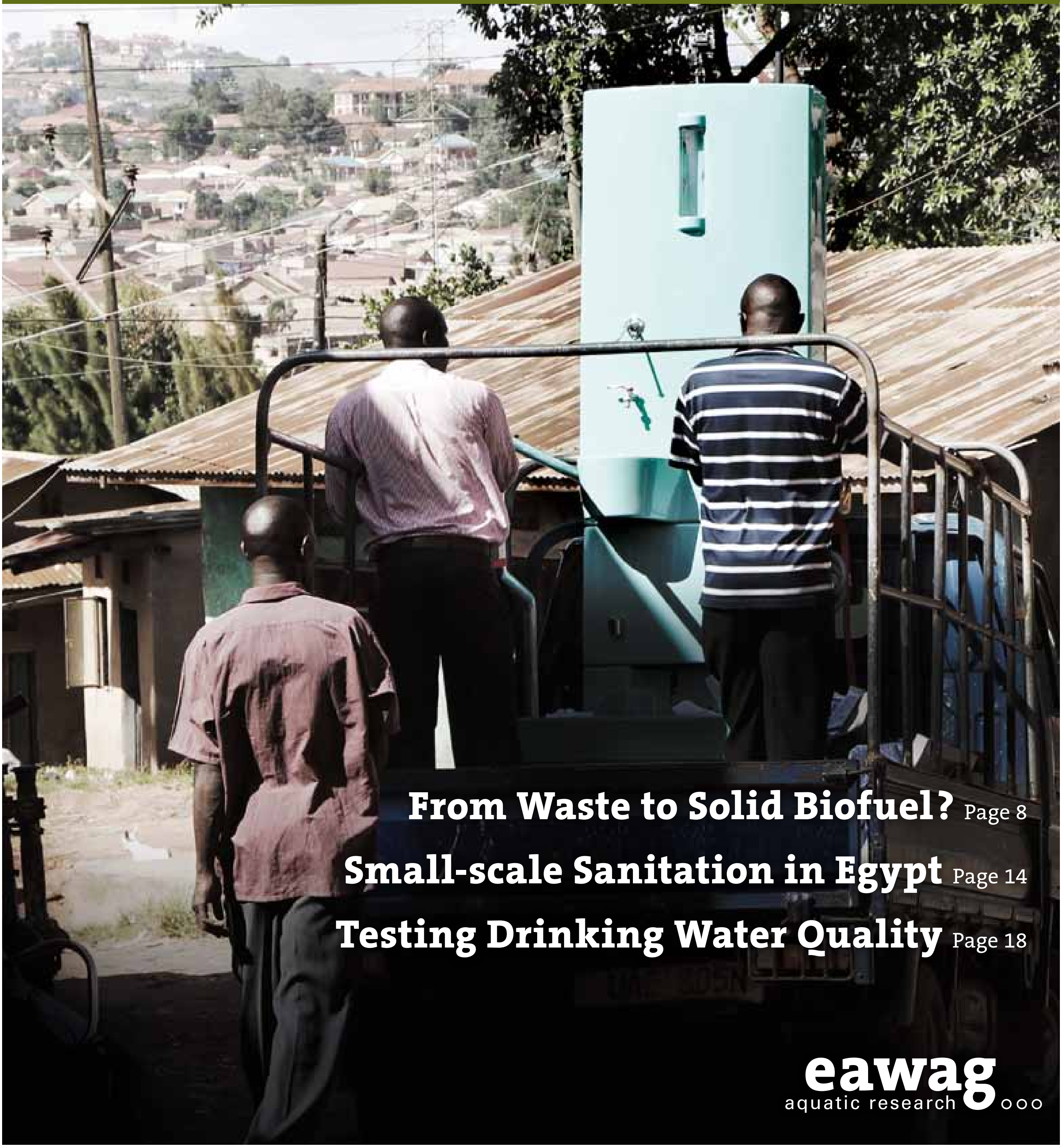
No. 14 07/13
Sandec: Department of Water and Sanitation in Developing Countries

sandec news



From Waste to Solid Biofuel?

Small-scale Sanitation in Egypt

Testing Drinking Water Quality

eawag
aquatic research

Table of Contents

Solid Waste Management

Excreta and Wastewater Management

Strategic Environmental Sanitation Planning

Water Supply and Treatment

In Brief

Sandec
Water and Sanitation in Developing Countries

Publisher: Eawag, P.O. Box 611, 8600 Dübendorf, Switzerland
Phone: +41 (0)58 765 52 86, Fax: +41 (0)58 765 53 99
caterina.dallatorre@eawag.ch, www.sandec.ch

Editors: Paul Donahue and Chris Zurbrügg, 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: Transport of the Eawag/EOOS blue diversion toilet into the Kifumbira slum for the first field tests in Kampala, Uganda (Photo: Harald Gruendl)

Layout and figures: Lydia Zweifel, Eawag

Photos: All 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

Closing the Knowledge Gap

"Highly trained WASH professionals, the world needs them now!"

When asked how effective sanitation improvements could be achieved, Professor Duncan Mara, a leading sanitation expert, answered that it is absolutely crucial to get the sanitation knowledge we already have to those who need it most: engineers and planners in developing countries at all levels – local, state/provincial, and central governments. If they do not know about the wide range of sanitation technologies, then how do they know if they are recommending and implementing the locally best option?

But, what is an effective way to ensure such massive knowledge transfer? Increasing web connectivity - also through widespread mobile networks - makes e-learning an exciting opportunity. E-learning can occur outside of a classroom and be self-paced, a requirement to reach practitioners on the job. It gives them the opportunity to complete their work in a low stress environment and within a more flexible timeframe, for instance, on evenings and weekends. E-learning should not substitute for face-to-face and tactile/kinaesthetic learning; however, it is an exciting option when affordability and time constraints hinder the latter. E-learning can also be integrated into face-to-face instructor-led, synchronous classroom learning. It relies heavily on self-motivation and self-discipline and this can be fostered using a wide range of learning approaches, such as audio and video courses, self-assessments, social networking, email, blogs, discussion boards, as well as web-supported textbooks and hypertext documents.

Sandec has recently joined forces with the Swiss Federal Institute of Technology in Lausanne (EPFL) to develop MOOCs on water supply, sanitation, hygiene and solid waste management. A MOOC (massive open online course) is a free of charge online course aimed at large-scale interactive participation and open access via the web. EPFL is a partner of two well established e-learning platforms, edX and Coursera, that partner with the top universities and organizations in the world to offer courses online for anyone to take, for free. It recently evaluated an IT-programming MOOC that reached 53 440 registered students with over 10 000 students completing the certificate. Just think about that: reaching 10 000 engineers with one course! Sandec's first MOOC, arriving at the end of 2013, will be on household drinking water treatment. We will keep you updated!

Besides education and training, Sandec obviously remains heavily engaged in applied research with local partners, covering the wide range of WASH issues. This newsletter gives you a teaser of what we do. For more detail on our projects, please contact the respective authors by email or access our web-page, www.sandec.ch, where most documents are available to download for free. To improve our outreach and communication efforts, since March, we are happy to have Paul Donahue as part of our team. This newsletter is already proof of his coordination, communication and editing skills. Please feel free to contact Paul if you have any suggestions on how to improve our newsletter or website.

To further advance application of the SODIS (Solar Water Disinfection) Method, the SODIS reference centre at Sandec has established a partnership with Helvetas, a Swiss NGO active in 32 countries of the developing world. This partnership enhances synergies between Eawag's research expertise and the wide experience of Helvetas in project development and implementation. Helvetas will integrate household water treatment methods in their drinking water projects and Sandec will provide support with research, technical advice, and advocacy at the international level.

In sanitation, the Eawag/EOOS team was awarded a special design prize "for outstanding design of a toilet user interface" by the Bill and Melinda Gates Foundation at the 2012 RTTC Fair in Seattle. While this allows us to further develop the toilet technology, we are also very pleased that the Swiss Development Agency (SDC) has committed to support us with research on the non-technical aspects of providing sanitation systems and services to urban slum dwellers. This includes transport logistics; business model development; and effective interventions for incorporating user perceptions, attitudes and behaviour change in projects.

Yes, this newsletter is published only once a year. I am sorry to disappoint you if you feel that this is not enough. If you would like to keep abreast of all Sandec activities in "real-time", I invite you to join Sandec's LinkedIn group. As member of this group, you will receive news about Sandec events, projects, results and publications.

Chris Zurbrügg
Director Sandec

Hydrothermal Carbonization (HTC): A Pressure Cooker for Biowaste

Hydrothermal Carbonization (HTC) is a thermochemical conversion process which transforms biomass under pressure into a solid coal-like product. To assess the suitability of this technology for developing countries, a pilot HTC reactor was developed, built and is being tested at Eawag. Christian Riu Lohri[1], Zeno Robbiani[1], Christian Zurbrügg[1]

Introduction

Although HTC has been known for a hundred years, interest in it as a possible way to transform organic waste into a stable, solid, sterile and valuable product has markedly increased only in the last decade. During the HTC process, the biomass is submerged in water and heated to approximately 200 °C for several hours. The water is kept in a liquid phase by keeping the mixture under saturated pressure in the reactor, allowing the pressure to rise to roughly 20 bar. One result of the HTC process is a solid product called hydrochar or HTC coal. It can be used as an energy carrier substituting for wooden charcoal in improved cooking stoves, as functionalized carbonaceous material, for soil improvement, or even as a means for carbon sequestration.

Component	Specifications	Cost (CHF)
Reactor	• Material: Stainless steel (thickness 6.3 mm) • Volume: 21.8 L • Pressure range: 10 – 25 bar • Max. pressure: 30 bar • Temperature range: 180 – 220 °C • Max. temperature: 300 °C • Max. number of load cycles: 1 000	5 700.–
Certification	• Applied regulation: PED 97/23 EC – AD 2 000 • Category III (fluid group 1)	6 000.–
Additional equipment	• Overpressure valve (30 bar) • Drain valve to release steam after process • Heating mantle (max. power: 2 500 W)	2 400.–
Measuring devices	• Pressure- and temperature meter (data logger) • Energy consumption meter (data logger)	2 900.–
TOTAL		**17 000.–**

Table 1: Specifications and costs of prototype HTC reactor.

Advantages of HTC

Compared to other biowaste treatment methods using biological processes, carbonization has various advantages. The reaction takes only a few hours compared to the days or months needed for biological processes. Furthermore, the high process temperature eliminates pathogens and inactivates other potential organic contaminants such as pharmaceuticals. The resulting coal product is sterile and hygienic [1]. In addition, HTC can handle varying feedstocks. In principle, any kind of biowaste, e.g. organic municipal solid waste, faecal and sewage sludge, and animal manure can be hydrothermally carbonized. Material with high moisture content of 90 % or more can be used [2]. Most of the carbon in the initial substrate stays bound in the final coal product (~ 75 %), while the carbon content in the process water (20 %) and the gaseous product (5 %) are much lower [3]. The water-carbon suspension after carbonization is less hydrophilic than the initial substrate, making the dewatering process of the HTC-coal easier compared to the original biomass before processing.

The first pilot HTC plants have recently been implemented, predominantly in Germany, for treatment of problematic biomasses like industrial waste, biowaste or sewage sludge [4]. However, these high cost and high-tech solutions are feasible only for industrialized countries. Given the numerous advantages of HTC, our research explores the potential of an adapted HTC system for biowaste and faecal sludge treatment that is suitable for developing countries.

Objective and research procedure

We first looked at existing HTC technologies to develop a sound understanding of HTC processes. Based on this, we designed and constructed a small prototype experimental reactor that ensures full functionality and operational safety in accordance with the technical requirements feasible for developing countries. Next, we tested its functionality, and analysed and compared the end products with results from experiments with a HTC reactor at the Zurich University of Applied Sciences (ZHAW), using the same substrate and carbonization conditions [5].

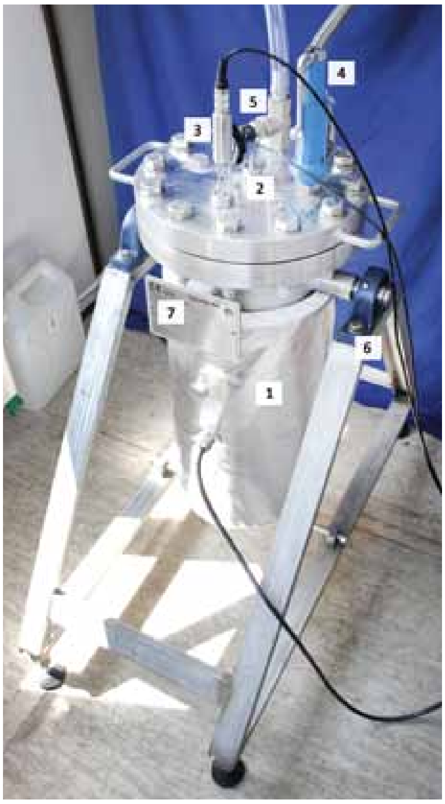
Design selection and construction

The main design criteria for the reactor were: low cost, the use of materials available in low- and middle-income countries, a low level of complexity, ease of handling, high durability and safety. These criteria were used to assess different HTC systems. We decided to build a stainless steel reactor that would operate in a batch-feeding mode and heated by an electric heating mantle (See Photo 1). Table 1 presents the HTC reactor's specifications and costs.

The cost of the required security certificate exceeded the cost of the actual reactor. Receiving the certificate implies, however, that the reactor is safe and adheres to strict regulations regarding the design, materials and welding work. Although substantial costs were involved to meet the required material standards and regulations, the total cost of the prototype reactor is nearly six times lower than the cost of the ZHAW reactor (Grenolmatik 25 by Grenol GmbH, Germany), which is similar in size. Their reactor's higher cost is partly due to its stirring device and its fully automated thermal oil heating system, although these factors at this scale add no significant value to the process.

First experiments and results

The HTC reactor at Eawag was first tested with water. Then, rice was used as a model substrate for carbonization under standard conditions. The reactor was filled with 1 kg of rice and 16.6 L of water (TS of load: 5.3 %). The internal temperature was stabilized at



Christian Riu Lohri

Photo 1: Prototype HTC reactor.
(1: Heating mantle, 2: Temperature sensor, 3: Pressure sensor, 4: Overpressure valve, 5: Drain valve, 6: Bearing, 7: Identification plate with CE sign)

around 200 °C. Over the 10.2 h of total reaction time (the temperature was above 180 °C for 6.7 h), 11.8 kWh of power were needed. Table 2 shows that the process led to a reduction of both oxygen and hydrogen content, thereby, increasing the C content of the initial feedstock. Carbon mass balance indicates that 58.4 % of C was found in the solid, 30.2 % in the liquid, and 11.4 % in the gaseous product. The results concerning dry matter (TS) content, calorific value, and the composition of elements compared well to those from the ZHAW HTC reactor.

Conclusion

The research revealed that a reactor's construction costs could be significantly reduced, especially when compared to the costs of other HTC experimental reactors. However, the total cost remains relatively high and, thus, is a barrier to use in developing countries. Roughly a third of the total cost is for the security certificates required for pressure-vessels. To ensure proper functioning and safety, additional cost reduction is not possible. The prototype HTC reactor was tested with rice and the resulting coal showed a heating value of approximately 27 MJ/kg. The elemental composition is comparable with the results produced by the HTC reactor at ZHAW.

Outlook

The constructed HTC reactor will be further tested using biowaste from the canteen. Experiments on variations of solid load, carbonization temperature and duration should reveal the optimal operational parameters. The goal is to treat the maximum amount of waste per batch with the lowest energy input possible and have a positive energy balance. Experiments with faecal sludge as feedstock are also being considered.

The possibility of upscaling, and of using the waste heat to reduce the energy requirements will be researched, as well as the use of photovoltaic panels for power to avoid dependency on electricity from the grid. In addition, how to treat the still organically loaded process water requires further research. In the near future, the HTC process will also be tested in a developing country to study on-site construction and operational issues.

		Unit	Raw rice	Experiment ZHAW	Experiment Eawag
In	Feedstock	(kg)		1.1	1.0
In	Water	(L)		15.8	16.6
Out (Solids)	HTC-coal (wet)	(kg)		2.3	1.9
Out (Solids)	TS output	(%)		18.4	18.1
Out (Solids)	Higher Heating Value	(MJ/kg dry basis)	17.7	27.7	26.9
Out (Solids)	C	(% dry basis)	44.1	69.4	66.9
Out (Solids)	H	(% dry basis)	6.5	5.2	4.9
Out (Solids)	O	(% dry basis)	49.4	22.7	23.8
Out (Solids)	N	(% dry basis)	1.2	2.2	1.9
Out (Liquid)	Process water	(L)		15.1	15.1
Out (Liquid)	pH			3.2	2.7
Out (Liquid)	EC	(µS/cm)		1 038.0	1 083.0
Out (Liquid)	TOC	(mg/L)		4 933.0	7 764.0

Table 2: Comparison of results (rice experiments) between ZHAW and Eawag reactors.

[1] Libra, J.A. et al. (2011): Hydrothermal carbonization of biomass residuals: A comparative review of the chemistry, processes and applications of wet and dry pyrolysis. Biofuels *2(1)*, 89–124.

[2] Funke, A., Ziegler, F. (2010): Hydrothermal carbonization of biomass: A summary and discussion of chemical mechanisms for process engineering. Biofuels, Bioproducts and Biorefining. 4:160–177.

[3] Titirici, M.-M. Arne, T., Antonietti, M. (2007): Back in the black: Hydrothermal carbonization of plant material as an efficient chemical to treat the CO_2 problem? New Journal of Chemistry, 31. 787–789.

[4] Glasner, C., Deerberg, G., Lyko, H. (2011): Hydrothermale Carbonisierung: Ein Überblick. Chemie Ingenieur Technik, 83, No.11, 1932–1943.

[5] Robbiani, Z (2013): Hydrothermal Carbonization of biowaste/faecal sludge. Conception and construction of a HTC prototype research unit for developing countries. MSc thesis. ETHZ (Dept. of Mechanical Engineering) and Eawag.

[1] Eawag/Sandec, Switzerland

We would like to thank Rolf Krebs, Marina Escala and Gabriel Gerner of ZHAW for sharing their expertise and lab facilities. The contributions of Roland Rebsamen (TFC Engineering), Thomas Kläusli (AVA-CO_2), Moritz Mildenberger (FH Trier), Erwin Wimmer (Initiative Zukunftsenergien), Michael Diestel (Agrokraft) and Sohail Khan (Loughborough University) are also much appreciated.

Contact: christian.lohri@eawag.ch

Waste-based Business Models for Resource Recovery

Waste-based business models for resource recovery could be the solution to the sanitation challenges of low and middle income countries. This is the research aim of the Triple R Project (Resource, Recovery and Reuse), which is analysing the factors of business success in this industry. Lars Schöbitz[1], Christian Zurbrügg[1], Heiko Gebauer[2], Linda Strande[1]

Introduction

The challenge of dealing with solid and liquid waste management in rapidly growing urban areas is a widespread problem in low and middle income countries. The three year Resource, Recovery, and Reuse Project (RRR) was developed to analyse and test the feasibility and scale-up potential of successful waste-based resource recovery business models in four countries on three continents: Kampala, Uganda; Hanoi, Vietnam; Bangalore, India; and Lima, Peru. The goal is to identify their success factors and to study whether they could be replicated elsewhere. The international project team consists of researchers from Sandec/Eawag, the International Water Management Institute, the Swiss Tropical and Health Institute, the World Health Organization, and the International Centre for Water Management Services in collaboration with research partners in each of the project cities.

Analysing key drivers of business success

During the project's first year, researchers identified 150 business cases, from which 50 detailed case assessments were generated. The case assessments were organized into 20 different business models, using the Business Model Canvas as a template [1]. The main criteria were: input materials (wastewater, faecal sludge, urine, municipal solid waste, and agro-industrial waste streams), resource recovery output (water, energy and nutrients), and transformation processes. The researchers then determined the drivers of business success of the business models. Three of the principal factors identified are: use of an input-product formerly regarded as waste, producing valuable end-products for local markets, and ascertaining specific local market factors that make expansion and the reduction of investment costs possible.

Case studies of two companies

Two business models provide good, contrasting examples of drivers of business success. They are: the Honeysuckers in Bangalore and Manila Water in the Philippines (See Figure 1).

The success of the Honeysuckers was achieved by high demand for faecal sludge from farmers in the region, leading to the replication of micro-enterprises. The market for faecal sludge had become so competitive that farmers began to pay the Honeysuckers to discharge into their drying beds. In addition, local truck and chassis manufacturers offer business loans for trucks at low interest rates, greatly reducing the cost for investing in trucks. Vacuum pumps are also locally made, lowering their cost.

Manila Water`s success was achieved by establishing the resources to provide clean, potable and affordable water to millions of households. The company organized a public-private partnership with the national government in 1997, requiring the development of a sound corporate strategy and business plan. This made it eligible to receive low cost funding, which the company used for investments. It expanded its water infrastructure, leading to higher revenues and the development of a fully operational Faecal Sludge Management service chain. All household water bills include a 20 % water tariff, covering the cost of regular emptying of the septic tanks. Even poor households can afford this because the piped water's cost is lower than what they used to pay.

Future work of the RRR project

The RRR Project's next phase is to do feasibility studies to evaluate whether it is possible to successfully implement the 20 business models in each project city. These studies, based on multi-criteria assessments, will look at the local contexts of the four cities and explore the potential for the replication and scaling-up of the business models. Sandec's role will be to quantify waste supplies through material flow analyses, conduct a technical assessment of the business model technologies, and carry out an environmental impact assessment of the identified technologies. Other team members will look at health related issues, do financial and institutional analyses, as well as analyze market demand and socio-economic characteristics. It is expected that the results of the RRR Project could lead to improvements in the implementation of successful waste-based business models for resource recovery throughout the world.

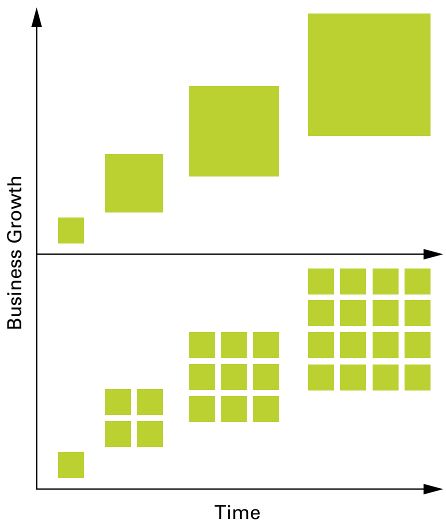


Figure 1: Traditional organic business growth and replication of micro-enterprises reaching the same type of coverage in Faecal Sludge Management.

[1] Osterwalder, A. et al. (2010): Business Model Generation. Self-published.

[1] Eawag/Sandec, Switzerland
[2] Eawag/ESS, Switzerland
Funding for the RRR project is provided by the Swiss Agency for Development and Cooperation.
RRR Project Website: www.sandec.ch/rrr
Contact: lars.schoebitz@eawag.ch

Co-management of Faecal Sludge and Wastewater Sludge in Vietnam

Sandec launched the Partnership for Urban Resource Recovery Project (PURR) in January, 2013. Concentrating on five urban areas in Vietnam, this project will evaluate, develop and test strategies for the co-treatment and resource recovery of faecal sludge and wastewater sludge. Magalie Bassan[1], Viet-Anh Nguyen[3], Christof Holliger[4], Linda Strande[2]

Introduction

Almost 30 % of the population of Vietnam lives in urban areas and this number is expected to increase by 1 million people annually. Urbanization increases the challenge of providing sanitation, and affects natural resources and the environment, especially, in terms of water pollution.

Vietnam has set a target for 80 % of all urban households to be connected to sewers with operational wastewater treatment plants by 2020. However, on-site sanitation technologies will still play an important role, as:

- the remaining 20 % of all households will continue to be served by septic tanks, and
- households with existing septic tanks will be connected, with the effluent going to the combined sewerage and drainage system.

Thus, faecal sludge from septic tanks will continue to be a sanitation management concern.

Context

KfW and SECO fund programs to improve drainage and sewer networks, and to build wastewater treatment plants in Vietnam. They have recently turned to projects that integrate strategies for faecal sludge and wastewater sludge treatment and resource recovery. PURR was developed by Sandec, the Hanoi University of Civil Engineering (HUCE) and École Polytechnique Fédérale de Lausanne (EPFL) to address this issue and is funded by SECO. Sandec's long-term experience in working with the Environmental Science and Engineering Department of HUCE, leaders in sanitation and wastewater management in rural and urban areas, led to the development of this three year collaborative project. It will take place in five cities in Vietnam (See Figure 1).

Objective and activities

The objective of PURR is to evaluate viable options for sludge management, treatment and resource recovery for mid-size cities in Vietnam with populations of 85 000 to 165 000 people. It will investigate anaerobic co-digestion of sludge, which is considered to be a promising technology for co-treatment, because it allows for simultaneous treatment and energy production.

Field studies to assess the appropriateness of technical solutions in local contexts will be done. Surveys will be conducted in the five project cities, focusing on the aspects that influence the production and types of sludge (e.g. onsite sanitation coverage and management systems). Market demand analyses will also take place in the five cities to assess the potential use of and demand for different end-products, such as biogas and soil amendments. The potential for reuse of the end products by agriculture and/or industry will be explored, according to the specific conditions of each urban area.

The anaerobic co-digestion component of the project will first focus on a detailed understanding of the characteristics of the waste streams, specifically, of the parameters that influence anaerobic degradation.

Figure 1: The five cities in the project.

Samples of faecal sludge and wastewater sludge will be collected and analysed in laboratories. Then, solutions in the lab will be made to mimic the characteristics of these samples. Bench scale tests of the solutions will take place in EPFL's Laboratory of Environmental Biotechnology to assess their anaerobic digestibility (e.g. mixing ratios and feeding rates). Afterwards, a pilot scale digester in Vietnam will be built to test operational parameters and treatment performance with real faecal sludge and wastewater sludge.

Challenges and perspectives

This project aims to simultaneously increase knowledge of the characteristics of faecal sludge, and its potential co-digestion with other organic waste streams, as well as to specifically assess solutions for the co-treatment of faecal sludge and wastewater sludge. Specific aspects that will be addressed include:

- the different geographic, socio-cultural and climatic contexts in Vietnam,
- the different management schemes of faecal sludge and wastewater sludge and how they affect co-treatment, and
- the wide variation of faecal sludge characteristics that make it difficult to reliably predict operating parameters and performance.

PURR aims to provide the required data to deal with variations in faecal sludge and wastewater sludge management in urban settings. We believe that the project's comprehensive laboratory analyses, bench scale experiments, and field pilot tests will produce results that could improve future work in the treatment and resource recovery of faecal sludge and wastewater sludge in Vietnam, and in similar urban areas worldwide. Watch here for future news….

[1] Eawag/Sandec and EPFL, Switzerland
[2] Eawag/Sandec, Switzerland
[3] HUCE/IESE, Vietnam
[4] EPFL, Switzerland
Contact: magalie.bassan@gmail.com

Faecal Sludge – From Waste to Solid Biofuel?

Research in urban areas of Senegal, Ghana and Uganda proved that there are widely untapped markets for faecal sludge end-products as financial drivers to sustain reliable and safe faecal sludge management. As a fuel, it especially shows promise as an industrial energy resource and a means to generate revenue. M. Gold[1], A. Murray[2], Ch. Niwagaba[3], S. Niang[4], L. Strande[1]

Introduction

Urban sanitation throughout Sub-Saharan Africa is characterized by poorly designed and maintained on-site sanitation systems, dysfunctional faecal sludge collection and transport, and unsafe disposal of untreated or inadequately treated faecal sludge into the environment. The SPLASH funded research project Faecal Management Enterprises (FaME) aims to improve dysfunctional sanitation chains by developing scalable reuse oriented value chains, changing faecal sludge management from a disposal problem into a profitable business. The goal of FaME research is fill the data gaps about the use of faecal sludge that limit scientific decision making and market implementation.

Market demand for faecal sludge

In collaboration with local partners, market demand studies, comprising of focus group discussions and interviews, were conducted with potential faecal sludge end-users in Dakar, Kampala, and Accra to identify possible markets for five faecal sludge end products. The products are: an industrial fuel, as a source to produce protein for animal feed, as a source to produce biogas, a component in building materials, and a soil conditioner or fertilizer. Already used to some extent as a soil conditioner in these locations, the end-products represent potentially sound revenue generating sources. Their market potential, however, depends on local factors, such as the faecal sludge characteristics, existing markets, local industry requirements, legal regulations, subsidies, and locally available materials [1].

Co-combustion of faecal sludge in industries

Industries in the three cities rely on a variety of fuel sources which could potentially be substituted or supplemented with faecal sludge. Our study showed that in Dakar and Accra, industries use electricity or liquid fuels (e.g., diesel, heating oil, or kerosene) for energy. In Kampala, some companies already use solid fuels, revealing a possible market potential for faecal sludge. And 45 % of the industry representatives interviewed expressed interest in immediately using it as fuel if it met their process requirements [1].

Faecal sludge as potential fuel

In contrast to sewage sludge, the heating value of faecal sludge has never been thoroughly evaluated. To estimate its energy potential and identify correlations with on-site sanitation technologies, faecal sludge was collected from pit latrines, septic tanks, anaerobic ponds and drying beds. Analysis proved that on average, the faecal sludge calorific value was 17.3 MJ/kg dry solids [2]; thus, it is highly competitive with local biofuels as shown in Figure 1 (FS=Faecal Sludge and WW=Waste Water).

Up-scaling of faecal sludge as a fuel

In general, fuel supply is a long-term decision for industries and their fuel requirements depend on their specific industrial processes. Given the low solids content of faecal sludge, developing cost-effective drying methods is required for it to be successfully used as a fuel. Research on the physical and chemical properties of faecal sludge is necessary to be able to predict the following characteristics: calorific value, ash content, corrosion potential, emissions and potential odour nuisance. The ideal form of the fuel, and transportation and storage issues, also require analysis.

The next step is to construct demonstration kilns in Dakar and Kampala in collaboration with local industries. In Dakar, different filter materials and natural coagulants will be tested to improve the performance of unplanted drying beds. FaME research results indicate that the potential market for faecal sludge end-products could offer a promising, profitable, and sustainable alternative for faecal sludge management in urban environments worldwide.

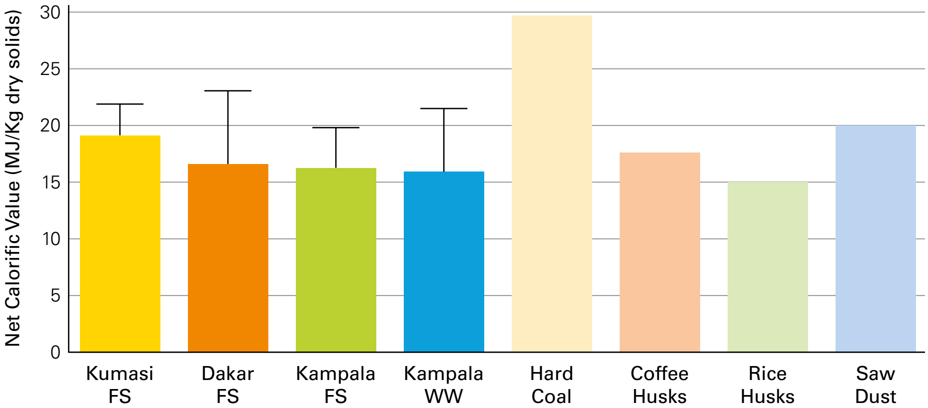


Figure 1: Average net calorific value of raw faecal sludge and wastewater treatment sludge compared to hard coal and biofuels [2].

[1] Murray, A., Nakato, T., Niwagaba, C., Dione, H., Kang, J., Stupin, L., Regulinski, J., Mbéguéré, M., Strande, L. (submitted): Fuel Potential of Faecal Sludge: Calorific Value Results from Uganda, Ghana and Senegal.

[2] Diener, S., Simiyaga, S., Niwagaba, C., Murray, A., Gning, J. B., Mbéguéré, M., Ennin, J. E., Strande, L. (in preparation): Enhancing the Value Chain: Market Demand for Faecal Sludge in Sub-Saharan Africa.

[1] Eawag/Sandec, Switzerland
[2] Waste Enterprisers Ltd, Ghana
[3] Makerere University, Uganda
[4] Université Cheikh Anta Diop, Senegal

The FaME project is funded by a SPLASH grant (www.splash-era.net). Further information about FaME can be found at www.sandec.ch/fame.

Contact: Moritz.Gold@eawag.ch or Linda.Strande@eawag.ch

Helminth Eggs Die-off and Nutrients: Human Excreta Storage Experiment

Are the current practices of handling human excreta for agricultural purposes by farmers in Vietnam good enough? This study set up an excreta storage experiment to research how to inactivate *Ascaris lumbricoides* eggs and still maintain the nutrient value of human excreta. T. Vu-Van[1,2,3], P. Pham-Duc[1], H. Nguyen-Viet[1,3,4,5], Ch. Zurbrügg[3], T. Huu Bich[1], J. Zinsstag[4]

Introduction

The use of human excreta as fertilizer creates economic and environmental benefits for farmers. However, it could pose potential health risks if not handled properly. In Vietnam, farmers often add locally available materials (e.g. ash, lime and rice husk) into excreta to reduce the bad smell and moisture content, and to prevent flies during excreta storage before using it as fertilizer. These current practices are likely to increase the inactivation of helminth eggs since dry conditions and increased pH often affect pathogen die-off. However, it is not yet clear if these practices meet the safety standards for the use of excreta in agriculture.

Excreta storage experiment and analyses

Our study tested the influence of different additive materials on helminth egg die-off in excreta, while maintaining its nutrient value, to improve the current practice of human excreta storage and identify the best option for the safe use of excreta in agriculture. The storage process we used simulated the current practices of farmers for excreta management.

First, we developed an experimental 24 vault storage system. Lime and rice husks were added into human excreta in varying proportions in the storage vaults and homogenously mixed to increase the pH (Table 1). Air pipes were introduced into 12 of the vaults to accelerate aeration. All the vault options met the WHO standard of hygienic quality for treatment of human excreta (< 1 egg per gram total solid).

Samples were taken from the vaults every two weeks over a 6.5 month period (sampling from T1 to T14). We used the Romannenko method to quantitatively analyse and count live and dead *A. lumbricoides* eggs and the Kendal method to measure the nutrient parameter (Nitrogen). The pH, temperature and moisture content were also recorded. A linear regression model of both uni- and multi-variable analyses was used to examine the effects of storage options, time, pH and temperature on the *A. lumbricoides* die-off.

Results

The number of live eggs per gram of sample decreased from 15 eggs to 0 eggs by the thirteenth sampling. Vault 42, containing 90 % latrine wastes mixed with 10 % powder lime, was the best option, reducing the number of live eggs to 0 over 4.5 months.

The average pH value progressively decreased from 10.6 to 7.9. The temperature inside the vaults varied from 17.4 to 32.6 °C, which was close to the ambient temperature. The linear regression model showed that the storage time and the mixtures in vaults 41 and 42 significantly influenced the die-off of *A. lumbricoides* eggs. The total explanation percentage in the regression model was 76.1 % by sampling the vault option, temperature, and pH.

The average percentage reduction of total nitrogen was 40 % (from 0.16 % to 0.55 %). The average percentage of total nitrogen per total solid decreased from 1.75 % (1.05 %; 2.17 %) at the first sampling to 1.35 % (0.89 %; 1.62 %) at the 11th sampling. However, the percentage reductions were not significantly different among the vault options ($p > 0.05$, two-way analysis of variance - ANOVA). It is also not clear what effects pH, temperature and moisture had on the die-off of *A. lumbricoides* eggs during the experimental period.

Conclusion

In conclusion, the study showed that the different additive materials did not greatly reduce the total nitrogen in the human excreta during the storage process. Yet, adding appropriate amounts of lime into excreta (10 kg lime / 90 kg latrine excreta – vault 42), coupled with enhanced aeration, quickly destroyed the helminth eggs, while maintaining the high nutrient values important for fertilizing agricultural fields. The results of this study could impact the way farmers in Vietnam handle human excreta for safe agricultural use.

Vault options	Excreta (kg)	Additive material (kg)		Air pipe	Replicate
		lime	rice husk		
11 (control)	100	0	0	No	3
12	100	0	0	Yes	3
21	97	3	0	No	3
22	97	3	0	Yes	3
31	90	5	5	No	3
32	90	5	5	Yes	3
41	90	10	0	No	3
42	90	10	0	Yes	3

Table 1: Experimental plan of excreta storage, air pipes, and additive materials.

[1] Center for Public Health and Ecosystem Research, Hanoi School of Public Health, Vietnam
[2] Hoa Binh Medical Secondary School, Vietnam
[3] Sandec/Eawag, Switzerland
[4] Swiss Tropical and Public Health Institute, Switzerland
[5] International Livestock Research Institute, Vietnam

This work has been supported by the Swiss National Science Foundation and the Swiss Agency for Development and Cooperation through the National Centre for Competences in Research North–South Program.

Contact: vuvantu@gmail.com

Treatment Technology for Leachate from Faecal Sludge Drying Beds

The use of planted drying beds for faecal sludge treatment is effective for solid-liquid separation, but the leachate produced requires further treatment prior to discharge or reuse. This study investigates the potential of a new and low-cost solution for leachate treatment. E. Soh Kengne[1], K. Ives Magloire[1], W. Arsenne Letah[1], A. Akoa[1], H. Nguyen-Viet[2,3,4], L. Strande[2]

Introduction

The use of planted drying beds for the treatment of faecal sludge in Sub-Saharan Africa is a recent development [1]. The beds achieve solid-liquid separation, stabilize sludge that can be used for agriculture, and produce plants that can be used as animal fodder. However, the leachate from drying beds is still high in nutrients, organic matter, and pathogens. Therefore, it requires further treatment prior to discharge into the environment or reuse. This research focused on the use of planted drying beds in series for the treatment of faecal sludge and the subsequent leachate, resulting in the leachate treatment effectively being achieved through the same principles as vertical flow constructed wetlands (VFCW).

Methodology

The experimental setup is illustrated in Figure 1. Physical-chemical (i.e. COD, BOD5, TKN, NH_4^+, NO_3^-, PO_4^{3-}, conductivity, TDS, and salinity) and bacteriological analyses (i.e. faecal coliform and faecal streptococci densities) were performed on the faecal sludge, leachate and effluent following standard methods [2]. The density of rhizospheric bacteria was determined using the Germida method [3].

Findings

Planted drying beds batch fed with leachate from faecal sludge dewatering beds at 50, 100 and 150 L/d were effective in removing on average more than 80 % of monitored pollutants (COD, BOD, NH_4^+, NO_3^-, PO_4^{3-}, faecal coliforms and faecal streptococci) at all three hydraulic loads. Peak loadings were associated with increased effluent concentrations. The treatment performance met the WHO guidelines for effluent discharge for most parameters (i.e., COD < 100, BOD_5 < 20, Conductivity < 2000 mg/L; Salinity < 500 mg/L and PO_4^{3-} < 10 mg/L). However, nitrates and faecal coliforms exceeded the limits of the WHO guidelines (i.e., NO_3^- > 30 mg/L; FC > 1000 UFC/100 mL). Degradation by bacteria, plant uptake, and adsorption on the filter medium are the most likely mechanisms for the observed removal [4]. The density of plants and bacteria increased with respect to hydraulic load. However, the increased bacteria and plant growth did not correlate to an increase in treatment performance.

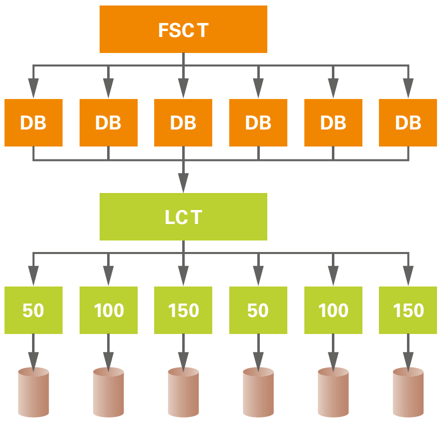


Figure 1: Experimental setup and operation.

1. Raw faecal sludge (FS) from Yaounde (typically 90% septic tanks, 4% pit latrines, 3% public toilets, 3% others)
2. Planted drying beds (DB) with *Echinochloa pyramidalis*, batch fed with raw FS at 200 kg TS/m^2/yr.
3. Leachate collection tank (LCT)
4. Planted beds (VFCW) with *Echinochloa pyramidalis*, batch fed with leachate at three different hydraulic loads: 50, 100 and 150 L/day
5. Barrels for collection of effluent from leachate treatment

Conclusion

Planted drying beds in series appear to be a very promising technology for the solid-liquid separation of faecal sludge, and the subsequent treatment of leachate. This treatment scheme is low-cost, relatively easy to operate, and produces plants that can be sold as fodder. However, the receiving environment of the effluent needs to be carefully evaluated due to the nitrate and coliform concentrations. The next phase of this research will evaluate the use of stabilization ponds for the treatment of leachate from planted drying beds.

Ebenezer Soh Kengne

Photo 1: View of the experimental setup.

[1] Kengne N.I.M. (2008) Potentials of sludge drying beds vegetated with *Cyperus papyrus* L. and *Echinochloa pyramidalis* (Lam.) Hitchc. & Chase for faecal sludge treatment in tropical regions. Ph.D Thesis, Cameroon.
[2] Greenberg, Arnold, et al. (2005) Standard methods for the examination of water and wastewater. AWWA, APHA, WEF.
[3] Germida, J.J. (1993) Cultural methods for soils microorganisms, in M.R. Carter (ed.), Soil Sampling Methods of Analysis. Boca Raton, FL, Lewis Publishers, 263–275.
[4] Kadlec, R. H. and Wallace S. D. (2009) Treatment wetlands, Second Edition. Boca Raton, FL, Taylor & Francis Group.

[1] Department of Plant Biology, University of Yaounde I, Cameroon
[2] Eawag/Sandec, Switzerland
[3] Center for Public Health and Ecosystem Research (CENPHER), Hanoi School of Public Health (HSPH), Vietnam
[4] SwissTPH (Basel, Switzerland) and ILRI (Hanoi, Vietnam)

This research is supported by the Swiss National Centre of Competence in Research North-South (NCCR North-South), IFS Grant No. W/4115–2, and by the Eawag Partnership Program.

Contact: sohkengnee@yahoo.fr.

Environmental and Health Impacts of Urban Sanitation Services in Côte d'Ivoire

Equitable access to urban sanitation services is necessary for populations' welfare and well-being and is one of the Millennium Development Goals. This study highlights how the lack of access to urban waste management infrastructure and services impacts human health and the environment. K. Parfait[1,2], D. Kouassi[1,2], H. Nguyen-Viet[3,4,5], Ch. Zurbrügg[3], B. Bonfoh[1,4], B. Jean[1]

Introduction

Since 2002, as a response to the adoption of the Millennium Development Goals, scientists and development agencies have been making efforts to find practical solutions to urban sanitation problems and to improve populations' wellbeing in developing countries worldwide. However, despite these attempts, recent statistics indicate that the urban sanitation situation in Sub-Saharan Africa remains very challenging [1, 2]. In Côte d'Ivoire, in particular, the urban sanitation problems are multiform. For instance, there is a lack of an institutional framework, an unsuitable intervention planning process, the absence of viable funding and inadequate infrastructure. The result is an exacerbation of health and environmental risks. This study evaluates the health and environmental impacts linked to the lack of access to sanitation services in Yamoussoukro, the capitol of Côte d'Ivoire.

Methodological approach

This study was conducted in Yamoussoukro, (6°30 – 7°35 North latitude, 4°40 – 5°20 West longitude) a city of approximately 450 000 inhabitants and the capital of Côte d'Ivoire. It entailed an interdisciplinary approach that included: a geographical survey to map uncontrolled solid waste disposal sites, cross-sectional surveys of 492 households to assess the link between sanitation and health status, and a seasonal analysis of the water bodies, including lake water and groundwater, to assess nitrogen contamination.

Environmental risk factors

The lake water and groundwater constitute the main water sources in Yamoussoukro and the water supply is outside the city. Chemical analysis of the lake water showed that it had concentrations of nitrates that varied from 0.3 to 8.3 mg/L and of ammonium from 0.1 to 4.5 mg/L. Organic pollution was between 10 to 39 mg/L for BOD_5 and 14 to 30 mg/L for COD. In the groundwater, the averages for nitrates and for ammonium were 22.8 – 80.3 mg/L and 0.06 – 7.5 mg/L, respectively. These results indicate a high risk of nitrogen [3].

Exposure status and disease burden

Household surveys attest to the potential health risks in the study areas of Yamoussoukro, finding evidence of three main water-borne diseases. These surveys also recorded the spatial distribution of the diseases. The geographical survey showed 172 illegal solid waste disposal sites in the city. About 90 % of city households have septic tanks, while 40 % of the peri-urban area households use pit latrines. The lack of sanitation negatively impacts the environment and places children at higher risk of exposure to diseases (See Photo 1). People living in settlements without sustainable sanitation services, i.e., Dioulakro, Nzuessy, Sopim, and Morofé, suffer from higher disease impacts than people in settlements with such services (See Figure 1).

Christian Zurbrügg

Photo 1: Exposure routes and health risks in Yamoussoukro.

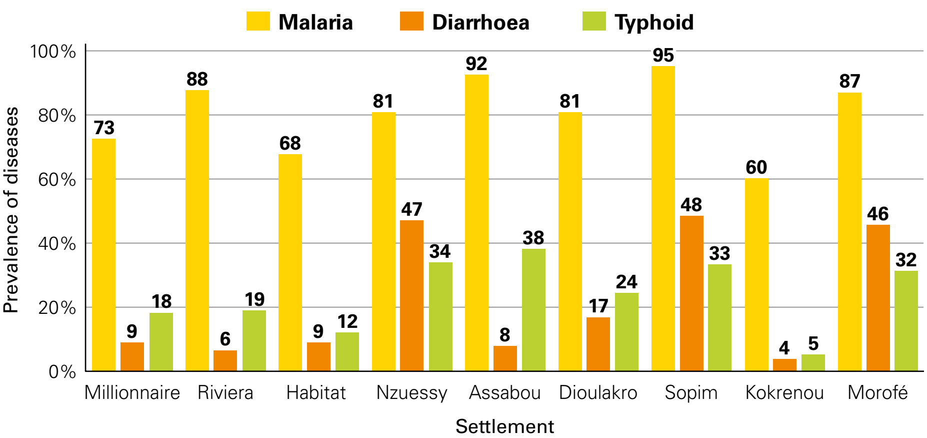


Figure 1: Distribution of water borne diseases in the settlements of Yamoussoukro.

Conclusion

Although Yamoussoukro is recognized as a model of a planned town, there is major environmental and health degradation in the city, especially in poor and low-income settlements. The lack of a well-functioning urban waste management infrastructure is one of the main causes of these environmental and health problems. Establishing integrated sanitation infrastructure and services in Yamoussoukro could reduce environmental pollution and hazards, and decrease human exposure to health risks.

[1] UNHABITAT/DSC (2008): L'assainissement un impératif pour les droits de l'homme, rapport, 56.

[2] WHO/UNICEF (2012): Progress on drinking water and sanitation 2012, Update, JMP report, 66.

[3] Dovonou F. et al. (2011): Pollution physico-chimique et bactériologique d'un écosystème aquatique et ses risques écotoxicologiques: cas du lac Nokoue au Sud Benin, article, 13.

[1] University of Felix Houphouët Boigny, Côte d'Ivoire

[2] Centre Suisse de Recherche Scientifiques en Côte d'Ivoire, Côte d'Ivoire

[3] Eawag/Sandec, Switzerland

[4] Center for Public Health and Ecosystem Research, Hanoi School of Public Health, Vietnam

[5] Swiss TPH (Basel, Switzerland) and LRI (Hanoi, Vietnam)

Contact: k.koffiparfait@yahoo.fr

Improving Sanitation and Hygiene in Low-income Neighbourhoods

A hot and dry desert environment, and underdeveloped sanitation infrastructure and services characterize the poor peripheral areas of Nouakchott, Mauritania's capital. Sandec research aims to demonstrate appropriate solutions to tackle Nouakchott's sanitation and hygiene challenges. Lukas Ulrich[1] and Pierre Bourqui[1]

Lukas Ulrich

Photo 1: Construction of a dehydration toilet in Nouakchott.

Introduction

Looking at today's map of Nouakchott, it is hard to imagine that this vast urban agglomeration was only a small village about 50 years ago. The reason why the capital was established on the Atlantic coast at the fringe of the Sahara desert in 1958 is its central location, where the Arab world and black Africa merge, and its comparatively moderate climate. At that time, no one expected that within 55 years Nouakchott would expand to a city of roughly a million inhabitants with neighbourhoods stretching to sand dunes far away from the city centre. The high in-migration and urbanisation rates are due to declining nomadism and pastoralism, drought and armed conflict. Consequently, particularly in the city's outskirts, tremendous challenges have arisen, such as precarious dwellings, deficient basic urban services, high living costs and unemployment. In terms of urban infrastructure development, Nouakchott has been unable to meet its growing needs, particularly, those related to water supply and sanitation.

A public-public partnership for water solidarity

To assist with these infrastructure challenges, the city of Lausanne and the Île-de-France region began a public-public partnership with the Communauté Urbaine de Nouakchott (CUN) in 2009. Lausanne's water utility eauservice supports projects that improve the urban poor's access to safe water and sanitation, and that foster capacity development at the municipal level. As part of these efforts, Sandec has received funding to handle various responsibilities from 2012 to 2014 that include: management of a sanitation baseline assessment with surveys in two targeted low-income neighbourhoods, construction of adapted on-site sanitation demonstration facilities along with on-the-job training of masons, development and dissemination of a best practice guide and construction manual, analysis of promising financing mechanisms to support the installation and operation of adequate sanitation infrastructure at the household level, and sensitization and hygiene promotion activities.

Sanitation and hygiene conditions in the targeted neighbourhoods

A household survey, conducted in collaboration with the University of Nouakchott and the National Public Health Research Institute, revealed that every third child five years of age or younger had diarrhoea at some point during the two weeks prior to the study. The prevalence of diarrhoeal diseases correlates with hand washing practices, water availability and access to sanitary toilets. Indeed, the outcomes of the survey indicate that less than a quarter of all respondents wash their hands at the recommended critical times, and that only every second household owns a toilet. In 80 % of the cases, when a full pit needs emptying, it is done manually. Because there is no faecal sludge collection and treatment site, pit contents are disposed of wherever convenient. Due to the low water consumption (~170 L/day for a family of six), greywater management is not a pressing issue, but its uncontrolled disposal leads to the spread of insect vectors and human contact therewith.

Infiltration, storage and dehydration benefits

The results of the baseline surveys clearly indicated the need for awareness-raising interventions, and affordable and hygienic sanitation hardware. Based on these results, Sandec proposed ventilated toilet technologies that are either waterless (except for anal cleansing) or pour-flush, and that handle on-site infiltration of liquids to reduce the volume accumulating in vaults. Infiltration of liquids into the ground is unobjectionable as the aquifer is saline and not used. However, in some areas of Nouakchott the high groundwater level and clayey soil challenge this approach and solutions may have to be proposed in the future. Storage and enhanced dehydration processes transform the remaining solids into an inoffensive, dry product that can easily be emptied and transported.

Sandec set up six household-level pilot toilets that include hand washing facilities and greywater filters to field-test the concepts and demonstrate sanitation solutions to the public in the two neighbourhoods (See Photo 1). The targeted local communities have confirmed their interest in having improved sanitation technologies; yet, affordability remains a major barrier to up-scaling. The next step is to study how to reduce hardware costs and analyse what financing mechanisms could support low income households' access to adequate sanitation infrastructure. Project results could show practical solutions to the urban sanitation infrastructure challenges facing Nouakchott and similar urban communities worldwide.

[1] Eawag/Sandec, Switzerland

Sandec's work is part of the "Projet Communautaire pour l'Accès à l'Eau" funded by Lausanne and other Swiss municipalities through the solidarit'eau suisse initiative (www.solidariteausuisse.ch).

Contact: lukas.ulrich@eawag.ch

Local Solutions for Sanitation Planning: Lessons Learned from CLUES in Nepal

As part of a global validation process, the Community-Led Urban Environmental Sanitation planning approach (CLUES) was tested in Nala, a peri-urban settlement in the Kavre District in Nepal. The aim of CLUES is to foster community participation in sanitation planning. Christoph Lüthi[1], Lukas Ulrich[1], Mingma Sherpa[2]

Introduction

The CLUES planning approach was tested in Nala, Nepal, in a series of participatory steps, leading to the successful development of an integrated environmental sanitation improvement plan in 2009–10, and its implementation in 2011–12. Nala is a densely built-up area about 35 kilometres from Kathmandu with a population of 2274 in 388 households. Although only 66 households did not have toilets prior to CLUES, the sanitation situation was poor. Most households had toilet facilities connected to single cesspits, simple pits lined with brick walls and covered with concrete slabs. Due to the high water table in the settlement's core, these pits had to be manually emptied very frequently and the sludge disposed onto nearby fields or into bodies of water.

Planning and implementation

In the first phase, Eawag/Sandec developed an environmental sanitation plan according to the CLUES planning approach, addressing blackwater, greywater and stormwater, solid waste management and hygiene promotion.

Treatment steps: • Screen bar chamber • Two units of settling tank each of 15.5 m^3 • Two units of anaerobic baffled reactors each of 24.6 m^3 • Two horizontal subsurface flow constructed wetlands (100 m^3)	
Total costs (CAPEX) (US$):	**165 000**
Simplified sewerage:	85 000
Dewats system:	25 000
Land acquisition:	31 000
Planning costs:	24 000
Per capita cost of sanitation system (incl. land):	**64**
Water consumption (lpcd):	**35**
Spatial footprint of DEWATS (m^2):	**350**
Treatment capacity (m^3/day):	**32**

Table 1: 2012 implementation costs of the simplified sewer network in Nala.

The participatory multi-stakeholder process involved household mapping and surveys, user needs identification and prioritisation, as well as a stakeholder assessment. Among the sanitation alternatives identified by local experts and presented to the community, people showed strong preference for a simplified sewer network connected to a decentralised wastewater treatment plant.

A detailed action plan, developed in close collaboration with the community, was the first implementation step. Design and cost estimates were prepared and presented to the community. The community also actively contributed to the project's construction and completion, both in terms of cash and in-kind labour.

To support the efforts of low-income households to construct toilets and/or connect to the sewer network, a microfinance revolving fund scheme was established. A local cooperative manages the fund, providing low interest rate loans with a flexible payback period of 12–24 months to eligible households. Part of the revolving fund goes to cover the sanitation system's Operation and Maintenance (O&M) costs.

Success factors in Nala

The following contributed to the success of CLUES planning and implementation in Nala:

Demand-driven and community-based: The Nala project was initiated due to strong demand from the community and their willingness to upgrade the existing sanitation facilities, and the good rapport between the planners and local leaders.

Strong community participation and ownership: Community demand for the project ensured peoples' strong participation. The community contributed approximately 48 % of all capital expenditures (including in-kind contributions like land), strengthening their sense of ownership [1].

Agency partnerships: The partnership approach facilitated by Eawag/Sandec and the NGO Centre for Integrated Urban Development (CIUD) played a pivotal role in the success of CLUES. With an environmental sanitation plan in hand, many partners, including the local authority, committed themselves to investing in it.

Institutional ownership: At the project's initiation, an ad hoc community level committee, the Nala Integrated Development Committee, was established to facilitate the implementation phase. It later merged into the Nala Water Supply and Sanitation Users Committee, a legal entity registered with the local authority. It has overall ownership of the project and is responsible for the sanitation system's O&M.

Financial and O&M security: The monthly service fees, collected from each household connected to the sewer network, are deposited in the revolving fund, guaranteeing the system's long-term O&M.

Technical soundness: Expert partners like CIUD and the Environment and Public Health Organization developed a well-designed sanitation system and supervised its construction. Regular community monitoring of the system ensures its sustainability and high quality.

CLUES helps communities make informed choices, promoting their ownership of sanitation systems. Results show that the CLUES approach can lead to and be a model for successful sanitation planning and implementation on the community level worldwide.

[1] Sherpa, M., Lüthi, C. and Koottatep, T. (2012): Applying the Household-Centered Environmental Sanitation Planning Approach: a Case Study from Nepal. Journal of Water, Sanitation and Hygiene for Development *2 (2)*, 124–132.

[1] Eawag/Sandec, Switzerland
[2] Asia Institute of Technology, Thailand
Contact: christoph.luethi@eawag.ch

Small-scale Sanitation in Egypt: 10 Points to Move Forward

In the framework of its advisory role to the Egyptian Government, the SECO-funded ESRISS Project issued a policy brief addressing the situation of small-scale sanitation in Egypt. Two recommendations, in particular, economies of scale and standardisation, are key if small-scale sanitation is to thrive. Philippe Reymond[1], Christoph Lüthi[1], Rifaat Abdel Wahaab[2], Moustafa Moussa[3]

Since before the Arab Spring, the Egyptian-Swiss Research for Innovation in Sustainable Sanitation Project (ESRISS) has supported the Egyptian Holding Company for Water and Wastewater (HCWW) and the Integrated Sanitation and Sewerage Infrastructure Project (ISSIP), funded by the World Bank, in developing upscalable small-scale sanitation strategies in the Nile Delta. The last Egyptian presidential election led to the establishment of a new Ministry of Water and Sanitation Utilities (MWSU) and a political will to develop small-scale sanitation solutions. Clear guidance is needed to promote sound development; thus, ESRISS published a policy brief [1], based on a thorough assessment of the challenges of small-scale sanitation in Egypt [2]. It identified the following 10 key action items:

1. **Development of a clear institutional strategy**
Isolated initiatives and lack of commitment by government agencies largely prevent wide-scale replication of successful sanitation planning; none of the effective approaches tested so far have been institutionalised. Developing a clear integrated strategy, including input from all stakeholders, is important.

2. **Standardisation of treatment units**
Wide-scale replication implies standardisation and production of prefabricated units. This would bring economies of scale, reduction of costs, reduction of the time needed for project preparation and implementation, and an increase in the quality of the infrastructure.

3. **Centralised O&M management under HCWW leadership**
Small-scale systems should be centrally managed, either by HCWW or a professional private company. Establishing an effective management scheme requires determining the minimum number of villages to be served, i.e., the "critical mass".

4. **Selection of appropriate collection and treatment options**
Sanitation options for each village should be tailor-made and based on: good planning, including adapted design criteria; feasible management schemes; and comparison with life-cycle cost analysis.

5. **Adaptation of laws, regulations and Codes of Practice**
Existing laws, regulations and Codes of Practice prevent the sound development of small-scale sanitation systems. An incremental approach should replace the current "all or nothing" philosophy.

6. **Move beyond "business as usual"**
Conventional wisdom says that "contractors do not like to go for small-scale systems because there is little money for a big effort". Actually, small-scale sanitation is profitable in terms of economies of scale.

7. **Development of baseline data**
The lack of baseline data about rural sanitation has led to inadequately designed infrastructure. Records of wastewater quantity and the characteristics specific to each village should be kept.

8. **Focus on preliminary assessments**
Thorough preliminary field assessments, leading to realistic design parameters, are key for cost-effectiveness and sound estimates. Planning should prioritize modular, flexible systems given the high uncertainty of future social developments.

9. **Improvement of the project management cycle**
Terms of reference, and tendering and bidding procedures should allow for flexibility, innovation and the inclusion of small stakeholders. Complicated procedures favour big consultancy firms that are specialists in meeting donor requirements, but not in small-scale sanitation. The accountability of consultants and contractors should be increased. Performance-based contracts should become the norm, and monitoring and evaluation must be strictly enforced.

10. **Transparency and dissemination of lessons learned**
Lessons learned are few and far between in Egypt. It is recommended that HCWW create an online document library on its website to prevent consultants from re-inventing the wheel and/or selling the same report to different parties.


Philippe Reymond

Photo 1: Village scene in Beheira Governorate, Nile Delta.

In the coming months, the ESRISS Project will further its analysis of sanitation system scenarios and its *Material Flow Analysis* model to better forecast the quantity and characteristics of wastewater in small settlements. Policy work will be driven by demand and the political decisions of MWSU and HCWW.

[1] Reymond Ph., Abdel Wahaab R., Moussa M. (2012): Small-scale Sanitation in Egypt – 10 Points to Move Forward. Research for Policy Brief. Eawag.

[2] Reymond Ph. (2012): Small-scale Sanitation in Egypt: Challenges and ways forward. Eawag.

[1] Eawag/Sandec, Switzerland

[2] Holding Company for Water and Wastewater, Egypt

[3] Helwan University, Egypt

We would like to thank all of our Egyptian partners and colleagues for their support, and the Swiss State Secretariat for Economic Affairs (SECO - www.seco-cooperation.ch) for funding this project.

For more information: www.sandec.ch/esriss

Contact: philippe.reymond@eawag.ch, based in Cairo

Predicting Geogenic Fluoride Contamination in Tanzania

Modelers at Eawag coupled an understanding of mobilization processes with geospatial data to develop a geostatistical model to predict the risk of fluoride in groundwater. Our research project tested the accuracy of its predictions, comparing them with measured fluoride levels in groundwater in Tanzania. Michael H. Shedafa[1], Richard Johnston[2]

Introduction

Low fluoride levels in drinking water (0.5–1.0 mg/L) protect young children against dental caries, but higher levels of fluoride intake can cause negative health impacts in both children and adults. To protect against dental and skeletal fluorosis, WHO recommends a guideline value of 1.5 mg/L [1]. Geological structures, such as volcanic series, weathering of rocks and groundwater chemistry, are among the main factors contributing to the natural occurrence of fluoride in groundwater [2,3]. The first generation global maps produced by Eawag's geostatistical model [4] showed high fluoride risks in the north and west of Tanzania (Figure 1). Fluorosis is a well-known problem in the north, but not in the west, and we conducted research to test the accuracy of the predictions.

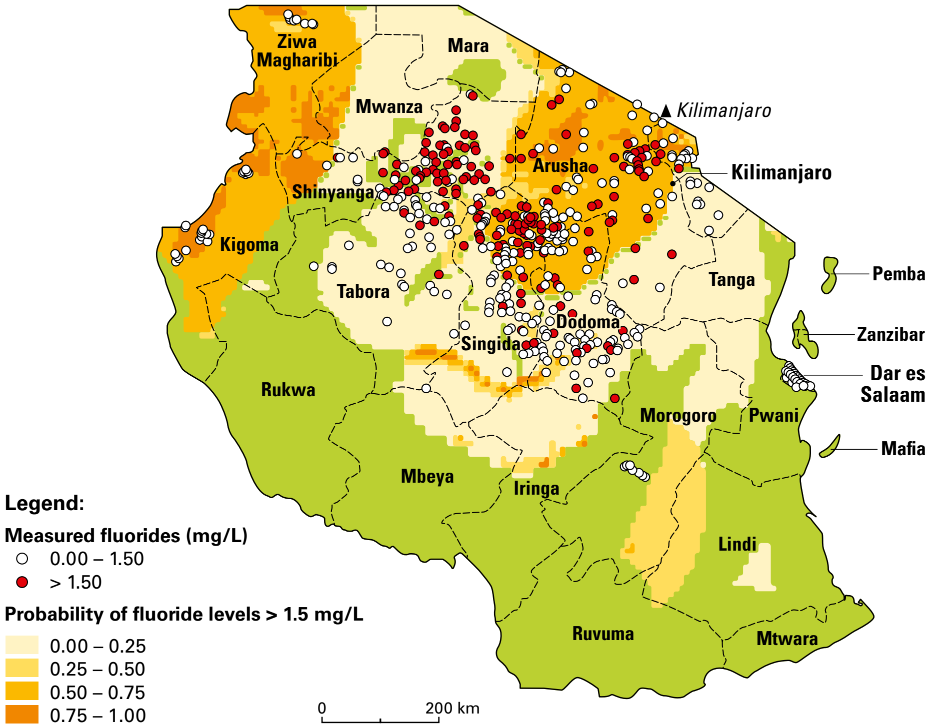


Figure 1: Measured fluoride levels as overlaid on the modelled 1st generation probability map [adapted from 4].

Methodology

A four-month field survey was conducted in Tanzania to collect primary and secondary data [5]. Secondary data on water quality in the Arusha, Kilimanjaro, Singida, Mwanza, Dodoma, Tabora and Dar es Salaam Regions were collected from the government and NGOs, such as the Ministry of Water, UNICEF, and the Geological Survey of Tanzania. Water samples were collected in Kigoma, Kagera and Morogoro, areas identified by the model as high risk where no fluoride data were available. 173 source water samples were analysed for fluoride using a portable photometer. In addition, 59 samples were transported to Eawag's reference lab to cross-check the fluoride results and for analysis of major cations and anions.

Results

Secondary data collection yielded a total of 1 687 data points, of which 1 067 could be georeferenced. Figure 1 shows elevated fluoride levels in Arusha and Singida, with median concentrations of 1.2 mg/L and 1.1 mg/L, respectively. These findings are in line with the geostatistical model predictions. However, the model predicts only a modest risk in Shinyanga, where the most serious contamination was found: 75 % of its samples were >1.5 mg/L, 37 % > 4 mg/L, and a remarkable maximum value of 80 mg/L was reported for one borehole. The model predicts modest contamination in Dodoma, Kilimanjaro and Tabora, in agreement with the data, which showed only 23 %, 20 % and 13 % of the samples >1.5 mg/L. It also predicts high risks (probability range: 0.5 to 1) in the western parts of Tanzania, but all water samples from Kigoma and Kagera (formerly known as *Ziwa Magharibi*) were <1.5 mg/L fluoride, with maximum values of 1.1 and 0.7 mg/L, respectively. Very low fluoride concentrations, ranging from 0 to 1.1 mg/L, were reported from 100 boreholes in Dar es Salaam, in agreement with the model's low risk predictions.

Conclusion

Although the geostatistical model predictions accurately matched the measured data of high fluoride risks in the Arusha, Manyara, Singida, and Kilimanjaro Regions, and the low fluoride risk data of Dar es Salaam, it overestimated the risk in Kigoma and Kagera, and underestimated the risk in Shinyanga. These discrepancies could be due to the poor spatial resolution of input data layers, or to inadequate characterization of the processes leading to fluoride mobilization. Our research indicates the need to develop a second generation model, using finer resolution inputs and a larger database, which would be capable of making more accurate fluoride risk predictions at global and regional scales.

[1] Organization, W. H. (2011): Guidelines for Drinking-water Quality: Fourth Edition. WHO, Geneva.

[2] Rao, N. S. (2011): High-fluoride groundwater. Environ Monit Assess, *176 (1–4)*, 637–645.

[3] Ozsvath, D. L. (2009): Fluoride and environmental health: a review. Reviews in Environmental Science and Bio/Technology, *8 (1)*, 59–79.

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

[5] Shedafa, M. (2012): Geogenic fluoride and arsenic contamination in groundwater of Tanzania including geological and geochemical triggers. MSc Thesis, University of Duisburg-Essen, Duisburg-Essen, Germany.

[1] University of Duisburg – Essen, Germany
[2] Eawag/Sandec, Switzerland
Contact: richard.johnston@eawag.ch

Achieving Effective Bone Char Regeneration at Large Scale

Bone char is a low cost, yet efficient fluoride removal filter material, and regenerating fluoride saturated bone char can increase its lifespan and make it more affordable. This study conducted field tests and laboratory experiments to test how bone char can be effectively and affordably regenerated. A. Schertenleib[1,2], M. Mathis[1], A. Bretzler[1], R. Johnston[1], A. Johnson[1]

Introduction

Fluoride is often present in excess concentrations in groundwater resources in the Ethiopian Rift Valley [1], causing serious health problems, such as dental and skeletal fluorosis. As many of the affected rural communities have no readily available alternative water sources, fluoride removal represents the only feasible mitigation option, at least, in the short term. Presently, bone char is one of the cheapest, locally available fluoride removal options [2], but it is still not very affordable for people in rural Ethiopian communities. The effective costs of bone char, however, can be significantly lowered by regenerating the fluoride saturated filter material.

From the laboratory to the field

When bone char filter media is saturated, the adsorbed fluoride can be removed with strong base according to the reaction: $Ca_5(PO_4)_3F + OH^- \rightarrow Ca_5(PO_4)_3OH + F^-$. Column experiments were carried out at Eawag laboratories to optimize bone char regeneration. The columns (34 mm diameter, 11 mm length) were packed with 75 g of Ethiopian bone char. A 10 mM $NaHCO_3$ solution spiked with fluoride (20 mg/L) and buffered to around pH 8.5 using CO_2 gas was pumped through the columns at a rate of 10 bed volumes (BV) per day, until the fluoride level in the outflow reached 1.5 mg/L, the drinking water standard in many countries. Regeneration was then initiated with a 0.1 M NaOH solution that was pumped continuously at 30 BV per day. This procedure was followed by a neutralization step, using approximately 10 BV of 0.02 M H_2SO_4 at 240 BV per day.

In order to implement full-scale regeneration of bone char in Ethiopia, the technological and economic constraints there have to be taken into account. The amount of water and chemicals required should be minimized, and regeneration should be done using locally available technology and reagents. Procedures should also be flexible enough to allow for unforeseen circumstances.

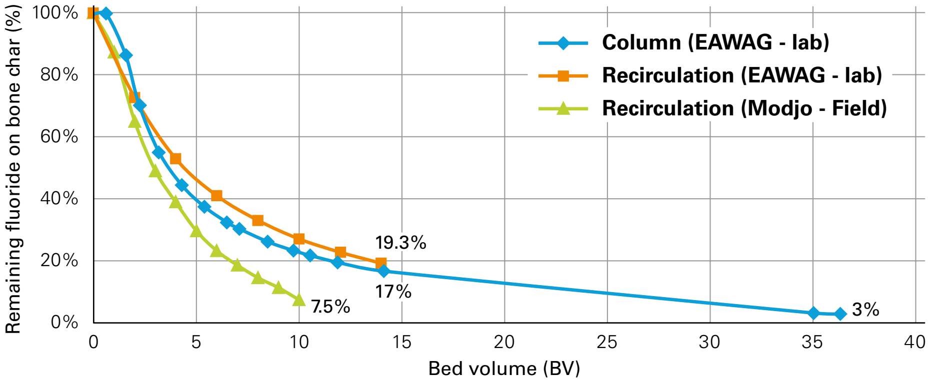


Figure 1: Fluoride remaining on the bone char as a function of the amount of NaOH solution used in regeneration (BV).

To meet these criteria a batch mode of regeneration with recirculation was tested at Eawag, to ascertain the minimum amount of reagents required to be effective. One BV of 0.1 M NaOH solution was recirculated through bone char columns until the dissolved fluoride levels reached a constant value. The fluoride-rich regenerant was then replaced with a fresh NaOH solution, and the procedure was repeated until the target amount of fluoride removal was reached. According to conventional adsorption isotherms (e.g. Langmuir or Freundlich), when solid and liquid phases are at equilibrium, a high concentration in the solid phase corresponds to a high concentration in the liquid phase, and a low concentration adsorbed corresponds to a low dissolved concentration. Consequently, less fluoride can be removed with each regeneration step, as seen in Figure 1. However, recirculation did not reduce the amount of NaOH required for regeneration – in fact, more base was required to reach a given level of residual fluoride. The experiment showed that the regenerated bone char was found to have a similar capacity for fluoride removal as fresh bone char. Figure 2 shows that after one regeneration, bone char was still able to remove more than 1 milligram of fluoride per gram of bone char, even though some residual fluoride remained adsorbed after regeneration.

Field implementation

The Ethiopian pilot regeneration project was carried out with a local NGO, the Oromo Self Help Organization (OSHO), that produces bone char and defluoridation filters. Regeneration was tested at the OSHO production compound in the Rift Valley, using approximately 1 500 kg of saturated bone char with an estimated fluoride load of 1.6 mg/g. One BV (2 000 L) of 0.1 M NaOH solution was prepared in two steps in one of OSHO's tanks (1 000 L) and recirculated through the saturated bone char in a washing tank at a rate varying from 6 to 9 BV per day. Samples were taken hourly from the bone char tank outlet to measure the fluoride concentration, and the NaOH solution was replaced when it reached a stable level. After the alkaline treatment, an acid solution (0.02 M H_2SO_4) was used to lower the pH in order to restore the fluoride uptake capacity. During the pilot, the bed volumes were recirculated between 1.3 to 7.5 times. However, dissolved fluoride reached a stable level after one cycle through the bone char. As in the laboratory, additional recirculation did not result in further fluoride desorption.

After the three week regeneration pilot, 10 BV of NaOH had been used, and only 7.5 % of the estimated initial fluoride remained on the bone char (Figure 1). If this regenerated material were to be used at the Bofo community filter in the Rift Valley,

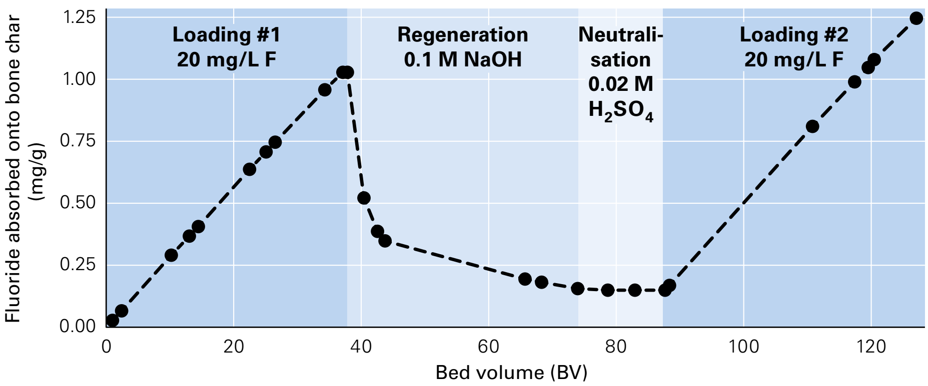


Figure 2: Column regeneration experiment with bone char in the lab: two loading and one regeneration cycle.

where there is an average water consumption per person of 3 m^3/day and an average fluoride concentration of 8.3 mg/L, it would in theory last 58 days before the fluoride in the filtered water reached 1.5 mg/L.

Interpretation and perspectives

Whereas the laboratory tests required 12–14 BV of NaOH to remove 80 % of adsorbed fluoride, the field pilot was more efficient, requiring only about 7 BV. These results must be interpreted with caution, however, as the initial fluoride loading on the saturated bone char in Ethiopia was an estimation based on the monitoring data, which could be inaccurate. Also, the fluoride concentration in the raw water differs from the field site (8–10 mg/L) when compared to the concentration in the lab experiments (20 mg/L). Due to a higher fluoride concentration in the raw water during the loading process fluoride ions may attach to surface sites which are more difficult to regenerate with NaOH. Finally, both the column and recirculation experiments conducted at Eawag tested bone char from the same batch, while the regenerated bone char in the Ethiopian pilot came from different production batches, and each might have different properties. The quality of the bone char, the fluoride concentration in the raw water and/or other ions can affect the regeneration process and may explain the differences in the regeneration behaviour seen in Figure 1. In any case, the Ethiopian pilot suggests that regeneration is feasible in the field, and would not require large amounts of NaOH solution.

Bone char cannot be regenerated indefinitely. With each regeneration cycle, adsorbed fluoride becomes harder to remove, and about 4–5 % of the bone char mass is lost. Therefore, a financial assessment of the costs of regeneration, including the chemicals and labour costs, is necessary to decide the optimal level of regeneration.

The next step in assessing the efficiency of regeneration would be to use regenerated bone char in a community filter and measure its fluoride removal efficiency under field conditions. If the regenerated bone char has a similar capacity to virgin material, as found in the lab experiment (Figure 2), the lifespan of bone char filter material could be significantly extended, lowering the costs of fluoride removal in Ethiopia.

[1] R. Tekle-Haimanot, Z. Melaku , H. Kloos, C. Reimann, W. Fantaye, L. Zerihun, K. Bjorvatn (2006): The geographic distribution of fluoride in surface and groundwater in Ethiopia with an emphasis on the Rift Valley. Science of the Total Environment, *367 (1)*:182–190.

[2] EAWAG (2013): "Water Resource Quality: Geogenic Contamination Handbook".

Ariane Schertenleib

Photo 1: Bone char production site in Ethiopia.

[1] Eawag/Sandec, Switzerland
[2] EPFL, Switzerland

This work is part of the cross-cutting Eawag project «Water Resource Quality» that focuses on geogenic contamination in groundwater used for drinking, in particular, arsenic and fluoride. Ariane Schertenleib and Marcel Mathis would like to thank their supervisors, Annette Johnson (W+T) and Richard Johnston (Sandec), the whole W+T team at Eawag, and their partners at OSHO for their help and support.

Contact: ariane.schertenleib@epfl.ch, marcel.mathis@eawag.ch

Beyond Improved Water: Household Surveys Measuring Water Quality

Monitoring drinking water safety is a crucial public health issue. New testing tools have been developed, however, that make it easier to do and that allow for better measures of water quality even on the household level. As a result, water quality testing is becoming a part of national household surveys. Richard Johnston and Kathryn Kazior[1]

It is nearly 2015, and the end of the Millennium Development Goals (MDGs) era is at hand. The WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation has declared that the water target, "to halve, by 2015, the proportion of the population without sustainable access to safe drinking water", was met in 2010, 5 years ahead of schedule. This announcement was met with some scepticism, however, since water coverage is calculated without considering water quantity, or the distance and time required for water collection. Critically, water quality is only measured indirectly, through a proxy indicator, "use of an improved drinking water source" [1]. Improved sources are those that, by their design and construction, protect drinking water from faecal contamination. But, in practice, improved sources often have technical shortcomings which can lead to microbial contamination. And even perfectly constructed improved sources are vulnerable to naturally occurring chemicals such as arsenic and fluoride.

Water quality testing methods

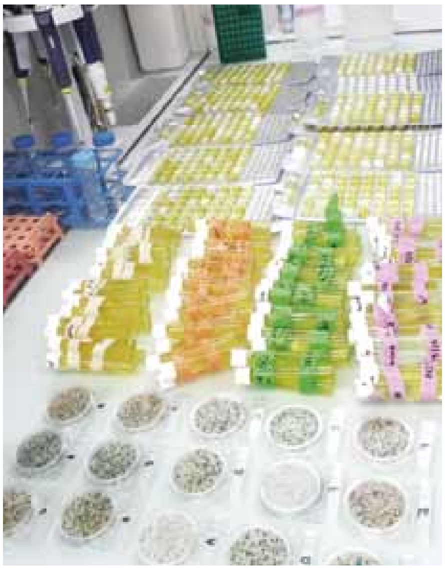
With the emergence of new, low-cost but robust testing methods, it is increasingly possible to measure water quality directly in household surveys. Monitoring chemicals is relatively easy, since they can either be quickly measured using test kits, or stored and later analysed in laboratories. In the past fifteen years, the quality of portable arsenic field test kits has increased dramatically, and their cost has dropped below $1 per test. Unfortunately, fluoride testing in the field is not as simple because available test kits are either unproven or involve hazardous materials [2].

Microbial testing poses more of a challenge. Conventional microbial tests require laboratory technicians and specialized equipment. Samples should be processed within a few hours of collection, posing massive logistical challenges for household surveys. Testing in the field is possible, but involves expensive and heavy equipment, and intensive training in complex procedures. A new generation of microbial tests, however, based on enzymatic growth media, greatly simplifies the testing process [3]. In these tests, bacteria such as *E. coli* (the preferred indicator of faecal contamination), make enzymes that chemically react with specific compounds in the growth media, producing a dye which is either coloured or fluorescent. Enzymatic media also come in commercially prepared formats, simplifying the job of field technicians and reducing the chances of errors.

Enzymatic tests are specific to particular bacteria and relatively robust to incubation without strict temperature control. Research at Eawag has shown that when the temperature is between 25 and 40 °C, the tests yield results comparable to certified reference methods. Between 20 and 25 °C, similar results could be achieved, but require a longer incubation period (i.e., 48 rather than 24 hours). After testing, materials can be effectively disinfected by submersion in hot water (at least 70 °C) [4].

Water quality testing in national household surveys

Water quality testing modules have now been included in a handful of nationally representative household surveys. In such surveys, testing may be done at a central location, or in the field. In the 2004 Bangladesh Demographic and Health Survey (DHS), field teams used Hach test kits for on-site measurement of arsenic in 10 000 households. The 2009 Bangladesh Multiple Indicator Cluster Survey (MICS) tested chemical quality at a central location: 15 000 sample bottles containing acid preservative were filled by enumerators and analysed in Dhaka using Wagtech Digital Arsenators. 20 % of the samples were cross-checked in a Canadian reference laboratory [5]. *E. coli* testing with enzymatic media (the Aquagenx multi-compartment bag test) was successfully piloted in 615 households during the 2009 Peru DHS, and two microbial (Nissui Compact Dry EC plates and IDEXX Colilert 10 mL tubes) and one arsenic test (ITS Econo-Quick) were tested in 768 households in Bangladesh during a Global MICS pilot in 2012.



Olivier Kanangire

Photo 1: Laboratory testing of enzymatic growth media for *E. coli* and total coliforms.

National surveys in Bangladesh and Ghana

Full-scale national surveys are currently underway in Bangladesh and Ghana that incorporate water quality testing modules, using Compact Dry EC plates for *E. coli* measurement and Econo-Quick kits for arsenic. In each country approximately 30 teams were trained to conduct on-site *E. coli* water quality tests on household drinking water. 100 mL samples are filtered at the households, using portable manifolds, and the filter papers are then incubated on Compact Dry plates at ambient temperature or using body temperature incubation. Sterile disposable materials are used to minimize the work load of the field teams (as well as the risk of contamination).

Drinking water is being tested for arsenic in 15 000 households in Bangladesh, and 3 600 in Ghana, and for *E.coli* in 3 000 households in Bangladesh and 3 600 in Ghana. Both surveys include testing of source water for a subset of households. The tests' consumable costs are estimated at roughly $5 per household; this rises to $10 per household when hardware is included.

Challenges in the national surveys

In these two national surveys, quality control is a major concern. Roughly 10 % of the samples are collected in duplicate and analysed in a reference laboratory using standard methods. Laboratory technicians routinely visit field teams to collect samples for cross-checking, giving the experts the opportunity to observe the field teams conducting tests and to offer corrective advice as needed. The surveys are on-going, but initial results show acceptable agreement between the field and laboratory results.

Another challenge has been to ensure that the tests do not pose risks to the testers, household members, or the environment. Surveyors were trained on microbial safety and, after the microbial tests, the plates are disinfected using hot water, which is readily available in the field. Arsenic testing materials are not hazardous apart from small strips of paper impregnated with mercuric bromide; these are stored by the testers for safe disposal after the survey is complete.

A final challenge is information management: how to share test results with households and communities. Survey teams are not equipped to instruct households on water quality management; however, they can share results with households and provide basic information, such as informational brochures produced by government agencies or development partners. At the national level, information management is also tricky: contamination levels in household drinking water may be significantly higher than expected. Even "improved sources" can provide water with high faecal contamination at the point of use, either due to technical defects (e.g., leaky distribution networks) or poor household hygiene. Engagement with sector stakeholders throughout the designing of surveys and their implementation is essential to ensure that water quality results are considered credible by all.

Lessons learned

Bangladesh and Ghana are the first countries to field water quality testing modules at scale, but will certainly not be the last. Lessons learnt are already informing plans for the next round of DHS and MICS surveys. Water quality modules will probably never become standard items included in all national surveys, but they do not need to be: once reliable data are available from a good number of countries representing a range of conditions, extrapolations can be made to estimate global coverage. This has been done using source data from five nationally representative surveys of water quality at the source [6]. Global estimates will be much more accurate once they are based on a dozen or more surveys of water quality at the household level.

Kathryn Kazior

Photo 2: Field analysis of water quality by survey teams in Ghana.

It is by no means certain that whatever follows the MDGs will include a Water Goal. If any kind of target is established for drinking water, however, it is likely that the indicators will include a direct measure of water quality. Microbial quality is highly variable in time, and a single measurement of *E. coli* is not a robust indicator of the long-term safety of the water source. Yet, aggregated to the national level, *E. coli* testing can give valid and meaningful information about the safety of drinking water. Such information is presently sorely lacking, but new tools such as enzymatic media tests are opening the door to more sophisticated monitoring of future water quality targets.

[1] WHO/UNICEF (2012): Progress on Sanitation and Drinking-water: 2012 Update, World Health Organization and United Nations Children's Fund, Geneva and New York.

[2] EAWAG (2013): "Water Resource Quality: Geogenic Contamination Handbook".

[3] Bain, R., et al. (2012): A Summary Catalogue of Microbial Drinking Water Tests for Low and Medium Resource Settings. International Journal of Environmental Research and Public Health, *9 (5)*, 1609–1625.

[4] Kanangire, O. (2013): Laboratory validation of low cost methods for the measurement of *E. coli* and total coliforms. MSc Thesis, UNESCO-IHE, Delft, The Netherlands.

[5] UNICEF/BBS (2011): Bangladesh National Drinking Water Quality Survey of 2009. UNICEF/Bangladesh Bureau of Statistics, Dhaka, Bangladesh.

[6] Onda, K., et al. (2012): Global access to safe water: accounting for water quality and the resulting impact on MDG progress. International Journal of Environmental Research and Public Health, *9 (3)*, 880–894.

[1] Eawag/Sandec, Switzerland

Contact: richard.johnston@eawag.ch

GeoGen2013

Groundwater quality can be inadequate for drinking purposes. Many groundwaters are saline or contain naturally-occurring substances that have serious adverse health impacts, such as geogenic contaminants like arsenic and fluoride. The GeoGen2013 conference explored sustainable solutions for the mitigation of geogenic contaminants in drinking water. Richard Johnston[1], Anja Bretzler[1] and Annette Johnson[1]

In February 2013, Eawag organized the first international conference to address two naturally occurring contaminants in drinking water: arsenic and fluoride. "GeoGen2013", co-hosted by World Vision, WHO and Addis Ababa University, drew 90 participants from 16 countries to Addis Ababa, Ethiopia. There were five session topics: health challenges; arsenic mitigation; fluoride mitigation; behaviour change; and drivers for implementation (policy and business). Conference participants were regionally diverse and came from a range of backgrounds, including physical and social sciences, business, development, and government.

Fikru Angelo

Photo: GeoGen2013 conference participants.

In a stimulating group discussion on the final day, several principal themes emerged:

1. **The importance of strategic plans**
   Governments are the principle stakeholders to manage the threats posed by arsenic and fluoride, and can establish a policy framework, i.e., policies, strategies, and action plans to deal with them. Policies should present long-term goals, while strategies and action plans may address more short-term priorities, which could change with time. Action plans should be specific, with concrete time-bound outputs and budgets. One example of "thinking big" is in West Bengal, where the government strategy has been to invest heavily in large-scale piped water systems in rural areas widely affected by arsenic contamination.
2. **Strategies for reducing contaminant exposure**
   Some participants argued that it is nearly always preferable to tap water resources low in arsenic and fluoride, rather than use removal systems. Others noted that where removal is promoted, systems are more likely to be managed well at a community rather than at the household level. But, consensus was reached that appropriate strategies are highly contextual. An example from the USA concerned a case where household level arsenic removal was the most cost-effective option. Transparent and rational analyses that rank alternatives, such as cost-effectiveness analysis or multiple criteria decision analysis, can help select the best approach for a given setting.
3. **Multi-sector responses**
   While contaminant exposure may occur through drinking water and food, the health sector manages the health impacts. Synergies can be gained by greater communication and coordination between sectors, especially water and health. The risk assessment and management framework promoted by WHO can help identify locally appropriate health-based targets, ideally supported by Quantitative Health Risk Assessments. Possible health impacts besides those induced by arsenic and fluoride should also be considered, especially from risk substitution caused by switching to chemically better, but microbially compromised water sources. Programmatic responses should be framed in a holistic, public health-centred way: using terms like "integrated fluorosis management" rather than "fluoride mitigation". Multi-sector approaches may take time to implement and should involve explicit capacity development components.
4. **Different stakeholders**
   The primary stakeholder in the management of fluorosis and arsenicosis is the government. Different government entities may play key roles in setting norms, delivering services, and providing regulatory oversight. International and local NGOs can sometimes be quicker to try out new approaches, and tap into different revenue streams. The private sector may also be critical in providing services or goods, though government has the responsibility to regulate such activities. Research support should be active in all circles.
5. **Getting the balance right**
   Reducing exposure to arsenic and fluoride requires sound, cost-effective technological solutions, which can be disseminated and maintained in socially responsible ways. Researchers can contribute on the technical side, developing and optimizing technological systems for safe water delivery. Social science research is equally if not more important, to reach the goal that people consistently use safe drinking water.
6. **Sustainability**
   The water supply sector is littered with failed projects. However, some "islands of success" could be identified, such as piped water schemes in the Ethiopian Rift Valley, and wellhead arsenic removal systems in West Bengal. Sustainable approaches involve early engagement with community members, and usually require long-term support, such as follow-up promotions, or technical support for problems beyond the ability of a local caretaker.

Overall, participants found the conference to be highly informative and productive. The second GeoGen meeting will be hosted in South Asia in 2015.

[1] Eawag/Sandec, Switzerland
Contact: annette.johnson@eawag.ch

Android App to Count *E. Coli*

New enzyme-based tests for indicator bacteria are changing the way microbial water quality monitoring can be done (See article, pp. 18–19). Sandec has partnered with the non-profit tech startup, mWater, to develop an Android app with which cellphone cameras can count *E. coli* and total coliform colonies on one such product, the Nissui Compact Dry EC plates. An automatic counter can reduce user error and simplify sample processing, especially when large numbers of samples must be analyzed. The mWater app already includes a colony counter for a similar testing product (3M Petrifilm), along with Sanitary Inspection forms and GPS functions. It requires a 5 MP autofocus camera for best results and is a free download in the Google Play store at: https://play.google.com/store/apps/details?id=co.mwater.clientapp

mWater

Anaerobic Digestion of Biowaste in Developing Countries

Anaerobic digestion (AD) of organic waste is an effective treatment option that reduces the amount of waste for disposal, and generates products of value, such as biogas and nutrient-rich digestate.

While there is a wealth of knowledge about and experience with small scale digesters in rural areas that use animal manure as feedstock, AD still plays a negligible role as a treatment option in urban settings for organic yard, kitchen and/or market waste. Popular in industrialised countries at medium and large scale, these systems often contain automated and mechanized control elements. Transferring this rather sophisticated technology to a low income country without considering local conditions and necessary adaptations would be predisposed to failure.

This book aims to fill the knowledge gap by compiling existing and recently generated information on anaerobic digestion of *organic solid waste* at small and medium scale with special consideration given to conditions in low and middle income countries. It has two parts: Part 1 focuses on practical information related to the AD supply chain (substrate-, process-, and product chain), and Part 2 presents selected case studies from around the world.

This publication is relevant to a wide range of individuals and organizations working in the waste and renewable energy sector. It provides insight to entrepreneurs and private investors intending to fund, set up or manage a biogas plant; to local authorities wanting to invest in or operate organic waste digestion plants as one element of their solid waste management master plan; to contractors managing biogas plants; and to staff of national and international donor and non-governmental organizations funding and supporting biogas projects.

The book will be available by autumn 2013 and can then be downloaded for free from www.sandec.ch.

Christian Riu Lohri

Photo: Construction of a fixed-dome underground biogas digester in Lesotho.

Concurrent Water Treatment in Safe Water Schools

The Safe Water School Project started in 2011 with the aim to improve the health of school aged children in developing countries. Its objective is to build the capacity of schools in the area of water, sanitation and hygiene (WASH).

An important part of the Project is training in two water treatment methods – the Solar Water Disinfection Method (SODIS) and chlorination. They are well suited to being taught together because they are complementary. Chlorination is a rapid method and treats large volumes of water, while SODIS is easy to do, has low costs and there is no change in/of the taste of the water.

In 2012 we started three pilot projects with 105 schools in Kenya, Bolivia and Haiti with approximately 60 000 students. We offered instruction in both water treatment methods and today they are currently practiced in the schools. Their use has also spread into the surrounding communities; for instance, many students practice SODIS at home.

The long-term goal of the Safe Water School Project is to develop a holistic approach for WASH in schools that can be used globally. The Project is jointly conducted by the SODIS Reference Center at Eawag, the Antenna Technologies Foundation and Helvetas Swiss Intercooperation.

http://www.sodis.ch/safewaterschool/index_EN

Fundación SODIS

Photo: Safe Water Station in the Magdalena Postel School in Tiquipaya, Bolivia.

Eawag: a WHO Collaborating Centre

On 27 September 2012, Eawag was designated as the WHO Collaborating Centre for Sanitation and Water in Developing Countries. Eawag has a long association with the World Health Organization. In fact, Sandec was originally established in 1971 as the "WHO International Reference Centre for Wastes Disposal". The 2012 re-designation extends the Collaborating Centre status to other Eawag departments active in research relevant to developing countries. WHO collaborating centres are institutions such as research institutes, university departments or academies, designated by the Director-General to carry out activities in support of the Organization's programmes.

As one of only fifteen Collaborating Centres throughout the world in the field of water and sanitation, Eawag is in a strong position to support the programs of WHO and its Member States at all levels. The collaboration between Eawag and WHO includes conducting basic and applied research, and sharing information, experiences and lessons learned in five specific areas:

1. Monitoring, management and evaluation of water supply, sanitation and solid waste management in developing countries.
2. Researching environmental sanitation systems and technologies, including aspects of reuse and recovery of resources (nutrients, organic matter, energy) from waste products.
3. Mitigating geogenic contamination in drinking water, especially arsenic and fluoride.
4. Developing appropriate technologies for improving the microbial quality of drinking water, with special reference to household water treatment and safe storage.
5. Promoting behaviour change in water and sanitation practices (acceptance and use of new technologies, hygiene practice, etc.)

Sandec is directly involved in all five of these areas, in collaboration both with other research departments at Eawag and partners in developing countries. Some of the first outputs of the new collaboration framework include: planned updates to training modules for Household Water Treatment and Safe Storage, contribution to the development of Sanitation Safety Plans, preparation of briefing notes on faecal sludge management, and co-hosting the recent GeoGen 2013 conference (See page 20).

eawag aquatic research

WHO Collaborating Centre for Sanitation and Water in Developing Countries

e-Compendium: Online Version of the 2nd Edition

The Compendium of Sanitation Systems and Technologies is an internationally peer-reviewed guidance document published in 2008. It has gained in popularity among engineers and planners because it provides information about the entire range of urban, peri-urban and rural sanitation technologies in low and middle income countries in one document. The Compendium is currently being revised and the 2nd Edition will be finished by the end of the year.

To increase its usability, Sandec partnered with seecon GmbH to integrate an electronic version of the Compendium on the Sustainable Sanitation and Water Management (SSWM) Toolbox website, www.sswm.info. This digital version will offer easy navigation and an intelligent filter function that facilitates combining searches for different technologies. Due to being part of the SSWM Toolbox, additional information, such as case studies, further reading suggestions, training material, videos, and an extensive glossary and library will be easily accessible.

The e-compendium will be online by early 2014 at: www.ecompendium.sswm.info.

e Compendium
The Online Compendium of Sanitation Systems and Technologies

Forthcoming Event

Sandec @ 3rd IWA Development Congress 15 October 2013 in Nairobi, Kenya
Sandec and BORDA will conduct an interactive workshop: "Is small beautiful? Building evidence for small-scale sanitation systems".

IWA the international water association

Small-scale sanitation systems are currently at an inflection point. In the past decade they have proven to be a viable alternative to conventional large-scale centralised systems. Some of their most significant advantages are: flexibility, modularity, and cost-effectiveness. They can be implemented in stages and built to exactly meet people's needs, reducing the possibility of accruing idle capacity costs. However, in many countries they are still not considered as proper treatment systems and are, therefore, commonly not acknowledged as capable of providing a proper alternative to large-scale systems. Even where wide-scale replication has succeeded, small-scale systems often suffer from the lack of proper management and insufficient monitoring schemes. This 1½ hour workshop will try to gather evidence from around the globe on the successes and challenges facing small-scale sanitation in low and middle-income countries.

For more information, please contact: info@sandec.ch

The Sandec Team

Lukas Ulrich

From left to right:
Standing: Phillipe Reymond, Linda Strande, Selina Derksen-Müller, Regula Meierhofer, Valentin Graf, Monika Tobler, Ulrike Messmer, Rick Johnston, Caterina Dalla Torre, Parfait Koffi Kouame, Ebenezer Soh Kengne, Bart Verstappen, Paul Donahue, Moritz Gold, Frederik Weiss, Chris Zurbrügg, Joel Kinobe
Kneeling: Lukas Ulrich, Amadou Gueye, Sämi Luzi, Fabian Suter, Christoph Lüthi, Christian Riu Lohri, Bastian Etter
Missing in photo: Hung Nguyen, Magalie Bassan, Maryna Peter, Lars Schöbitz

New Faces

Paul Donahue, MFA in Film, Video, Animation from the University of Illinois at Chicago and MA in Cultural and Media Studies from the University of Illinois at Urbana-Champaign, joined Sandec as the Editor/Communication Specialist in February 2013. His main tasks include editing Sandec News, translation work and handling Sandec's social media and Internet presence. He worked previously as a video cameraman and video editor, as a fundraiser for non-profit organizations, as well as a writer and editor in the publishing industry.

Bart Verstappen, MSc in Bioscience Engineering from the University of Ghent, Belgium, specialised in the control of insect pests in tropical regions. He joined Sandec's organic waste management research group in February 2013 and will manage an applied R&D project that will establish municipal bio-waste conversion operations in East Java, Indonesia. He will also investigate opportunities to develop bio-waste conversion technologies into viable sustainable businesses through the production and sale of marketable products like compost, biogas, biochar and insect-protein.

Moritz Gold has an Environmental Engineering degree from the University of Stuttgart and joined the Excreta and Wastewater Management Group at Sandec as a Project Officer in March 2013. He works on the FaME project in support of local partners in Senegal, Ghana, and Uganda to develop innovative end-uses for faecal sludge, cost-effective drying methods, and improved value chain management with a focus on using faecal sludge as a fuel in industrial processes. Previously, he was involved with the implementation of the National Urban Sanitation Policy in India, and he is active in the German chapter of Engineers Without Borders.

Frederik Weiss has an MSc in Environmental Science from Goethe University Frankfurt am Main. Specializing in interdisciplinary study of environmental chemistry, toxicology and biology, he worked as a scientific research assistant in Eawag's Environmental Toxicology Department and joined Sandec in May 2013. He will do a global assessment of anthropogenic, chemical pollution and study its environmental and social impacts, especially in low and middle-income countries. His project will also identify high risk areas worldwide where humans and the environment are endangered by unsafe and unregulated exposure to man-made chemicals.

Imanol Zabaleta Altuna recently completed his MSc in Urban Environmental Management and Technology at Wageningen University. His Master's Thesis focused on a material and energy flow analysis of the nitrogen, phosphorus and carbon contained in biodegradable waste on a regional level. During his internship in the Netherlands, he contributed to the development of Polydome, a closed cycle approach to manage resources for greenhouse agriculture. He has a BSc in Agricultural Engineering and joined the Solid Waste Management Group as Junior Researcher and Project Officer in July, 2013.

On the Bookshelf

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

Technologies for Sustainable Development: A Way to Reduce Poverty?
This book brings together the best 20 papers from the 2012 Conference of the EPFL-UNESCO Chair in Technologies for Development with the aim to explore and discuss ways how to link scientific research with development practices to assist practitioners and reply directly to social needs. It aims to explore and answer questions concerning appropriate technology and on how science and technology can foster sustainable, integrated development. Focusing on the importance of improving working relationships between stakeholders, researchers and decision-makers; scientists and industrial sectors; and academics and the population; Technologies for Sustainable Development opens a dialogue that is important to creating and implementing the best scientific and technical solutions to meet social needs. Available in book form and as an eBook.
By Bolay, J. C., et al., Springer, 2013, 287 pages, ISBN 9783319006383.

Water Supply and Treatment

Water, Sanitation and Hygiene Evidence paper

Undertaken by the DFID-funded Sanitation and Hygiene Applied Research for Equity (SHARE) research programme consortium, this WASH document aims to provide an accessible guide to available evidence on the benefits and cost-effectiveness of WASH interventions. It includes a conceptual framework for understanding how WASH impacts health and well-being, and describes methods used for ascertaining the health, economic and social impacts of WASH.
By UK Department for International Development, 2013, 128 pages.
Available as pdf download at: https://www.gov.uk/government/publications/water-sanitation-and-hygiene-evidence-paper

Achieving Water Security: Lessons from research in water supply, sanitation and hygiene in Ethiopia
This collection of essays documents findings from the first five years of a major WASH intervention supported by DFID, *Research-inspired Policy and Practice Learning in Ethiopia and the Nile Region* (RiPPLE). RiPPLE worked closely with Ethiopian Government officials at central and local levels, to find ways in which action research could support improved practices and policies in the water sector. Innovations such as Learning and Practice Alliances proved to be effective fora for bringing together stakeholders, exchanging knowledge, fostering a learning environment, and at different scales. The experiences of RiPPLE in creating environments and mechanisms whereby research can impact policy and practice at scale are relevant not just for Ethiopia, but for all of Sub-Saharan Africa, as well as globally.
By Calow, R., et al., ODI, UKAID, and Practical Action Publishing, 2013, 202 pages, ISBN: 9781853397639.

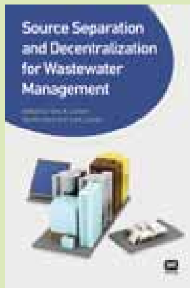
Toolkit for Monitoring and Evaluating Household Water Treatment and Safe Storage
This toolkit proposes 20 indicators that can be used by organizations that promote or use household water treatment and safe storage (HWTS) methods. It lays out nine simple steps to follow when developing a monitoring and evaluation plan, and has good illustrations of HWTS interventions. Also, it includes a detailed bibliography with many web links, as well as helpful examples of easily adaptable surveys and formats.
By World Health Organization, 2012, 62 pages, ISBN: 9789241504621.
Available as pdf download at: http://www.who.int/household_water/resources/toolkit_monitoring_evaluating/en/index.html

Strategic Environmental Sanitation Planning

Green Infrastructure for Sustainable Urban Development in Africa
This book takes a critical view at what went wrong with infrastructure development in urban Africa. It provides a major rethinking of the role of infrastructure in urban society and how green infrastructure can work in an African urban context. The focus is on Africa's fast-growing secondary towns, where 70% of Africa's urban population lives. It presents a well-argued critique of inappropriate Western development models, such as networked and centralized sewer systems, which fail to provide equitable services for all. The last section explores how infrastructure needs to respond to the economies, societies and natural environments of 21st century urban Africa.
By Abbott, J., Earthscan, 2012, 487 pages, ISBN: 9781849714723.

Menstrual Hygiene Matters
This book provides a comprehensive resource on menstrual hygiene. It aims to address the knowledge gaps related to menstrual hygiene and to help break down the taboos that prevent women and girls, especially in lower and middle-income countries, from talking openly about it. The book brings together good examples of good hygiene practice from around the world and provides guidance on building competence and confidence to address the subject, and encourages increased engagement in advocacy on menstrual hygiene. There are nine modules and associated toolkits that cover key aspects of menstrual hygiene in different settings, including communities, schools and emergencies. The target audience is professionals concerned with improving the lives of girls and women, particularly, WASH sector professionals.
By SHARE and WaterAid, 2012.
Available as pdf download at: http://www.wateraid.org/mhm

Source Separation and Decentralization for Wastewater Management



This book sets up a comprehensive view of the resources involved in urban water management. It explores the potential of source separation and decentralization to provide viable alternatives to sewer-based urban water management, and provides a comprehensive review of the state of the art of these two areas. It also deals with the technical possibilities and practical experience learned from source separation in different countries around the world, providing insights from countries such as Sweden, Australia, South Africa and China.
By Larsen, T. A., et al., IWA Publishing, 2013, 491 pages, ISBN: 9781843393481.

Excreta and Wastewater Management

Manuel de Formation Technique: Vidange Hygiénique à Faible Coût (Sludge Removal Training Guide)

Developed by practitioners working in Faecal Sludge Management (FSM) in Madagascar, this manual (in French) provides guidelines for better, cleaner and more professional manual sludge emptying services based on the use of gulpers. It targets entrepreneurs, municipalities and operators involved in FSM by introducing the essential principles of how to control, at each step, the sanitary risks incurred by the handling of faecal sludge. It is richly illustrated, including equipment descriptions, information on gulper use and plans of planted disposal sites.
By Practica Foundation, 2013, 22 pages.
Available as pdf download at: http://www.washplus.org/sites/default/files/practica-desludging_manual2013.pdf