: Lake Tota and its onion residues.

## Introduction

The Lake Tota Basin, located in the tropical Andean highlands of Colombia, is a Páramo watershed [1] with a unique rich ecosystem. Given its uniqueness, it has attracted a lot of interest. Institutions and NGOs have made its development into an integrated and sustainable watershed area a priority as it could serve as a model for other areas of Colombia and for other highland Latin American countries.

The area's economic output is estimated at 200 million US\$/year and Aquitania is the biggest municipality (15 000 inhabitants). However, intensive onion farming, trout farming and overall unsustainable waste and wastewater management in Aquitania pose a significant threat to this important lake ecosystem [2]. The local authorities recognize the need to improve waste management around the lake, and agreed to be a test-site for the application of SOWATT.

## Applying SOWATT in Aquitania

SOWATT (Selecting Organic Waste Treatment Technologies) is based on the "Multi Attribute Value Theory". It promotes a structured decision making process that considers social, economic and technological conditions when comparing and choosing from organic waste treatment alternatives [3]. The application prioritises six technologies: windrow composting, in-vessel composting, vermicomposting, anaerobic digestion, black soldier fly processing and slow pyrolysis.

Assessments in Aquitania determined that 150 tons/week of organic waste (OW) are produced. This comprises 105 tons/week of the aquatic plant, Elodea, which is harvested from the lake, 31 tons/week of onion residues from processing facilities and 14 tons/week of municipal organic waste. SOWATT was applied to determine the most adequate form of OW treatment for Aquitania. Slow pyrolysis was ruled out from the start because of the overall low lignocellulosic content of the biowaste.

The other five technologies were assessed against the array of SOWATT criteria or objectives: technical reliability, economic sustainability, social acceptance, environmental pollution, hygiene and community health. Each objective was weighted through a participatory process involving local stakeholders. In Aquitania, four stakeholder groups were consulted: 1) local authorities (Mayor's office, governmental entities, etc.), 2) entities managing or with OW management experience, 3) productive sectors related to OW management and 4) local NGOs.

## Results

Results showed that NGOs prioritized environmental and social aspects, whereas local authorities favoured environmental and economic objectives, and the OW managers prioritised economic issues (Figure 1).

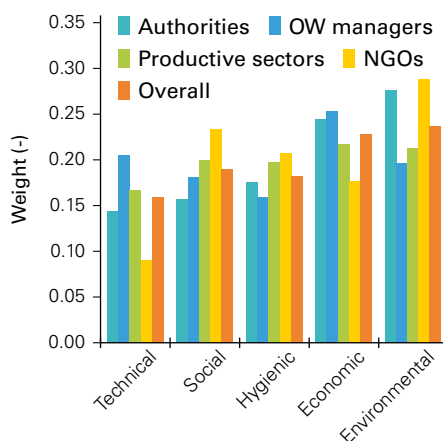


Figure 1: The weight of the objectives given by the stakeholders.

The soil amendment was of major interest to all stakeholders as a replacement for the fresh chicken manure and large amounts of pesticides currently in use, which severely pollute the surface waters. The composting technologies selection criteria were: a low level of human resources, minor mechanisation, and the need for a technology that provides easy control of the process parameters with few emissions. Given these requirements, the highest ranked choice for Aquitania was in-vessel composting.

Important challenges were identified, however, concerning the possible use of the soil amendment by local farmers. Currently, only 25 farmers among the 7 000 in the watershed are certified and committed to sustainable agricultural practices, and showed interest in it. Enhancing awareness among the local authorities and farmers is necessary to increase market demand. If this cannot be ensured, anaerobic digestion was the next best choice for OW treatment.

## Conclusion

SOWATT is a promising tool for evaluating organic waste treatment options if used as a first step. Including the local authorities in the decision-making process enhances their interest in OW management. Its main weakness is the lack of evidence regarding the performance and costs of the six different treatment technologies, as some are still in the early development phase. With more documented case studies, we will be able to better judge how the technologies perform and to make more reliable cost projections, furthering the improvement and reliability of the SOWATT model.

- [1] Páramo are "alpine tundra ecosystems".
- [2] Mertenat, A., Velasco, F.A., and Meulemans, J. (2015): Lake Tota Basin - Water, Managing the source of life. Report produced for Fundación Montecito.
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# The Potential of Slow Pyrolysis of Urban Biowaste in Tanzania

Tests with the new vertical slow pyrolysis reactor had promising results in regards to char quality and energy balance. A comprehensive local stakeholder assessment showed that although the technology attracts high interest, implementation requires overcoming major challenges. Imanol Zabaleta<sup>1</sup>, Manuel Rohr<sup>2</sup>, Christian Riu Lohri<sup>1</sup>, Fabia Zermin<sup>3</sup>, Chris Zurbrugg<sup>1</sup>

## Introduction

Sandec is partnering with the University of Dar es Salaam to analyse the potential of treating urban biowaste by slow pyrolysis to generate a marketable char product that could be used as cooking fuel. If successful, this treatment and valorisation process could help address the waste management and deforestation problems in Tanzania. In Dar es Salaam alone, it is estimated that about 4100 tons of waste are generated daily (roughly 60 % is biowaste) of which only 40 % is collected. Most of it is inadequately dumped [1]. Wood-based charcoal is the primary cooking fuel in Tanzania, and is used by over 90 % of the households. Its use has caused widespread deforestation in the country.

## Experimental set up

A small scale, semi-continuous slow pyrolysis reactor was designed and constructed at the University to test the effectiveness of this technology. It is comprised of a furnace, two oil-barrels and a chimney, stacked on top of each other (Figure 1). Each barrel has seven metal pipes, containing the feedstock, and the pipes are sealed at the top and have metal lids at the bottom. The furnace is fuelled by LPG (HHV=50 MJ/kg), heating the bottom barrel to achieve carbonisation. Pyrolysis gas exits the pipes, generating additional heat, and the excess heat from the bottom heats the upper barrel, drying the feedstock within it.



Figure 1: Prototype of the vertical reactor.

## First results

8 kg<sub>db</sub> of shredded cardboard waste were used for the first experiments. All resulting chars showed satisfactory high heating values (HHV) (21.6–24.3 MJ/kg<sub>db</sub>) similar to those of bituminous coal. The volatile solids (VS) content decreased from 79 %<sub>db</sub> (cardboard) to between 8.5–40 %<sub>db</sub> in the chars (lower values indicate a higher quality). The fixed carbon (FC) increased considerably from 8 %<sub>db</sub> (cardboard) to values around 50–57 %<sub>db</sub> in the chars, and the char yields ranged from 23–27 %<sub>db</sub>. Figure 2 presents the proximate analysis and HHVs observed in the best practice mode experiments. Three of these were conducted with only one barrel (Series 1) and two with two barrels (Series 2). Both series compared well with previous slow pyrolysis tests [2].

The trials with one barrel had a net positive energy balance (Figure 3). In the best case

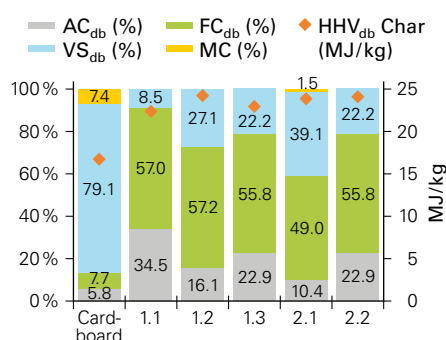


Figure 2: Proximate analysis and HHV of cardboard and obtained chars.

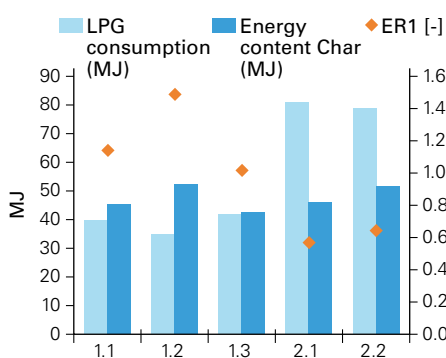


Figure 3: Energy balance per experiment.

(experiment 1.2), 0.67 MJ of LPG were needed to generate 1 MJ of char. The trials with two barrels had a negative energy balance. We assume this is because the double stacking of barrels increased the flow velocity of hot air, i.e. the chimney effect, rapidly removing the hot air from the system and diminishing the heating rate in the lower drum. Further research is underway to optimise this air flow and to evaluate the emissions of the slow carbonisation process.

## Assessment of local stakeholders

62 local stakeholders were identified who had connections to the charcoal business or the waste management and recycling sectors. Their potential to become future successful biowaste-to-char producers was evaluated using a set of criteria developed with local experts. The criteria included: access to biowaste, access to capital, access to space and available skill levels. Two stakeholders showed especially great potential: a waste collection enterprise currently servicing the city centre and a large recycling company that already processes different fractions of waste, but not yet biowaste. Interviews with the stakeholders revealed great interest in biowaste carbonisation among many of them, while also disclosing several bottlenecks needing to be addressed, i.e. limited market demand by households for char briquettes, limited access to space in the city for a scaled-up facility, and difficulties in accessing well sorted biowaste.

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# The Fate of Nitrogen and Phosphorous in Hydrothermal Carbonisation

Hydrothermal carbonisation of biowaste has two main outputs: hydrochar and process water. Fate analysis showed that most of the nitrogen is in the hydrochar, while the phosphorus is mainly in the process water. Amounts of both elements in the hydrochar were ready for plant uptake. Imanol Zabaleta<sup>1</sup>, Hala Jamhoury<sup>2</sup>, Chris Zurbrüggen<sup>1</sup>

## Introduction

Hydrothermal carbonisation (HTC) or wet pyrolysis, is gaining increased attention as a potentially sustainable biowaste treatment technology. End products from HTC treatment are hydrochar, a sterile and carbon-rich solid material, and process water (PW), an acidic liquid with dissolved organic compounds. The majority of HTC studies focus on energy recovery from hydrochar due to its high heating values, which range between 13.8 and 36 MJ/kg depending on feedstock and process conditions [1]. Other uses for hydrochar, i.e. soil conditioning and carbon storage, have also been suggested due to its carbon content and chemical and physical characteristics [2]. Process water is considered mainly as a waste product. It needs to be treated before discharge given its low pH and high COD values, similar to landfill leachate [1]. Although HTC treatment is known to preserve the nutrients contained in the original feedstocks [3], little is known about their fate. This research assessed the fate and plant-availability of nitrogen (N) and phosphorus (P) after HTC treatment of biowaste.

## Methodology

HTC experiments were conducted at different temperatures and with a total solid content (TS) of 25 %. The feedstock consisted of a mix of banana peels, potato, cabbage, rice and dried maize stem pellets, all mixed in water. Total nitrogen (TN) and total phosphorus (TP) were measured in the feedstock, hydro-

char and process water. To determine the plant-availability of N and P, Ammonium ( $\text{NH}_4^+$ ) and Nitrate ( $\text{NO}_3^-$ ) were measured in the hydrochar and the process water and water-dissolvable TP was measured in the hydrochar.

## Results

The feedstock's TN content was approximately 62 g for all experiments. Figure 1 shows the amounts (g) of N recovered in the hydrochar and process water. 65–68 % of the output TN was in the hydrochar, while 32–35 % was in the process water. 30–35 % of the total output-N was readily plant-available, most of it contained in the process water. On average, only 11 % and 1.3 % of the output-N in the hydrochar were plant-available, as  $\text{NO}_3^-$  and  $\text{NH}_4^+$ , respectively. The remaining 88 % was bound to the organic matrix as organic-N, most likely due to the relative low temperatures in the experiments which were not high enough to break down cellulose, hemicellulose and lignin [4]. As for the output-N in the process water, on average 28 % consisted of organic-N, while the plant-available fractions comprised most of the output-N, 70 % was  $\text{NO}_3^-$  and 1.6 %  $\text{NH}_4^+$ . The low amounts of  $\text{NH}_4^+$  were unexpected as the hydrolysis of the proteins at high temperatures should yield organic acids,  $\text{NH}_4^+$  and  $\text{CO}_2$  [5] and, therefore, result in higher  $\text{NH}_4^+$  concentrations. We assume that  $\text{NH}_4^+$  molecules reacted with the solid matrix during polymerization, or that they were precipitated as salts [3].

The feedstock's TP content was on average 9 g. Figure 2 shows the amounts (g) of P recovered in the hydrochar and process water. Around 70 % of the TP was in the process water for which a TP characterisation into organic-P and non-organic-P was not done. The hydrochar contained 30 % of the total output-P, from which 50–90 % consisted of plant-available P. This percentage decreased in higher temperature experiments (Figure 2).

## Conclusion

Nutrient analysis revealed that most N was in the form of organic-N and was contained in the hydrochar, whereas most P was measured in the process water. One third of the output-N and more than half of the P contained in the hydrochar were readily plant-available, indicating that the output materials from HTC have good short-term plant fertilising properties. Further research is needed to assess the long term release of the nutrients embedded in the organic matrix.

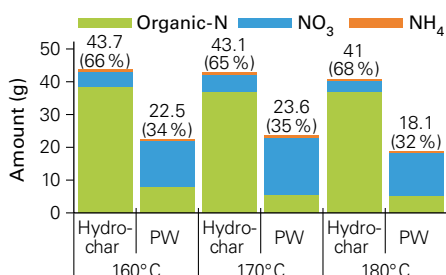


Figure 1: N amounts (g) & fractionation. Upper figure: absolute amount measured. In parentheses: % of total output-N contained in output materials.

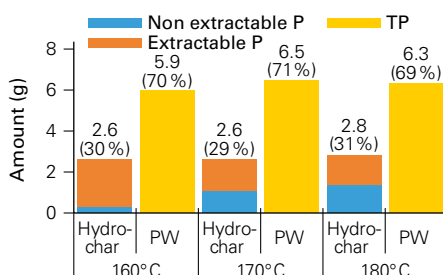


Figure 2: P amounts (g) & fractionation. Upper figure: absolute amount measured. In parentheses: % of total output-P contained in output materials.

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# Identification of Fodder Plants for Treatment with Planted Drying Beds

This study identified grass plants with market value in Senegal that had not previously been used for faecal sludge treatment in planted drying beds. It evaluated their potential to grow with faecal sludge effluent and their use as animal fodder. Amadou Gueye<sup>1,2</sup>, Mbaye Mbéguéré<sup>3</sup>, Cheikh Diop<sup>2</sup>, Seydou Niang<sup>4</sup>, Linda Strande<sup>1</sup>



Photo 1: Barrels used for planted drying bed trials (Cambérène Faecal Sludge and Wastewater Treatment Plant).

## Introduction

Planted drying beds (PDBs) are a promising technology for faecal sludge (FS) treatment and resource recovery in low-income countries. This technology generates stabilised sludge that can be used for agriculture, and plant biomass that can be used as animal fodder. However, the most commonly used plants (i.e. *Typha*, *Cyperus* and *Phragmites*) have limited economic benefit. To maximize the benefits of resource recovery, plants need to be identified that have greater market value and are adaptable to regional conditions [1].

## Methods

This study was conducted in Senegal in Dakar, St. Louis, Richard Toll, Dagana, and Tambacounda. Potential plants were identified and collected in natural wetlands and wetlands impacted by anthropogenic contaminants. Interviews were then done with vendors and urban livestock holders to collect data on their market value. The next step was a pot study at the Cambérène Faecal Sludge and Wastewater Treatment Plant in Dakar. The plants were irrigated with FS

to evaluate which of the collected species had potential for use in PDBs. Based on the following: ability to grow in FS effluent, market value, and not having previously been used for FS treatment in PDBs, three species of grass plants were selected for further treatment and resource recovery analysis: *Echinochloa crus-galli*, *Paspalidium geminatum* and *Paspalum vaginatum*.

These three species were grown in 200 L barrels filled with a 10 cm layer of coarse gravel, a 10 cm layer of fine gravel and a 15 cm layer of sand to replicate drying bed conditions, and with perforated PVC pipes at the bottom for drainage (Photo 1). During acclimatisation, the plants were irrigated with tap water and FS effluent. Following acclimatisation, the barrels were irrigated three times weekly at a loading rate of 200 kg TS/(m<sup>2</sup> yr) for three months. For each application, FS was loaded onto the barrels and the leachate was collected and analysed for TS, TSS, COD, TN, NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>, TP and PO<sub>4</sub><sup>3-</sup> as outlined in Standard Methods ([www.sandec.ch/fsm\\_tools](http://www.sandec.ch/fsm_tools)). After three months, a composite sample was taken to study above ground dried biomass and fodder quality, and total mineral (ash), protein, fibre, TP, and TKN concentrations.

## Results

All three species were effective for forage production and FS treatment in barrel trials. The concentrations of monitored pollutants (TS, TSS, COD, TN, NH<sub>4</sub><sup>+</sup>, TP and PO<sub>4</sub><sup>3-</sup>) in the leachate were ≥ 70 % lower than in the FS loaded. However, the leachate did not meet Senegalese standards for discharge, as seen in Table 1.

These results are similar to previous research with *Echinochloa pyramidalis* in PDBs for FS treatment in Senegal [2]. The concentrations of protein, mineral, nitrogen and phosphorus in the plant leaves were similar among all treatments, and were two to three times higher than those reported for grasses grown in natural areas. All plants met the recommended nutritional requirements of livestock and were well below toxicity levels.

## Conclusion

The results indicate that the indigenous fodder plants, *E. crus-galli*, *P. geminatum* and *P. vaginatum*, could be up-scaled for FS treatment in PDBs including forage production. Although the leachate does not meet Senegalese standards and requires further treatment before discharge, this can be achieved with an additional series of PDBs [3]. The fodder produced from PDBs can generate revenue to help offset treatment costs.

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Pollutant Discharge Standards	Leachate Concentrations: <i>E. crus-galli</i>	Leachate Concentrations: <i>P. geminatum</i>	Leachate Concentrations: <i>P. vaginatum</i>
100–200 mg/L for COD	264 ± 214 mg/L (COD)	232 ± 149 mg/L (COD)	317 ± 257 mg/L (COD)
30 mg/L for total nitrogen (TN)	159 ± 78 mg/L (TN)	169 ± 85 mg/L (TN)	197 ± 99 mg/L (TN)
10 mg/L for total phosphorus (TP)	38 ± 19 mg/L (TP)	36 ± 20 mg/L (TP)	46 ± 25 mg/L (TP)

Table 1: Senegalese Pollutant Discharge Standards (NS 05-06) and Leachate Concentrations.

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This research was supported by the Volkswagen Foundation, the Swiss Agency for Development and Cooperation, the Eawag Partnership Program, the USAID/ERA Local Scholarship Program of Excellence Fellowship and the International Foundation for Science grant No W/5705-1.

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# Energy Recovery with Faecal Sludge Fuels in Kampala, Uganda

Fuels from dried faecal sludge could generate larger revenues than soil conditioner. Market demand exists for crushed fuel and char briquettes; fuel pellets provide benefits for faecal sludge drying. M. Gold<sup>1</sup>, D. Turyasiima<sup>2</sup>, M. Cunningham<sup>1</sup>, F. Studer<sup>3</sup>, S. Tukahirwa<sup>4</sup>, S. Nantambi<sup>4</sup>, R. Arnheiter<sup>5</sup>, M. Bleuler<sup>5</sup>, W. Getkate<sup>4</sup>, A. Schönborn<sup>5</sup>, Ch. Niwagaba<sup>2</sup>, M. Babu<sup>6</sup>, Ch. Kanyesigye<sup>6</sup>, L. Strande<sup>1</sup>

## Introduction

Faecal sludge (FS) treatment and its sustainable operation is often limited by available financial resources. Yet, the sale of FS treatment endproducts could offset these costs. With sufficient market demand, fuels and other treatment endproducts could generate revenue to pay for FS treatment [1, 2].

## Pellets

Our research shows that dewatered FS can be turned into fuel pellets (Photo 1), which are homogenous in size and easy to transport, store and dry (see [www.sandec.ch/seek](http://www.sandec.ch/seek)). Passive drying of FS pellets from a moisture content of 40–60 % to 10 % required one week, much faster than the time required on drying beds. There is, however, no existing market currently for this product, but the potential to develop such a market in Uganda and elsewhere exists.

## Char briquettes

FS char briquettes are made through carbonisation and briquetting with a binder. They can be produced with locally available equipment and skills, and look like other briquettes. CNN and the Daily Monitor recently reported that several businesses in Kampala are trying to tap into the existing charcoal market with FS briquettes and that FS briquettes could significantly reduce deforestation [3, 4]. The latter, however, is disputable. If all faeces produced in Kampala were used

for carbonisation, this would only offset around 2 % of the current charcoal consumption.

FS char also has several disadvantages, i.e. a high ash and low energy content. Char from dried FS from drying beds had an ash content as high as 70 % and a calorific value of 7 MJ/kg, while charcoal is less than 5 % ash and has 22–30 MJ/kg. However, FS briquettes made from material that comes from source separation toilets could be more suitable as they would have a lower ash content. And high ash briquettes can still be used by industries with less sensitive fuel quality needs, unlike households, although the emissions would have to be controlled to provide environmental benefits. Ongoing research is evaluating the fuel performance of FS briquettes compared to wood based charcoal and briquettes produced from agricultural waste, as well as the optimal operating conditions for FS pyrolysis.

## Crushed fuel

Dried FS can be crushed and used as a fuel without pelletising, carbonisation or briquetting; this has been demonstrated in pilot-scale experiments and industrial trials [2]. The advantages of crushed FS include an existing market and competitive energy content compared to solid biofuels [5]. Cement and clay companies in Uganda are interested in using dried FS as a crushed fuel, especially since it is compatible with their combustion technology and currently used fuels. The

disadvantage is, however, that FS treatment capacities cannot yet meet industry demand (i.e. several tons per day).

## Conclusion

Pilot tests by researchers and businesses have demonstrated that FS fuel pellets, briquettes and crushed fuel have a market and/or are technically feasible. Up-scaling is also possible if local FS characteristics (e.g. ash content) and quantities (i.e. amount of fuel produced per day) match market needs. Meeting market demand could benefit FS management because the revenue generated from the sale of FS endproducts could offset treatment costs.

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Photo 1: Pellets (top), briquettes (bottom) and crushed fuel produced from FS (right).

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This research is funded by the Symphysis Foundation, REPIC (Renewable Energy & Energy Efficiency Promotion in International Cooperation) and the Swiss Development Corporation.

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# Working Towards Improved Faecal Sludge Dewatering

As faecal sludge is comprised mainly of water, dewatering is one of the most important treatment processes. In collaboration with its research partners, Sandec is working on increasing the understanding of the dewatering process and developing appropriate solutions. Moritz Gold<sup>1</sup>, Hidenori Harada<sup>2</sup>, Richard Kimwaga<sup>3</sup>, Charles Niwagaba<sup>4</sup>, Linda Strande<sup>1</sup>

## Introduction

Commonly, over 95 % of the faecal sludge collected by vacuum trucks is composed of water. Consequently, a truck with a capacity of 6000 litres transports 5700 kg of water and only 300 kg of solids. Improvements in dewatering could reduce faecal sludge management costs by:

- Reducing faecal sludge transport costs, e.g. through decentralized dewatering.
- Reducing treatment footprints by increasing treatment efficiency, e.g. use of conditioners to increase dewaterability.
- Increasing the resource recovery value of effluent and solids, e.g. producing faecal sludge that is 90 % dry, which can be used to generate energy.

This article gives an update on Sandec's research on the faecal sludge dewatering process and the development of efficient faecal sludge dewatering solutions for low- and middle-income countries.

## Dewatering process

Dewatering properties, and hence the effectiveness of dewatering technologies and conditioners, vary between different sludge types. Among other factors, this is due to the different degrees of stabilisation and concentrations of total volatile solids, dissolved solids, sand, surface charge, particle size and protein content. Comprehensive research has been conducted on wastewater sludge dewatering, but is lacking for faecal sludge. Also, in urban areas, faecal sludge is normally collected from different onsite sanitation technologies, with different designs and operation and maintenance, causing a large variability in faecal sludge characteristics and dewaterability. To address this, we analysed more than 70 faecal sludge samples from different onsite sanitation technologies in Uganda, Vietnam and Japan for their dewatering and physical and biochemical properties. These are being compared with 18 wastewater sludge samples from Switzerland and values from a literature review.

Preliminary analysis shows that dewatering and the parameters influencing faecal

sludge dewatering, for example, surface charge, which is a proxy for conditioner demand, vary between faecal sludge and wastewater sludge. The drivers for this variability are currently being analysed. This data is expected to inform how dewatering can be improved, for example, by operating onsite sanitation technologies differently or by pre-treatment, and to show whether wastewater sludge results are transferable to faecal sludge.

## Geotubes

Apart from drying beds, geotubes, which are made from engineered geotextiles, are potentially an interesting technology for faecal sludge dewatering. In contrast to mechanical dewatering technologies (e.g. filter press or screw press), this technology does not rely on electricity or difficult to obtain parts for maintenance. Also, geotubes are already widely used for wastewater sludge dewatering, yet rarely in faecal sludge treatment. Solids in the sludge are contained in the geotube, while the free water drains out through the geotextile. Once the geotube is completely filled with solids, it is cut open so that they can be removed and used for resource recovery, and the geotextile is then disposed of. In Kampala, Uganda, faecal sludge dewatering with geotubes is being investigated in laboratory and pilot scale experiments. Performance metrics, such as total suspended solid concentrations in the effluent, filtration rates and other factors, are being analysed. This study will also assess faecal sludge dewatering costs with geotubes, alternative geotextile materials, and reuse and disposal options for geotubes.

## Locally produced conditioners

Worldwide, dewatering technologies are usually combined with conditioners to increase their performance and reduce treatment plant footprints. Chitosan has been identified as an effective conditioner for faecal sludge and has the potential to be produced locally from shrimp waste [1]. However, chitosan has only been researched in



Photo 1: Faecal sludge dewatering research facility at the University of Dar es Salaam in Tanzania.

laboratory and bench-scale experiments with faecal sludge from septic tanks. In Kampala, Uganda, and Dar es Salaam, Tanzania, faecal sludge conditioning with chitosan is currently being evaluated with different types of faecal sludge, pilot-scale drying beds and geotubes (Photo 1). Along with optimal dosages, this research will also evaluate optimal operation (i.e. mixing time and speed, dosing location, etc.); this is required prior to full-scale implementation of chitosan as a faecal sludge conditioner.

## Conclusion

The goal of our research in this area is to produce results that provide solutions and can be implemented at full-scale, thereby, improving faecal sludge dewatering. Stay tuned for further results at [www.sandec.ch/fsm\\_tools](http://www.sandec.ch/fsm_tools).

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<sup>3</sup> University of Dar es Salaam, Tanzania

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# Engineering Approach for Selection and Design of Treatment Technologies

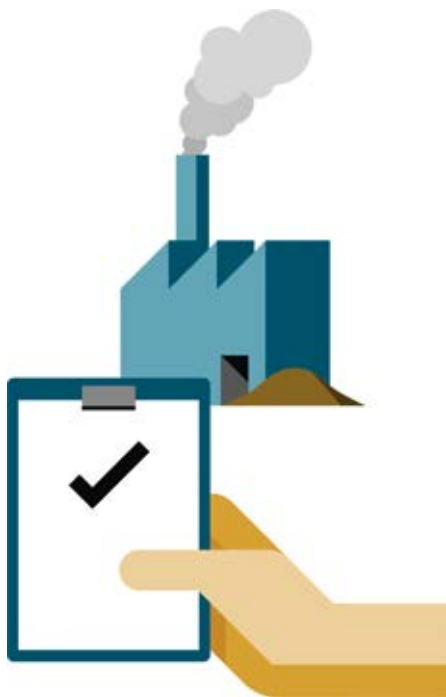
Faecal Sludge Management (FSM) is a relatively new and rapidly growing field. There is a great need in FSM for practical and reliable approaches that allow engineers to select and design appropriate treatment technologies.

Presented here is how our research addresses these gaps. Linda Strande<sup>1</sup>, Moritz Gold<sup>1</sup>, Lars Schoebitz<sup>1</sup>, Magalie Bassan<sup>1</sup>



Figure 1. Schematic of Engineering Design Approach, including: 1) Treatment Objectives and Resource Recovery; 2) Faecal Sludge Quantification and Characterization; and 3) Treatment Technologies for Resource Recovery. (© Sandec)

## Treatment Objectives and Resource Recovery



The definition of engineering design is the formulation of a plan that allows an engineer to build a product with a specified performance goal. Unfortunately, perfor-

mance goals and the specific local context are all too commonly ignored in low-income countries when designing treatment technologies. Designing such technologies for resource recovery in low-income countries can provide a method to define the performance goals which need to be met, while at the same time increasing financial flows to offset treatment costs, and providing an incentive for the efficient operation of treatment plants. Designing for the specific enduse is critical, as under-designing treatment technologies do not provide adequate protection of human and environmental health, and over-designing wastes money and resources.

Depending on the form of resource recovery, the defined performance goals are quite different. For example, pathogen reduction in faecal sludge (FS) is not as important for its combustion as a fuel, whereas it is of utmost importance for FS use as a soil amendment with edible crops. The Market Driven Approach methodology was developed jointly between engineers and experts in economics and business development to assist in the identification of FS treatment endproducts that are appropriate for local

contexts and have the largest market potential for volume and growth.

Our recent publications in this area are:

- Report: Market Driven Approach: Tool to aid in selecting treatment endproducts (2016)
- Paper: Market based selection of faecal sludge resource recovery: Field results from Uganda, Senegal and Vietnam (in preparation)
- Paper: A value proposition: resource recovery from faecal sludge – Can it be the driver for improved sanitation? (2014)

## Faecal Sludge Quantification and Characterisation



Prior to the design of full-scale treatment plants, engineers first need to know the quantities and characteristics of the FS that will be treated. However, no reliable methods currently exist to determine the quantities and characteristics of FS on this scale. Reliable estimations are quite complicated due to the informal nature of FSM, and the high variability of FS characteristics. Research on understanding what will be delivered at treatment plants includes: identifying reliable predictors of FS characteristics, GIS analysis of collection and transport trucks, and reliable and reproducible standard methods for laboratory analyses.

Our recent publications in this area are:

- Paper: City wide characterization of faecal sludge in Hanoi: Influence of local factors (submitted)
- Paper: Reliable estimators for faecal sludge characterization on a city-wide scale: Towards developing methodologies (submitted)
- Paper: GIS tools for optimization of faecal sludge collection and transport at city-wide scale (submitted)
- Report: Results of faecal sludge analyses Kampala, Uganda: Pictures, characteristics and qualitative observations for 76 samples (2016)
- Report: Laboratory methods for the analysis of faecal sludge: 1. Vietnam (2016)
- Report: Laboratory methods for the analysis of faecal sludge (2016)
- Paper: FAQ: Faecal Sludge Quantification and Characterization – Field trial of methodology in Hanoi, Vietnam (2014)
- Paper: Characterization of Faecal Sludge in Dry and Rainy Seasons, Ouagadougou, Burkina Faso (2013)

## Treatment Technologies for Resource Recovery



After the definition of performance goals and deriving estimations of FS quantities and characteristics, then treatment technologies can be designed. Because available space in urban areas is very limited, and most current FS treatment technologies are space intensive, our research in this area focuses on how to increase the treatment capacity of existing technologies. This can increase the amount of sludge treated, and/or reduce the required footprint of treatment plants, in addition to optimising technical aspects of resource recovery.

One of the most important treatment objectives in FSM is dewatering. FS is mainly comprised of water, and water is heavy and expensive to transport. Discharging polluted water into the environment also has significant negative impacts. Dewatering FS is required prior to its being used in resource recovery applications, such as composting or combustion as a fuel.

Our recent publications in this area are:

- Paper: Faecal sludge as fuel for brick production and oil regeneration in Sub-Saharan Africa (2016)
- Paper: Locally produced natural conditioners for dewatering of faecal sludge (2016)
- Paper: Identification of novel plant species for faecal sludge treatment and forage production in planted drying beds (2016)
- Paper: Technology development of unplanted drying beds for resource recovery from faecal sludge: Fuel production in Sub-Saharan Africa (2015)
- Paper: Fuel Potential of Faecal Sludge: Calorific Value Results from Uganda, Ghana, and Senegal (2014)
- Paper: Effect of hydraulic loading frequency on performance of planted drying beds for the treatment of faecal sludge (2014)
- Paper: Performance of Vertical Flow Constructed Wetlands for Faecal Sludge Drying Bed Leachate: Effect of Hydraulic Loading (2014)
- Paper: Results from FaME (Faecal Management Enterprises) – Can dried faecal sludge fuel the sanitation service chain? (2014)

## Sustainable Implementation



Most importantly, one must keep in mind that the engineering design of treatment technologies is only one aspect of sustainable FSM! This also must include integrated planning and management schemes. For more information, please refer to the book, *Faecal Sludge Management: Sys-*

*tems Approach to Implementation and Operation*, which is available for no charge along with all our other publications at [www.sandec.ch/fsm\\_tools](http://www.sandec.ch/fsm_tools).

Our recent publications in this area are:

- Paper: Success and failure assessment methodology for wastewater and faecal sludge treatment projects in low-income countries (2015)
- Paper: Looking beyond technology to provide adequate and sustainable sanitation in low income countries (2014)
- Paper: Integrated faecal sludge management scheme for the cities of Burkina Faso (2013)
- Paper: Technologies for sanitation: how to determine appropriate sludge treatment strategies in Vietnam (2014)
- Paper: Capital and Operating Costs of Full-Scale Faecal Sludge Management and Wastewater Treatment Systems in Dakar, Senegal (2012)
- Report: Capacity strengthening in sanitation: benefits of a research - operator collaboration (2011)

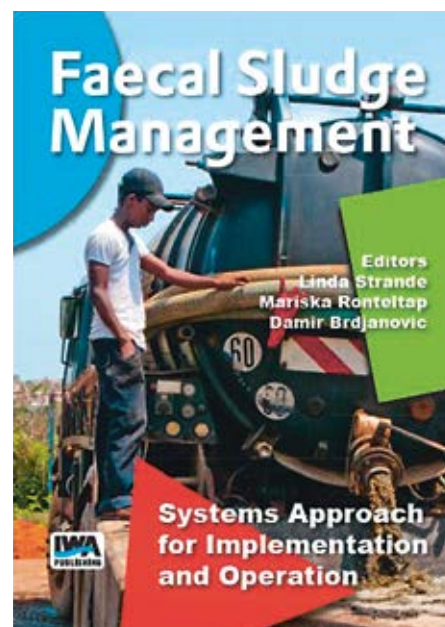


Figure 1. Faecal Sludge Management: Systems Approach for Implementation and Operation.

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# Illustrating the Fate of Excreta: The SFD Methodology in Eight Cities

The Shit-Flow-Diagram (SFD) Promotion Initiative has developed a methodology and tools to estimate excreta flows on a city-wide scale, in a way that ensures credible and transparent results. Shit-Flow-Diagrams are designed to present complex information in an easy to understand fashion. Lars Schoebitz<sup>1</sup>, Linda Strande<sup>1</sup>

## Introduction

Appropriate urban sanitation planning, that includes a design approach for adequate wastewater and faecal sludge treatment infrastructure, is a key element to protect public and environmental health (see Strande et al., pp. 12–13). This incorporates the assessment of excreta flows that need to be managed, which is quite challenging. Unlike estimating wastewater on a city-wide scale for which reliable methods exist, a reliable method to calculate quantities of produced and accumulated faecal sludge is still lacking.

## Background

In their work on comprehensive service delivery assessments (SDAs), Peal et al. developed an approach to estimate wastewater and faecal sludge quantities [1]. This resulted in the first generation of Shit-Flow-Diagrams (SFDs), which represent one element of a SDA. The SDA is used to assess overall faecal sludge management from containment to emptying, transport, treatment and disposal and/or end-use [2]. The authors highlight the challenges in producing SFDs that are comparable among cities and also identified the need to develop a common approach that can be implemented worldwide.

## SFD Promotion Initiative

The SFD Promotion Initiative is a collaborative research project established to address the above challenges by developing a methodology and tools for the production of credible SFDs. Figure 1 presents the institutions involved in the project.

Over the last year, field- and desk-based methodologies were implemented in several cities in a variety of global regions (for more information, refer to the project website). The outputs include a detailed report with a four-page executive summary and a SFD for each city. Also, the reports contain a detailed description of the steps taken to produce the SFD, including all calculations, data sources and assumptions that were made. In addition, there is a service delivery context description or analysis, depending on the level of data collection.

The four-page executive summaries, including the SFDs, provide a highly powerful communication and advocacy tool when discussing excreta management among representative stakeholders. Presented here are highlights of the results and lessons learned by Eawag/Sandec while implementing the SFD methodology in eight cities.

## Learning from experience

### Desk- and field-based assessment

Figure 2 shows the eight cities where the methodology was implemented by Eawag/Sandec. Field-based SFDs were conducted in Dar es Salaam and Khulna, supported by research assistants and local partners. For these, the project team emphasised the engagement of local stakeholders, such as ministries, city authorities, and water and sanitation utilities, to start dialogues about excreta management, receive confirmation of obtained results and to create a sense of ownership. This included key informant interviews, focus group discussions and field observations.

In the other cities, a desk-based methodology was implemented. Both methods rely almost entirely on secondary data; however, the engagement with local stakeholders that was part of the field-based approach provided a highly valuable, detailed understanding about the city context that was also useful for the triangulation of data. The use of the SFD as an advocacy and communication tool began with this field-based stakeholder engagement. Doing this increases the potential that the results would be used in the planning of future infrastructure and legal frameworks to improve sanitation service delivery. In contrast, it was found that desk-based SFDs were more difficult to produce, as access to local stakeholders only through email and phone calls could not replace the personal interactions and observations that result from the field-based approach.

### SFD approach

The SFD method is a way to estimate percentages of people that have access to sanitation service delivery at each stage of the sanitation service chain, for example, offsite (sewer) or onsite (faecal sludge) sanitation, and to faecal sludge emptying, transport and treatment. Starting with containment, the SFD method evaluates whether faecal sludge is contained or not contained, based on the potential risk of groundwater pollution. This is estimated

SFD Promotion Initiative



Figure 1: Institutions involved in the SFD Promotion Initiative.



by analysing soil conditions, source of drinking water, and level of drinking water treatment. The type of containment technology used influences whether excreta are categorised as contained or not contained.

For example, if the containment is fully lined (watertight) without an overflow, it is considered safe regardless of groundwater conditions. A pit latrine with lined walls, but with an open bottom, is only considered safe if the risk of groundwater pollution is low. These distinctions highlight the importance of field observations, as such detailed technical information about containment technologies is rarely available from secondary data.

This process continues through the sanitation service chain. Following containment analysis, the percentage of people with emptying services is estimated. Then, the percentage of faecal sludge that is actually delivered to treatment is calculated followed by estimations of the percentage of faecal sludge and wastewater that are adequately treated. Each step requires innovation on the part of the implementer to calculate reasonable estimates.

## Results and discussion

The eight cities in Figure 2 have populations ranging from 45 000 to 5 000 000, and have a wide variety of sanitation technologies in place. Because the cities are very different, this enabled evaluation of the applicability of the SFD method in different contexts. Figure 2 provides a summary of safely and unsafely managed excreta for all eight cities, including population numbers and fraction of onsite and offsite sanitation. Details regarding containment, emptying, transport and treatment can be found in the executive summaries and reports accessible on the project website. In six of the cities, more than 90 % of the population relied on onsite sanitation. Durban had the highest access to sewer-based sanitation, with 56 % of the population connected. Excreta in Nonthaburi and Durban are more than 70 % safely managed, while in Hanoi and Khulna more than 80 % are not safely managed.

An important outcome of making a SFD is the ability to identify areas for priority intervention along the sanitation service chain. For example, if a high percentage of faecal sludge is not contained, this indicates a significant risk of groundwater pollution and, therefore, a significant risk to public health. This situation is particularly evident in Khulna, but also in Dar es



Figure 2: Summary of safely and unsafely managed excreta in eight cities.

Salaam and Kampala, where slums are in areas with high groundwater and permeable containment technologies. In these situations, improvements to the containment infrastructure are required. However, in cities with a low risk of groundwater pollution, according to the SFD methodology, faecal sludge is considered contained and, therefore, safely managed even if not emptied. This situation exists in rural areas of Durban, where urine diverting dry toilets are used and provide an appropriate sanitation solution, and can also be found in medium- and high-income areas of Dar es Salaam and Kampala.

Results of the SFDs also illustrate the importance of faecal sludge treatment infrastructure and the role of the private sector in the emptying, collection and transport of faecal sludge. For example, in Hanoi and Nonthaburi, there is wide access to faecal sludge emptying services through the private sector. But, in Hanoi, there is no legal discharge location for the private service providers; the only option for them is, therefore, to dump the collected sludge directly into the urban environment. In Dar es Salaam, treatment plants exist, but it was still estimated that 56 % of the emptied faecal sludge is not delivered to treatment. The pervasive dumping of faecal sludge in the environment has obvious public health implications that will not be resolved without adequate treatment infrastructure.

## Outlook

Now that a SFD methodology has been developed, in the coming year the SFD Promotion Initiative will start a help-desk to provide support for people implementing the method on their own. Quality assurance and control measures will be further developed to enable a consistent

review process. Work will also be done to further improve the method to increase the accuracy of results, for example, to be able to more precisely estimate the flows of treated or untreated faecal sludge and wastewater than is currently possible. With increasing experience and results, the methodology will continue to improve and become a standardised tool that can be used globally to produce credible representations of unsafely managed excreta on a city-wide scale. Other possible future adaptations include analysis at a neighbourhood scale for priority interventions, or at a national scale for the monitoring of development goals.

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<sup>1</sup> Eawag/Sandec, Switzerland

SFD Project website:  
[www.sfd.susana.org](http://www.sfd.susana.org)

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# What Role Should Small-Scale Sanitation Systems Play in South Asia?

Sandec is doing the first systematic assessment of small-scale sanitation systems in South Asia with IIT Madras, BORDA, CDD Society, NMBU and ENPHO. The goal is to develop evidence-based policy recommendations for improved system design, implementation, operation and management. Rohit Chandragiri<sup>1</sup>, Lukas Ulrich<sup>1</sup>



Photo 1: Small wastewater treatment plant for office buildings in Chennai, India.

Ever growing South Asian cities need huge financial resources to construct and operate wastewater infrastructure. Achieving the ambitious Sustainable Development Goal 6.3 target (halving the proportion of untreated wastewater by 2030) requires making well-thought-out investments with these resources. Since decentralised wastewater treatment approaches have proven to be a valid alternative to conventional large-scale treatment plants, small-scale sanitation systems are gaining more attention, particularly in South-Asia.

A few Indian cities have mandated the installation of small-scale sanitation systems for newly constructed buildings. Bengaluru, Karnataka's capital, is among them. In 2006, the Karnataka State Pollution Control Board adopted a policy requiring residential establishments of more than 20 000 m<sup>2</sup> within sewerage areas, and 5 000 m<sup>2</sup> or 50 apartment units outside sewerage areas, to install a treatment plant with zero discharge of treated wastewater. Commercial establishments larger than 2 000 m<sup>2</sup> (outside sewerage areas) must also have an on-site treatment plant [1]. There are now more than 4 300 small-scale systems, which currently treat 10 % of the city's wastewater [1]. The authors estimate that there are more than 20 000 decentralised sanitation systems in South-Asia, the majority in India. Though the number of documented installations in Nepal (50–60) and Pakistan (25+)

are small, they are likely to increase. Interestingly, very few installations have been recorded in Bangladesh, despite 99 % of its population now having access to toilets [2].

## Scale up small-scale sanitation systems?

Where connections to centralised systems are not realistic, increasing numbers of small treatment units are being installed. Yet, authorities in places with many units struggle to maintain up-to-date databases and to monitor their performance. Scaling-up small-scale sanitation entails more than replicating a large number of discrete projects. It requires standardisation, innovative management and institutional schemes, the private sector and innovative financing [3]. It can be promoted through: a) national and state-level strategies and policies; b) systematic implementation where appropriate and sustainable, using suitable financing mechanisms; c) development of adequate training and university curricula to foster engineering and management know-how; and d) establishment and institutionalisation of corresponding maintenance, monitoring and management structures and capacities.

## The need for research

To go to scale, the "How" first has to be understood. To date, there have been many studies on small-scale treatment systems in South Asia and findings reveal that a majority of existing systems – whatever technology is used – are underperforming. This is mainly due to inadequate operation, maintenance, monitoring and funding [4, 5, 6]. Technology and design are most often not the source of the problem, but are determinants of operating costs.

While previous research has contributed important insight into sustainable system design, the question posed in this article has not yet been fully answered. The goal of the BMGF-funded 4S project (Small-Scale Sanitation Scaling-Up) is to advance small-scale sanitation by understanding the multi-faceted dynamics of existing decentralised approaches and enabling contexts. Analysing

technical aspects, financial mechanisms, institutional setups and management gaps will reveal what factors impact the success and sustainability of small-scale sanitation approaches. A Life Cycle Assessment will also enhance our knowledge of the environmental friendliness of different technologies and scales of application, and assist decision-makers when they consider issues in system design, such as climate change. 4S will develop recommendations on how small-scale sanitation can be designed and managed to ensure that future up-scaling of wastewater infrastructure in South Asia is possible and sustainable.

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This research project is funded by the Bill & Melinda Gates Foundation.

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# Genderised WASH in Ugandan and Indian Public Health Care Facilities

This article highlights the second phase of the two year interdisciplinary G-WASH research project [1]. G-WASH combines social anthropology, gender studies and sanitary engineering to research different users' needs about WASH infrastructure in health care facilities. Petra Kohler<sup>1</sup>, Samuel Renggli<sup>1</sup>, Christoph Lüthi<sup>1</sup>

## Introduction

Water, sanitation and hygiene (WASH) in health care facilities in developing countries often fail to provide user friendly and gender sensitive services, putting the most vulnerable user groups (e.g. pregnant women, small children and disabled persons) at risk. In addition to health issues, women are confronted by social norms, which often hinder proper hygienic habits during menstruation, affecting their health and challenging their dignity. Through the application of our assessment tools, our research is providing data on the sanitary requirements of health care facilities to address the gendered realities of intimate needs in the face of inadequate or poorly designed infrastructure.

## Research interests and methodological procedure

In order to respond to the shortcomings of existing WASH facilities in public health centres and the needs of specific user groups, G-WASH is assessing the sanitary infrastructure of four selected public health centres in India and Uganda. A District and a Sub-District

health care facility are being investigated in both countries. These facilities offer various health care services and face similar recurring challenges: underfunding, understaffing and the lack of basic infrastructure. A quantitative assessment of the four sanitary infrastructures was done with a tool that was adapted and refined by Eawag/Sandec. This assessment tool includes specific gender indicators and is one of the project outcomes. It will be further developed into an Open Data Kit based tool (for mobile phone applications) that can be used to evaluate and monitor WASH services in health care facilities worldwide.

The specific needs and priorities of the different user groups, patients, attendants and staff members were explored using a modified, gender sensitive focus group discussion tool, "Gender Action Learning System" (GALS), that was modified for this project [2, 3, 4] (Photo1). GALS facilitates the collection of sex-disaggregated data, mixed plenary discussions and the identification of sensitive topics (e.g. defecation and menstrual hygiene management concerns). It

also promotes the active expression of the viewpoints of all participants, leading to social exchange and mutual learning among them. Health centre staff, facility managers and key stakeholders were also interviewed using a semi-structured interview technique. Analysis and interpretation of the qualitative data is being done with Atlas.ti software and is ongoing.

## Conclusion

The overall data from the three different assessment tools will give evidence of needs-based, gender sensitive, technically appropriate and socially acceptable solutions to the problems identified at the health care facilities. The results will be shared with the corresponding stakeholders from the medical departments, management and health authorities. An academic article and a policy brief are currently in production as further project outcomes.

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Photo 1: Gender Action Learning System (GALS) exercise with its two core elements: Gender Diamond (left) and Action Trees (right) in India.

<sup>1</sup> Eawag/Sandec, Switzerland

Partners: Makerere University and Sustainable Sanitation and Water Renewal Systems, Uganda, and Tata Institute of Social Sciences, India

Further research affiliates are the Interdisciplinary Centre for Gender Studies and the Institute of Social Anthropology, both at the University of Bern.

This research project is funded by the Swiss Network for International Studies (SNIS), Geneva.

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# Research to Policy: The Five Year Experience of the Egypt ESRISS Project

From 2010 to 2015, the SECO-funded ESRISS project researched scaling up small-scale sanitation systems in unserved settlements in the Nile Delta, together with the Egyptian wastewater utility. The project's policy recommendations were shared with Egypt's decision-makers [1]. Philippe Reymond<sup>1</sup>, Rifaat Abdel Wahaab<sup>2</sup>, Moustafa Moussa<sup>3</sup>

## Introduction

Rural sanitation in Egypt encompasses around 4 700 villages and 30 000 scattered settlements. More than 85 % of the wastewater management in rural areas is informally managed, either via onsite systems with emptying by trucks or through sewer networks built by communities. In official terms, rural sanitation coverage is less than 15 %. The majority of the rural population lacks proper sanitation services and/or clean irrigation water for their fields. This situation also means high operational costs for poor service (up to 20 times higher than for urban dwellers [2, 3]), only to remove the wastewater without treatment. Regaining control of the situation, which represents a substantial health and development threat, is a challenge. However, international experience has shown that policies that combine incremental implementation of standards with innovative management schemes can be successful and lead to cost-effective solutions [4].

## Large versus small

If large-scale centralised systems remain the first option for most of Egypt, it is clear that many small settlements will be left out for decades to come, mainly because it is not possible to cost-effectively connect them to such systems. Thus, it is important to develop alternative decentralised small-scale systems that can effectively treat the wastewater at settlement level and minimise the costs of sewer networks. Analysis of past small-scale sanitation initiatives in Egypt shows that the lack of an enabling environment prevented the institutionalisation and replication of any implementations [5, 6]. In particular, the lack of specific effluent standards for small-scale wastewater treatment plants in rural areas, as is the case in Europe, for example, is a major barrier to the development of pragmatic solutions. The lack of constructive collaboration between government Ministries, especially those dealing with wastewater, irrigation and health, is also a major issue.

## Economies of scale

Small-scale compact sanitation systems are successfully run in Egypt's numerous tourist resorts. How can this model be transposed to rural settlements? The first step is to think in terms of economies of

scale, both at the implementation and management level. One has to go beyond the trial of isolated pilots because these remain prototypes and, as such, are not cost-effective or sustainable, do not receive the attention required, and are often

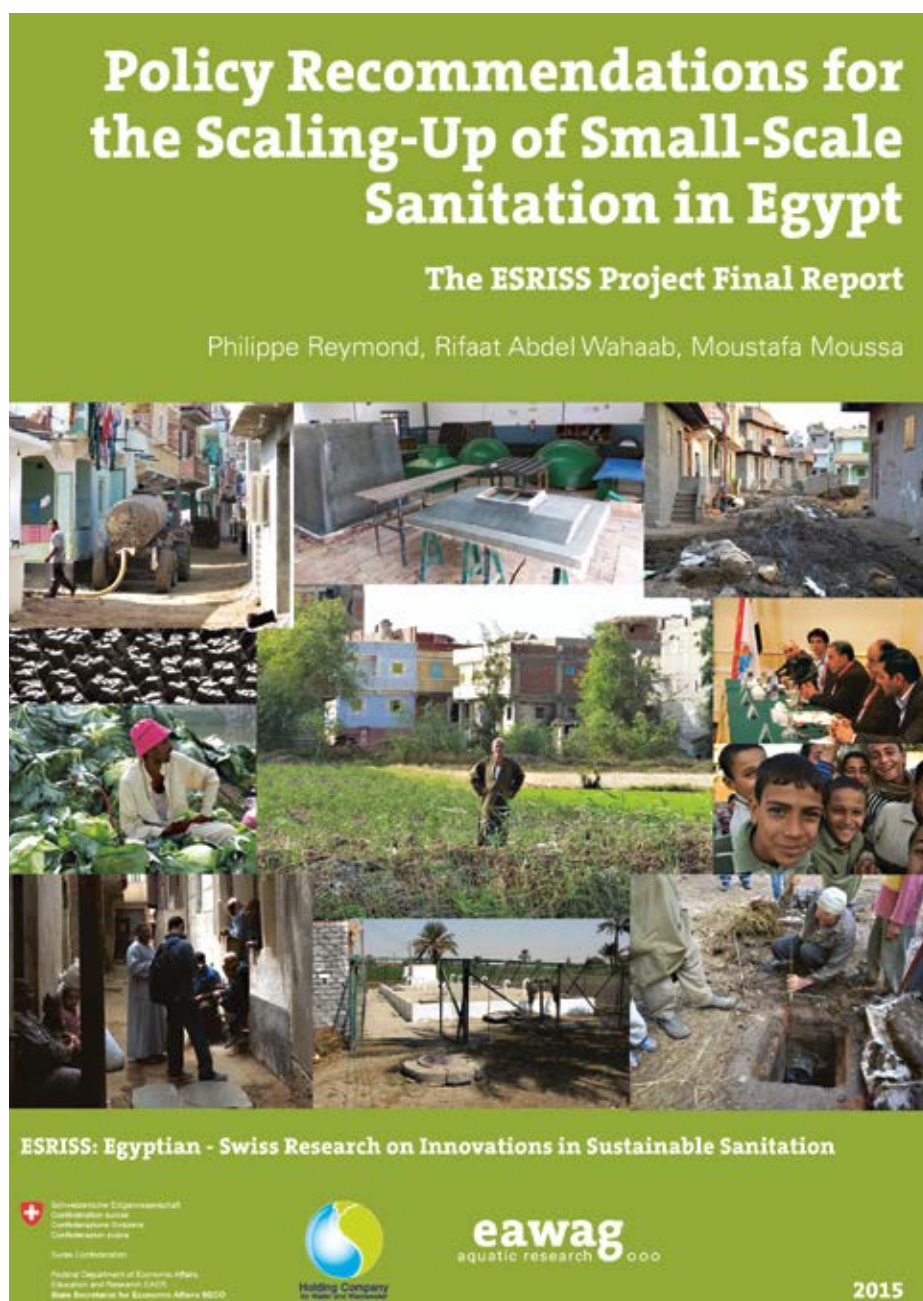


Figure 1: Policy Recommendations for the Scaling-Up of Small-Scale Sanitation in Egypt.

too expensive and/or prone to failure. For all of these reasons, they are not replicated. It is necessary to start with a critical mass of projects from the beginning as this allows for economies of scale and would involve the private sector.

Economies of scale at the implementation level can be achieved through standardisation of the sanitation systems. A limited number of simple and robust treatment systems should be selected and implemented. Different components of the sanitation chain could be prefabricated, which lowers costs, improves quality control and significantly reduces implementation time. To further increase cost-effectiveness, a modular and incremental implementation approach is recommended, with a planning horizon that does not go beyond 10 to 15 years for the treatment units.

Economies of scale at the management level imply the centralised management of decentralised systems. Yet, there is no need for permanent staff at small-scale treatment plants. Instead, a dedicated structure should be created with specifically trained professionals. This would provide the trained staff necessary for proper management and reduce the human resource management bottleneck of "overstaffing with under skilled people". Management units would have the task to monitor the planning, implementation and operation of the systems in the villages, while management of the sewerage networks could be delegated to the communities. Activities, such as effluent quality monitoring and troubleshooting, could be centrally managed.

### Opening a new market

Adapted business models and proper incentives should be developed, building on the experience in the tourist resorts. Incentives to engage in rural sanitation should include a guarantee from the State for cost recovery, licenses and certification. In addition, design-build-operate mechanisms should be encouraged and local engineers and masons at the governorate-level should be trained. Two scenarios could be foreseen: (1) an incremental approach that starts at the local level in a defined area (strategic niche management) or (2) direct implementation as a national strategy.

There are specific challenges to the implementation of small-scale sanitation in rural Egypt. This is a new market, but it offers potential to the private sector and for job creation. This should be highlighted to enlist strong governmental support. The technical know-how is not fully available, but

local industry could produce prefabricated components when supported by experts. Advocacy for a national sanitation policy at the top level of the State is currently required since it has been shown that trying to reform regulations one by one does not work. Only a decision from the top can lead to quick change.

These recommendations are synthesised in the ESRIS project's final report (Figure 1). Figure 2 shows the main short- to long-term steps that could lead to wide-scale replication of small-scale sanitation systems. Because the situation in Egypt is similar to that in many countries, the project's recommendations are also applicable in other contexts. In short, scaling up small-scale sanitation systems can happen through implementing the following drivers of change:

- Thinking at scale
- A critical mass of projects and a centralised management scheme
- Piloting economies of scale, both at the implementation and management levels
- Convincing governments through the business and job potential
- Implementing effluent standards incrementally
- Facilitating the work of consultants and contractors [2, 7]

### Conclusion

The 5-year ESRIS research project was embedded within the Egyptian Holding Company for Water and Wastewater (HCWW), which works with the main sector stakeholders and decision-makers. It was supported by high-level collaboration between SECO and HCWW, which gave it the unique opportunity to work at the science-policy interface. ESRIS researched and developed fact-based recommendations for small-scale sanitation systems in rural settlements in Egypt. These recommendations are now on the table of Egypt's decision-makers, and require only the right political momentum to be implemented. It has been shown that in such a complex and shifting institutional and interpersonal environment, scientific evidence, pragmatism and good will are not always sufficient to bring about change. There is now the need for a strong political drive to implement innovative sanitation schemes that would bring sanitation coverage to all as this would greatly benefit Egypt's large rural population.

#### SHORT TERM:

- Agreement on the incremental implementation of the effluent standards, at least for treatment plants under 5000 pop. equivalent.
- Definition of business models for rural small-scale sanitation systems
- Agreement with the Ministry of Irrigation on the integration of small drains in the wastewater treatment schemes
- Provision of technical support to communities willing to build a sewer network

#### MIDDLE TERM:

- Implementation of a large number of small-scale systems in a selected region, allowing a centralised management scheme
- Engagement of the private sector and local industry
- Adaptation of water tariffs

#### LONG TERM:

- Replication at national level

Figure 2: Prioritisation of actions for the wide-scale replication of small-scale sanitation systems in Egypt.

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We would like to thank all of our Egyptian partners and colleagues, and the Swiss State Secretariat for Economic Affairs (SECO - [www.seco-cooperation.ch](http://www.seco-cooperation.ch)), in particular, Edi Medilanski and Iman Radwan, for their support.

To download project documents and tools and to see the project video, go to: [www.sandec.ch/esris](http://www.sandec.ch/esris).

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# Safer Water for Remote Nepal – Novel Pathways Towards SDG 6.1

Can novel adaptations of water quality monitoring and risk management help remote communities comply with the new water safety standards? Insight into how simple experiments can identify and reduce public health risks in rural water schemes. Arnt Diener<sup>1</sup>, Moa A. Kenea<sup>3</sup>, Irfan Y. Pratama<sup>3</sup>, Madan Bhatta<sup>2</sup>, Mohan Bhatta<sup>2</sup>, Sara Marks<sup>1</sup>



Photo 1: Community tap stand in the Nepalese mountains.

## Introduction

Recent studies estimate that inadequate drinking water quality causes about 500 000 diarrheal deaths annually [1]. In response, 193 countries have adopted the Sustainable Development Goals (SDGs), and SDG 6 challenges the sector to “achieve universal and equitable access to safe and affordable water for all” by 2030 (Target 6.1). To ensure compliance with the standards for access, quantity and quality, the agreement calls for worldwide monitoring and evaluation (M&E) of water supply schemes even in very remote regions [2]. Credible M&E typically requires complex laboratory setups and technical expertise; thus, there is the need for new methods that are affordable and viable for remote and/or capital-restricted water schemes.

## Background and research setup

There are many technical and economic barriers to water supply monitoring in remote mountain villages of Nepal. HELVETAS Swiss Intercooperation's Water Resource Management Program (WARM-P) installed 56 piped supply systems in western Nepal, and these gravity-fed schemes are operated and maintained by the local communities. They provide water intermittently for two-to-six hours per day, and the reservoir tanks buffer seasonal variations in the springs' discharge – similar to many of the region's 5 169 schemes. The piped schemes have significantly improved households' access

to water; however, no system-level treatment or quality control has been implemented yet, mainly due to sustainability concerns [3].

SANDEC partnered with HELVETAS to study the technical, social and economic viability of the M&E of their water schemes from October to December 2015. Four WARM-P schemes with 35 water points on the hilly slopes of Dailekh district were selected for the study. The goals were to understand the implications of SDG 6.1 for small rural water schemes and initiate the development of a generic Water Safety Plan (WSP) for such schemes based on national and global guidelines for safe drinking water [4, 5]. The objectives were to: assess the spatial and temporal dynamics of the water quality parameters in the piped water schemes, evaluate the feasibility of various M&E measures, including mobile applications and adapted laboratory setups, and work to understand the effectiveness of scheme adaptations for contamination mitigation and prevention.

We developed and installed an off-grid field laboratory with a low-watt incubation system and a simplified disinfection and cooling approach to replace autoclaving and grid-electricity. We validated the laboratory's suitability for remote areas and trained local staff prior to doing daily water testing for seven five-day cycles. The water quality was tested for: microbial contaminants (*E. coli*, *V. cholerae*, *Enterococcus sp.*, and coliform) using membrane filtration and culture-based enumeration, and physio-chemical parameters (electrical conductivity, pH, turbidity, temperature and free chlorine) with automatic probes and a colorimeter. Comprehensive chemical tests were also done on selective samples at EAWAG's main laboratory. To understand the risk management options, 15 pilot experiments were done, including salt-based contamination tracing and scheme adaptation effectiveness, spring protection and drip chlorination. Treatment interventions were evaluated together with the schemes' committees, and the criteria included: financial and technical viability, community acceptance, and contamination

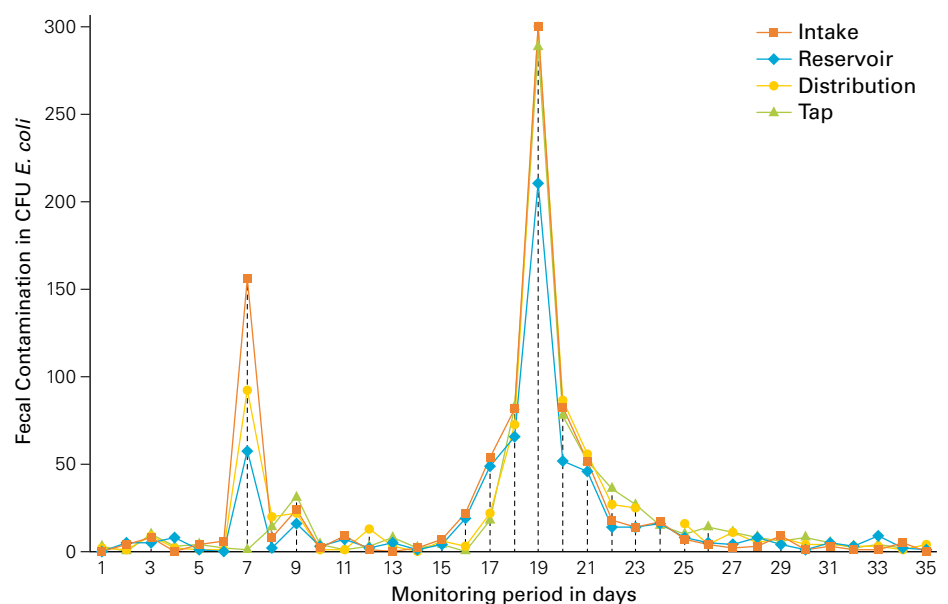


Figure 1: Daily variability of CFU *E. coli* per 100mL along iPWS No IV.

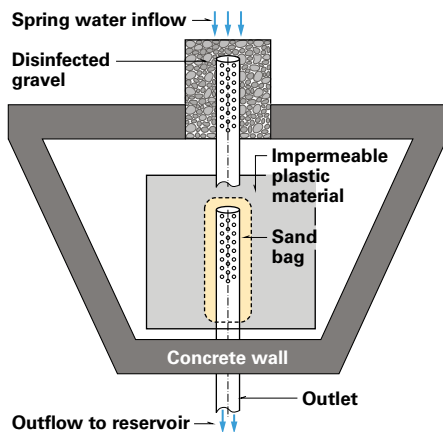


Figure 2: Adapted intake protection for the scheme's spring source.

reduction efficacy under intermittent conditions. In addition, sanitary inspections of 32 water points were done using the mobile phone application *mWater* [4].

## Results and lessons learned

Monitoring revealed significant temporal dynamics of microbial contamination in all the systems. At the 35 sampling points, over 85 % of the samples showed *E. coli* concentrations above the national and international standards of 0 CFU/100mL, and daily measurements revealed the temporal sensitivity of water quality compliance. 60 % of all water points met the standards at least one sampling day during the two-month period, but only 4 % were compliant throughout each day during the whole time. The concentration of faecal contaminants showed significant spatial variation among water points, even within schemes. In many cases, the faecal contamination passed from spring intake to the tap. Salt tracer experiments at the intake confirmed contaminant intrusion around the springs. Figure 1 depicts the spatial and temporal dynamics for *E. coli* (CFU/100mL) and identifies the intake as the likely contamination source. In addition, hydro-geologic analyses supported the likelihood of contamination influx in the vicinity of the spring. Assessments of the underlying aquifers of the springs based on physio-chemical and hydro-chemical parameters yielded no evidence of an anthropogenic impact on them.

Sanitary inspections indicated medium to high risk levels for different pathways along the schemes, including pipe leakages, which may explain the occasional increases observed in contamination between the reservoirs and taps. Quantitative correlations

between risk scores and actual contamination events were not found to be statistically significant, and statistical analysis was limited by the small sample sizes and limited variation. Qualitatively, the schemes' inspection scores generally aligned with the overall laboratory results. Operational hours and turbidity levels as alternative indicators were not correlated overall with microbial concentrations and cannot, therefore, be regarded as a replacement for microbial assessment or sanitary inspections.

The measured contamination levels and sanitary risk scores were followed by upgraded intake protection pilots and several effective treatment trials at the reservoir and community level. The preventative measures for contamination influx around the intake (Figure 2), i.e. deepening the inlet 1 m and installing a rapid sand filtration element to retain soil infiltration, performed well in terms of efficacy (2-log removal for *E. coli*), financial viability and community acceptance. The combination of UV disinfection and in-line filtration achieved the expected treatment efficacy, but their technical implementation at system level proved problematic despite an adapted setup. The users accepted the use of a continuous chlorinator as an alternative in spite of its adverse odour and taste consequences. This proved technically feasible and effectively deactivated *E. coli* during the monitored period by providing residual chlorine from the reservoir to household storage level.

## Conclusion

The project cross-checked results by combining regular water quality monitoring with a comprehensive water scheme assessment and assessed the suitability of both management tools for remote areas. The combined evaluation permitted us to credibly identify the main contamination pathway, which was at the intake rather than pipe level, in contrast to earlier studies on intermittent schemes. At the springs' intake, the observed sanitary inspection scores aligned with the monitored contamination levels and with a hydrogeological assessment.

Our study revealed high daily contamination variability, which discouraged the use of an end-of-the-pipe approach to microbial contamination monitoring. The results also highlighted the benefits of a thorough system assessment and regular audits. The assessment tools (e.g. the salt-tracer experiment) and the modified laboratory proved feasible and were able to facilitate WSP implementa-

tion by filling the gap between certified laboratories and field test-kits. Combined with the successfully tested adaptive interventions, the study showed that communities can advance their schemes towards meeting national drinking water quality objectives. What can we conclude about the implementation of measures to meet SDG target 6.1 regarding access to safe water in remote areas? The lessons apply to small rural water schemes in hilly areas across the globe. Due to the dramatic temporal and spatial dynamics of the study schemes, we found that singular water parameter tests do not offer overall safety for this common water scheme type. National monitoring for SDG 6.1 will profit from integrating thorough risk evaluations for such schemes, e.g. the sanitary inspection score, prior to the successful establishment of basic control measures. These risk evaluations can be used to develop generic WSPs, and the WSPs will add value to the SDG water quality surveillance targets and support national risk management. They will also motivate further research aimed at prioritizing interventions, leading to an increase in the understanding of different scheme types, and of locational and seasonal influences on water quality risks.

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# Multiple-use Water Services, Livelihoods & Health – a Two Country Study

The Water Supply and Treatment Group partnered with USAID and the GLOWS programme to evaluate the impact of multiple-use water services in rural communities throughout Burkina Faso and Tanzania. Sara Marks<sup>1</sup>, Ariane Schertenleib<sup>1</sup>,

Honoré Biaou<sup>2</sup>, Kees Vogt<sup>2</sup>, Boukari Salifou<sup>2</sup>, Muganyizi Ndyamukama<sup>2</sup>, Ilyasse Kabore<sup>2</sup>, Emily van Houweling<sup>3</sup>, Vincent G. Vyamana<sup>4</sup>, Vivienne Abbott<sup>4</sup>, Mary Renwick<sup>2</sup>

## Introduction: MUS versus business as usual

Multiple-use water services (MUS) is an integrated water service delivery approach that takes into account households' range of needs when planning, financing and managing water services. As compared to the standard model for rural water supply planning, MUS recognizes household- and community-level synergies among domestic and productive activities with water. Past studies have shown the benefits of MUS in terms of enhancing water-based income generation [1, 2], especially in the presence of enabling factors, such as markets and electricity [3]. In rural Senegal, productive uses of water were linked to improved livelihood diversification among women [4] and technical operation of water systems [5]. Yet, little is known regarding other potential MUS benefits beyond income and livelihood. A better understanding of the poten-

tial benefits arising from MUS projects is essential for justifying the relatively expensive upfront investment required to establish this higher level of water service.

## MUS in Burkina Faso and Tanzania

The objective of the study was to rigorously assess the impacts expected to arise from MUS, including improvements in child health, safety during water collection, food security and nutritional status [6]. Sandec's Water Supply and Treatment group collaborated with USAID and the GLOWS programme, as well as partner organisations Winrock International, Virginia Tech, and Florida International University, to systematically evaluate the MUS component of two rural water supply programmes.

The first programme, the West Africa Water, Sanitation and Hygiene (WA-WASH) programme in Burkina Faso, launched in 2011 and offered households the option to invest

in a subsidised self-supply option (upgraded private wells equipped with rope pumps) along with other programme activities. The second programme, the Integrated Water, Sanitation and Hygiene (iWASH) programme in Tanzania, launched in 2010 and used a demand-led approach to engage community members during the installation of new or upgraded communal water supply systems (reticulated networks, upgraded wells with rope pumps, and/or livestock troughs). Both programmes featured "MUS impact boosting activities" tailored to local conditions, such as seed distribution networks, market garden demonstrations, support for improved poultry housing (kinengunengu) and livestock husbandry (Photo 1).

## Study design and methods

Baseline (pre-intervention) data on outcomes of interest were not collected prior to the launch of the programmes, making it not possible to directly measure the before-after status of households receiving MUS. This study instead relies on a two-step strategy to estimate impacts: (1) randomised sampling of various MUS typologies, as well as a control group, and (2) statistical matching techniques. This article reports results for the first step only.

Communities participating in iWASH and WA-WASH at least one year prior to the study could enrol in the treatment group. Communities located within the programme area that qualified for participation, but had not yet applied, were eligible to enrol in the control group. The communities were selected purposively to optimise variation in the intervention(s) received and ensure accessibility to the research team.

Based on community visits and discussions with field staff, the study team pre-defined and randomly sampled several household typologies. The WA-WASH household typologies were: (a) investors, (b) neighbours of investors (i.e. those accessing an investor's upgraded well), or (c) non-neighbours (i.e. those who did not invest in, nor use an investor's upgraded well). In iWASH, the household typologies were: (d) those living in



Photo 1: WA-WASH and iWASH impact boosting activities, e.g. support for market gardens and poultry and livestock husbandry training.

Category	Household typology	Household interviews	Focus group discussions	Key informant interviews
<b>WA-WASH (19 communities)</b>	a. MUS investors	146	8	19
	b. Neighbours	292		
	c. Non-neighbours	451		
<b>iWASH (7 communities)</b>	d. MUS interest group members	322	0	7
	e. Non-members	410	0	
<b>Control (12 communities)</b>	f. Control	1 083	0	12
<b>Total sample size</b>		2 704	8	38

Table 1: Household typologies and sample sizes for WA-WASH and iWASH.

iWASH communities who were members of MUS interest groups or (e) those who were not members of a MUS interest group. In both countries, households located in communities not participating in the programme were defined as: (f) control households (Table 1). Between May and October 2015, field teams conducted 2704 household interviews. Surveys probed on the water sources used throughout the year for any purpose, health status, self-reported food security, and other measures of well-being. In addition, semi-structured interviews were held with a key informant in each community to estimate population, proximity to markets, and other community-level measures. Focus group discussions were held with men and women in Burkina Faso to better understand the changes experienced since their participation in WA-WASH (Table 1).

## Key findings

**Illness and injuries.** As compared to control households, MUS households reported fewer episodes of diarrheal and respiratory illnesses in the past week, as well as fewer injuries due to fetching water. In bivariate tests, only the difference in the rate of injuries among households in the iWASH programme (3 %) and control communities (12 %) was statistically significant ( $p < 0.05$ ). Other health measures were not found to be significantly different across MUS and control communities.

**Food security.** The survey asked respondents to rate their own household's food security in the past year and interviewers explained the concept of food security in the local language. Results show that whereas food insecurity existed to some extent in all communities, the share of households identifying as insecure was significantly lower within communities receiving MUS. For ex-

ample, within iWASH communities, 84 % of MUS interest group members identified as "very secure," while 65 % of non-members reported the same.

**Nutritional status.** The household survey included a standardised set of items to assess the overall nutritional status of women of reproductive age [7]. Three measures were analysed: (1) the total number of food types consumed in the past week, (2) consumption of animal products (meat, milk and eggs), and (3) consumption of leafy green vegetables. Statistical comparison revealed that overall dietary diversity was somewhat greater among households in iWASH, as compared to control households. In both programmes, households receiving MUS were more likely to have consumed animal products in the past week, as compared to control households. For example, 92 % of WA-WASH investors and 91 % of iWASH interest group members had consumed meat, milk or eggs in the past week, as compared to only 82 % and 77 % of control households, respectively (Figure 1).

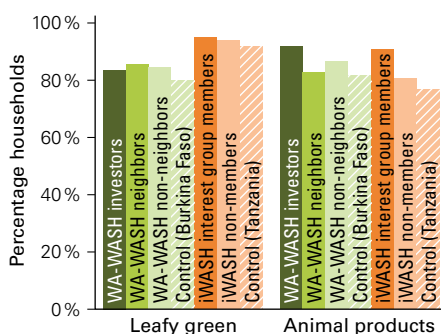


Figure 1. Share of households consuming leafy green vegetables and animal products within the past week.

## Policy message

Our preliminary analyses of these two large-scale MUS programmes in Sub-Saharan Africa are limited due to the lack of controls for potential confounding factors. Nonetheless, direct comparisons across various household typologies reveal a consistent trend demonstrating the benefits of MUS one to four years after programme implementation. Households participating in WA-WASH and iWASH experienced fewer injuries while fetching water, were more food secure, and were more likely to consume protein-rich foods. These results expand the growing evidence base regarding the benefits from higher levels of water services in rural communities globally. In future analyses, we will use multivariate statistics to minimize bias and to investigate the potential spillover effects of MUS among neighbouring households.

- [1] Crow, B., Swallow, B., & Asamba, I. (2011): Community organized household water increases not only rural incomes, but also men's work. *World Development*, 40(3), 528–541.
- [2] Noel, S., Hoang, T., Soussan, J., & Lovett, J.C. (2010): The impact of domestic water on household enterprises: evidence from Vietnam. *Water Policy*, 12(2), 237–247.
- [3] Davis, J., Hope, R.A., & Marks, S.J. (2011): Assessing the link between productive use of domestic water, poverty reduction and sustainability: Kenya country report. Report to the World Bank Water and Sanitation Program. Stanford University, Oxford University.
- [4] van Houweling, E., Hall, R.P., Diop, A.S., & Davis, J. (2012): The Role of Productive Water Use in Women's Livelihoods: Evidence from Rural Senegal. *Water Alternatives*, 5(3), 658–677.
- [5] Hall, R.P., Vance, E.A., & van Houweling, E. (2014): The Productive Use of Rural Piped Water in Senegal. *Water Alternatives*, 7(3), 480–498.
- [6] Water service quality was also examined as an outcome measure, with results reported in a separate Sandec News article (See Schertenleib et al., pp. 26–27).
- [7] FAO & FANTA. (2014): Introducing the Minimum Dietary Diversity–Women (MDD-W). Global Dietary Diversity Indicator for Women, Washington, D.C.

<sup>1</sup> Eawag/Sandec, Switzerland

<sup>2</sup> Winrock International, USA

<sup>3</sup> Virginia Tech, USA

<sup>4</sup> iWASH/GLOWS Tanzania, USA

Data for this study were sourced from USAID and the GLOWS programme, with support from Winrock, Florida International University, and Eawag. The data are publicly available and subject to USAID regulations.

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# Drinking Water Quality in Improved Water Supplies in Burkina Faso

In rural Burkina Faso, the use of traditional wells is widespread. Through the WA-WASH programme of Winrock International, people could invest in upgraded water points. The Water Supply and Treatment group assessed the quality of the different water facilities used [1]. Ariane Schertenleib<sup>1</sup>, Honoré Biaou<sup>2</sup>, Boukari Salifou<sup>2</sup>, Mary Renwick<sup>2</sup>, Sara Marks<sup>1</sup>

## Introduction

Under the SDG Target 6.1, the Joint Monitoring Programme defines “safely managed water” as an improved source located on premises and available when needed, as well as free of faecal contamination [2]. In Burkina Faso, between 2000 and 2015, the percentage of households with access to improved water supplies in rural areas increased from 54.5 % to 75.8 % [3]. However, whereas previous research has shown that improved water sources on premises have better water quality [4], little is understood about other water service attributes.

## Data sources and methods

Winrock International, through the USAID-funded West Africa Water, Sanitation and Hygiene (WA-WASH) programme in Burkina Faso, used a demand-responsive, modified self-supply approach to deliver multiple-use water services (MUS) to rural households across a three-region area. Households were given the option to invest in an upgraded water point (upgraded well with rope pump), which was installed and maintained by the private sector.

In the study area, a total of 1 327 household surveys were conducted in 28 rural communities. Four household typologies were defined in the study: investors receiving upgraded wells through the programme, neighbours of investors (those who reported using an investor’s upgraded well), non-neighbours (households within programme villages who did not invest or access investor’s upgraded water points), and the control group (households outside of the MUS intervention areas). Investors and neighbours will be referred to as the “MUS group” and the non-neighbours and control group as the “non-MUS group”.

The study made use of a strategic sampling approach. All investors were offered the opportunity to enrol, while investors identified neighbours who were then chosen at random and offered the chance to participate (snowball strategy). The non-neighbours and control households were mapped and every *n*th household could enrol (stratified random

sampling strategy). The survey instruments collected, amongst other questions, information on water sources used and water service features.

In addition to the interviews, water quality testing at the point of collection was conducted using compartment bag test (CBT) kits, indicating the microbial quality (*E. coli* concentration). Sampling took place in two of the programme regions. In total, 181 public and private water points were tested: 57 unimproved sources (traditional wells) and 124 improved wells.

## Findings

**Satisfaction.** The survey revealed overall satisfaction in the MUS group. People were asked how satisfied they were with their current water supply situation and 47 % were “generally satisfied” and 47 % were “somehow unsatisfied”, with only 5 % declaring being “very unsatisfied”. In contrast, people in the non-MUS group were 26 % “generally satisfied”, 58 % “somehow unsatisfied”, and 16 % “very unsatisfied”.

**Resilience.** Results showed two different trends with respect to the resilience factors. Resilience was assessed by probing the availability of the households’ main drinking water source throughout the year, as well as the duration of recent interruptions. A greater proportion of MUS households (34 %) reported waiting at some point during the year for their main drinking water source to recharge, as compared to non-MUS households (19 %). However, MUS households typically waited half the time as the non-MUS households, approximately 60 minutes compared to 120 minutes. Furthermore, over 20 % of non-MUS households waited for 24 hours or longer, as compared to only 5 % of MUS households. In terms of water service availability, results show that a full-day interruption in water service within the past six months was a relatively rare occurrence for both groups. MUS households experienced fewer (16 %) interruptions in water service as compared to non-MUS households (23 %). In addition, less than 25 % of the MUS households ex-

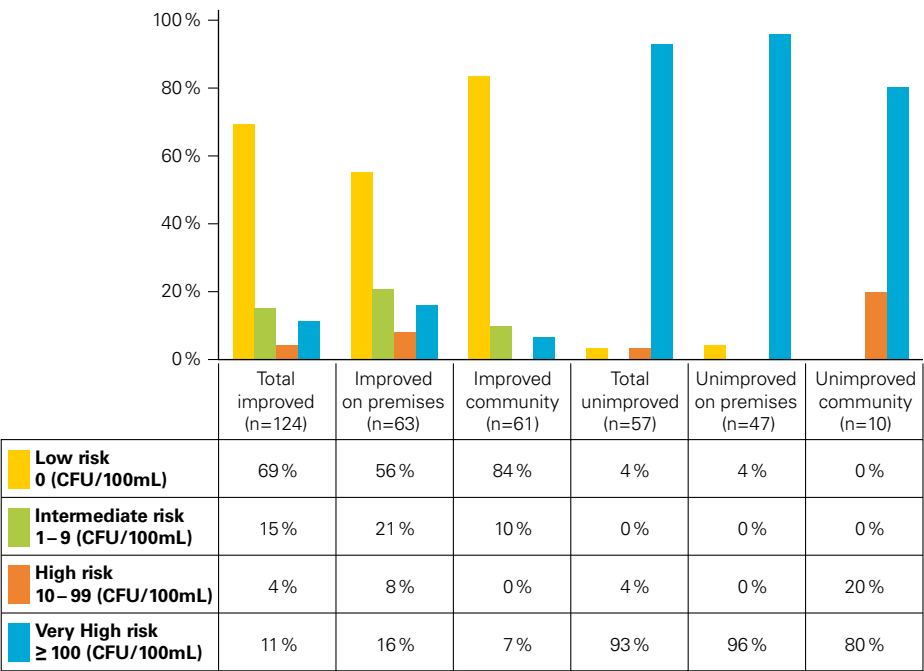


Figure 1: Microbiological water quality (*E. coli* contamination).



periencing interruptions had to wait more than 10 days for repairs, whereas over 40 % of non-MUS households had to wait longer than 10 days.

**Types of water points.** The survey revealed key differences in the types of water points used by MUS and non-MUS groups. The majority of all groups interviewed used an upgraded well as their main drinking water source at the time of the survey (MUS group: 94 %, non-MUS group: 70 %), while the traditional wells were used by 29 % amongst the non-MUS group. Within the MUS group, the majority of investors used a private water point on premises at the time of the interview (93.2 %), as did 36 % of the neighbours, while 34 % of the neighbours used a private point not on their premises and 31 % used community points of collection. In the non-MUS group, most people (77 %) used a community water point and only 18 % owned a private water point on premises.

**Microbiological quality.** Water quality testing confirmed the relationship between an improved water point and better water quality, but revealed unexpected relationships regarding the households' category, the location of the water point, and microbiological water quality. The majority (69 %) of upgraded wells with rope pumps provided water categorized as low risk, according to the WHO standards at the time of sampling. By contrast, nearly all traditional

	MUS group	non-MUS group
<b>Satisfaction</b>	Equally generally satisfied and somehow satisfied	Majority somehow unsatisfied
<b>Resilience</b>	Interruptions more frequent but shorter in duration	Interruptions less frequent but longer in duration
<b>Types of water points</b>	94 % upgraded well	70 % upgraded well
	Majority private water points (neighbours group: their own or investor's)	Majority community water point
<b>Microbiological water quality</b>	Investors: 53 % low risk, 22 % intermediate risk	47 % low risk, 47 % very high risk

Table 1: Summary of findings regarding households' categories.

wells (93 %) were highly contaminated with *E. coli* and categorized as very high risk. When examining the quality of the main drinking water source reported by households, most investors accessed a source categorized as safe (53 %) or probably safe (22 %), but 17 % still used unsafe water. However, the non-MUS group was evenly split across the categories of safe and very unsafe drinking water sources (47 % each). Finally, when comparing improved water points located on premises to community water points, we find a higher share of improved community wells meeting WHO standards (84 %) than improved wells on premises (54 %). Similarly, the share of samples categorized as posing a health risk was always higher for water points located on premises compared to community water points (Figure 1 and Table 1).

## Conclusion

Greater satisfaction, improved resilience, a shorter queue time, more frequent but shorter service interruptions, and higher water quality were observed among households in the MUS group, most of whom used an upgraded water point on premises. However, safe water quality is not guaranteed based on water point type alone. 45 % of the samples taken from improved water points on premises did not meet WHO standards for safe drinking water. The results of this study confirm that not only the type of drinking water point is crucial, but also underline the importance of regular treatment and monitoring.



Photo 1: Upgraded well with rope pump on premises.

- [1] Data for this study were sourced from USAID, in partnership with Winrock and Eawag. Data are publicly available and subject to USAID regulations.
- [2] [www.wssinfo.org/fileadmin/user\\_upload/resources/JMP-WASH-Post-2015-Brochure.pdf](http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-WASH-Post-2015-Brochure.pdf)
- [3] [www.wssinfo.org/data-estimates/tables/](http://www.wssinfo.org/data-estimates/tables/)
- [4] Shields, K.F., Bain, R.E., Cronk, R., Wright, J.A., Bartram, J. (2015): Association of supply type with fecal contamination of source water and household stored drinking water in developing countries: a bivariate meta-analysis. *Environ Health Perspect* 123(12), 1222–1231.

<sup>1</sup> Eawag/Sandec, Switzerland

<sup>2</sup> Winrock International, USA

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# Internet of Things for Enhanced Water Service Provision in Senegal

The Internet of Things represents a new bundle of technologies, enabling machine-to-machine communication, and is linked to ideas and markets based on remote and smart services. These technologies are transforming how we live and work, even in low- and middle-income countries. Caroline Saul<sup>1</sup>, Heiko Gebauer<sup>1</sup>



Photo 1: Staff in Switzerland assessing the performance of treatment units in Senegal.

## Introduction

The Internet of Things (IoT) allows companies to provide a higher level of service to their customers, enables new business models, and generates valuable data, which can contribute to faster technical iterations and highly customized products and services. Companies operating in industrialized markets have already been using IoT to innovate. And our research has found that service providers in low-income countries are also exploring IoT opportunities, particularly in the water, sanitation and energy sectors. A promising example is Swiss Fresh Water SA, which operates in Senegal.

## Pilot

Just over four years ago, with support from a grant from the Renewable Energy and Energy Efficiency Promotion in International Cooperation Platform, Swiss Fresh Water set up a pilot project in 12 coastal Senegalese villages that have water which is typically salty and contaminated with fluoride. The villages are quite remote and have to import drinking water in bottles, jerry cans, or sachets, and these cost between 0.02 and 0.80 USD per litre and have unreliable quality. To address this, Swiss Fresh Water built a water treatment unit that produces good quality water at a lower price point. The first generation of treatment units were relatively small, weighed less than 100 kilo-

grams, and produced around 60 litres of drinking water per hour, depending on the model and input water quality. Piloting simultaneously in the 12 villages allowed for analyses of different configurations of electricity supply (solar PV vs. diesel generators), pumps and maintenance options.

Swiss Fresh Water produces and installs the equipment, while the community or an entrepreneur operates it. The entrepreneurs interact with consumers under the brand name Diam'o. The equipment is small in size and can easily be transported to remote areas even by boat, without requiring large trucks. Compatible solar panels and battery systems are included with the units. The systems are branded and clearly display the water's price, along with the contact information of the parent company.

Each unit is equipped with sensors that monitor real-time pressure, temperature, and flow rate at different points in the treatment system. These data are relayed via cellular networks in real-time to remote servers. This allows the units' current and historical performance to be observed anywhere in the world, from the regional maintenance centres that Swiss Fresh Water has set up, to their headquarters in Switzerland (Photo 1). When certain values are exceeded, the operator and the local maintenance centres, which maintain and service the equipment, are alerted via text messages. Concerns are then addressed over the phone, with the aid of a comprehensive library of repair videos, or in person within 48 hours. Besides responding to calls, the technicians based at these centres perform preventative maintenance, visiting each machine on a monthly basis.

In addition to contributing to the smooth functionality of the treatment units, the remote monitoring system provides transparency regarding how much water is treated and sold, and insight into demand. The system can also receive commands; thus, if an operator attempts to raise the water's price, the machine can be remotely shut down.

## Scaling

After testing the system in the 12 villages and learning about the performance of the machines, Swiss Fresh Water used a combination of equity, investors and a loan from the Swiss BlueTech Bridge to finance expanding the number of machines they have on the ground. Swiss Fresh Water has now scaled-up to 90 units. The monitoring systems were an important trigger for the scaling process in two ways by: (1) facilitating quick technical iterations of the treatment technology and (2) controlling costs. These systems also affect all aspects of the business model.

Between 2011 and 2015, Swiss Fresh Water was able to develop five different equipment generations, each more robust and customizable than the previous versions. Performance data enabled the treatment technology to be tweaked and optimized, tripling the output from 50–60 litres per hour to a maximum of 170 litres per hour, while reducing energy consumption and removing smaller particles. Additional treatment configurations were developed for water with heavy metal contamination and for brackish water.

The remote monitoring system enables Swiss Fresh Water to maintain their equipment in a cost efficient way, to optimise the work of the local service technicians, and to control the operation and water pricing. Reliably functioning equipment means more predictable revenues for the operator and the expectations of the end consumer are well met. By continuously improving the quality of their treatment technology, embracing data, and refining their service through the application of IoT technologies, Swiss Fresh Water is able to successfully provide access to safe and affordable drinking water to hundreds of thousands of people in Senegal.

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## Sandec's MOOCs are Flipping the Classroom

Sandec's MOOCs are flipping the classroom! Students are viewing the MOOC videos at home to prepare for courses and Professors are using the videos in their lectures.

Pictured here is Dr Elizabeth Oloruntoba, using MOOC sequences in her "Water Supply and Quality Management" course at Idaban University in Nigeria.

Please contact Sandec if you would like to use our MOOCs for educational purposes (fabian.suter@eawag.ch).



Flipped classroom at University of Idaban, Nigeria.

## Sandec Relaunching Sanitation MOOC



Official Eawag EPFL Vignette for Sanitation MOOC.

In October 2016, Christoph Lüthi and his team will relaunch the Sanitation MOOC. It will have new content on urban sanitation planning at the city and local/community level, and cover different sanitation systems and technology configurations.

The course will be launched in English and French and will have subtitles in four languages (English, French, Spanish and Hindi) to satisfy the needs of the global learning community. The MOOC is part of Sandec's MOOC "Sanitation, Water and Solid Waste for Development" series, which is an initiative of Sandec/Eawag and EPFL.

For more information and to enrol, please go to <https://www.coursera.org/learn/sanitation> (English) or <https://www.coursera.org/teach/sanitation-fr> (French).

## A Day in the Life of a Swiss Civil Servant in Nepal



Sandec offers civil service placements abroad for Swiss men who do not want to do military service. Environmental engineer Marius Klinger (pictured above) is currently working in Nepal on small town sanitation planning in Tikapur in western Nepal.



## Key to Good Analytical Research is a Safe, Well-equipped Laboratory

This year, the Polytechnic in Blantyre, Malawi, worked with Eawag and the University of KwaZulu-Natal in Durban, South Africa, to enhance the capacity of the microbiology lab to better serve the university community and produce high-quality results. Due to high import tariffs on new materials and the substantial transport costs to landlocked Malawi, the country faces great financial obstacles in obtaining new equipment. Therefore, high-quality used materials are a low-cost, viable way to equip laboratories when financial resources are scarce.

With this in mind, several enthusiastic Eawag employees\* collected, cleaned and, in some cases, repaired unused lab equipment before it was shipped via container to Malawi. In total, several cubic metres of material set sail, and arrived six short weeks later. The highlights, among the hundreds of items of

glass and plastic ware, were a vacuum pump (for filtration) and a drying oven. Both will be invaluable for student tutorial sessions and researchers alike.

To ensure that the best health and safety lab practices are implemented, the Bill & Melinda Gates Foundation sponsored a team of South African experts\*\* to work with the technicians in Blantyre. During the two-day intensive workshop, systems to deal with biowaste, sample preservation, and machine maintenance were implemented. The workshop's appeal was its focus on low-cost or no-cost improvements that can have significant impact, i.e. simple signage directing workers to first-aid and fire-fighting equipment, and sign-in protocols that ensure accountability for theft and damage.



Students in Polytechnic lab.

Health and safety, along with procedures and maintenance, require constant attention and effort. The laboratory staff at the Polytechnic will continue to face a variety of challenges, but, with these small inputs and continued Eawag support, the task of keeping the lab in top condition will be noticeably easier.

\* Michael Burkhardt, Samuel Derrer, Kirsten Klappert, Patrick Turko

\*\* Merlien Reddy, Thabiso Zikalala



Symptoms of chronic arsenic poisoning.

## Eawag's GAP Platform is Now Online!

A third of the world's population uses groundwater as its source of water for drinking or cooking and for agriculture. Especially in developing countries, groundwater contains fewer pathogens than does water from lakes or rivers and may even be the only available source. Overall, however, about 10 percent of all wells are contaminated with arsenic or fluoride. These contaminants are usually of natural (geogenic) origin, being leached from aquifer rocks and sediments.

At high concentrations or when ingested over long periods of time, arsenic and fluoride have serious effects on human health. Excessive fluoride intake can lead to pitting of the teeth and bone and joint deformities. Chronic exposure to arsenic is associated with discoloration and thickening of

the skin and can also cause cardiovascular disorders or cancer.

To assist in mitigating this situation, Eawag developed the GAP project, the Groundwater Assessment Platform. It allows users to produce probability maps of the risk of geogenic contamination in a given area, using geological, topographical and other environmental data without having to test samples from every single groundwater resource. GAP also allows users to upload their own data and generate hazard maps for their areas of interest, and provides state-of-the-art global arsenic and fluoride contamination risk maps, as well as information on how to remove these toxic substances from water.

GAP is available online and can be used for free at [www.eawag.ch/gap](http://www.eawag.ch/gap).

## Forthcoming Event

**Sandec/Eawag Hosting Informational Event at the SIWI 2016 World Water Week**  
**31 August 2016, 12:00–14:00, Stockholm City Conference Center**

Sandec/Eawag are hosting an Informational Event at the Swiss Water Partnership booth at World Water Week. Information will be presented and made available on current and future research projects dealing with water, sanitation, solid waste and behavioural change. Experts from both Sandec and Eawag will be present and available to answer questions.

The World Water Week is organised by the Stockholm International Water Institute (SIWI) and takes place in Stockholm, Sweden. It has been the annual focal point for the globe's water issues since 1991.

For more information, contact Christoph Lüthi: [christoph.luethi@eawag.ch](mailto:christoph.luethi@eawag.ch).



## The Sandec Team



From left to right

**Front row:** Elizabeth Tilley, Nicolas McFadden, Adeline Mertenat, Christian Riu Lohri, Jasmine Segginger, Imanol Zabaleta

**2nd row:** Sara Marks, Barbara Jeanne Ward, Lars Schoebitz, Paul Donahue, Regula Meierhofer, Lukas Ulrich, Fabian Suter, Caterina Dalla Torre, Anja Bretzler, Chris Zurbügg

**Back row:** Petra Kohler, Samuel Renggli, Stefan Diener, Moritz Gold, Christoph Lüthi, Phillipe Reymond, Arnt Diener, Hussain Etemadi, Linda Strande

**Missing in photo:** Bart Verstappen, Magalie Bassan, Ariane Scherteinleib, Rohit Chandragiri

## New Faces



**Rohit Chandragiri,**

MS in Urban Management from the Technische Universität Berlin. During his Master's study, he interned at the Institute for Advanced Sustainability Studies in Potsdam. Prior to his Master's degree, he worked on city sanitation and urban planning related projects. He joined Eawag in November 2015, and works on the 4S (Small-Scale Sanitation Scaling-up) project, which is assessing small-scale sanitation systems in South Asia. Rohit is currently based in India.



**Adeline Mertenat,**

MSc in Environmental Engineering, specialised in water, ground and ecosystem engineering. She joined the Solid Waste Management Group in March 2016, and works on redaction of the SOWATT manual and the FORWARD project in Indonesia. In 2014, she did a Master's thesis at Sandec on assessing organic waste availability and suitability for anaerobic co-digestion in Vietnam, and worked in 2015 as an Academic Guest, testing the SOWATT method in Colombia.



**Barbara Jeanne Ward,**

MS in Environmental Engineering, joined the Excreta and Wastewater Management group in April 2016. She works in the new Nest WaterHub, Sandec's first dedicated domestic research space, where she manages the start-up of the faecal sludge dewatering lab. Barbara J. comes to Sandec from the University of Colorado, where she worked with the RTTC Sol-Char Toilet project, evaluating the suitability of pyrolysed excreta and faecal sludge for use as a solid fuel.

## On the Bookshelf

Apart from the publications cited in the previous articles, we would like to recommend the following new books and key readings in the areas of sustainable development, municipal solid waste management, excreta and wastewater management, strategic environmental sanitation planning and water supply and treatment.

### Municipal Solid Waste Management Wasted Health: The Tragic Case of Dumpsites



This published report lays out how untreated waste is today leading to premature deaths, ill-health and stunted growth among millions of people. It is a condemning report, because no international aid, no international focus, is being given to this issue. And dumpsites are growing in size and number as cities grow in developing countries, representing the most polluted sites on earth.

By Mavropoulos, A., Newman, D., ISWA, 2015, 38 pages. It is available as a pdf download at <http://goo.gl/NcYzLC>.

### Global Waste Management Outlook



UNEP's International Environmental Technology Centre in collaboration with the International Solid Waste Association developed the Global Waste Management Outlook to provide the first

comprehensive global overview of the state of waste management around the world in the 21st century. It gives an authoritative overview, as well as recommendations of policy instruments and waste management financing models, and is a timely status report and call for action to the international community.

By United Nations Environment Programme, 2015, 346 pages. ISBN: 9789280734799. It is available as a pdf download at <http://goo.gl/rhLZRR>.

### Excreta and Wastewater Management

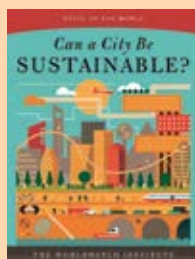
#### Manejo de lodos fecales

The first book dedicated to faecal sludge management is now in Spanish. It compiles the current state of this rapidly evolving field, integrates information on technology, management and planning, and covers the entire FSM service chain, from collection, transport and treatment options, to end use or disposal. It details operational, institutional and financial aspects of FSM, and gives guidance on how to involve stakeholders in the planning of a city-level FSM project.

By Strande, L. et al., IWA Publishing, 2016, 400 pages, ISBN: 9781780408019.

### Strategic Environmental Sanitation Planning

#### Can a City Be Sustainable?

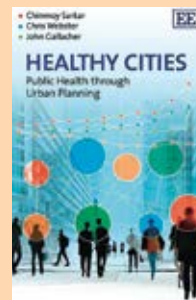


This book examines the core principles of sustainable urbanism and profiles cities that are putting them into practice, while also looking at the basic elements of cities: materials and fuels, people and economics, and biodiversity. It compiles first hand experiences of professionals working on in-

ventive urban sustainability projects, and examines such issues as the handling of waste, public transportation, civic participation and how to navigate dysfunctional government.

By The Worldwatch Institute, Island Press, 2016, 414 pages, ISBN: 9781610917551.

### Healthy Cities: Public Health through Urban Planning



Much scientific evidence has been gathered about the role of cities' built environments in shaping our health and well-being. In this book, the authors conceptualise the 'urban health niche' as a novel approach to public health and healthy-city planning that integrates the diverse and multi-level health determinants present in a city system.

By Sarkar, C. et al., Edward Elgar Publishing, 2014, 424 pages, ISBN: 9781781955710.

### Water Supply and Treatment

#### Integrated Water Resources Management in Water-scarce Regions

This book provides a comprehensive view on the complexity and interconnectedness in the Cuvelai-Etoshia Basin. The project developed and implemented technologies and measures to support an Integrated Water Resources Management (IWRM) for the people in the Cuvelai-Etoshia Basin. It presents the work of technical, social and natural scientists and media professionals, as well as the overarching process towards IWRM in Namibia.

By Liehr, S. et al., IWA Publishing, 2017, 220 pages, ISBN: 9781780407906.

## Pick of the Year!

We would like to recommend these videos that deal with issues in our area of research.

### MECYG – A Story About Youth Led Development



Inspiring video about youth led development in Mathare slum in Kenya.  
Produced by: Mathare Environmental Conservation Youth Group. 6:52.  
It can be seen at: <https://vimeo.com/141649171>.

### How did wealthy countries achieve universal water and sanitation...



An interesting vlog about public finance's role in establishing water and sanitation systems and the limits of the private sector.  
Produced by: Dr Jay Graham. 2:21.  
It can be seen at: <https://goo.gl/d14b8o>.

### The Sanitary Movement – A John Snow Epilogue



A very engaging animation on the development of sanitary cities, the wiping out of cholera, and the role of John Snow in this sanitary movement.  
Produced by: EXTRA History. 6:34.  
It can be seen at: <https://goo.gl/5GtqQv>.