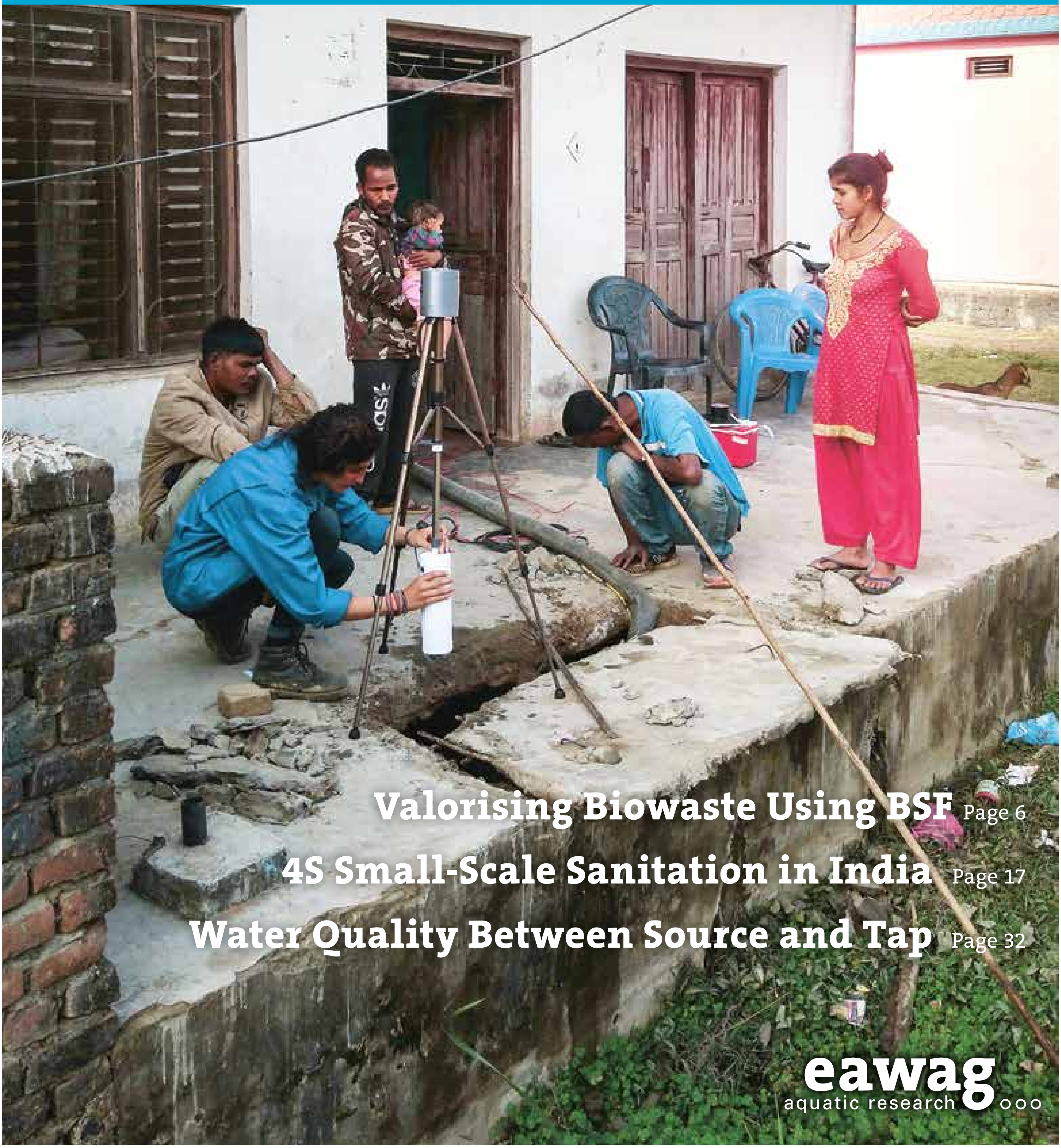
No. 20
07/19

Sandec: Department of Sanitation, Water and Solid Waste for Development

sandec news



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From Solid Waste to Emergency Sanitation

“Looking forward to many more decades of applied research, capacity development and advocacy of sustainable water, sanitation and hygiene solutions.”

50 years ago, the WHO International Reference Centre for Waste Disposal (IRCWD) was established at Eawag. It was initially located in a small house at Physikstrasse near the ETH main building in Zurich and consisted of very few people. This was the origin of what is known today as ‘Sandec’. IRCWD was initially a pure reference centre mainly collecting information and literature on solid waste issues; in 1980 it became a research centre focusing on issues related to sanitation, water supply, solid waste management and faecal sludge management in the Global South. Eventually, in 1995 IRCWD was renamed Sandec and it got the status of a full research department at Eawag. We look forward to many more decades of applied research, capacity development and advocacy of sustainable water, sanitation and hygiene solutions.

Sandec looks back on a long track record of research and development that explores the value potential of human waste and municipal solid waste. Successful research projects in the past, such as SEEK (Sludge to Energy Enterprises, 2014–2016) and FORWARD (From Organic Waste to Recycling for Development, 2013–2019), aim to protect public health and the environment, while following circular economy principles whereby end-products, i.e. sludge pellets or animal feed from black soldier fly larvae, are valorised and can complement existing service revenue streams.

Because human and organic waste is a growing natural resource (thanks to population growth and urbanisation) there is huge potential in the sanitation value chain. The budding resource recovery industries in many countries in Africa and Asia are a case in point.

A new field of activity for Sandec is emergency sanitation. Last year, we published the *Compendium of Sanitation Technologies for Emergencies* and we are currently field-testing a mobile faecal sludge lab with Swiss and Austrian partners. This low-tech lab with its off-grid power supply allows for process control of faecal sludge treatment in humanitarian emergencies. We plan to roll out an improved beta version of the lab by early 2020.

Water supply and treatment are currently the focus of projects in Nepal, where Sandec, in collaboration with the NGO Helvetas, is implementing strategies to expand risk management approaches and assessing the impact of hygiene and water quality interventions at household and community levels. Field activities include testing innovative in-line chlorination technologies and developing a low-cost adaptable incubator designed for use in remote areas, see pages 23 and 26–27 for more information.

We are always keen to hear from you. Please keep abreast of our work and in touch via our social media channels on Facebook, YouTube and Twitter. As of this year, we are also active on Instagram, featuring some of our best pics from around the world.

Christoph Lüthi
Director Sandec

Sandec
Department of 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

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: Quantifying faecal sludge in a septic tank in Kohalpur, Nepal, by using the Volaser. (Photo: Samuel Renggli)

Layout and figures: Lydia Zweifel, Eawag

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

Printer: Mattenbach AG, Winterthur, Switzerland

Circulation: 3 500 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

Municipal Solid Waste Management

Management of Excreta, Wastewater and Sludge

Strategic Environmental Sanitation Planning

Education and Training Programme

Water Supply and Treatment

Environmental and Social Sciences

Environmental Microbiology

Alumni Portrait

Safe Water Promotion

In Brief

Towards a Circular Economy at School – Insights and Best-practices from Nepal

'Towards Zero Waste at Schools' aims at developing innovative solutions for reuse and recycling at schools, maximising on synergies between water, sanitation, waste, environment and energy. The approach was applied at a school in Kathmandu, Nepal. Adeline Mertenat[1], Alexander Garcia Kappeller[1], Anjali Sherpa[2], Mingma Sherpa[2], Christian Zurbrügg[1]

Introduction

The concept of a circular economy has gained a lot of traction as a positive, solution-based perspective for achieving economic development within increasing environmental constraints. Best-practices and case studies from low- and middle-income countries are rare and public awareness and understanding of the related benefits of maximising closed-loops for resource management is still limited. For many years, we have been conducting applied research on different biowaste valorisation options. Through this experience, a solid knowledge base exists and forms one part of a holistic solution to achieve 'circular waste management'. In 2018, we started the project 'Towards Zero Waste at Schools' (ZW@S), which focuses on moving towards a 'Circular-Waste' approach at school level. Project materials will be developed to introduce environmental education and effective circular economy approaches in any school setting. This project engages teachers and the future generation – the students – by connecting them to experiential learning around sustainable development. And it targets learning, application and practice, so that students become agents of change and ambassadors for sustainable behaviour and a cleaner world with a circular economy.

Step-by-step approach

The approach designed for achieving a 'Circular-Waste' solution in schools consists of four main steps. First, an overview study at national level is done, regarding all past and existing educational environmental sanitation initiatives in schools, to identify successes, barriers and key stakeholders in the specific country. The second step then, at school level, is to conduct a baseline assessment to obtain in-depth information related to waste, water and sanitation management, as well as assess existing curricula content and behaviour practices. Based on the results obtained from this participatory assessment phase, the next step initiates a planning phase, comprising the development of possible improvement scenarios for waste reduction and recycling solutions, as well as curricula development. The main school stakeholders decide when the last step takes place, and what curricula and resource recovery activities would be covered during the implementation, monitoring and adjustment phase. During implementation, research questions related to effective behaviour change interventions at the schools and the impact of behaviour change in surrounding communities, as well as innovative waste management solutions, are addressed by the research team. Participatory approaches are used throughout the whole process to ensure that the real needs and expectations of the schools are considered, and to ensure the long-term sustainability and ownership of the selected improvements.

This step-by-step approach is currently being applied at Budhanilkantha School in Kathmandu, Nepal, as a first case-study. Preliminary results are presented below, with a special focus on solid waste management issues.

Photo 1: Students group – Action Plan development workshop.

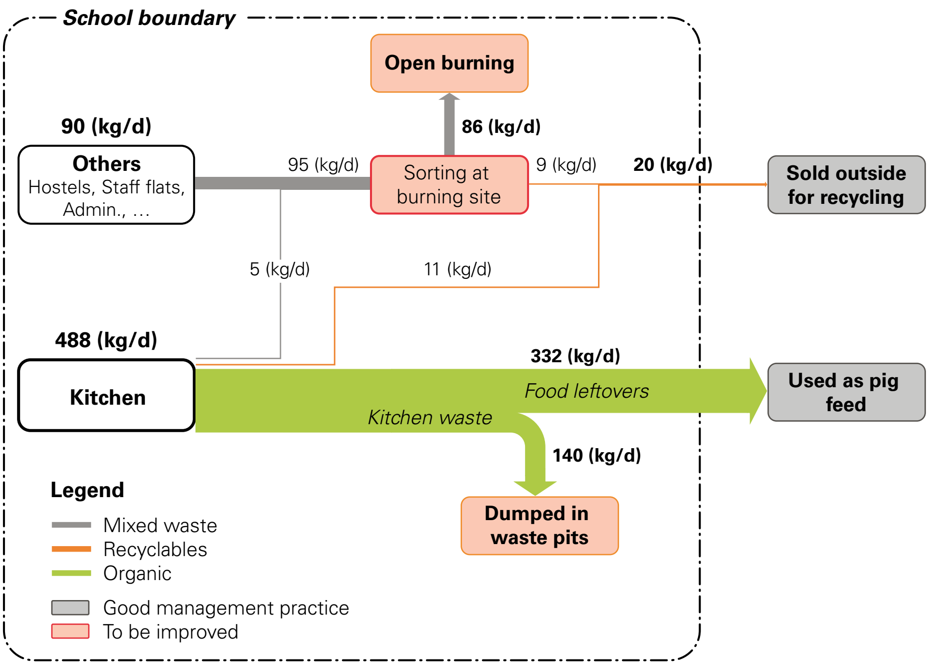

Figure: Simplified waste flow, management practices and room for improvements in BNKS.

Budhanilkantha in Nepal

Budhanilkantha School (BNKS) is a boarding school with grades 5 to 12, including the Advanced Level of Cambridge University, UK. With around 1 100 students coming from all over Nepal, it aims at quality education for 'rich and poor alike' in an environment that fosters unity and equality. Apart from high academic standards, BNKS also imparts multi-dimensional skills and leadership qualities through an array of sports and extracurricular activities. Due to the school's policy to strive to continuously improve the quality of education and services provided to the students and the staff residing on the school campus, BNKS was identified as an appropriate location to implement a 'Circular-Waste' approach.

Waste assessment

The current solid waste management situation and practices at BNKS, presented in the Figure, were assessed by observations done of the school infrastructure and current waste-related practices, interviews with school stakeholders, as well as an on-site waste audit that measured solid waste quantities and composition. Results showed that ~580 kg of waste are produced daily, of which 86 % is organic, 10 % are inorganic recyclables and 4 % is non-recyclable (sanitary pads, diapers, dust, light plastic, etc.). When looking at the source of the waste, the kitchen contributes 84 % of the total waste produced, of which 96 % is organic. 70 % of this organic waste, which consists of leftover cooked food, is currently collected by a farmer to feed pigs at his farm. The other organic waste from the kitchen is dumped in a waste pit inside the school compound. The waste produced in the other school areas, such as student hostels, staff flats, administration offices, etc., is collected as mixed waste and disposed at a burning site located inside the school compound. Before the waste is burned, some recyclables are extracted by a waste picker and sold outside the school to a scrap dealer.

The assessment showed mainly two challenges for waste management at BNKS:

1) **Resource recovery:** The low recycling rate of inorganics is due to the mixed collection system, which reduces the quality of the recyclables. Furthermore, the waste picker and scrap dealer are not actively integrated in the school waste management system.
2) **Disposal:** Most of the inorganic waste is openly burnt at a designated site on the school premises. Furthermore, a significant part of organic waste from the kitchen and staff flats is dumped without resource recovery.

Action Plan

The results of the waste assessment were shared and discussed among all school stakeholders (i.e. students, teachers, administration and non-teaching staff) in a workshop (Photos 1 & 2). Different groups were formed to discuss waste management improvement scenarios. This fed into the development of an Action Plan that summarised the main options for improvement, which was then presented to the school authority. The main strategies presented in the Action Plan are as follows:

1) **Segregation:** Organising systematic segregation of the waste using a three-bin system (organic, paper and cardboard, and mixed recyclables) and segregated collection; implementation and monitoring of reduce/reuse strategies.
2) **Resource recovery:** Installing a site for sorting, storage and recyclable sales; potentially build upon the existing organic recycling system.
3) **Safe disposal:** Stopping open burning and putting in place a safe management system for non-recyclable and medical waste.

For each of these three strategies, several suitable options were presented by means of factsheets, containing technical and non-technical information. For the organic waste management component, factsheets on composting, vermicomposting, anaerobic digestion and animal feed were presented. For enhancing sales of recyclables, three potential buyers were identified. For safe disposal, information on how to build a manual sanitary landfill, as well as information on how to construct a small DeMonfort incinerator and autoclave for the medical waste fraction, was included.

Anonymous

Photo 2: Teachers group – Action Plan development workshop.

Conclusion

Currently, the Action Plan is being reviewed and discussed by the school authority for implementation. From a waste management research perspective, these first phases of the ZW@S project at Budhanilkantha School highlighted the need to further investigate management options for specific waste fractions, e.g. disposable sanitary products (diapers and sanitary pads) and light plastics. Disposable diapers and sanitary pads are increasingly being used and their management as waste is particularly challenging due to their potential hazard, composition, moisture content, volume and/or cultural beliefs about them. Light plastics, such as food packaging, wrappers and plastic bags, are currently not recycled at large scale due to their heterogeneous composition. Both of these fractions are typically burnt or dumped at present. It is, therefore, on our agenda to find suitable and sustainable solutions on how to manage disposable sanitary products and light plastics to achieve a zero waste approach.

[1] Eawag/Sandec, Switzerland

[2] 500B Solutions Pvt. Ltd., Nepal

We would like to thank Budhanilkantha School for support and motivation throughout the process, as well as the Swiss Agency for Development and Cooperation (SDC) for funding this research.

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Valorising Biowaste Using BSF: A Cost Model and Market Assessment

Technical viability of the Black Soldier Fly biowaste conversion system has been shown. Economic viability, however, requires cost analysis of the technical system and analysis of what products could be substituted by BSF products. These are needed to plan viable business models. Bram Dortmans[1], Grégoire Virard[1], Early Antarest[1], Putu Putri Indira Sari[1], Christian Zurbrügg[1]

Introduction

Two Eawag projects are currently ongoing in Indonesia with a focus on Black Soldier Fly (BSF) biowaste conversion. From Organic Waste to Recycling for Development (FORWARD) started in July 2013 (funded by the Swiss State Secretariat for Economic Affairs, SECO) and had the main objective to improve biowaste recycling by exploring local market opportunities for biowaste conversion products. After evaluating waste amounts, waste accessibility and the market potential of different biowaste conversion products, results showed that the most promising biowaste derived value product is protein for animal feed. FORWARD then piloted a facility where biowaste conversion by Black Soldier Fly Larvae (BSFL) was developed as the core technology. The project is now in its final phase, assisting private partners and the local government of Surabaya to set up BSF facilities and develop financially viable business models.

Although BSF biowaste conversion is now being replicated worldwide by private enterprises, municipalities and waste utilities, it remains an innovation. More evidence on product development, respective markets and economic feasibility is required to make a stronger case for BSF technology. Therefore, in December 2017 a second project, Sustainability of Insect-Based Recycling Enterprises (SIBRE) (funded by the Swiss-Re Foundation) started, focussing on the financial and business aspects of the BSF biowaste conversion system.

Figure: Black Soldier Fly life cycle at the BSF biowaste conversion pilot facility in Sidoarjo, Indonesia.

Early Antarest

Photo 1: Survey work by the SIBRE team in the local markets around Surabaya.

Activities

In 2018, SIBRE worked on two main activities: 1) cost analysis of setting up and running a BSF facility, using the data from the FORWARD pilot site in the city of Sidoarjo and 2) market analysis exploring the potential for BSF conversion products in Eastern Java (Figure). Cost analysis work started by structuring each operation of the BSF system with its inputs and outputs in a flow chart. This flow chart was then used to collect the data for a cost model. The market analysis study targeted two customer groups: 1) the farmed animal market (poultry and aquaculture feed) and 2) the domesticated animal market (bird, ornamental fish and reptile feed). For the farmed animal market, existing reports and literature were used to estimate the market size based on sales of existing products that could be substituted by BSF conversion products. Such data was, however, not available for the mostly informal, small-scale, domesticated animal market. Therefore, surveys and interviews were done to identify potential products to substitute and better understand the existing supply chains and business models (Photo 1).

Results

A first version of the cost model, structured as an Excel spreadsheet, was finalised at the end of 2018. It includes an overview of all costs and revenues of a BSF biowaste conversion system, comprising all individual components, starting from biowaste sourcing to biowaste processing, up to marketing of conversion products. Given its activity-based structure, an operator can choose to analyse only one section of the system as a potential business scenario, much like in the poultry industry where hatching and breeding of chicks, fattening the chickens, and slaughtering and processing the meat into products are often divided into separate businesses.

More than 80 interviews with breeders, retailers and customers in the domesticated animal market were done for the SIBRE market analysis (Photo 2). Results estimate that the market size of this segment for the Surabaya region is ~3331 tons/year, and that there are around 40 potential products that could be substituted by BSF conversion products. Survey results show that interest in BSF products is high and because of the informal environment, there is no obvious obstacle that could hinder the introduction of BSF products in this segment. In contrast to the domesticated animal feed market, the prices for potential substitute products fed to farmed animals are low. Therefore, based on this study, this market segment is not considered a viable option for BSF conversion product sales in eastern Java.

The survey team also managed to compile data on current pricing for most products that could be replaced by (processed) BSF products. Preliminary cost-analysis data of the post-processing equipment and other operational costs show that the production costs would allow for a generous margin if sold at the same prices collected by the surveying team. Yet, respondents faced a major issue. Handling insects as a feed for pets requires storing the product. Live insects cannot be purchased in bulk and even if the insects are processed, their expiration date is often only a few months. The respondents would, however, accept these challenges in handling the product. 80 % answered that they would buy the product because insects are a natural part of their pets' diets.

Early Antarest

Photo 2: Preparation for a singing bird contest in Surabaya.

Conclusion

As the BSF cost model is still quite complicated to use, SIBRE will focus on verifying and simplifying the model as a planning tool for those interested in setting up a BSF system. The currently available version can serve to analyse the performance and cost optimisation of an existing BSF facility.

Besides continuing research to optimise BSF operations at scale, both projects will continue their support and dissemination activities of the BSF technology for worldwide use. Specifically, for Indonesia, in collaboration with SECO and the Ministry of Public Works and Housing, the project will provide technical support to private enterprises and the Municipality of Surabaya. The results will be disseminated to the government of Indonesia and other stakeholders to help them improve waste management at the local level.

[1] Eawag/Sandec, Switzerland

FORWARD project funding is provided by Swiss State Secretariat for Economic Affairs (SECO) and SIBRE project funding is provided by SwissRe Foundation.

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Increasing the Efficiency of Biowaste Digestion by Black Soldier Fly Larvae

Although biowaste conversion with black soldier fly larvae can effectively reduce waste, differences in waste content influence the output. A literature review identified that macronutrients and microbes are key for efficient and reliable biowaste conversion performance. Moritz Gold[1,2], Jeffery K. Tomberlin[3], Stefan Diener[4], Alexander Mathys[2], Christian Zurbrügg[1]

Introduction

Black soldier fly larvae conversion is a new biowaste treatment technology. Larvae consume biowaste, convert it into larval biomass, and leave behind a compost-like residue, with characteristics similar to immature compost. Besides reducing waste dry mass by up to 70 %, the insect biomass that is produced has a high market value as animal feed. Revenues from this treatment product could provide an incentive for waste management and contribute to offsetting waste management costs, while providing more sustainable animal feeds.

Challenges to black soldier fly larva conversion are reliable and efficient operation. High quality waste sources often have competing uses and practice shows that it is not easy to obtain good quality waste for the processing. Poor waste management results in mixing of wastes with inorganics, incentivises landfilling of organic wastes, or involves complex logistics, thus, hindering access to black soldier fly larvae processing. Processing lower quality wastes typically result in a high variability of waste reduction, low larval biomass production and poor larval composition (e.g. lipids and proteins). This not only affects day-to-day operations (e.g. operation over or under the treatment capacity), but also compromises the sustainability and scalability of this treatment technology.

Well-studied fly larvae

A literature review was done to identify the factors influencing performance parameters, concerning black soldier fly larvae and four other fly species whose larvae also feed on biowaste. The latter have been studied in more detail and are: pests for humans/animals (i.e. house and stable fly), used in maggot therapy (i.e. green bottle fly) or used as a model to understand biological processes (i.e. common fruit fly). The goal was to increase understanding of black soldier fly larvae digestion, and then use this knowledge to enhance performance and product quality. The complete review is available for free at http://bit.ly/2UVYSmB.

System description

Figure 1 shows a conceptual description of the black soldier fly larvae conversion as two reactors. The fly larva is depicted as a single reactor in which all processes happen inside the larva, and the second reactor – the biowaste – includes all processes happening in the biowaste, outside the larva. Processes in both reactors are influenced by operational parameters, such as container dimensions, temperature, larval density, humidity, feeding rate, and feeding interval. The larval reactor and waste reactor are connected by processes, such as ingestion, secretions, and excretions.

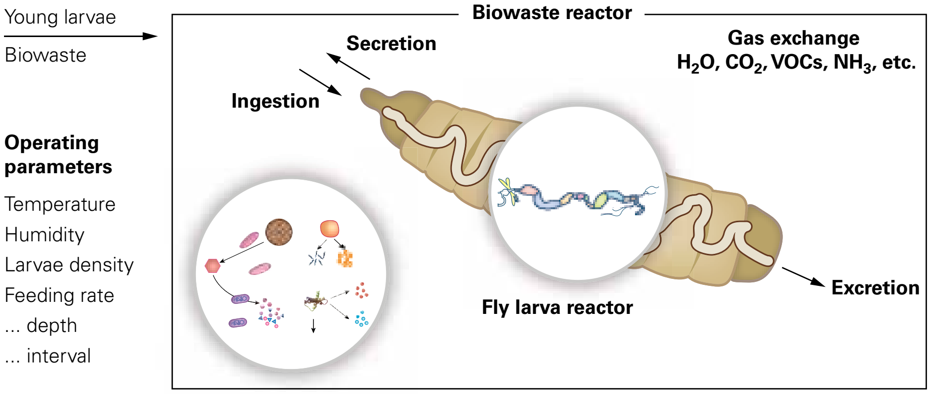

Figure 1: System description of black soldier fly biowaste conversion [1].

Larval digestive tract

Whereas larval development has been studied using a variety of biowastes, little attention has yet been given to what happens inside the larva following biowaste ingestion. A schematic of a fly larva gut is shown in Figure 2. The digestive tract is a long tube (around 10 cm in length in developed larva) that doubles back and forth upon itself between the anterior and posterior end of the larva. The gut is divided into different regions with distinctive physical and chemical (e.g. pH and enzymes) characteristics. Our ongoing research aims at mimicking the digestive tract in vitro, both as a research tool and as a model to estimate the process performance of different biowastes.

Biowaste macronutrient decomposition

Biowaste macronutrients include proteins, carbohydrates, fibres and lipids. Similar to humans, fly larvae eat to obtain these nutrients to gain buildings blocks and fuel for their metabolism and development. Biowaste macronutrient decomposition starts in the biowaste reactor triggered by microbes and associated environmental conditions, then followed by the ingestion and action of enzymes in the anterior midgut. Analogous to the human mouth, the anterior midgut appears to be mostly responsible for starting the decomposition of carbohydrates into glucose. Thereafter, the food passes into the mid-midgut. Similar to the human stomach, this section has a low pH and thereby plays a vital role in the inactivation of microbes. Analogous to the human small intestine, the posterior midgut is the longest part of the midgut and is important for the terminal decomposition of carbohydrates, proteins and lipids into its typical building blocks, i.e. glucose, and amino and fatty acids, and for their absorption into the haemolymph. The haemolymph is analogous to human blood and distributes the substances throughout the body. Non-digestible waste constituents are then excreted from the hindgut.

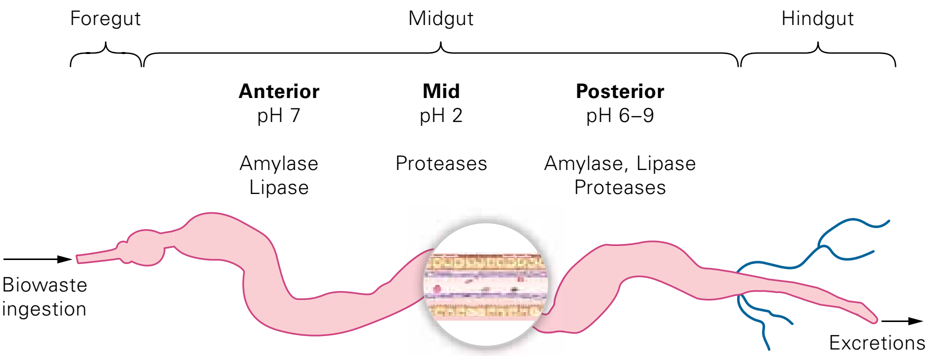

Figure 2: Schematic of a black soldier fly larva gut [1] adapted based on [2].

Macronutrients and process performance

Amino acids, the building blocks of protein, and carbohydrates are considered to be the nutrients that have the largest influence on process performance. Larvae adjust their ingestion, decomposition (e.g. enzyme production) and absorption of these nutrients based on their current nutritional demands. Providing too much or too few nutrients can either bear a metabolic cost or lead to nutrient deficiencies, slowing development.

The results of our review suggest that amino acids are important for larval development time. Larvae feeding on biowaste with low protein content show slower development. Due to the deficiency of amino acids in the larval fat body, analogous to the human liver, the excretion of hormones needed for larval development are suppressed. In contrast, carbohydrates appear to be most influential for the accrual of larval lipid content. Larvae fed on biowaste with high carbohydrate content have higher lipid content. On low-protein and high-carbohydrate diets, larvae convert carbohydrates into lipids. Fibres are difficult to digest or not-digestible for larvae, thus, lowering waste reduction.

Biowaste and larva microbial community

Fly larvae feed on diets containing a high number and diversity of microbes. These microbes have multiple functions that are important for black soldier fly larvae biowaste conversion. Microbes influence the decomposition of biowaste inside the biowaste and reactors. They are also a direct source of food, and produce essential nutrients and metabolites. Adding certain bacteria to the biowaste can increase process performance. For example, addition of *Lactobacillus buchneri* to soybean curd residue increased larval weight production by 39 % in comparison to a control without the bacteria [3]. It is as of yet unclear whether this performance increase is due to processes predominantly happening in the biowaste reactor or in the larva reactor (or a combination of the two). Our research suggests the biowaste microbial community is very important for the black soldier fly conversion system. Removing the microbial community from canteen waste by high-energy electron beam treatment shows decreased larval weight by 35 % compared to an untreated control [4].

Parameter	Measurement methods	Influence
Protein	Determination of nitrogen and multiplication with a waste-specific k value, accounting for different amounts of non-protein nitrogen	+
Digestible Carbohydrates	e.g. starch and sugars, by enzymatic assays or following acid hydrolysis	+
Lipids	Extraction with a solvent (e.g. petroleum ether in a Soxhlet system)	±
Fibres	Neutral and acid detergent fibre as an estimate for hemicellulose, and cellulose and lignin content	–
Ash	Residue following combustion, estimate for minerals and non-digestible constituents	–

Table: Parameters to assess biowaste characteristics for black soldier fly larvae conversion. The plus and minus symbols indicate whether an increase in this parameter tends to increase or decrease process performance.

Conclusion

Our research suggests that one reason for the variable process performance of black soldier fly larvae conversion is the varying amounts of protein, carbohydrates, lipids, fibres and inorganics in biowaste. These components influence waste reduction, larval development and larval composition. Formulating the biowastes to ensure similar nutrient contents would reduce this variability, but a comprehensive biowaste characterisation would have to be done to obtain this information. The Table summarises the relevant parameters to measure. Ongoing analyses of different biowastes identified that typical low-value biowastes do not usually lack protein (> 10 % dry mass), but rather lack digestible carbohydrates. Biowastes high in digestible carbohydrates, however, may already be used as animal feed and are, therefore, not accessible or come at a price. Another likely reason for process variability is the microbial composition of biowaste. Pre- and co-treatment of biowaste with beneficial microbes has a large potential to increase process performance.

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[1] Eawag/Sandec, Switzerland

[2] ETH Zurich, D-HEST, Sustainable Food Processing, Switzerland

[3] Texas A&M University, USA

[4] Biovision Foundation, Switzerland

Funding:
Engineering for Development (E4D) programme of ETH Zurich, Sawiris Foundation for Social Development, Eawag, ETH Zurich Foundation and Bühler AG

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From Design Assumptions to Actual Operation: The eFSTP Research Project

Knowledge is lacking on the actual operating conditions of existing faecal sludge treatment plants (FSTPs). Faecal sludge characteristics are also highly variable and difficult to predict. Given this, how can new FSTPs be designed to meet actual operating conditions? Marius Klinger[1], Amadou Gueye[2], Anjali Manandhar Sherpa[3], Becaye Sidy Diop[2], Bipin Dangol[3], Linda Strande[1]

Introduction

Over the last decade a shift has taken place worldwide about the acceptance of faecal sludge management (FSM). Many now consider it as a viable solution alongside sewer-based systems in achieving citywide inclusive sanitation. Hence, FSTPs are being constructed throughout Asia and Africa, with hundreds being planned. This scaling up is urgently needed, as every year tons of faecal sludge is discharged directly into the environment. However, information is lacking about adequately functioning FSTPs upon which to base this scaling up, and inadequate design could likely lead to plant failure. Therefore, there is a pressing need to learn from the failures and successes of existing FSTPs.

Project objectives

The eFSTP project (Evaluation and Monitoring of Faecal Sludge Treatment Plants) is addressing this knowledge gap by engaging local partners in extensive monitoring and capacity development of their existing FSTPs. The project objectives are:

- to improve institutional commitment for the sustainable implementation and operation of FSM including FSTPs;
- to understand how to predict faecal sludge quantities and qualities (Q&Q) in a simple, affordable and reliable way;
- to learn how operators and managers can adequately deal with the variability of Q&Qs of faecal sludge with limited resources (Photo);
- to research how engineers can better design FSTPs for real operating conditions;
- and to foster South-South capacity building and sharing of knowledge.

Scoping study of current state of FSTPs

A scoping study was recently completed in collaboration with Delvic Sanitation Initiatives (Senegal) and the Environmental and Public Health Organization (ENPHO, Nepal).

COUNTRY	Total FSTPs	Operational	Start of operation	Under construction	Range of design capacity	Drying bed dewatering	Mechanical dewatering
SOUTH ASIA							
Bangladesh	15	7	2014–2017	1	2–180 m³/d	15	0
Bhutan	1	1	2017	0	3 m³/d	1	0
India	37	30	2015–2018	7	1–100 m³/d	26	11
Nepal	4	2	2015–2017	2	1–27 m³/d	4	0
WEST AFRICA							
Burkina Faso	4	4	2014–2016	1	125–250 m³/d	4	0
Ghana	6	5	2002–2016	1	450–800 m³/d	1	2
Ivory Coast	1	1	2017	0	100 m³/d	1	0
Senegal	10	10	2006–2017	0	60–400 m³/d	10	0
EAST AFRICA							
Malawi	3	0	–	3	10–50 m³/d	3	0
Rwanda	1	1	2015	0	100 m³/d	0	1
Uganda	35	2	2014	33	1–400 m³/d	2	0
Tanzania	4	3	2012–2018	1	1–10 m³/d	3	0
Zambia	2	2	2013–2014	0	3 m³/d	2	0

Table: Summary table of the collected data during the desk and field based scoping study of the eFSTP project.

A desk-based landscaping study identified more than 120 existing FSTPs in 13 countries in South Asia (SA) and Sub-Saharan Africa (SSA). Then, an evaluation of the FSTPs, their treatment technologies, and models of operation led to 23 FSTPs in eight countries being selected for site visits. The aim was to learn more about their actual operating conditions (Table).

In India, Bangladesh and Nepal, FSM has risen in importance over the last five years. Many new FSTPs have been built in cities and towns of all sizes, from small semi-urban municipalities serving populations of tens of thousands, to big urban centres with millions of inhabitants. The visited FSTPs were mostly small- to medium-size (treating from 1 to 75 m³ of faecal sludge per day) and often operate under capacity. A wide range of public, private, private public partnership (PPPs) and non-governmental organisations (NGOs) are involved in their design, implementation, and/or operation. The main challenges identified are bringing faecal sludge to the FSTPs, high variability of Q&Q of faecal sludge, and lack of capacity on how to operate the FSTPs.

In Senegal, Burkina Faso and Ghana, the need for FSM was acknowledged earlier than in SA. The FSTPs are older (four to ten years old) and an institutional regulatory framework was developed. Information was readily available for FSTPs in the capitals or larger cities, and they are the responsibility of the national sanitation utilities. They have larger treatment capacities (60 to 150 m³/d), and frequently operate at over capacity. In Dakar and Ouagadougou, the FSTPs take six to eight times the designed faecal sludge load every day. The main difference between the two cities is the management and knowledge capacity, which is higher in Dakar, where a highly educated and trained private company (Delvic) is responsible for management. The result is that overloading is being managed in Dakar, whereas overloaded FSTPs in Ouagadougou struggle to treat incoming sludge and have to routinely be shut down.

In Ivory Coast, the national sanitation utility (ONAD) is testing an integrated FSM ap-

Marius Klinger

Photo: Easy and innovative way to keep track of the sludge loading at Karunguzhi FSTP drying beds in Tamil Nadu, India.

proach in the small northern town of Korhogo (fewer than 300 000 people in 2014) with the operation of one medium size (100 m^3/d) FSTP. From this experience, they plan to scale up in the rest of the country. More FSTPs are already planned in Abidjan and other cities. The main challenge at the Korhogo FSTP is that the design assumptions did not take into account the absence of regionally available sand for the filter media. The FSTP is currently operating only because it is underloaded and the manager is skilled and motivated at implementing adaptive measures.

In Zambia, Malawi and Tanzania, non-governmental organisations have initiated several FSTPs, targeting small, densely populated, low-income areas at community scale (three to eight m^3/day). In addition, existing wastewater treatment plants are often used for faecal sludge discharge and some are being refurbished as FSTPs. The main issues observed were FSTPs operating at overcapacity and lack of capacity, clearly dedicated management and operating personnel, and design and construction issues.

In Uganda, the Lubigi FSTP has operated in Kampala since 2014 (400 m^3/d) and Uganda has an FSM institutional regulatory framework in place. In addition, the National Water and Sewerage Corporation (NWSC) and the Ministry of Water and Environment are scaling up FSM throughout Uganda, with an ambitious countrywide plan to construct more than 30 FSTPs in small towns, and a second FSTP in Kampala. Information about these new FSTPs was difficult to find; this highlights the communication and sharing of knowledge challenges among the sector stakeholders.

Identified challenges

Although results confirmed that FSM is rapidly evolving, and that there are different patterns of development throughout SA and SSA, important challenges exist that need to be addressed:

- **Institutional recognition:** In general, institutional frameworks for the regulation of FSM are mostly not well established. For FSM to succeed, governments have to acknowledge this need.
- **Q&Q of faecal sludge:** Q&Q of faecal sludge are highly variable, which greatly complicates plant operation. Typically, financial and technical resources for analytical methods to determine Q&Qs of faecal sludge are lacking, although Q&Q analysis is necessary to design plants for actual operating conditions. Sandec recently developed and field-tested a method to address this gap (See pages 14–15).
- **Capacity for operation:** Due to the rapid growth and implementation of management and treatment solutions, there is a lack of trained design, operation, and management capacity. Many planned FSTPs will be located in small towns or peri-urban areas. Therefore, they will require the development of stand-alone, relatively easy to implement, adaptive operating management guidelines.
- **Design for operation:** Designs are typically based on estimated average values, even though FS does not follow a normal distribution pattern and the design assumptions are often not valid during operation. This results in treatment technologies not being loaded accordingly, which leads to poor treatment performance and/or failure. There is an urgent need to figure out how to design FSTPs for real actual operating conditions so that they can operate effectively.
- **Communication:** There is little to no information available on the actual operation of existing FSTPs, and existing information is commonly not shared. There is, therefore, no way to learn from existing experience to improve future designs or operations; the need exists for South-South communication between stakeholders to share lessons learned.

Way forward

Based on the results of the scoping study, in-depth monitoring and evaluation of the selected FSTPs is under preparation, which includes incoming Q&Qs, treatment performance, and operation and maintenance (O&M). Recommendations will be made for immediate improvements, including how to determine appropriate loadings of drying beds given the high variability of FS characteristics and limited resources. The final project planned outputs include:

- regional dissemination workshops and policy briefs;
- improved evidence-based guidelines on how to predict faecal sludge Q&Q in an affordable and reliable way;
- guidelines on step by step implementation to optimise treatment performance;
- guidelines on how to improve O&M of FSTPs with limited resources;
- recommendations on how to design FSTPs that meet actual operating conditions; and
- workshops and online courses to foster knowledge dissemination and capacity development for designers, managers and operators of FSTPs.

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More about the project, its evolution and publications at: www.sandec.ch/efstp.

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Predicting Faecal Sludge Dewatering Performance for Improved Treatment

This article is an update on our ongoing dewatering research and its potential applications for practitioners. We identified physical-chemical and demographic information that correlates with faecal sludge dewatering performance, including conductivity and sludge source. B.J. Ward[1,2], S. Sam[1,2], A. Gueye[3], B. Diop[3], E. Morgenroth[1,2], L. Strande[1]

Introduction

Our research has two goals: 1) developing methods to manage the current faecal sludge crisis, and 2) developing innovative and sustainable treatment and management solutions for the future. Dewatering is the most important technical issue to overcome to meet both goals. Separating water from solids is a bottleneck due to the unpredictable and variable quantities and qualities (Q&Q) of faecal sludge arriving for treatment. Until very recently, hardly any research has focused on developing a fundamental understanding of faecal sludge dewatering in order to improve treatment performance.

Currently, the most well established technology for dewatering of faecal sludge is drying beds. However, they have a large footprint, take a long time to dewater sludge (several weeks to several months per batch), and their performance is dependent on variable influent Q&Q. To adapt technologies to the high variability, methods of monitoring incoming faecal sludge to predict its dewatering performance are required. These methods could also be used in the development of low-footprint, high-throughput technologies, or to enable the transfer of existing technologies from other fields (e.g. wastewater treatment).

The current state of knowledge is based on empirical observations by practioners or researchers. For example, practitioners have observed that faecal sludge from public toilets takes longer to dewater and behaves more unpredictably during dewatering than sludge from household septic tanks [1, 2]. Other studies found that containment type, not sludge source, is important for dewatering performance [3]. There is a common belief among treatment plant designers, operators, and field researchers that 'freshness' or level of faecal sludge stabilisation is important for dewatering performance [2]. Our goal is to incorporate and quantify this practical knowledge, and determine whether there are consistent parameters that predict dewatering performance that can be rapidly and quantitatively measured.

Methodology

Sandec collaborated with Delvic Sanitation Initiatives to collect faecal sludge samples and questionnaire data from 20 sites in Dakar, Senegal. Information of demographic parameters (source, i.e. households, public toilets, offices, schools), as well as of environmental (microbial community) and technical (containment type, residence time)

Eawag, Barbara J. Ward

Photo 1: A photographic comparison of faecal sludge samples after prolonged settling. Left: less stabilised faecal sludge samples (higher EPS concentrations, slow dewatering). Right: more stabilised faecal sludge (lower EPS concentrations, fast dewatering).

parameters, which were expected to influence dewatering performance, was collected. In addition, physical-chemical parameters were characterised (i.e. TS, TSS, VS, VSS, EC, pH, cations, and extracellular polymeric substances or EPS). EPS is organic material secreted by microorganisms in the sludge, and is important for dewatering performance in wastewater sludge. Dewatering performance was also measured, i.e. settling efficiency (turbidity of supernatant after settling), settling compactness (sludge volume index), dewatering time (capillary suction time, CST), and cake solids after dewatering (dry solids after centrifugation). The faecal sludge samples all originated from septic tanks connected to pour-flush toilets with similar residence times in containment, but came from a variety of sources.

Results

In general, the faecal sludge samples settled into compact cakes, but about 30 % still had turbid supernatant after prolonged settling. Almost all of the samples produced dewatered cakes with high solids content (> 12 % ds), but over 30 % of the samples dewatered slowly (CST > 120 s). Faecal sludge from public toilets took longer to dewater than all other sources, and had turbid supernatant after settling [4]. As shown in Photo 1, this is most likely because it was less stabilised than the sludge from other sources (quantified by higher EPS concentration). In general, less stabilised sludge had slower dewatering with higher turbidity in the supernatant than more stabilised

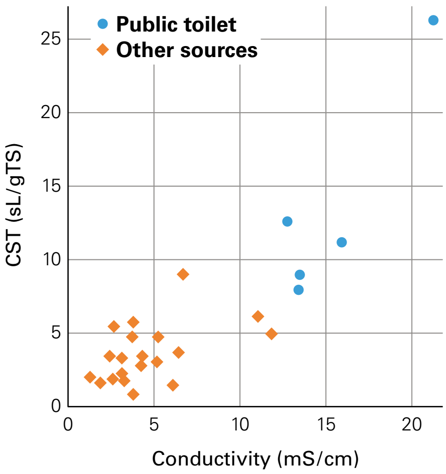

Figure: A plot of conductivity vs. dewatering time (CST) normalised by total solids concentration. High CST indicates slow dewatering.
Points are coloured based on source: public toilet faecal sludge is in blue, sludge from other sources is in orange.

Eawag, Aldo Todaro

Photo 2: PhD students Stanley Sam and BJ Ward measure dewatering performance of faecal sludge using a bench-scale Bucher filter press.

sludge [4]. This is likely related to higher concentrations of undegraded organic matter, which clog pores in drying beds, filters, and other dewatering technologies.
Less stabilised sludge also had higher conductivity, pH, and cation concentrations, which could be indicators of higher urine concentrations [4]. Interestingly, the residence times in containment were similar for less and more stabilised sludges, indicating that time is not the only factor important for stabilisation. This could be a hint that high urine concentration could inhibit the degradation and stabilisation of faecal sludge during storage in containment. In general, all of the sludges had similar dewatered cake solids, and the level of stabilisation did not appear to make a difference (i.e. EPS and VSS) [4]. More detailed information about the results and implications of this study are available in Ward et al. [4].

Next Steps

Our ongoing research includes further investigating relationships that were observed between dewatering time and conductivity and pH (Figure). If this trend is robust, it could be used in online monitoring of faecal sludge. Conductivity and pH probes could be rapid and inexpensive methods for online monitoring and predicting dewatering performance, or for enabling the transfer of other technologies, i.e. dosing of conditioners for dewatering with mechanical presses (Photo 2).
We are also further investigating the links between microbial communities and stabilisation of faecal sludge, and researching the role that urine plays in inhibiting stabilisation during storage in onsite containment. These could inform storage and treatment strategies, e.g. urine diversion or co-digestion with low ammonia substrates.

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Funding:
Engineering for Development (E4D) programme of ETH Zurich, Sawiris Foundation for Social Development, Swiss National Science Foundation (SNF), Eawag Discretionary Funds

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Development of SPA-DET Approach for Faecal Sludge Quantities & Qualities

The forthcoming book *Methods for Faecal Sludge Analysis* has a chapter on the 'SPA-DET' approach for determining faecal sludge quantities and qualities, developed by Linda Strande [1]. This article provides an update on lessons learned during field-testing of this approach. Nienke Andriessen[1], Samuel Renggli[1], Linda Strande[1]

Introduction

Estimating quantities and qualities (Q&Q) of faecal sludge at community to citywide scales is of vital importance for sanitation planning and management purposes. Previous attempts at estimations have been largely based on average values reported in the literature or values taken from other cities, but in reality this is inaccurate due to the high spatial variability of Q&Q. A solution is needed to make more accurate estimates that can be applied locally by practitioners.

In a previous issue of Sandec News [2], an approach for determining faecal sludge Q&Q was introduced. It is based on the hypothesis that SPA-DET data (demographic, environmental, and technical information that is spatially analysable) can be used as easy-to-measure predictors for Q&Q. This method is evolving over time, and is currently still in the beta phase. During 2018, the approach underwent several (iterative) field-tests, which helped to shape it as a method and make it more applied and user-friendly. The full methodology will be available in the forthcoming *Methods for Faecal Sludge Analysis* [1].

Lessons learned

The SPA-DET approach for faecal sludge Q&Q was field-tested in: Kampala, Uganda; Hanoi, Vietnam; Dar es Salaam, Tanzania; Sircilla, India; Blantyre, Malawi; and Kohalpur, Nepal. Difficulties encountered during field-testing included the local availability of SPA-DET data, adequate resources for a statistically relevant number of samples and developing meaningful sampling plans based on these resources, sampling that is dependent on emptying operations, integration of the methodology into existing planning approaches, i.e. City Sanitation Plans and modelling capacity. The following covers the lessons learned.

It was found that the types of SPA-DET data available on location varied per context. We tested the methodology in cities of various sizes, and in most, some SPA-DET could be obtained from local or national authorities (e.g. national bureau of statistics, census data, and water authority). In contexts where no SPA-DET was available, for example, in Kohalpur, Nepal, a pre-questionnaire was used to collect SPA-DET, and an informed sampling plan developed from this information. In contexts with no pre-existing data or sanitation capacity, it is challenging to define a meaningful objective for determining Q&Q. The first step could then be to get a general overview, which, together with making a Shit-Flow Diagram (sfd.susana.org), can create the basis for defining more specific objectives.

The type of sampling *(in situ* or *ex situ)* can be a trade-off and has to be selected according to the study objectives and available resources. *In situ* and *ex situ* sampling approaches have been trialled. *In situ* entails taking a representative sample directly from the containment with a core sampler device, and measuring the volume of sludge with the Volaser. This requires validation of the accuracy of these methods, and also depends on the study objective. It is important to recognise that what is measured *in situ* could be different from what arrives at a treatment plant. For example, water might be added during the emptying operation. *Ex situ* sampling entails following an emptying service provider to a customer for an emptying operation, conducting a questionnaire, and then following the emptiers to the discharge point to take a representative sample during discharge. A limitation of this method is that it relies on existing businesses' and customer demand, which makes it challenging to obtain a sample distribution for a designated sampling plan. If there are funds available to pay for designated containments to be emptied, this could improve the possibility of obtaining the planned sampling distribution.

Quantifying the volume of faecal sludge *in situ* is difficult, since containments are underground and their design is typically not standardised. To address this difficulty, the Volaser device was developed (Figure). The Volaser uses two distance-lasers and a depth stick to determine the volumes of faecal sludge and of the containment *in situ*, regardless of shape, and is operated with a smartphone app. Three prototypes currently exist that have been field-tested in India and Nepal (Photos). The main lesson learned from field-testing is that it is capable of *in situ* measurements, but needs to be more robust for field implementation. One limitation is that the current version of the laser is only able to measure from the top, while some containments have side openings. Keep an eye on our website and Facebook page for the most up-to-date information on the Volaser development!

Our work showed that the step-by-step SPA-DET approach to determine Q&Q of faecal sludge can be implemented by any skilled practitioner by following the steps described in the book [1]. If people are not feel comfortable with statistics or modelling, consultants or researchers could be hired to assist in implementation depending on desired outputs. Q&Q of faecal sludge typically do not follow a normal distribution. Therefore, different summary statistics than mean and standard deviation are required. Median values and quartiles should be reported and the raw

1 App controlled winch
2 Laser for horizontal and vertical measurements
3 Pole for depth measurement

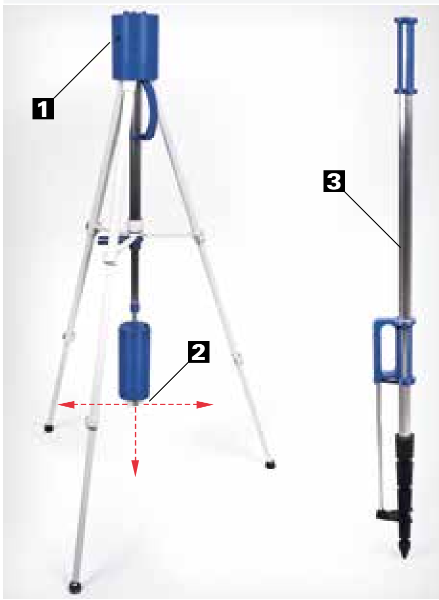

Figure: Schematic of the Volaser.

Kayla Coppens

Photo: Field testing the Volaser during SPA-DET field trials in India.

data shared. Data analysis should include checking for normality, and using non-parametric statistical tests if needed.

Using statistical relationships can improve usefulness and reduce data collection costs. In six cities with overall 450 samples taken, a linear correlation between Total Solids (TS) and Chemical Oxygen Demand (COD) was observed, with an R^2 ranging between 0.67 and 0.91. TS was easier and less costly to measure, and could be used to extrapolate values for COD.

A modelling approach can be used to improve estimates of Q&Q. Predictive models can contribute to improved planning, design and management solutions, and in the future, as more data is collected, could lead to the development of mechanistic relationships for universal understandings for faecal sludge management [3,4]. For example, separating data in Kampala and Hanoi by containment types, i.e. pit latrine or septic tank, improved model accuracy [3,4].

Lastly, for flow-through containment technologies with an outlet, such as septic tanks, it can be difficult to define a relevant sludge accumulation rate. When the overall volume of septage in the containment is constant because of outflow to a drain, only the sludge blanket layer with solids is accumulating. Depending on the objective, different definitions of accumulation could be relevant to measure. For example, to model future emptying frequency, sludge blanket accumulation is more relevant, but to model what will arrive at the treatment plant, the total volume of sludge that is delivered to treatment is more relevant. In collaboration with CDD Society, accumulation was measured for newly constructed elliptical septic tanks in Sircilla, India, which always have the same level of liquid. Sludge blanket accumulation was measured with a core sampler, and total accumulation rate, based on truck volume and emptying frequency, were both collected. The results will be analysed in a forthcoming publication.

Conclusion & future research focus

Due to the complex nature of the problem, estimating Q&Q of faecal sludge on a city-wide scale will in reality never be a simple, cookie-cutter approach. However, following the SPA-DET approach with a minimum level of resources will help to provide better estimates than previous attempts using simple average values, and can be employed in an iterative fashion as more resources become available. With increasing implementations, the methods for data collection and analysis [4] will be improved and expanded upon.

Our next steps include a planned full-scale implementation to estimate Q&Q of faecal sludge with GIZ and the University of Zambia in Lusaka, Zambia; continued testing and improvement of the Volaser; and collaboration with Z_GIS at the University of Salzburg to evaluate remote sensing for collection of SPA-DET data.

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Revenue Loss of an Emptying Service Provider Due to Informal Services

Revenue loss of an official faecal sludge emptying service provider was estimated as great due to informal services in Mandalay, Myanmar. Shortening the time from service request to delivery may contribute to formalise emptying services in the city and increase the revenue of the provider. Hidenori Harada[1], Wutyi Naing[2], Shigeo Fujii[1]

Introduction

Financial barriers are one of the most common challenges to sound faecal sludge emptying businesses, even if previous studies report that emptying services are profit-making businesses [1, 2]. We investigated the potential revenue loss of a formal service provider due to unofficial emptying services in Mandalay, Myanmar, and analysed the reasons why people use illegal services.

Methodology

Mandalay has only one formal emptying service provider (Mandalay City Development Committee, MCDC), and there is a city regulation that people need to visit the MCDC office to request emptying services. Besides the formal emptying service, three types of informal services in the city were confirmed: the service delivered by the formal service provider through informal contact, that delivered by informal service providers with vacuum trucks, and service by informal service providers with manual equipment. The following information was collected by interviewing 400 households: demographics, sanitation facilities, emptying experience, recognition and actual choice of emptying services, contact manner to providers, waiting time from service request to delivery and payment to providers. According to our survey, the median emptying frequency was 0.0925 time/year/unit. Multiplying this frequency and the number of onsite sanitation units, we estimated the number of units emptied per year in the target area (19 712 units). The theoretical maximum revenue was estimated by multiplying this number with the official service fee (21.8 USD/unit). The present revenue of the formal service provider was estimated based on the reported number of emptied units.

Results

The formal provider provided 95.5 % of the emptying service in the area. However, 64.8 % of this was requested in an unofficial manner: people called the office or drivers directly. Even though there is an official system and procedure in place, which is technically the only legal way to request emptying, this was only utilised 33 % of the time. This indicates that the official provider needs to update its system to better match what customers want. By doing this, they could greatly increase the amount of faecal sludge that is safely emptied and managed by the formal service provider.

Waiting time from service request to service delivery was significantly shorter for informal services (median = 2 days) than formal service (7 days). Also, people paid higher fees for informal services (median = 34 USD) than formal service (25 USD). The shorter the waiting time, the more people paid (Figure). Results showed that customers were willing to pay more through the informal system to have shorter waiting times. This indicates that if the official provider made their procedure less bureaucratic, more customer-friendly and quicker, they could also charge more and increase profitability.

The theoretical maximum revenue and the present revenue of the formal service provider were estimated to be 430 000 and 86 000 USD per year respectively, indicating that the provider gained only 20 % of the theoretical maximum revenue as formally recorded revenue. As mentioned above, a large proportion of the informal services were done by the official provider. This was not declared as official revenue by the formal provider and, combined with the money made by other informal service providers, caused much revenue loss for the formal provider.

Conclusion

According to interviews with city municipal employees, a main challenge for faecal sludge management in Mandalay was the financial issue related to investing in more trucks and installing faecal sludge treatment technology. By implementing these improvements in emptying services, the official provider could greatly reduce its losses by shortening the time to complete service requests, increasing official revenue and leading to more people having access to safely managed sanitation.

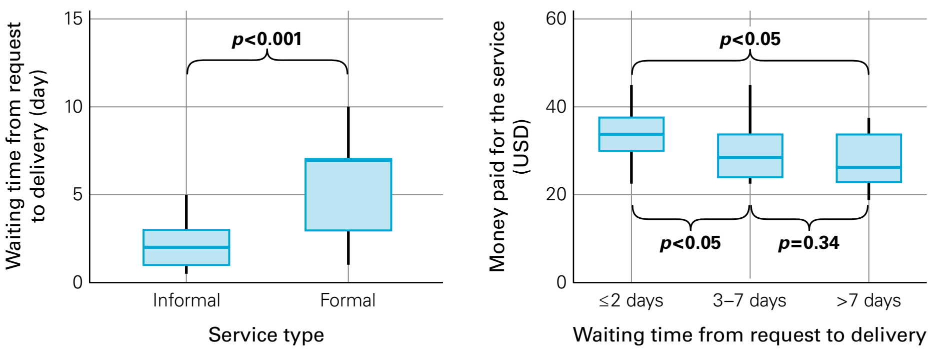

Figure: Waiting time from emptying service request to delivery for formal and informal service (n=107) (left) and emptying service fee depending on waiting time (n=107) (right). The statistical difference was tested by the Kruskal-Wallis test followed by Dunn's test. Boxplots indicate 1st, 2nd and 3rd quantiles with whiskers extending up to 1.5*IQR from the median.

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Small-Scale Sanitation in India: 4S Reports and Further Research Needs

From 2016 to 2018 Sandec and partners conducted the largest and most comprehensive evaluation of small-scale sanitation in India to date. An overview of the resulting publications and a summary of future research requirements are presented here. Lukas Ulrich[1], Marius Klinger[1], Philippe Reymond[2], Christoph Lüthi[1]

Introduction

The project Small-Scale Sanitation Scaling-Up (4S) is the first systematic assessment of small-scale sanitation in South Asia. The research project aimed to develop evidence-based policy recommendations for the successful implementation of small-scale wastewater treatment and reuse systems at scale. 4S was implemented under the auspices of the Indian Ministry of Housing and Urban Affairs, and in collaboration with the Indian Institute of Technology Madras, BORDA (Germany) and other partners.

What is small-scale sanitation (SSS)?
A SSS system is a sewer-based sanitation system that uses a small-scale sewage treatment plant (SSTP), allowing for water reuse. In 4S, a SSS system is defined as one that serves 10–1000 households (or 50–5000 person equivalents, i.e. treating about 5–700 m^3 of wastewater per day). SSS systems can be installed for individual buildings or for clusters of buildings.

Anonymous

Photo: Wastewater sampling for the 4S Project at an SSTP in Tamil Nadu.

The 4S project carried out a technical field evaluation of more than 300 sanitation units, as well as in-depth governance and financial analyses. These main project components generated three separate detailed thematic reports, which provide details for the scientific community and readers interested in more comprehensive information. A synthesis report was also produced, highlighting the overarching project findings, conclusions and recommendations. This report is designed for decision-makers of government agencies at national, state and city levels, as well as practitioners and SSTP owners. All reports can be downloaded at: www.sandec.ch/4S.

Further research needs

The 4S project has made an important contribution to the understanding of SSS, allowing stakeholders to make evidence-based decisions for sector improvement. Compared to conventional, large-scale wastewater management approaches, SSS is, however, a recent and rapidly evolving field. Practitioners have limited knowledge of how SSS systems are optimally implemented, operated and managed at scale. There is, therefore, a wealth of opportunities for continued scientific research at all levels, such as:

- Technology, implementation and operation: cost-effective nutrient removal, remote monitoring, and performance benchmarking using large databases to inform standards development and design
- Governance: evaluating mechanisms for efficient performance monitoring and for matching supply and demand of treated water, using an online database
- Financial sustainability: optimal degree of (de)centralisation for sewage treatment and reuse systems and testing innovative mechanisms (e.g. performance-based contracts)

For the SSS sector to grow effectively in India, it is crucial to ensure that there is a thorough scientific accompaniment to all future developments and an institutionalised learning mechanism that facilitates the uptake of newly gained knowledge. The 4S project and its reports are examples of the kind of work necessary for capacity development in the sector.

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Project Reports:
Vol. I: Technology, Implementation and Operation of Small-Scale Sanitation in India, Vol. II: Governance of Small-Scale Sanitation in India, Vol. III: Financial Sustainability of Small-Scale Sanitation in India and Synthesis Report: A Roadmap for Small-Scale Sanitation in India: Fulfilling its Potential for Healthy and Water-Secure Cities

Funding:
Bill & Melinda Gates Foundation, German Federal Ministry for Economic Cooperation and Development

Project Partners:
IIT Madras, BORDA (Germany), CDD Society (India) and ENPHO (Nepal)

The research team would like to thank all the individuals who voluntarily contributed their valuable knowledge, opinions, feedback and data throughout the project period.

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Determining the Indicators of High Quality Shared Sanitation Facilities

Shared sanitation has immensely contributed to sanitation access, but is at best considered a 'limited' solution due to the lack of quality standards within SDG6. The Quality Indicators of Shared Sanitation Project (QUISS) aims to identify key criteria of what constitutes 'high quality' shared toilets in urban contexts. Vasco Schelbert[1], Christoph Lüthi[1]

V. Schelbert

Photo: GALS meeting (Kumasi, Ghana): Women presenting collected priorities and related issues from the women's group to the plenary.

Introduction

Between 1950 and 2018, urban population increased from 751 million to 4.2 billion, comprising 55 % of the global population [1]. Urbanisation rates typically surpass economic growth rates and infrastructure development, particularly in low-income urban areas. High population density coupled with high poverty levels often make shared sanitation facilities (SSF) the only viable sanitation option, and the number of SSF users has increased from 249 million in 1990 to 603 million in 2015. SSF is three times more likely in urban contexts of low- and middle-income countries than rural areas.

Shared sanitation is an appropriate solution if adequately managed and the new *WHO Guidelines on Sanitation and Health* has recently acknowledged this [2]. Yet, the WHO/UNICEF Joint Monitoring Programme (JMP) categorises SSF as a 'limited' solution. This excludes it from the 'basic' category and may incentivise donor agencies and governments not to allocate resources to SSF.

Research targets

Excluding SSF from the JMP framework is usually justified because of operation and maintenance (O&M) problems, particularly, lack of cleanliness [3]. Better understanding of user preferences, priorities and behaviours regarding SSF, including a gender focus, and of O&M, cleaning arrangements and cultural barriers is required. QUISS is commissioned under WSUP's (Water & Sanitation for the Urban Poor) Urban Sanitation Research Initiative to identify key criteria of what constitutes 'high quality' shared toilets in urban contexts.

Qualitative Research Phase

QUISS takes place in Bangladesh, Ghana and Kenya and its qualitative research phase was designed to provide insight about user perceptions and priorities, and of the social organisation aspects of O&M, which is essential to sustain SSF quality, functionality and cleanliness. A literature review was done to draft 'quality categories'. Then, community meetings were held based on the Gender Action Learning System (GALS) [4]. Gender-sensitive information about user's individual sanitation priorities and challenges was gathered and discussed. In each country, two gender-balanced meetings were held with 30 to 50 participants each.

Information from the GALS meetings contextualised the guidelines used for the Focus Group Discussions (FGD), in which user needs and priorities and the challenges of how O&M is socially organised among the users were discussed. At least two women-only, two mixed and one men-only FGDs were conducted in each country. The data was analysed using directed and inductive qualitative content analysis, and led to the determination of qualitatively deduced categories, relating to SSF quality, which were used in the design of an evidence-based quantitative user survey.

Quantitative Research Phase

The categories and drivers of high-quality shared sanitation will be tested in large-scale quantitative surveys, and the sample size is a minimum of 1200 participants in each country. There will also be structured quality inspections of a minimum of 600 SSF in each country. For triangulation purposes, a remote visual quality inspection of each SSF will be done, and an independent third party will evaluate the SSF photos. Regression analysis, cluster analysis and machine learning techniques will determine the main drivers of high-quality sanitation, and enable the development of key indicators of high-quality shared sanitation.

Conclusion

The expected deliverables are a detailed empirical assessment of the drivers and determinants of user experience and the identification of the minimum standard criteria for 'high-quality' shared sanitation. The analysis will support the current agenda-setting debate and provide the basis for implementation decision-making and assist policy makers. The developed criteria will also provide the basis for high-level progress monitoring for future funding decisions and programme design.

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[1] Eawag/Sandec, Switzerland

Project timeline: Oct 2018 – Mar 2020

www.sandec.ch/quiss

www.wsup.com/research

Project partners:
ETH Nadel, NHance Development Partners Ltd (Ghana), Great Lakes University of Kisumu, (Kenya), Icddr,b (Bangladesh)

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Ex-ante Cost Estimations for Sanitation Systems Based on Mass Flows

Costs of sanitation systems (SanSys) are important indicators for decision-making. Yet, there is a lack of methods to quantify the costs for a broad range of SanSys at the planning phase. This article presents an approach to perform ex-ante cost estimations using mass flows. Dorothee Spuhler[1], Verena Germann[2]

Introduction

Enhancing the sustainability of sanitation facilities worldwide requires doing the complex task of SanSys planning. One challenge planners face is identifying SanSys options at the structuring phase of the planning process. Within the GRASP project [1], a procedure to identify a diverse set of locally appropriate SanSys options as input into structured decision making (SDM) and multi-criteria decision analysis (MCDA) was developed. It is systematic, generic and transparent, and, therefore, extendable to any novel technology. It also explicitly factors in uncertainties, enabling its use in developing urban areas in the Global South [2, 3].

There are three steps: (1) screening for appropriate sanitation technologies from all potential ones; (2) generating all valid SanSys from these technologies; and (3) selecting a limited but diverse set of appropriate SanSys as a basis for participatory decision-making. A model for the quantification of mass flows of nutrients (phosphorus and nitrogen), total solids, and water was also developed. It allows for estimates of resource recovery and loss potentials, i.e. relevant indicators for evaluating options as an input into SDM, using e.g. MCDA.

Estimating information on SanSys costs, required for balanced decisions especially in cases of low financial resources, is difficult because while cost functions for technologies are available, it requires data that are often unavailable at the structuring phase. We developed an approach to estimate ex-ante and automated SanSys cost ranges, using mass flows as technology-specific information (see [4]). This allows for automating and generalising cost estimations and comparing a large and broad range of SanSys. It was applied to over 40 technologies and 100 000 SanSys options for emerging small towns in Arba Minch District, Ethiopia.

Method

Available cost functions for technologies are adapted to depend on inflow masses of nutrients, water, or total solids. Some technologies, primarily for conveyance, require additional input data, mainly distance of transport. Cost functions describe the costs of one facility (e.g. one septic tank). To account for scale, the minimum and maximum number of facilities *(n)* for the given case is defined by technological constraints (e.g. maximum volume and minimal inflow). Using n_{min} and n_{max} and the inflow masses per facility, the cost ranges for each technology within a SanSys can be quantified, and aggregating these then result in cost ranges for the entire SanSys.

Example of Arba Minch

One SanSys approach for Mehal Ketema, a settlement with about 6600 inhabitants in Arba Minch, is shown in the Figure. Cost functions for initial investment costs (IIC) and operation and annual maintenance costs (O&MC) were adapted from the CLARA SPT, a simplified planning tool that compares costs of various sanitation alternatives [5], based on unit costs in Ethiopia. Reuse and disposal technologies are not considered as they do not contribute to SanSys costs.

For the pour-flush toilet, *n* was set with 5 to 25 person equivalents (PE) per facility. For the ABR, *n* was restricted using an inflow of 10–1000 PE with 80 $LPE^{-1}d^{-1}$ and a maximum area of 0.02 km^2 per facility. For motorised transport, *n* was defined based on truck size, collection interval, and volume collected per location per interval. *n* of co-composting was estimated using 1–500 m^3 total compostable waste per day. The resulting SanSys cost ranges were estimated to be 280 000–330 000 € IIC and 15 000–30 000 € $year^{-1}$ O&MC.

Conclusion

To make the approach applicable in other cases, generic cost functions and limiting *n* values need to be formulated for all potential technologies. Regional differences for the cost functions can be accounted for using, e.g. the international construction cost index. Our approach is based on information given by available generic models and provides ex-ante cost estimations with some degree of uncertainty (minimum and maximum costs) for a broad range of SanSys. Although the results can serve as an indicator to evaluate different SanSys already at the structuring phase of SDM, they cannot replace detailed cost calculations in the further planning process.

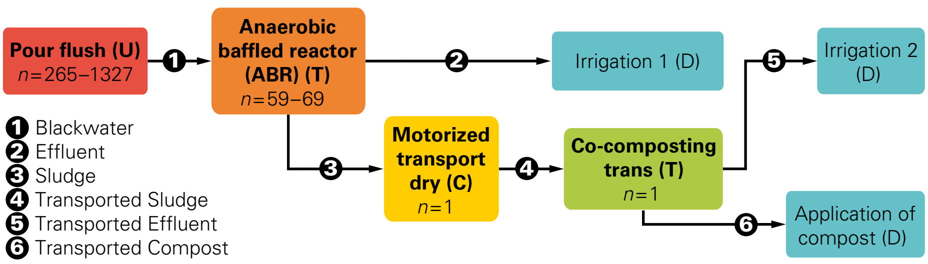

Figure: Example of a sanitation system and corresponding numbers of facilities per technology *(n)* in Mehal Ketema, Arba Minch in Ethiopia.

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Citywide Inclusive Sanitation: Old Wine in a New Bottle or a New Paradigm?

Citywide Inclusive Sanitation (CWIS) is the new paradigm shift in urban sanitation that both research and practice are championing. In many ways, it is becoming the sanitation counterpart to water security. The historical context and evolution of CWIS from its conception to definition is outlined. Abishek S. Narayan[1], Christoph Lüthi[1]

Introduction

Sanitation as a development agenda received widespread recognition at the turn of the century through the Millennium Development Goals. Attention towards urban sanitation since then has been increasing in both research and international development. However, the challenge remains for cities of the developing world to manage the entire sanitation value chain [1].

Genesis

Conferences are not just a platform where research findings and development agenda are showcased, but also meeting points at which sector professionals can ideate. That is what happened in the case of 'Citywide Inclusive Sanitation' (CWIS) at a conference in 2016 dedicated to urban sanitation, where a Call for Action was released by a consortium with the aim of combining global efforts towards a united cause at the Stockholm Water Week in 2017 [2]. CWIS was broadly put forth under four pillars: human rights, economy, partnerships, and the sanitation value chain.

Progress

In the following years, a large number of efforts, both CWIS labelled and otherwise, were found to be aligned with this cause [3]. From the World Bank's sanitation strategy to the Gates Foundation's city-level grants, the intent to deliver a unified effort was clear.

Figure: Evolution of CWIS.

In 2018 at the Beijing Toilet Expo, a commitment to unlock 1 Billion USD towards CWIS, through the Urban Sanitation Innovation Partnership, was jointly made by Bill Gates and Jim Kim, then President of the World Bank [4].

Since CWIS required definition and operational indicators, a set of principles was drafted at the Manila Conclave, and then matched with corresponding quantitative indicators in 2019. These draft principles include: safe and equitable service delivery, resource recovery, business models, technologies, planning and political will. The Manila CWIS Principles would be the first major update to urban sanitation after the Bellagio Principles on Sustainable Sanitation [5]. The CWIS initiative is new and live; refinements to the principles through a consultative process are ongoing.

Unpacking CWIS

This new paradigm shift has inclusion as its centrepiece. The term 'inclusive' encompasses informal and peri-urban, sewer and non-sewer technologies, the entire value chain, all stakeholders, larger urban goals, and importantly marginalisation based on gender, disability, age, religion, caste and income level. Emphasis is placed equally on the process of inclusive urban sanitation planning as on the end results. CWIS could therefore, be defined as a: state of urban sanitation, where all members of the city have access to safe and affordable sanitation services through appropriate sewered and non-sewered systems, without any contamination to the environment along the sanitation value chain.

Conclusion

Since its conception, CWIS has been criticised as a repackaging of the status quo, with most efforts based on well-established principles and foundations of sustainable urban sanitation. However, CWIS is the first such holistic initiative of a united front on a global scale with the backing of finance and expertise, using the latest research and developments to face the urban sanitation challenge. Even if it seems to be old wine in a new bottle, CWIS may likely be the valuable impetus that is needed.

Abishek Narayan

Photo: Looking beyond sewers.

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[1] Eawag/Sandec, Switzerland

CWIS at Sandec:
The project focuses on selected mega and secondary cities in India with the aim to develop a novel methodology that could bridge top-down and bottom-up sanitation planning to achieve CWIS. For more information: www.sandec.ch/CWIS

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Ensuring the Provision of Sanitation Services in Emergencies

Emergency situations, i.e. natural disasters and human-made conflicts, leading to protracted humanitarian crises, are on the rise. Protecting human and environmental health and the dignity and safety of people makes the provision of adequate sanitation services crucial. S. Renggli[1], Ch. Friedrich[1], M. Fernández Cortés[1], V. Schelbert[1], G. Monnard[2], G. Ecker[3], Ch. Lüthi[1]

Introduction

Right now, as you are reading these lines, we are experiencing the highest levels of human displacement ever recorded. According to UNHCR, 68.5 million people around the world were forced to flee their homes in 2017 [1]. Displaced people find refuge mostly in cities or humanitarian camps. In these settings, basic services need to be provided in a short time and at a large scale to respond to the needs of people forced to flee their homes.

Water, Sanitation and Hygiene (WASH) services are among the most important basic needs that have to be provided during a humanitarian crisis. Without adequate provision of WASH services, people, especially children, the elderly and immuno-suppressed, are at risk of falling sick from water borne infectious illnesses. Inadequate WASH provision can also pose a health risk to other local communities and threaten the natural environment.

Collaboration with Swiss Humanitarian Aid

The Strategic Environmental Sanitation Planning group at Sandec is leading various efforts to support the humanitarian sector in terms of emergency WASH by assisting the efforts of Swiss Humanitarian Aid (SHA). The backstopping includes capacity building, project consultancy and innovation, e.g. the Faecal Sludge Field Laboratory. SHA is working in several humanitarian crises around the world, where the provision of WASH services is a priority.

Eawag published the Compendium of Sanitation Technologies in Emergencies in partnership with the German WASH Network in 2018 [2]. A Massive Open Online Course about Public Health Engineering was launched in collaboration with the International Committee of the Red Cross in 2017. These capacity-building efforts are complemented with on-site training in the sanitation sector at several locations around the world, including North Korea, Jordan and Switzerland.

Samuel Renggli

Photo: Participants are learning about Shit Flow Diagrams during a regional SHA workshop in Pyongyang, North Korea.

The Faecal Sludge Field Laboratory

One of the innovations Sandec is currently working on is the improvement of the Faecal Sludge Field Laboratory. This was first developed by a consortium of organisations lead by the Austrian Red Cross and the Austrian University of Life Sciences BOKU in Vienna. It can be used to monitor parameters for process control of faecal sludge treatment, and to check if the treatment reaches the standards for effluent discharge of the respective country in which it is operating. This can help organisations to design informed planning strategies and improvements to their treatment systems. The laboratory is able to test standard parameters (such as COD, Total Solids, *E. coli,* etc.) with adapted field methods, it can be run on a low energy source or with wind and solar power, and due to its high mobility, it can be easily deployed and set up. In addition, all applications are open source. After a first series of trainings in Uganda and Switzerland, it is being deployed for the first time with the International Federation of Red Cross and Red Crescent Societies in Cox's Bazar, Bangladesh.

Mobile data collection

The disruptive power of IT and mobile phones offers new opportunities for state-of-the-art data collection and management, also in the case of emergencies and reconstruction. A regular and transparent flow of information can help inform the responsible entities of the status of their sanitation services and help them improve, manage, operate and maintain them. Together with a SHA delegation from Myanmar, a new WASH data collection tool (developed by Eawag and Terre des hommes) to evaluate the condition of WASH services in schools was successfully tested for applicability. This supported reconstruction efforts after Cyclone Nargis hit in 2008.

Conclusion

This year, Sandec will continue building capacity in the humanitarian WASH community. An online version of the Compendium of Sanitation Technologies in Emergencies with content updates and new interactive features, e.g. a technology finder, will be published. Present field testing of the faecal sludge field laboratory in Bangladesh is deepening understanding of the need for monitoring and evaluating treatment options in humanitarian crises. Feedback from the field testing is leading to upgrades and improvements of its physical components and processes to bring about higher efficiency, more versatility and higher durability. Christopher Friedrich, who joined Sandec in September 2018, starts his PhD on faecal sludge treatment in humanitarian emergencies this year at Eawag. These efforts point to Sandec's strong contributions to the emergency WASH sector in the upcoming years.

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[1] Eawag/Sandec, Switzerland
[2] Swiss Humanitarian Aid
[3] Austrian Red Cross
www.sandec.ch/emergencywash
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www.roteskreuz.at
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Sandec's Training Contributions to Close the WASH Capacity Gap

Sandec is increasing its capacity building efforts. A mix of online courses, blended learning programmes and face-to-face training are being produced and distributed to satisfy the ever-increasing demand for WASH education in low- and middle-income countries. Most users are from Asia, Africa and Latin America. Fabian Suter[1], Christoph Lüthi[1]

Introduction

Sandec's capacity building initiatives are mainly developed for students and practitioners in low- and middle-income countries. Our learner numbers increase every year; the students are professionally diverse and want content enabling them to understand and develop solutions for real water, sanitation and solid waste problems. While scalable online programmes are essential to satisfy the ever-increasing demand of WASH learners, they cannot fully replace face-to-face trainings. Sandec's capacity building programme, thus, comprises online courses, face-to-face trainings and blended learning programmes.

Online courses

There have been more than 90 000 enrolled learners and 10 000 course completers of the four courses of the MOOC series 'Sanitation, Water and Solid Waste for Development'. The majority are from Asia, Africa and Latin America. Hardik Bhatiya, our 10 000th course completer, is highlighted on page 34. The courses run continuously on Coursera and attract around 1 000 new students each month [1].

The Solid Waste MOOC was redone in 2018 with new modules on crucial topics, such as plastic waste management. It also includes a series of practical, hands-on modules (e.g. how to do a waste generation and characterisation study). These help learners understand current WASH related problems and how to solve them. Sandec plans to update its other MOOCs with new topics, practical modules and case studies about successful WASH initiatives.

Blended learning

Blended learning systems combine face-to-face and computer mediated instruction, and when done well offer improved pedagogy, flexibility and cost-effectiveness [2]. Sandec offers three blended learning approaches.

1. Embedding Sandec's digital learning materials into existing lectures and training: Since the launch of the first MOOC in 2014, Sandec has shared its online materials and capacity building know-how with dozens of universities and training institutes. This option is demand driven, highly flexible and mostly used by individual lecturers, who embed video modules into their courses (Photo).

2. Programme of Open Studies – 'Sanitation, Water and Solid Waste Management': In 2017 / 2018, Sandec tested and validated its blended learning Programme of Open Studies 'Sanitation, Water and Solid Waste Management' with partners in India (BITS Pilani), Nepal (Kathmandu University) and Malawi (University of Malawi). The Programme of Open Studies (POS) combines the MOOC series with meet-ups at the university, field visits and capstone project work. It is open to all interested students, and successful students earn a joint certificate from Eawag-Sandec and the partner university. The number of enrolled participants (115 in India, 32 in Nepal, 59 in Malawi), the number of times the programme has been offered (3 in India, 2 in Nepal, 1 in Malawi), the percentage of enrolled practitioners (0 % in India, 56 % in Nepal, 78 % in Malawi) and exam results (successful exam completion: 100 % in India, 100 % in Nepal, 61 % in Malawi) differ from partner to partner. The programme structure works best when partners can tailor the onsite components according to their needs. Based on feedback, Sandec has updated the overall programme, enhancing its manageability and increasing the potential for sharing among partners. In fall 2019, Sandec will roll out POS with strategic partners in Africa, Asia and Latin America.

3. New blended learning initiatives: Partners who wish to develop a blended learning initiative can use Sandec's online courses. It is demand-driven, jointly planned, and Sandec further contributes on a case-by-case basis. The first blended learning initiative will be the course 'Sanitation and Solid Waste Management' offered at the Institute of Rural Management Anand in Gujarat, India.

Face to Face teaching and training

Sandec also does teaching and training activities at Swiss (ETH Zurich and EPF Lausanne) and European universities (TU Berlin, IHE Delft and University of Brescia). In 2019, we launch a new three module course with two partner universities in Switzerland, the Certificate of Advanced Studies in Water Sanitation and Hygiene for humanitarian and developing contexts.

Anonymous

Photo: MOOC in the class room at University of Education, Winneba in Ghana.

[1] www.eawag.ch/mooc
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[1] Eawag/Sandec, Switzerland

Further information:
Websites:
MOOC Series 'Sanitation, Water and Solid Waste for Development': www.eawag.ch/mooc
CAS-WASH: www.supsi.ch/go/caswash
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Self-built Low-cost Mobile Incubator for Field and Laboratory Use

There is broad demand for a low-cost, portable incubator for microbial testing of drinking water. This self-built incubator is based on widely available materials, can operate under a range of field conditions, and still offers the advantages of higher-end laboratory-based models. Ariane Schertenleib[1], Jürg Sigrist[2], Max Friedrich[3], Christian Ebi[4], Frederik Hammes[2], Sara J. Marks[1]

Introduction

Incubators are essential for a range of culture-based microbial methods for assessing drinking water quality. Under Sustainable Development Goal 6.1, governments have committed to regularly report on the bacteriological quality of drinking water at the national level [1]. In addition, operational monitoring of water infrastructure is regularly undertaken at the local or regional level [2]. These surveillance and monitoring campaigns are often in remote locations where infrastructure and resources are limited. In these contexts, conventional incubators may be inadequate or unavailable. Field incubators are commercially available, but manufacturers usually offer a fixed design and use is limited to specific settings or sample sizes. There is, thus, a need for an adaptable incubator that offers the advantages of laboratory-based models while remaining suitable for field applications (Table).

The purpose of this project was to develop an adaptable, low-cost and portable incubator that can be built using readily available components, and designed to combine the advantages of both conventional and field-based models.

Ariane Schertenleib

Photo: Incubator shells tested. Polystyrene foam box (left), hard plastic cooler box (middle), and cardboard box covered with a survival blanket (right).

Performance

The electronic core of the incubator was first developed. It was then tested under a range of conditions with three types of shells made of common materials: a polystyrene foam box, a hard plastic cooler box and a cardboard box covered with a survival blanket (Photo). Each set-up was tested at three ambient temperatures: moderate (27 °C), cold (3.5 °C and 7.5 °C) and hot (39 °C), while the inner temperature was set at 37.0 °C and 44.5 °C, the typical temperature settings used for detection of faecal contamination indicators in drinking water.

The electronic core performed similarly to a standard laboratory incubator in terms of the time required to reach the set temperature, inner temperature stability, temperature spatial dispersion, power consumption, and microbial growth. The incubator set-ups were also effective at low and moderate ambient temperatures (3.5 °C and 27 °C). At higher ambient temperatures (39 °C), the incubator designs presented here were prone to overheating, unless the set temperature was even higher (i.e. 44.5 °C). Better insulating shells (polystyrene foam box and hard plastic cooler box) showed better performance in terms of power consumption and time to reach the set temperature in a cold environment.

Conclusion

This incubator prototype is low-cost (< $300 when the material is purchased in Switzerland), adaptable to a variety of volumes and field conditions, and can be built from different materials. It can be used in both established laboratories with grid power or in remote settings when powered by a car battery. It is useful as an equipment option for field laboratories in areas with limited water quality monitoring resources. Practitioners with limited capacity can use this incubator to establish permanent or seasonal laboratories at reasonable costs. Through its use, it is possible to increase the number of laboratories in remote areas, making efforts to conduct regular water quality surveillance or punctual monitoring of system operations more feasible.

Characteristic	Laboratory-based	Field-based	Adaptable
User friendly design	✓	✗	✓
Large capacity	✓	✗	✓
Robust to wide range of ambient temperatures	✓	✗	✓
Maintains constant temperature	✓	✗	✓
Low cost	✗	✓	✓
Easily transported	✗	✓	✓
Energy efficient	✗	✓	✓
Resilient to intermittent power supply	✗	✓	✓

Table: Characteristics of commercially available incubators (laboratory- and field-based) and the adaptable approach. ✓ Advantages, ✗ Disadvantages

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15 years of Water Safety Plans Development and Implementation in Uganda

The World Health Organization recommends Water Safety Plans as the most effective means to ensure the safety of drinking-water supplies, but their application in developing countries remains low. This study is about the status of the Water Safety Plans and the factors that led to their uptake. Ch. Kanyesigye[2], J. Nakanjako[2], F. Kansiime[3], G. Ferrero[4], S.J. Marks[1]

Introduction

Target 6.1 of the Sustainable Development Goals (SDGs) aims at achieving universal and equitable access to safe and affordable drinking water for all by 2030. Achievement of this target is measured using indicator 6.1.1, which emphasizes the proportion of the population using safely managed drinking water services [1]. The challenge of sustainably providing safe drinking water can be addressed through the implementation of risk assessment and risk management approaches, such as Water Safety Plans (WSPs). The objectives of WSPs are to identify risks from catchment to consumers, prevent contamination of raw water sources, appropriately treat water to remove contaminants and prevent re-contamination during distribution, storage and handling [2].

By 2017, Uganda was among the eleven African countries that carried out WSP implementation. Piloting of WSPs was carried out by the National Water and Sewerage Corporation (NWSC) between 2002–2004 in two major cities, Kampala and Jinja. By 2009, WSPs were developed and implemented in 20 Water Supply Systems (WSS) under the jurisdiction of NWSC. This study assesses the status of WSP development and implementation in Uganda for the period 2002–2017, focusing on the NWSC experience and the factors that influenced WSP uptake.

Methods

The study focused on the 20 WSPs located across Uganda that are under the jurisdiction of NWSC (Figure 2). A mixed methods approach was used, consisting of documentary review, field observations, semi-structured interviews with NWSC staff and stakeholders, and an internal informal audit. The audit was carried out through a desk review of all WSP documents for each of the 20 WSS. The audit objectives and questions were based on the WHO's grading system for assessing WSS performance [3], ranging from a grade of "excellent" for top scores and "priority attention needed" for the poorest performing WSS.

Result and Discussion

1. Status of WSP development and implementation

The level of WSP development and implementation varied greatly across the 20 WSS. No WSS scored excellent (115–≥120), very good (103–114) or good (91–102). Three WSS attained average scores (79–90), four scored below average (61–78), and the rest were at "needed priority attention" (≤60) (Figure 1). Each WSS had carried out hazard identification, risk assessment, determination of control measures and development of improvement plans. Most of the WSS failed to document plans for monitoring, verification, corrective actions and review of the WSPs. These findings reflect those found in a WSP global status report, that attention was focused on the front end of the WSP development to the detriment of the operational monitoring, management and review, which are key for sustainability [4]. In addition, all 20 WSS implemented improvement plans, although for most, these activities were not up-to-date. Over the study period, internal and external verification audits were documented by five and two WSS, respectively. Similar findings of inadequate WSP implementation were obtained in audits of utilities in Uganda, Kenya and Tanzania [4].

2. Factors influencing the WSP status

The factors having a positive and negative influence on WSP implementation were examined, and those having a negative influence were:

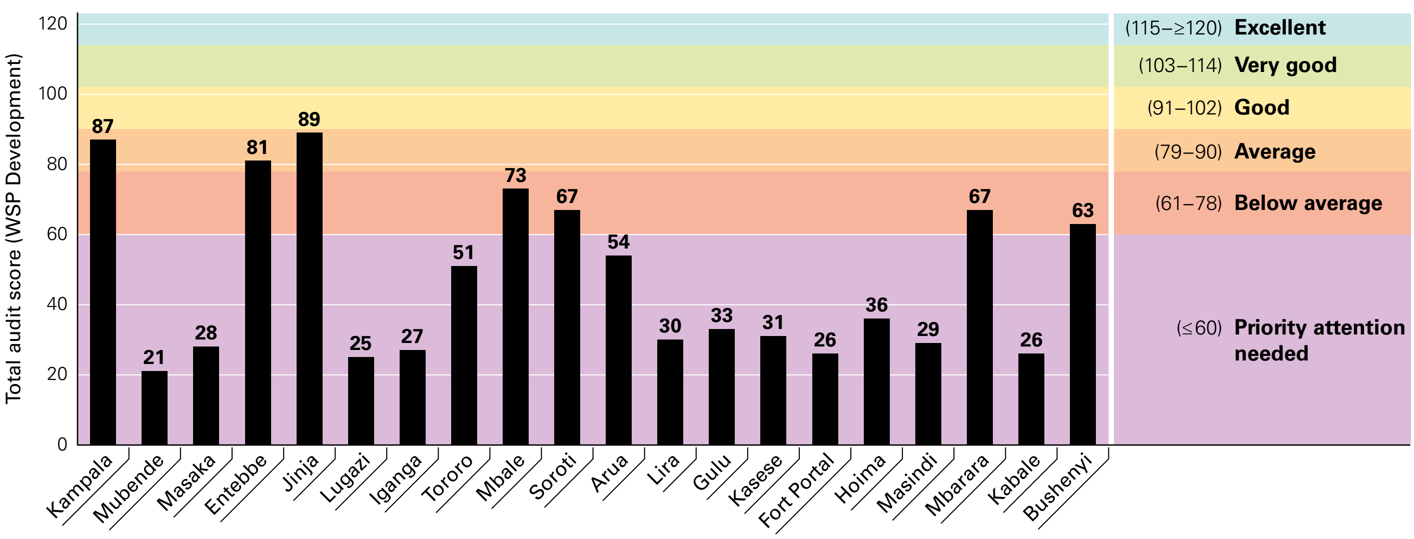


Figure 1: Summary of the informal internal audit results.

WSP team composition: 50 % of management and operational staff interviewed believed that WSP implementation was the responsibility of technical departments. This is opposed to the basic principles of WSP team formation [2]. Audit results showed that about 50 % of the 20 WSS had complete, qualified and experienced multidisciplinary WSP team membership. However, inadequate mechanisms for handover and training of transferred staff resulted in gaps within WSP teams.

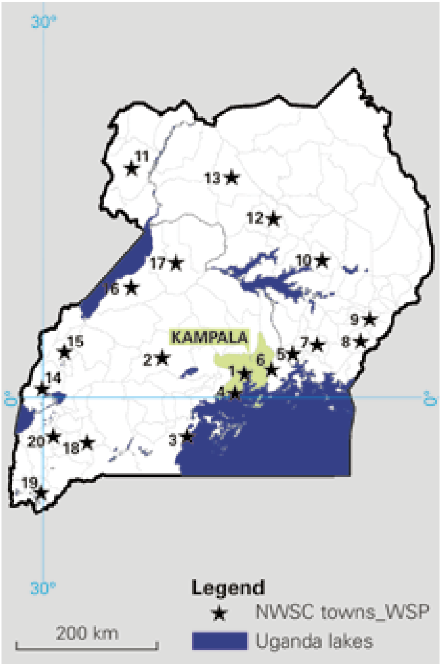
Perception of WSP effectiveness: About 25 % of management and staff interviewed reported that some managers did not appreciate WSPs as a worthwhile risk management approach, claiming that the quality of water supplied usually complied with national standards. This indicates a lack of knowledge regarding the value of preventive risk management for effectively sustaining drinking water quality [2]. The audit, however, revealed that water quality results for 13 of the 20 WSS did not consistently comply with the standards.

Managerial commitment: Less than 33 % of top management and staff interviewed responded that area management was committed to invest in WSPs. The audit revealed that about 50 % of the WSS had documented and implemented plans for the monitoring of control measures. They had also prepared procedures for management of the systems, and had developed and documented support programs for WSP sustainability. However, a few top managers expressed concern that some teams did not continue implementing after receiving training.

Incapacity for WSP evaluation: Less than 33 % of management and staff interviewed expressed difficulty in evaluating the performance of WSPs. They could not quantify the benefits of WSP implementation that would help in soliciting management buy-in. The reason for this failure, as shown by the audit, was that the WSP verification steps had not been completed in nine out of the twenty WSS.

Inadequate training: Almost all management and staff interviewed stated that there was a lack of regular WSP training. Similarly, six out of the twenty WSP teams expressed concern about a lack of knowledge among staff for WSP implementation. From the audit, nine out of the twenty WSS mentioned training as one of the WSP support programs, but stated that it had been poorly implemented.

Heavy workload: The audit results showed that six out of the twenty WSS had carried out complete documentation of the WSPs, i.e., supply chain and manual steps. Failure of the rest of the WSS to carry out complete documentation could have been due to workload and competing management priorities, as mentioned by four out of twenty WSP team members.



Source: NWSC - GIS/Block Mapping_October 2018

Figure 2: Location of the 20 NWSC WSS implementing WSPs.

The factors that had positive influence were:

Public health responsibility: About 50 % of top management and staff interviewed reported that NWSC has a duty to provide potable water to the public, and believe that this cannot be achieved without WSP implementation. The respondents said that management was supportive by providing human resources and finances in response to water quality challenges in the service areas.

Good customer relations: The audit findings showed that in seven of the twenty WSS, customer engagements were planned and implemented as part of WSP supporting programs. Over 50 % of management and staff reported good customer relations, in line with NWSC's motto: "the customer is the reason we exist". The respondents reported that customers provided feedback on performance through the front desk and the call centre.

Enhanced reporting culture: Less than 33 % of management and staff interviewed said that through social media platforms, e.g. WhatsApp, employees were updated on operational incidents and events. The audit findings revealed that internal communication platforms were part of WSP support programs and were applied in nine out of the twenty WSS.

Enhanced corporate image: Over 25 % of management and staff interviewed stated that NWSC had a good public image due to the quality of service and recognised WSPs as a means of maintaining that image. Among the WSP support programs was customer engagement and feedback on complaints, particularly through the call centre.

Reliable laboratories: The audit revealed that well equipped laboratories enabled planned monitoring of control measures in nine out of the twenty WSS. Detailed water quality analysis for the smaller WSS took place at regional laboratories to back up their limited basic process control and monitoring.

Conclusion

The status of WSP development and implementation varied greatly among the 20 WSS. From the audit, a few WSS scored average, while most scored below average. All the WSS carried out hazard analysis and risk assessment, but only a few documented and implemented the monitoring and management steps. The factors that negatively affected WSP status were inadequate teams, WSP appreciation, commitment, training, WSP evaluation and heavy workload. Those with positive effect were customer relations, public health responsibility, reporting culture, corporate image and reliable laboratories.

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[2] Bartram, J., Corrales, L., Davison, A., Deere, D., Drury, D., Gordon, B., Howard, G., Reinhold, A. and Stevens, M. (2009): Water Safety Plan Manual: Step-by-step risk management for drinking-water suppliers. World Health Organization. Geneva.

[3] WHO & IWA (2015): A practical guide to auditing water safety plans, Geneva.

[4] WHO & IWA (2017): Global status report on water safety plans: A review of proactive risk assessment and risk management practices to ensure the safety of drinking-water, Geneva.

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System-level, Automatic Chlorination in Community-managed Water Systems

The effectiveness of in-line, passive chlorination technologies are investigated as part of a larger study that aims to improve piped water systems in rural Nepal. This article describes the selected technologies used and reports on baseline results of microbial water quality. Y. Crider[1], S. Sainju[2], R. Shrestha[3], G. Clair-Caliot[4], A. Schertenleib[4], M. Bhatta[3], S.J. Marks[4], I. Ray[1]

Introduction

Access to safe drinking water is recognised as both an essential human right and a public health priority, and the United Nations Sustainable Development Goals call for access to microbiologically safe drinking water for all by 2030. The dominant strategy for low-cost safe water treatment has been promotion of household-level treatment methods, for example, household filters, solar disinfection (SODIS), boiling, or chlorine products. However, this approach has notable limitations. The daily burden of treatment falls on the household, often to women and girls, and products must be maintained or repurchased, a separate added task for busy, low-income households. Unsurprisingly, correct, consistent, and long-term use of these treatment products is typically quite low [1]. In recent years, a growing number of low-cost chlorination technologies have been developed for system-level, automatic water treatment. These may be especially appealing for small, rural systems, which often have limited technical and managerial capacity for sustaining the operation of complex treatment systems. Furthermore, residual levels of chlorine protect drinking water from recontamination during distribution and storage, an important benefit where water is intermittently supplied, which is a common characteristic of small, piped water systems.

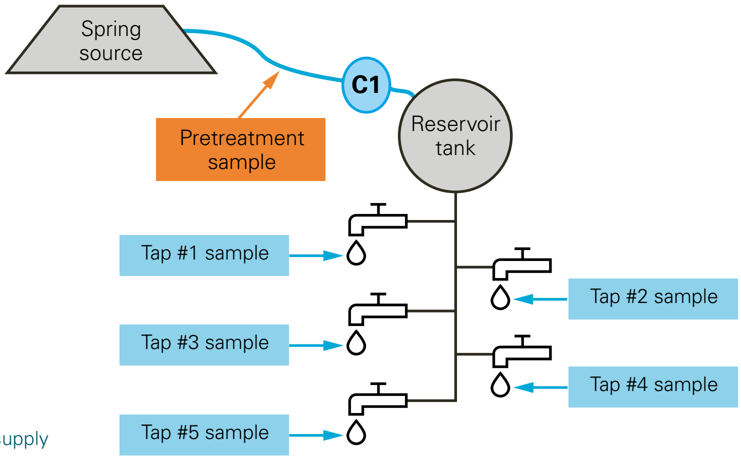

Figure: Piped water supply sampling locations.

Overview of methods

This study is implemented in a rural area of Nepal. The selected communities are part of a larger study, run by Eawag and Helvetas-Nepal, which is implementing and evaluating a risk-based water safety strategy for gravity-fed piped schemes in rural Nepal. As part of the larger study, Helvetas has trained local staff in selected communities to manually add powdered bleach to reservoir tanks for drinking water treatment. In the sub-study described here, a sub-set of these communities were selected to test in-line, passive chlorination as an alternative to the manual dosing approach. Six reservoir tanks were selected, each of which supplies piped water to a small distribution system with community taps, and microbial water quality at the system taps was characterised. Reported flowrates were measured in triplicate and averaged. Prior to the installation of chlorination technologies, water samples (100 mL volume) were analysed for *E. coli* and total coliforms at field labs, using solar powered incubators described elsewhere by co-authors [2] (See p. 23). The Figure illustrates the sampling locations within the pipe network.

The results of our baseline assessment of system water quality and flowrates are shown in the Table. At some sites, water at the reservoir tank was free of *E. coli*. However, on average, *E. coli* was detected in water samples collected at taps. Water quality declined further during storage in the household, and, in total, these results clearly indicated a need for additional treatment, such as chlorination.

	E. coli		Total coliforms		
	Pretreatment* (log10 CFU / 100 mL) *(n=1 per system)*	Taps (mean log10 CFU / 100 mL) *(n=4–6 per system)*	Pretreatment (log10 CFU / 100 mL) *(n=1 per system)*	Taps (mean log10 CFU / 100 mL) *(n=4–6 per system)*	Flowrate at reservoir tank inlet (L / min)
1	0.48	0.26	2.48	1.94	7.0
2	1.11	1.43	2.48	2.48	6.3
3	0	0.24	2.48	1.89	6.6
4	0	0.06	1.08	0.52	5.7
5	1.43	0.22	2.48	2.08	11.2
6	0	1.30	2.48	1.60	6.5

* Minimum reported value is 0 for log10 transforms of 0 CFU / 100 mL results

Table: Baseline (before chlorinator installation) water quality and flowrate at each system.

Selection and installation of low-cost passive chlorination technologies

Not all passive chlorination technologies are suitable for a given setting, yet little evidence exists to guide technology selection across different settings. Technology

Yoshika Crider

Photo 1: PurAll 100 chlorinator.

options are differentiated by factors, such as type of chlorine (i.e., solid versus liquid), cost, maintenance frequency, and compatibility with flowrates and pipe size. In these communities, solid chlorine options were determined to likely be best because they are more concentrated than liquid options and easier to transport.

The range of flowrates observed at the reservoir tanks further narrowed technology options, and two tablet chlorine-based, passive technologies were selected to evaluate: PurAll 100 and Aquatabs Flo (Photos 1 & 2). The PurAll 100 chlorinator is manufactured by Easol Ltd. and is imported from India. The cost of all installation materials, including all pipe fittings and excluding chlorine, was 679 USD. The cost of chlorine is 0.06 USD per cubic meter of water treated, assuming a dose of 1 mg/L chlorine. The Aquatabs Flo is manufactured by Medentech Corp. (Wexford, Ireland) and has been evaluated in Bangladesh and installed in many other locations. The cost of all installation materials is 87 USD, with a chlorine cost of 0.16 USD per cubic meter of water treated. The unique characteristics of each site means that the same technology can perform quite differently across even nearby systems. The variability in flow rate (Table) among the small piped systems selected in our study, for example, necessitated slightly different configurations of the same devices in order to achieve the same dosing.

Ongoing and next steps

The data presented here represent a small portion of the study baseline results. For example, other activities include household surveys of user satisfaction and an assessment of household stored water quality. Monitoring will continue of the performance of these devices through fall 2019, which will allow for assessments over nine months of device performance, including analysis of all costs associated with ongoing maintenance.

Yoshika Crider

Photo 2: Aquatabs Flo chlorinator.

Conclusion

The efficacy of chlorination for drinking water treatment has long been known, and much of the household water treatment literature focuses on how best to motivate the individual-level behaviour change required to consistently and correctly use these products. Where individuals are connected to piped supplies, however, automatic system-level chlorination offers clear advantages. There are still maintenance requirements, but that task can be delegated to a small number of community members, rather than to every household. While the lack of appropriate technologies may have limited the usefulness of this approach even a few years ago, more products are available and being further developed for low-maintenance applications. But, as with household products, technical efficacy is only one factor that determines the long-term effectiveness of these safe water solutions. This small study will allow for a better understanding of the factors, such as cost and maintenance requirements, that will determine whether these new system-level passive disinfection approaches may be a strategy to pursue for increasing safe water access in rural communities.

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[2] Schertenleib, A., Sigrist, J., Friedrich, M.N., Ebi, C., Hammes, F., Marks, S.J. (2019, March 19): Construction of a Low-cost Mobile Incubator for Field and Laboratory Use. J. Vis. Exp. *(145),* Retrieved from: https://bit.ly/2YfZY9M (protocol and video).

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A Study of Nairobi's Heterogeneous and Splintered Sanitation Sector

Analysis of Nairobi's sanitation situation was done with concepts from the emerging field of sustainability transitions. This led to the identification of a potential future transition pathway towards a citywide inclusive sanitation sector that includes existing service offerings. Pauline Cherunya[1,2], Mara van Welie[1,2], Bernhard Truffer[1,2]

Introduction

Nairobi's sanitation sector is very heterogeneous and consists of a mixture of diverse service providers, access options, user practices, technologies and infrastructures. We analysed this complex sector in a systemic way to identify challenges and areas of improvement that can result in more reliable and inclusive sanitation services for Nairobi's inhabitants. We conceptualised that Nairobi's sanitation sector consists of five entrenched 'service regimes'. *Service regimes* are stable combinations of technologies, user routines and organisational forms of providing and accessing a service such as sanitation. A service regime is hard to change once established because service providers perceive it as the normal way of working (e.g. establishment of standardised ways to construct septic tanks or routinised payment methods). Similarly, users establish (unsafe) practices that enable convenient access, safety and resource maximisation in a routinised way. For example, certain informal settlement dwellers practice in-home coping strategies at night because it is unsafe to access toilets that are located outside.

Sanitation Service Regimes

Through an analysis of sanitation provision and access practices based on more than 100 expert interviews [1] and secondary data, we identified five service regimes in Nairobi that vary greatly in one or more of the following dimensions: infrastructure & artefacts, organisational mode, time and space, rationale / meaning and dynamics in social interactions. These five regimes are: (1) the *domestic sewer regime* encompasses a pour or cistern flush toilet used by one household connected to the sewer system, which is provided and operated by the utility. (2) The *shared on-site sanitation regime* encompasses an on-site toilet, which is located either inside a plot or off-plots. It is shared by multiple households and is mostly provided and installed by a landlord or an NGO. (3) The *public sanitation regime* consists of pay-per-use toilet services in public places. They are mostly operated by Community Based Organisations (CBOs) or by private enterprises. (4) The *container based regime* consists of toilets in the form of containers or biodegradable bags to collect the faeces and urine. The containers or bags are regularly collected and the waste treated and the resulting sludge is re-used. Container-based services function as a public pay-per use or as in-home toilets and are provided by social enterprises. Finally, (5) the *coping sanitation regime,* i.e. user practices where people relieve themselves into improvised domestic items or defecate in the open. Though considered unsafe, coping is an established form of self-provision and, thus, a service regime of its own [2]. The Table summarises the core dimensions of the five service regimes.

The five service regimes do not enable reliable and adequate access to services, leaving many city dwellers to depend on non-hygienic alternatives. In addition, service providers are challenged by inadequate working environments and non-organised and unproductive competition between alternative options. In the different service regimes, infrastructures are not complementary and providers do not work together. This often results in negative outcomes, such as high costs and environmental pollution. Because of all these inefficiencies, the missing links, and lack of complementarities between the service regimes, we call the sanitation sector in Nairobi *splintered.*

Conclusion

The analysis of the dynamics within and of interactions between the co-existing service regimes allows for the projection of potential future developments in the sector – or transition pathways. The findings suggest that the existing diversity of service regimes will remain, because user and provider practices have existed for many years and are established and highly institutionalised around particular technologies, socio-cultural norms, and historical planning practices. In addition, the splintered nature of the sector is likely to remain as well, because providers within the different service regimes have differing views about how future services should look like and specific ideas about how services should be improved. For example, the aspirations of most of the influential policy makers are to align Nairobi to the 'modern infrastructure ideal' comparable with other 'world-class' cities. Thus, the state-based provider advocates for centralised sewer-based solutions. In contrast, the private sector providers and NGOs see the need to further develop different types of small-scale decentralised technologies and provision modes. Therefore, the diverse actors are working towards different aspirations.

These diverse mind-sets and the already existing variety of service regimes suggest that the potential for a transition towards a citywide inclusive sanitation sector lays in improving complementarities of the different service regimes. For example, infrastructures could be connected, planning frameworks and regulations could include all different service options and technologies, and the competences of different providers could be better coordinated. It is, thus, important that the different sanitation providers (e.g. utilities, NGOs, CBOs, and enterprises) complement each other's services instead of acting independently, in an uncoordinated manner and even in competition with one another. Enabling smooth inter-operability between the different service regimes would result in more reliable access to services for users, as well as more effective service provision. The inter-operability would also eliminate service access gaps, which often lead users to resort to such non-desirable coping strategies as open defecation. Our analysis, thus, suggests that improving the complementarities of the current service diversity instead of striving for a homogeneous and costly sewered-sanitation sector could be an important alternative transition pathway, leading to a more sustainable and inclusive sector.

[1] The first two authors conducted the interviews as part of their PhD projects in Nairobi between 2016 and 2018.

[2] Service regimes 3 and 5 are considered 'unimproved' and 'unsafe' by WHO/JMP.

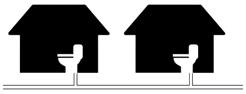
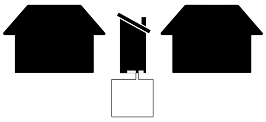
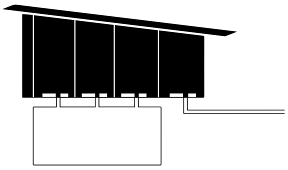
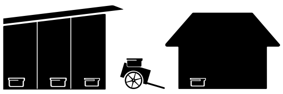
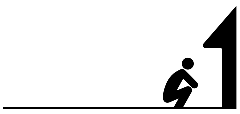
	Infrastructure & Artefacts	Rationale & Meaning	Social interactions	Organisational mode	Time & Space
Domestic sewer regime 	Central sewer system + (pour) flush toilet	• Users: Comfortable, good image, costly, consumes too much water • Provider: Sanitation using high quality modern technologies	• None	• Daily maintenance by households • Waste management by utility	• Timing users: Anytime • Location: Inside the house or on the plot
Shared on-site regime 	Latrine + pit or septic tank	• Users: Accessible, convenient, low costs, dirty, conflicts among households • Provider: Arranging sanitation for tenants	• Coordinating access and cleaning among households	• Organised by landlords or NGOs • Daily maintenance by households • Waste management by manual emptiers or private exhauster trucks	• Timing users: Anytime when on-plot and only during the day-time when off-plot • Location: Off-plot or on-plot
Public sanitation regime 	Latrine + pit or septic tank, bio- & compost latrines, hanging toilet, central sewer system + pour flush toilet	• Users: Convenient, costly, dirty, risk of diseases, insecure during the night • Provider: Business opportunity	• Trust building: Being a 'customer' • Everyday interaction between operator and user	• Daily operations by CBO, NGO or enterprise • Waste management by manual emptiers, private exhauster trucks or utility	• Timing users: During the day when user has money • Location: Commercial areas, public residential, hanging over a river
Container based sanitation regime 	Waterless system with urine diversion, biodegradable bags, containers	*As in-house access* • Users: Convenient, indignity, not appropriate for adults, culturally unfit & uncomfortable for men, useful for children, useful at night *As public access* • Users: Convenient, costly, risk of diseases • Provider: Environmental friendly sanitation, creating value from recycling waste	*As in-house access* coordination within the family *As public access* • Trust building, being a 'customer', a lot of interaction between operator and user	*As in-house access* • Daily maintenance by household • Enterprise collects the waste and re-uses it as fertiliser, biogas, animal feed *As public access* • Daily operations by enterprise • Waste is collected and re-used as fertiliser, biogas, animal feed	*As in-house access* - Timing users: Anytime, especially at night • Location: In-house toilet *As public access* • Timing users: During the day when user has money • Locations: Public commercial areas, public residential
Coping sanitation regime 	Cleaning bucket, plastic bag	• Users: Convenient option, no costs, useful in the setting of informal settlements, shameful, indignity, bad smell, done secretly, dirty, risk of diseases, insecure, acceptable for children	Coordination within the family, being accompanied by others	• Organised by households and individuals • No safe disposal of the waste	• Timing users: Anytime • Location: Inside the house, close to the home, around shared toilets, at open defecation hotspots (rivers, bushes)

Table: The characteristics of the five service regimes found in Nairobi.

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For the detailed study, see van Welie, M.J., Cherunya, P.C., Truffer, B., Murphy, J.T. (2018). Analysing transition pathways in developing cities: The case of Nairobi's splintered sanitation regime. Technological Forecasting and Social Change *137,* 259–271. The table used in this article is extracted from the detailed study.

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Estimating the Transfer of Pathogenic Viruses between Skin and Liquids

Viral pathogens that are responsible for diarrhoeal disease frequently spread through people / environment interactions. We quantified virus transfer at the skin / liquid interface to understand people's exposure to pathogenic viruses due to interaction with liquids, e.g. drinking, surface waters and urine. A.K. Pitol[1,2], H. Bischel[3], A. Boehm[4], T. Kohn[2], T.R. Julian[1,5,6]

Introduction

Every day, more than a thousand children younger than five years old die due to diarrhoea, and most of these deaths are preventable [1]. One of the leading causes of diarrhoea is enteric viruses. Despite the importance of water-related transfer of virus on public health, not much work has been done to understand it, especially for cases where indirect transfer (i.e., transfer from water-to-skin and skin-to-mouth) is relevant. To quantify the transfer of pathogenic viruses between people and contaminated environments, scientists typically perform experiments with human volunteers. Because pathogenic viruses pose a risk to the volunteers, however, estimates of transfer are made using safe virus surrogates, such as bacteriophages, which are viruses that infect bacteria. One problem with this approach is that bacteriophages do not always behave similarly to human pathogenic viruses and, therefore, transfer estimates may be inaccurate. In this work, we developed a safe method to quantify pathogenic virus transfer at the liquid/skin interface and used this method to estimate the transfer of two enteric viruses and one enteric virus surrogate [2,3].

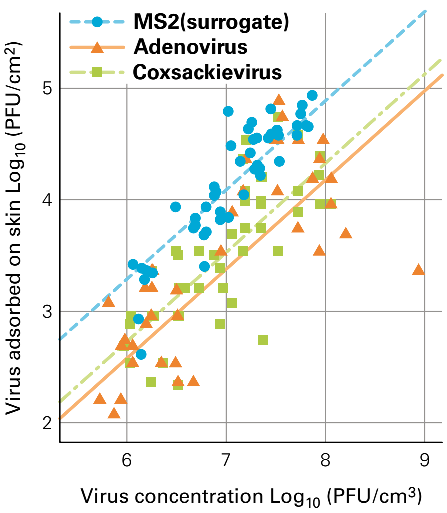

Figure: Number of viruses adsorbed onto the skin as a function of concentration for two pathogenic viruses (Adenovirus and Coxsackievirus) and one human virus surrogate (bacteriophage MS2). Figure adapted from Pitol 2018 shared under cc-by license [3].

Methodology

We selected a commonly used surrogate, bacteriophage MS2, to identify an adequate human-skin model for virus transfer experiments. We compared the transfer of MS2 from liquid to artificial skin, cadaver hands and arms, and volunteers' hands and arms (Photo). MS2 transfer to the skin of volunteers was similar to the transfer to cadaver skin, but different than that to artificial skin. Therefore, we proceeded using cadaver hands and arms to quantify the transfer of MS2 and two enteric pathogenic viruses: adenovirus and coxsackievirus.

Results

We found that virus adsorption to human-skin per surface area is primarily a function of the concentration of viruses in the liquid (Figure). We further found that the models developed to estimate the transfer of the human pathogens adenovirus and coxsackievirus are significantly different than those of the bacteriophage surrogate MS2 (Figure). Therefore, quantification of virus retention on the skin and subsequent risks would be overestimated based on data on MS2 adsorption.

Conclusion

Our study provides models of pathogenic virus transfer that can be used to assess the potential risk of water-related activities. For example, we have used the models to estimate the potential benefits and risks of washing hands with contaminated water [4]. Additionally, our work suggests that cadaver-skin is an adequate model for human-skin in virus transfer experiments, although existing artificial skin is not. Therefore, cadaver skin provides a good alternative for studying the interaction of pathogenic virus and human skin without unnecessary exposure to human volunteers, as it allows for using the virus of interest as compared with a virus surrogate, which gives a more accurate estimate of the transfer.

Paul Donahue

Photo: Virus transfer experiments using bacteriophage MS2 (enteric virus surrogate).

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[4] Verbyla, M.E., Pitol, A.K., Navab-Daneshmand, T., Marks, S.J., Julian, T.R. (2019): Safely-managed hygiene: A risk-based assessment of handwashing water quality. Environmental Science and Technology. http://dx.doi.org/10.1021/acs.est.8b06156

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Dr Agnes Montangero, Director of Helvetas Programmes in West Africa

Arnold FIDELIO, Helvetas Madagascar

Exchange with a cocoa producer on the vulnerability of cocoa trees to water-related risks such as flooding and drought periods in Madagascar.

Introduction

Dr Agnes Montangero is from Switzerland and has a PhD in Environmental Engineering from ETH Zürich.

How did you find out about Eawag-Sandec?

I learned about Sandec while working on my MSc thesis at another Eawag department, and found out there was an open position for a Project Officer. At that time, I was closely following reports on international cooperation in the media, and had doubts about its effectiveness. In spite of this, I asked if I could learn more about Sandec's vision and position, and met with Roland Schertenleib. This first exchange opened a new world for me.

What did you first do at Eawag-Sandec?

I joined the Faecal Sludge Management Group as Project Officer in 1998. Many cities in the 90s' invested in building latrines and septic tanks, but had no clear strategy what to do when the pits were full. We were contacted by many municipal officers asking for concrete solutions.

How was Eawag-Sandec beneficial to your career?

I worked with Martin Strauss, and he had a lot of experience abroad and an incredible sense of humour! I had so much fun and learned so much from him, in particular, how to develop and nurture partnerships with people and institutions in different countries. He provided me opportunities to work with our partners overseas from the very beginning, and to participate in global conferences. I learned tremendously and developed a network of friends and passionate WASH professionals all over the globe.

What was the most eventful aspect of your time at Eawag-Sandec?

After joining Sandec, I soon had the opportunity to go to the field and spent about a month in Ghana. I shifted to rice and beans for breakfast and learned not to look for the timetable when travelling by bus. We spent entire days at the Accra faecal sludge treatment plant (even for picnics on Saturdays), and were fascinated by our studies on the behaviour of different types of sludge at the lab. The sludge emptiers 'adopted' me and often picked me up in the morning to accompany them on their emptying trips, which was highly insightful in terms of understanding their work conditions and the real challenges of Faecal Sludge Management.

What are you presently doing?

I am currently in charge of Helvetas programmes in West Africa that focus on WASH, youth employment/skills development, market systems/value chains, governance, and conflict prevention.

Additionally, I am supporting the Helvetas suspension bridge unit (South-South Cooperation Unit) in market development with the idea to possibly transition the unit into a social enterprise. Finally, I am also involved as WASH advisor.

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Water Quality Between Source and the Tap of Ceramic Filters in Nepal

Locally produced ceramic water filters are increasingly available in remote rural contexts in Nepal. Low quality of these products and inadequate filter handling practices pose a challenge to water quality at the point of consumption. Regula Meierhofer[1], Carola Bänziger[1], Sandro Deppeler[1], Bal Mukund Kunwar[2], Madan Bhatta[2]

Introduction

Household water treatment, if applied correctly and consistently, is a strategy to reduce health risks related to the consumption of unsafe drinking water. In the context of the total sanitation campaign launched by the government of Nepal, development organisations working in this field started to promote improved practices for drinking water treatment, sanitation and hygiene and to trigger the private sector to make ceramic filters available in more remote areas. Consequently, locally produced low-cost ceramic candle filters are increasingly sold in rural areas of Nepal. This study was conceived to gain a better understanding of water quality changes between the water source, water transport containers and the tap of ceramic water filters, and to assess the influence of critical water and filter handling factors on filter performance and water quality.

Methods

Data was collected from 42 rural households using locally produced ceramic water filters in a remote mountainous region in Midwestern Nepal. Interviewers conducted structured observations on how the users handled the water transport containers before filling them at the public community water tap. Subsequently, they observed the filling and cleaning process of the ceramic water filters and water samples were taken before and after cleaning. To assess the contamination of clean water through the filtration process by using an eventually contaminated filter, the interviewers emptied the filters that were cleaned by the users and filled sterile water into the upper bucket. To analyse the performance of a clean, not contaminated filter, the filter was emptied and disinfected by filling the upper and lower receptacles with boiling water. After this, the interviewees again filled the upper bucket of the filter with water they had previously collected at the source and interviewers took a sample from the tap of the filter after filtration.

The quality of water at the source, in the transport container and at the tap of the filter before and after cleaning was analysed using membrane filtration. Bacteriological swab tests were taken of different filter parts, cleaning tools and hands. All water samples were kept in Whirl-Paks inside cooler bags and analysed at the field site, using membrane filtration techniques. 100ml water samples were passed through 0.45 µm Millipore cellulose membrane filters, using sterilised filtration equipment. Filter pads were plated on Nissui Compact Dry Coli-scan plates and incubated for 24 h at 35 ± 2 °C. Colonies of total coliforms and *E. coli* were counted.

Quantitative, structured household interviews were conducted after the observed filter cleaning process. People were questioned on demographics, the handling of containers used for the transport and storage of water, and the operation and maintenance practices of ceramic water filters. Also, questions and observations on sanitation and hygiene infrastructure and practices were included as proxy indicators for hygienic conditions in the household.

Carola Bänziger

Photo: Nepali woman cleaning her ceramic water filter.

Results

Filling the containers with water from the source and transporting them led to a statistically significant deterioration of water quality ($t = -3.09$, $p = 0.004$, $r = 0.43$). Counts of *E. coli* increased from a geometric mean of 22 CFU / 100 mL (10 – 90 Percentile: 1 – 282 CFU / 100 mL) at the source to 41 CFU / 100 mL (10 – 90 Percentile: 3 – 456 CFU / 100 mL) in the transport container.

Water quality measured at the tap of the ceramic filters varied highly among different households. The geometric mean of *E. coli* was 64 CFU / 100 mL (10 – 90 Percentile: 8 – 954 CFU / 100 mL) before the observed cleaning process and 44 CFU / 100 mL (10 – 90 Percentile: 1 – 945 CFU / 100 mL) after it. This difference was not significant ($t = 1.3$, $p = 0.2$). The use of the filter after the observed cleaning process improved water quality for 21 households (50 %).

The water quality taken from the tap of the ceramic water filter was statistically not different from the water poured into the filter, neither before ($t = -1.1$, $p = 0.3$), nor after the observed filter cleaning process ($t = -0.2$, $p = 0.8$), with mean LRV's for *E. coli* of – 0.2 CFU / 100 mL and – 0.04 CFU / 100 mL, respectively. The Figure shows that the filters contaminated the sterile water with a mean LRV for *E. coli* of –1.6 (SD = 0.8). When water from the transport container was filled into the filters that had been disinfected by the researchers, the household filters achieved a mean LRV for *E. coli* of 0.42 (SD = 1.2) and contained a geometric mean of *E. coli* of 8 CFU / 100 mL after filtration.

Filter cleaning practices of the households were highly inadequate. People used raw water and their hands to clean the filters, and a majority used a cloth to wash the hygienic parts of the filter. 5 % of the households said that they use boiled water to wash the lower bucket of the filter. Peoples' hands and the cloths used for cleaning were both highly contaminated, with a geometric mean of *E. coli* of 110 CFU / 100 mL (10 – 90 Percentile: 6 – 2 000 CFU / 100 mL) on hands and 80 CFU / 100 mL (10 – 90 Percentile: <1 – 2 000 CFU / 100 mL) on the cloths. Bacteriological tests on sterile water poured into the lower bucket of the filters found a geometric mean of 30 *E. coli* CFU / 100 mL (10 – 90 Percentile: 1 – 1 940 CFU / 100 mL) before the observed cleaning process. The geometric mean was 70 *E. coli* CFU / 100 mL 10 – 90 Percentile: 2 – 2 000 CFU / 100 mL) after the observed cleaning process. Swab

Model: Dependent variable: LRV *E. coli* (*E. coli* in the transport container — *E. coli* at the tap of the ceramic water filter)				
	B	**SE (B)**	**Beta**	**p**
Use of boiled water to clean the filter	1.19	0.43	0.300 **	0.009
Availability of slippers (shoes) in the toilet	0.70	0.29	0.280 *	0.021
Daily cleaning of the transport container with a soft cloth	–0.66	0.30	–0.270 *	0.037
Contamination level of *E. coli* in lower bucket (reservoir for filtered water)	0.00	0.00	–0.300 *	0.016
Cleaning of the filter with a soft cloth	–0.58	0.30	–0.240	0.062
Constant	0.08	0.22		0.718

$R^2 = 0.63$, * $p < 0.05$, ** $p < 0.01$

Table: Linear regression model: Factors influencing the filter's LRV.

tests on the outflow of the ceramic candle and the tap of the filter did not detect any *E. coli*.

Multivariate linear regression with the filter's LRV before the observed cleaning process as outcome variable revealed that the performance of the filter could be significantly improved by the use of boiled water during filter cleaning (Table). Households with slippers (shoes) in the toilet room had higher LRV's, indicating that better sanitary hygiene conditions positively influence the filter's effectiveness. The filter's performance was negatively affected if there were higher contamination levels of *E. coli* in the lower bucket (the reservoir for the filtered water) and if households said that they used a soft cloth for daily cleaning of the transport container.

Conclusion

Previous studies documented the significant impact ceramic water filter interventions had on improving drinking water quality and reducing health risks [1, 2]. However, contrary to our expectations, current filter promotion interventions in Nepal did not achieve satisfactory improvements in drinking water quality at the point of consumption. This is partly due to poor filter handling practices and use in an environment with low hygiene. Even households with disinfected, clean filters only achieved a LRV for *E. coli* of 0.4. This is significantly lower than the disinfection efficiency of the same filter brands obtained during laboratory analysis, which achieved a LRV of 1.5–2 [3, 4], and indicates that extended use of these filters by local households in the field reduced their performance. It was observed that users regularly brushed candles, sometimes extensively, to obtain higher flow rates, leading to the removal of ceramic layers to such an extent that even a few holes were found in some of them, thereby reducing filtration efficiency.

To achieve a stronger impact and to significantly improve drinking water quality at the point of consumption, future interventions should place more emphasis on adequate handling of ceramic water filters. Improved practice should consist of the regular use of boiling water to disinfect the filters. Raw water, and hands or cloths should not be used to clean hygienic parts of the filter. Using a brush to clean the filter candle should only happen when the candle is blocked.

In addition to training on proper filter handling, providing users access to filters of higher quality can significantly improve the impact of water quality interventions. The introduction of higher priced ceramic water filters into the markets of poor and remote mountainous areas, such as the region where our intervention took place, however, faces challenges. People in the local communities mostly lack the resources to pay for higher priced filters. Filters adequate for use in such settings should fulfil quality, as well as pricing criteria.

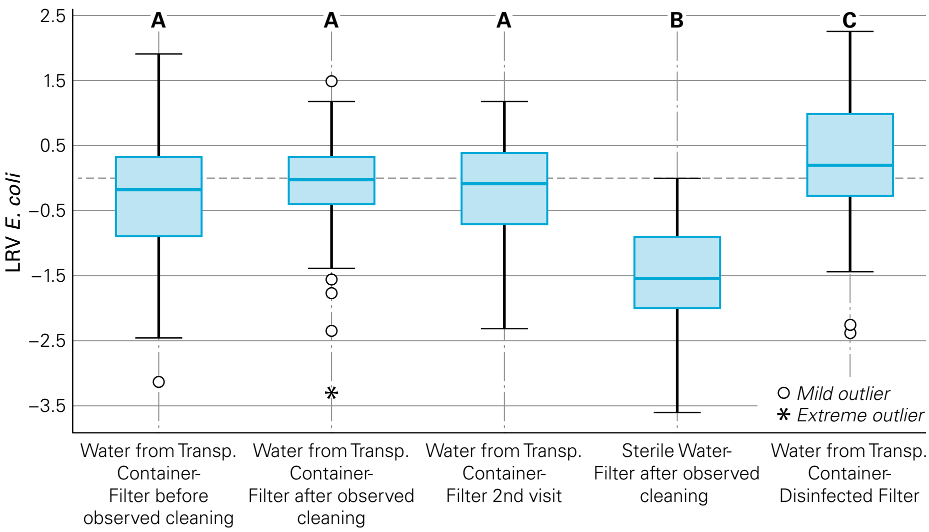


Figure: Log removal values of contaminated and disinfected household filters: (A) water from the transport container passed through a contaminated filter; (B) sterile water passed through a contaminated filter and (C) water from the transport container passed through a disinfected filter.

[1] Clasen, T., Schmidt, W. P., Rabie, T., Roberts, I., Cairncross, S. (2007): Interventions to improve water quality for preventing diarrhoea: Systematic review and meta-analysis. BMJ, *334 (7597)*, 782–785.

[2] Brown, J., Sobsey, M. D., Loomis, D. (2008): Local drinking water filters reduce diarrheal disease in Cambodia: A randomized, controlled trial of the ceramic water purifier. Am J Trop Med Hyg, *79 (3)*, 394–400.

[3] Kunwar, B. M., Bhatta, M., Shrestha, R., Saladin, M. (2018): Life span and performance test of ceramic filters in Nepal. Paper and presentation at the International Conference on Water and Climate, Kathmandu, April 2018.

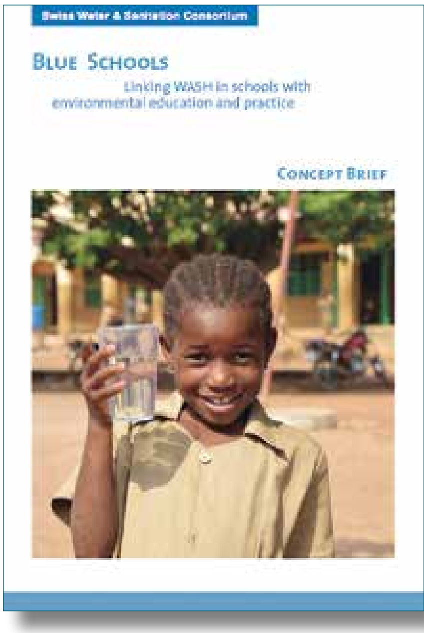
[4] ENPHO (2016): Study on Efficiency of Ceramic Candle Filters; Environment and Public Health Organization. ENPHO, Kathmandu, Nepal.

[1] Eawag/Sandec, Switzerland

[2] Helvetas, Nepal

Contact: regula.meierhofer@eawag.ch

The Blue Schools Kit is Now Available!



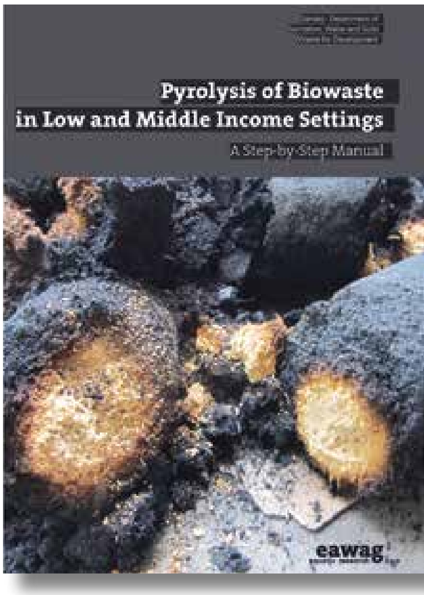
A Blue School goes beyond activities related to Water, Sanitation and Hygiene (WASH). It promotes a school garden as a practical place to demonstrate the relationship between food production and efficient water management, and to show watershed, waste and land management practices. It also offers a healthy learning environment and exposes students to environmentally-friendly technologies and practices that can be replicated in their communities. Blue Schools inspire students to be change agents in their communities and to become the next generation of WASH and environmental sector champions.

Since 2011, the Swiss Water & Sanitation Consortium (SWSC) has piloted the Blue School concept at more than 200 schools in Bangladesh, Benin, Ethiopia, Madagascar, and Nepal with support from the Swiss Agency for Development and Cooperation. Based on the experiences of SWSC, and with technical support from Sandec, the Blue School Kit was developed. The Kit provides concrete assistance to project staff, education authorities and school stakeholders on how to transform their schools to Blue Schools.

On the SWSC homepage, there is more information and the kit can be downloaded in English, French and Spanish for free: https://bit.ly/323G1pm

Contact: adeline.mertenat@eawag.ch

Published: Pyrolysis of Biowaste in Low- and Middle-income Settings



This is a comprehensive and user-friendly manual on how to build and operate a low-tech slow pyrolysis reactor. Slow pyrolysis is a thermochemical process that exposes biomass to high temperatures in the absence of oxygen, yielding char and gases. The char can be used as renewable fuel and as soil amendment (biochar). The value created can trigger improvements in sustainable waste management practices in low- and middle-income settings and impact public well-being.

There are numerous ways to design and operate a slow pyrolysis unit. They can be made from locally available construction material and equipment, and rely on human labour not automation. The manual lists the materials, equipment and actions required to build and operate a reactor. Typically, slow pyrolysis processes require a homogenised and dry material (e.g. wood) as feedstock; however, as this manual shows, urban biowaste can also be used as feedstock material.

The manual is open source and can be downloaded for free at: https://bit.ly/2t5LnAj

10 000th Completer of Sandecs MOOC Series

Hardik Bhatiya is Assistant Professor at the Government Engineering College in Gujarata, India, and is the 10 000th completer of our MOOC series. He took the four courses to update his knowledge of public health engineering. And now he plans to incorporate the learning materials in his lectures.

His preferred course is Municipal Solid Waste Management in Developing Countries. Currently, India faces a huge problem related to municipal solid waste management, and he credits this course with covering almost all possible aspects of treatment and management. However, he finds all the courses useful in the context of Gujarat, India.

His suggestions are to include a case study of Gujarat state in the Introduction to Faecal Sludge Management course. Also, household level treatment techniques and case studies about water treatment in India would be helpful in the water MOOC.

For further information on our MOOC Series, go to: www.eawag.ch/mooc

Contact: fabian.suter@eawag.ch

The Sandec Team


Anonymous

From left
Front row: Paul Donahue, Samuel Renggli, Christoph Lüthi
2nd row: Marius Klinger, George Wainaina, Fabian Suter, Ashanti Bleich, Nienke Andriessen, Regula Meierhofer, Dorothee Spuhler, Imanol Zabaleta, Stanley Sam, Christopher Kanyesigye, Bram Dortmans, Abishek Narayan, Chris Zurbrügg
Back row: Lukas Dössegger, Guillaume Clair, Sara Marks, Ariane Schertenleib, Linda Strande, Barbara J. Ward, Marta Fernández Cortés, Adeline Mertenat, Caterina Dalla Torre, Elizabeth Tilley, Vasco Schelbert
Missing in photo: Christopher Friedrich, Jasmine Segginger, Moritz Gold

New Faces

Lukas Dössegger, MSc in Environmental Engineering from ETH Zürich, joined the Safe Water Promotion group in April 2018. In his current position, he supports project management activities, looks for solutions to chlorinate drinking water on the scheme-level and is in charge of testing prototypes for a UVC-LED household treatment device. Previously, he worked for this group as a Civil Servant in 2017 on the Gravity-driven membrane filtration project in Uganda. He worked on water quality tests and the installation of new water kiosks.

Christopher Friedrich, MSc in Environmental Science from the University of Natural Resources and Life Sciences, Vienna, and the Swedish University of Agricultural Sciences, joined the Strategic Environmental Sanitation Planning Group in September 2018. During his studies, he focused on water and wastewater as a resource and worked with the Red Cross in international humanitarian emergencies as a WASH expert. He works in the area of faecal sludge treatment and analysis in humanitarian emergencies.

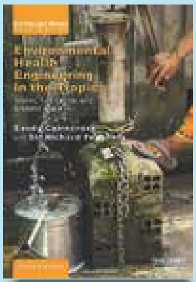
Ashanti Bleich is from Geneva, but grew up in different African countries. She completed her Bachelor's in Socio-Economics at the University of Geneva, and has a Master's in Environmental Technology and Water Management from Imperial College, London. She acquired her professional experience in water quality at WHO, and also from working on WASH projects for UNICEF Cambodia. Currently, she is working in Sandec's Strategic Environmental Sanitation Planning Group since October 2018.

George Kiambuthi Wainaina, MSc in Water Policy from the Pan African University's Institute of Water and Energy Sciences, is doing PhD research in collaboration with the Sandec and ESS departments of Eawag since January 2019. His research aims to understand the spatial, institutional and resource conditions necessary for successful slum upgrading initiatives with a focus on basic services provision in African cities. He has also previously conducted research on household water treatment and storage in Northern Kenya.

On the Bookshelf

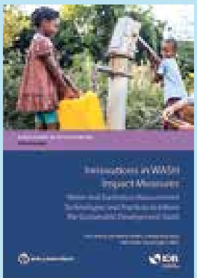
Apart from the publications cited in the previous articles, we would like to recommend the following new books and key readings in the areas of our research, including some of our own new publications.

Environmental Health Engineering in the Tropics: Water, Sanitation and Disease Control



This is a fully updated third edition of one of the most important and useful books for health engineering and disease prevention. It describes infectious diseases in tropical and developing countries, and the measures that may be used effectively against them, and includes new sections on arsenic in groundwater supplies and arsenic removal technologies.
By Cairncross, S., Feachem, R., Routledge, 2019, 384 pages. ISBN: 9781315883946.

Innovations in WASH Impact Measures: Water and Sanitation Measurement Technologies and Practices to Inform the Sustainable Development Goals



This book reviews the landscape of proven and emerging technologies, methods and approaches that can support the measurement of the WASH indicators proposed for SDG 6.1 and SDG 6.2. It provides a comprehensive review of topics from big data to behaviour change, satellites to safe sanitation, and presents these issues in an accessible and applicable way.
By Thomas, E., et al., The World Bank, 2018, 123 pages. ISBN: 9781464811975.

Water Supply and Treatment

How Humans Get in the Way of Clean Water

How might household water treatment be improved? That is the question looked at in this insightful historical analysis of the attempts to provide safe water to the world's poor regions.
By Lindzi Wessel, Knowable Magazine, 26 January 2019. It is available online at: https://bit.ly/2COBQ56.

Management of Excreta, Wastewater and Sludge

Faecal Sludge Management: Highlights and Exercises

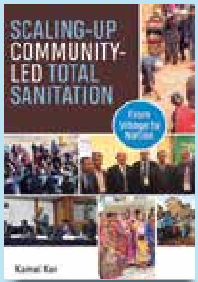
This book provides updates in the field of faecal sludge management, and is intended to be used as a companion to the book: 'Faecal Sludge Management: Systems Approach for Implementation and Operation'. It especially focuses on new developments concerning treatment technologies and innovations in FSM.
By Englund, M., Strande, L., Eawag, 2019, 200 pages. ISBN: 9783906484709.
It can be downloaded for free at: https://bit.ly/2JGdZb0.

Strategic Environmental Sanitation Planning

Guidelines on Sanitation and Health

These guidelines provide comprehensive advice on maximising the health impact of sanitation interventions. They summarise the evidence on the links between sanitation and health, and offer guidance for international, national and local sanitation policies and programme actions.
By World Health Organization, WHO, 2018, 198 pages. ISBN: 9789241514705.

Scaling-Up Community Led Total Sanitation: From Village to Nation



The book elaborates upon the history and genesis of the CLTS movement, and how the approach came to be adopted by various governments, non-governmental organisations, and international agencies. It also elucidates various methodologies to end the practice of open defecation, and describes in detail a methodology for influencing sanitation policies nationally.
By Kar, K., Practical Action Publishing, 2019, 268 pages. ISBN: 9781853399756.

On the YouTube Channel

We would like to recommend this new videos produced by Sandec/Eawag that deal with issues in our areas of research.

Safe Drinking Water in Eastern Uganda Through Gravity Driven Membrane Filtration

2.1 billion people lack of access to safely managed drinking water services worldwide. This video describes the Gravity Driven Membrane project in Eastern Uganda, which is providing safe clean water to more than 4000 people in eastern Uganda.
Produced by: Sandec/Eawag.
Filmed and edited by: Paul Donahue. 2018, 8:38.
It can be seen at: https://bit.ly/2Xwc0vy.

Arsenic au Burkina Faso: Solutions

In Burkina Faso, groundwater can be contaminated with arsenic, an element naturally occurring in rocks and minerals that can be hazardous to human health. This video explains the origin of the contamination, the location of contaminated areas, treatment methods and potential transfer to food products.
Produced by: Manivelle and Sandec/Eawag.
Filmed and edited by:
Manivelle production. 2018, 4:53.
It can be seen at: https://bit.ly/2Y8n31C.