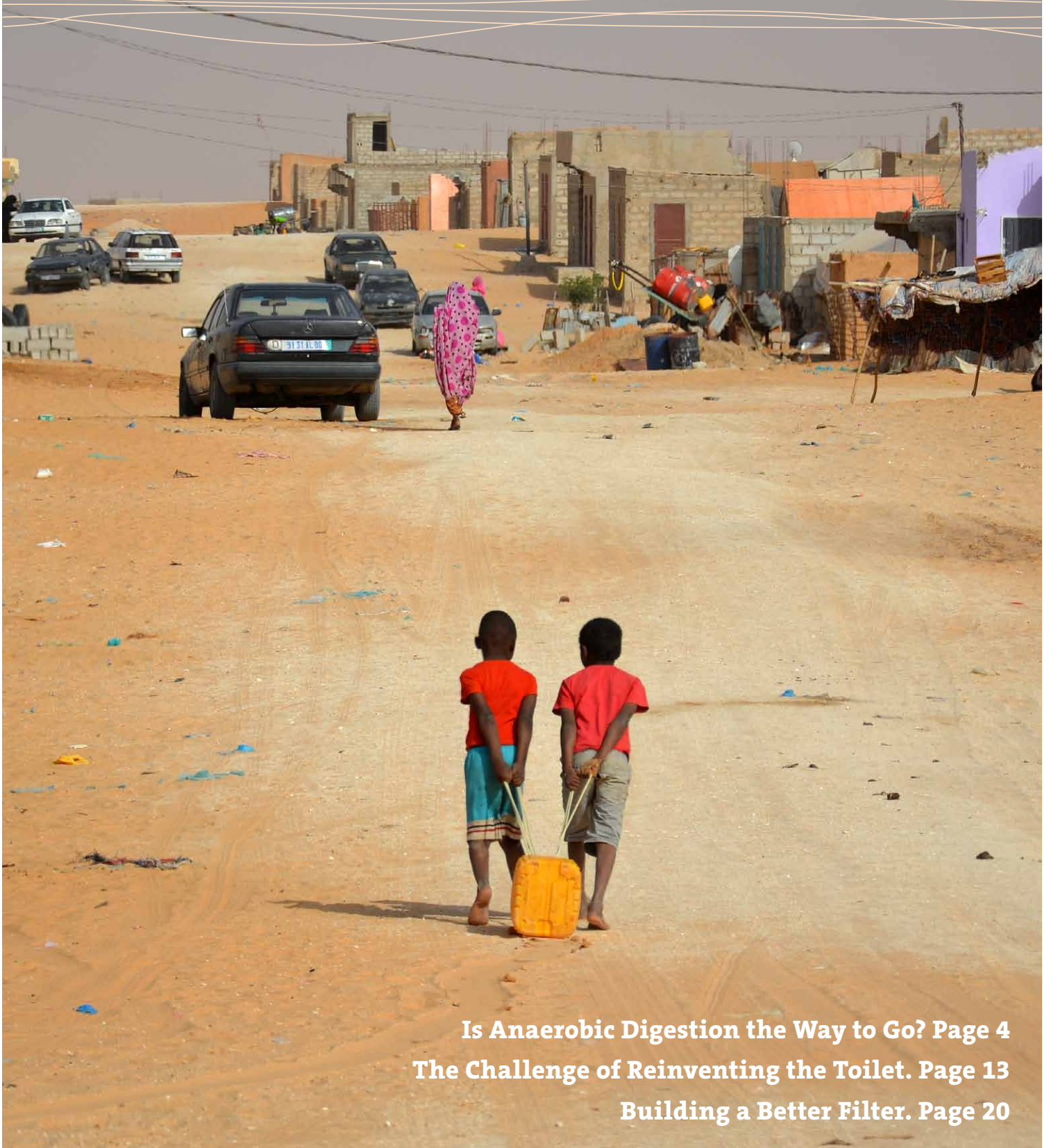


Sandec News



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Cleantech in Developing Countries – People Matter!



“Green economy, cleantech and greentech seem to be the buzzwords of the decade”

Green economy – an economy intended to improve human well-being and social equity, while significantly reducing environmental risks and ecological scarcities – is what we used to and still call “sustainable development for poverty alleviation”. Though the buzzwords are new, for Eawag and Sandec it is business as usual. Eawag has been pursuing such issues through research, education and consulting for no less than 75 years with emphasis on the least developed countries for over 40 years. The concept of “clean” technologies embraces a diverse range of products (i.e. technologies), services and processes inherently designed to provide superior performance at lower cost, significantly reducing or eliminating environmental impacts and, in doing so, improving the quality of life. Though services and processes are included in this definition, there seems to be a tendency to fall back on the belief that by using new technologies we can solve all the problems. This editorial is a plea not to forget what we have learned in many decades of research on sustainable development: that people matter! Empowerment, participation, socio-cultural appropriateness, acceptance, and ownership are key preconditions for success. All water, sanitation, hygiene, and solid waste improvements rely heavily on behavioural change and on an ensured accurate operation and maintenance of the technical system. This necessarily comprises distribution and service models benefitting the “bottom of the pyramid” based on a sound business approach. Sandec is involved in several projects in this field and goes far beyond the technology itself. This Sandec News issue is thus merely a snapshot of our current activities.

Last year, Sandec received the IWA Development Solutions Award for “Applied research and high quality science that provides leadership and partnership for the academic community working in low and middle-income countries”. This is a great honour and recognition of our efforts. It was only made possible thanks to the long-term and continuous commitment of Eawag’s directorate, as well as the interest and interaction among all Eawag colleagues who provide their expertise for the benefit of the developing world. At Sandec we consider it fundamental to partner with universities and research centres throughout the world, as we not only generate joint knowledge, but also quickly develop a sense of trust and friendship, a feeling of kinship and family within the team.

Hence, it is often painful when “family members” move on to pursue other career opportunities. This year, Mbaye Mbeguere of Senegal has left the Sandec team to lead a large Gates-funded project on faecal sludge management in Dakar. Yes, we lose a valuable team member; alternatively, it offers such a great opportunity to improve sludge management in Africa. And anyway, once family, always family, so we shall certainly keep in close touch. Similarly, also Stefan Diener is leaving Sandec to pursue his academic career and, if funding permits, to continue research on his beloved black soldier flies. Yvonne Voegeli, now a mum, is moving on to new challenges. Last but not least, Sylvie Peter a “founding member” of Sandec, supporting us for so many decades with multilingual editing and translation in English, French and Spanish, will be leaving for a well-deserved retirement. Regrettably, this will be her last Sandec News as editor. I know that we will be struggling without her help, but we shall try to cope as best as we can.

Since many good colleagues and friends have left or are leaving Sandec to work for other organisations throughout the world, we at Sandec have decided to make a special effort to maintain contact with our former staff, researchers, students, interns etc. We have therefore created a LinkedIn network group dedicated to Sandec friends and family and hope to count you as friends of Sandec! So, why not benefit from regular updates through LinkedIn and remain in contact with us? Sign up and register at www.linkedin.com.

Wishing you a stimulating read with this issue of Sandec News. Those wanting further details on projects and results should not hesitate to contact the respective authors of the articles by email or access our website www.sandec.ch containing all the documents for free download.

A handwritten signature in blue ink, reading "Chris Zurbrugg".

Chris Zurbrugg
Director Sandec

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Sandec Water and Sanitation in Developing Countries

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Is Anaerobic Digestion the Way to Go? – A Feasibility Assessment Tool

Prior to implementing an urban biogas project to valorise the organic fraction of municipal solid waste, an in-depth evaluation is essential to determine its appropriateness in the specific local context. A tool was thus developed and tested in Bahir Dar, Ethiopia, to facilitate this crucial step in project planning. Christian Riu Lohri¹, Ljiljana Rodić², Christian Zurbrügg¹

The high fraction of biowaste in developing countries presents a double-edged sword. On the one hand, it poses a considerable health and environmental risk if not properly managed and treated. On the other, the material has a significant valorisation potential. Anaerobic digestion (AD) is not only a well-known technology in manure treatment, but it is also considered a promising method to address the issue of organic solid waste, i.e. it is an effective treatment option to reduce the amount of waste destined for disposal and also to generate valuable products, such as energy-rich biogas and nutrient-rich digestate.

Yet, experience reveals that many AD projects at institutional and municipal level in developing countries face severe operational problems or have even failed [1]. One of the reasons is that AD installations are often chosen and implemented based merely on their theoretical potential. If any feasibility assessment is conducted, only technical and short-term financial criteria are primarily accounted

for. The challenge of selecting the most appropriate setup (including technology, scale, location, and stakeholder involvement/responsibilities) adapted to the local social, economic and environmental context thus remains.

Moving beyond the technical

Our research developed an integrated feasibility assessment tool that accounts for the experiences and lessons learned from various AD projects in low-income countries. It also focuses specifically and systematically on the enabling environment [2]. The objectives comprised development of a tool:

- using sustainability factors as feasibility criteria
- specifying key requirements for successful AD projects
- revealing differences in stakeholder perspectives and priorities
- creating a basis for discussion and negotiation
- quantifying feasibility
- allowing capacity testing of the institu-

tion designing and installing the system

- comparing the different AD technologies and their respective suitability in a given context.

The tool, designed to be used in a participatory manner, helps to identify strengths and weaknesses of a specific AD setup. This thereby allows, already during the planning and decision-making stage, to adapt the project to the needs and capacities of the stakeholders involved.

Structure of the assessment tool

The feasibility assessment tool defines four distinct yet interrelated dimensions, each answering a specific question (Fig. 1):

- **WHY?** What are the **driving forces** and motivations behind an AD project?
 - Social drivers (public awareness or pressure from other stakeholders).
 - Environmental drivers (resource recovery to achieve environmental sustainability).
 - Economic drivers (financial considerations, valorisation of resources).
 - Other drivers (e.g. tourism, institutional changes, political or academic interests).
- **WHO?** Who are the **stakeholders** and what are their roles, powers (high, medium, low), interests (supportive, neutral, disruptive), and means of intervention?
- **WHAT?** What are the proposed **physical components and flows** in the AD process chain, which can be divided into:
 - Substrate chain (waste generation, collection, transport).
 - AD technology (pretreatment, AD process, posttreatment).
 - Product chain (distribution and use of biogas and digestate).
- **HOW?** How are the **sustainability criteria** met by the proposed AD system?
 - Technical-operational feasibility criteria: Issues related to the substrate chain (waste quantity and quality, water use, distance of generation to AD plant), the AD technology (space and

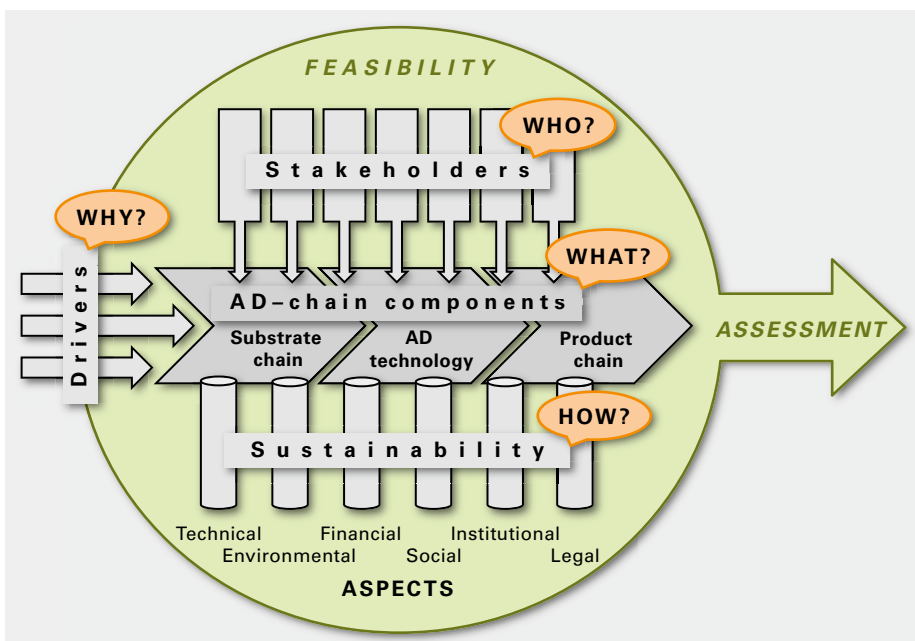


Figure 1: Structure of feasibility assessment tool for urban anaerobic digestion in developing countries.

material availability, performance, maintenance strategy, flexibility and robustness), and product chain (biogas quality, digestate quality).

- Environmental feasibility criteria: Use of non-renewable materials. Degree of environmental degradation as well as destruction of habitat and natural ecosystems.
- Financial-economic feasibility criteria: Funding sources, extent and conditions to cover capital investments in AD projects, running costs, expected revenue from AD-derived products, cost-benefit analysis.
- Socio-cultural feasibility criteria: Stakeholders' acceptance of AD-derived products, willingness to change behaviour, impacts enhancing people's capacities to meet their needs.
- Institutional feasibility criteria: Institutional capacity, stakeholder cooperation.
- Policy and legal feasibility criteria: AD-related policies, legislations and standards.

The first three dimensions (Why? Who? What?) outline the specific context of the AD project and test it for thorough project planning. The fourth dimension (How?) examines the six sustainability criteria the project is embedded in and on which it has an impact.

How to use the tool

Each dimension includes a comprehensive set of questions, which can be answered by AD project documentation and by consulting the stakeholders (through interviews and/or stakeholder workshops). Moreover, the stakeholders involved accord a certain priority (weight) to each sustainability aspect, thereby expressing the relative importance given to the individual aspects. A simple mathematical algorithm used in the feasibility assessment matrix then combines the results of the assessment (*scores*) and their relative importance (*weights*), while accounting for the risk that conditions may develop differently than planned or that the data used for the assessment is uncertain (*uncertainty factors*). An Excel spreadsheet facilitates applicability and visualisation of the results. The sequence of questions is similar to that of a checklist covering all relevant items that ought to be considered during the planning stage. Disruptive constellations or potential pitfalls in the AD proposal are thus revealed

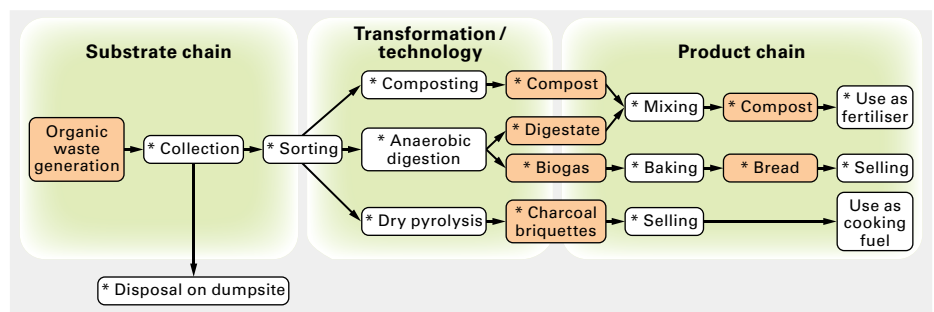


Figure 2: Schematic material flow in the pilot project of Bahir Dar (*conducted/controlled by Dream Light).

(red flags) and can be addressed, clarified and improved during discussions with the respective stakeholders.

Organic waste recycling in Bahir Dar

The solid waste management system of Bahir Dar, a city of 220000 inhabitants in the northwest of Ethiopia, is characterised by a successful collaboration between the municipality and the private company Dream Light (DL). This public-private partnership has improved waste collection coverage from 51% in 2005 to 71% in 2010 [3]. Waste is still predominantly disposed of in an open dumpsite. DL initiated an Organic Recycling Centre using three different biowaste valorisation technologies, i.e. composting, anaerobic digestion and charcoal-briquetting (Fig. 2).

Feasibility assessment in Bahir Dar

The developed tool was tested in Bahir Dar and subsequently adapted according to the feedback received from a stakeholder workshop. The assessment showed that one of the main strengths of the project is Dream Light's overall responsibility and control over the entire supply chain (cf. Fig. 2). This allows DL to rapidly influence the activities along the AD chain according to their motivation of keeping the project operational and thus profitable. The idea of a diversified portfolio of waste recycling products (compost, biogas, charcoal-briquettes) addresses different market segments and thus offers a risk distribution option. These products either show high demand (biogas used in a bakery), a guaranteed market (sale of charcoal-briquettes to an organisation disseminating improved cooking stoves) or the product is used by DL itself (compost for their agricultural fields). The marketing strategy related to the use of an AD product (biogas) to make another product with an existing or high potential demand (bread) prevents the sale of a product not yet established qualitatively or accepted by the public at large. How-

ever, application of a wide range of technologies requires in-depth knowledge of an array of different processes and technologies, an aspect still lacking in DL. This concern is partly addressed by starting the project on a pilot scale, learn from experiences and mistakes, modify, expand, and scale-up.

Yet, the technical weaknesses and the absence of a maintenance service strategy are decisive elements requiring additional efforts so as to ensure successful and long-term project operation.

Outlook

After having proven its merits in Bahir Dar, the assessment tool needs to be validated and its usefulness tested in various AD projects in other cities. If you are interested in the feasibility assessment tool, we will send you the Excel version of the tool together with a brief user manual. Sandec welcomes critical feedback to further refine this assessment tool.

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Preserving the Value of Household Waste

The initial value of recyclable material is significantly reduced if separated from other refuse only after collection or at disposal sites. Improved solid waste management at household and community level can help prevent this loss. Anne Matter¹, Christian Zurbrügg¹

Solid waste collection and safe disposal is an overwhelming task for municipal authorities in developing countries. Bangladesh, with its rapid population growth, urbanisation and increasing consumption levels, is no exception. Industrial waste, though not considered part of the municipal waste stream, often lands in municipal waste collection points, thus increasing the municipal collection and treatment burden.

In Bangladesh's capital city, Dhaka, 50–60 % of the generated waste remains uncollected [1]. Also waste from health care centres and other miscellaneous hazardous waste is rarely separated or treated properly. This situation leads to serious health and environmental risks in and around Dhaka.

The population of Dhaka has raised concern about the waste management situation, however, the public at large assumes that the municipality is responsible for solving this problem [2]. Nevertheless, in several areas of Dhaka communities have organised themselves to ensure that waste is collected regularly from households by cycle-van drivers. This improves the hygienic conditions in the neighbourhoods; however, the problems remain acute at communal collection points, as the municipality does not empty these regularly.



Photo 1: Informal recycling workers at a municipal waste collection point in Dhaka, Bangladesh.

The informal recycling sector

Compared to industrialised countries, where recycling activities are legally regulated and advocated as environmental awareness, in developing countries these activities are driven by the economic value of the recycled materials. Recycling comprises sorting, cleaning and further processing of the recyclables before they are sold to formal dealers or directly to the industries. Recycled materials are very competitive with raw materials given the low labour costs of recycling. National and international demand for recyclables is thereby significant. In Bangladesh, for example, recycled plastic pellets can be produced at 2–3 times lower cost than the imported raw resin [3].

There is a growing market interest for organic compost produced from bazaar waste, and composting facilities are thus gaining in importance. This is particularly interesting as organic waste makes up 60–75 % of municipal solid waste [4].

The role of households in waste segregation

Recycling is conducted at different points along the waste management line. On the one hand, door-to-door buyers can purchase recyclables from households. On the other, the cycle-van drivers, hired by community organisations to collect waste from households, also separate materials of value from the waste collected. Finally, waste pickers sort out some recyclables at municipal collection and/or disposal points (Photo 1).

Households can play a pivotal role in improving access to recyclables by segregating certain waste materials, thus preventing them from mixing with other refuse and preserving their value. Presently, however, household segregation of recyclables is rather limited. A study in Uttara, a middle-to-higher income neighbourhood in Dhaka, reveals that only 8 % of the households segregate some recyclables [4]. The main drawback of source segregation is the fact that managing, storing and

selling recyclables require additional work and space. Also unreliable and irregular collection or purchase of recyclables aggravates these concerns.

Based on the results obtained, two main issues need to be tackled for efficient promotion of household segregation: i) practicality of segregation and ii) regularity of service. As perceived by most households, these two problems currently outweigh the potential cash income they may achieve from recycling. Though awareness about impacts of segregating waste for the well-being of the inhabitants and wider environment can be actively enhanced, the study reveals that these measures need to be accompanied by practical recommendations on how to best store the various materials at household level. Project assistance should also focus on helping the informal sector to organise and structure itself to ensure a reliable and qualitatively high service for its "household customers".

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The authors acknowledge the kind collaboration of Swisscontact SARO in Dhaka, with whom the main author worked from February to October 2011 and who provided key data for this article.

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Comparing Costs of On-Site Sanitation Infrastructure in Asia & Sub-Saharan Africa

Why are sanitation facilities like dry toilets or septic tanks so much more expensive in sub-Saharan Africa than in Asia? How can costs be reduced to affordable levels? A new Eawag/Sandec research project in collaboration with ETH-Nadel seeks to answer these questions. Lukas Ulrich¹

Inability to pay, often characterised by a limited up-front investment capacity, is one of the main reasons why access to adequate sanitation infrastructure remains low in both rural and urban areas of low and middle-income countries. In Uganda's capital Kampala, for instance, a ventilated improved pit (VIP) latrine costs around USD 500, which exceeds the average annual income of a slum dweller [1]. The Kampala case is characteristic of the challenges in sub-Saharan Africa, where sanitation hardware is too expensive and unaffordable for many (Photo 1).

Asia, however, reveals a different situation with sanitation infrastructure components often available at relatively low prices and thus within the means of poorer households. The most famous example of low-cost toilets comes from rural Bangladesh: after a social mobilisation campaign in the mid-1990s, the demand for toilets rose considerably. Since then, thousands of small private workshops sell latrines (pan, slab and rings) for USD 6–10 [2],[3].

Our project aims at finding answers to the questions of why there are such tremendous cost differences as revealed by the Uganda and Bangladesh comparison, and how the prohibitive costs of household-level sanitation infrastructure in sub-Saharan Africa can be reduced. The answers to these questions are complex as:



Photo 1: Sub-standard double stance pit latrine in Kampala, Uganda.

1. Apples and oranges cannot be compared.

The conditions underlying the examples above are different and do not allow for a direct comparison of costs (e.g. superstructure not included in Bangladesh, pit lining technique and material not the same as in Uganda). The fact that different materials have different lifetimes also has to be taken into consideration. For costs to be comparable, they have to be related to a specific facility performing during a defined time span for a given number of users. The costs in different contexts can only be compared if the same system boundaries are used.

2. Local needs demand local designs.

In order for a system to function properly, its technical parameters have to meet the requirements of the specific socio-cultural and physical context (e.g. preference of sitting or squatting user interface, watertight construction for wet and flood-prone areas). Such special requirements have to be taken into account as they can have a significant impact on the costs.

3. Life cycle cost perspective is necessary.

When analysing the cost reduction potential, not only material costs and expected lifetimes should be taken into consideration but the entire life cycle costs, including costs for operation and maintenance (O&M) as well as disposal and replacement.

4. Markets are influenced by complex factors.

The factors governing investment costs for sanitation hardware at a certain geographical location are manifold and complicated. Material prices are determined by market structures and regulations (e.g. taxes or monopolies), programmes and policies of governments and donors, as well as properties of supply chains and distribution channels (e.g. production sites and processes, transport).

Sandec's new 3-year project, funded by SDC's Water Initiatives Division, in collaboration with economists from the Centre for Development and Cooperation (Nadel) at the Swiss Federal Institute of Technology in Zurich (ETHZ), aims to identify the factors determining the capital costs of a variety of widespread on-site sanitation options (including VIP, urine-diverting dehydration toilet (UDDT) and pour-flush toilet with septic tank or twin pits). Together with local partners, the cost and influencing factors will be analysed in four countries in sub-Saharan Africa (Uganda, Kenya, Burkina Faso, and Ghana) and in three countries in Asia (India, Bangladesh and Nepal). A comparison of the results from these countries will then help to explain the reasons behind the cost differences outlined above.

Based on the understanding of the current situation, the project will eventually try to find ways to optimise costs and make sanitation hardware more affordable for the poor – particularly in sub-Saharan Africa. This will include an assessment of the potential of non-conventional construction materials, but also the exploration whether some of the good experiences from Asia can be transferred.

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For further information and updates, refer to the project website: www.sandec.ch/costing

Interdisciplinary Research on Urban Sanitation in Kampala's Slum Settlements – Preliminary Results

Understanding the sanitation situation and behaviour among urban slum dwellers is the focus of a joint four-year transdisciplinary NCCR North-South and EU Water Initiative Splash U-ACT research project. The research conducted in Kampala, Uganda, aims at understanding the main social and economic drivers as well as the constraints regarding access and sustained use of on-site sanitation facilities in poor urban contexts. Innocent K. Tumwebaze¹, Alexandra Horst², Christoph Lüthi¹

Research objective

Researchers of Eawag/Sandec and the Centre for Development and Cooperation (Nadel) at ETH Zurich are jointly conducting this transdisciplinary research. Two PhD students (one in environmental psychology and one in development economics) are involved in this project. Both dissertations will contribute to gaining a deeper understanding of the main psychological and economic determinants affecting demand and use of sanitation facilities in urban poor settlements.

Environmental psychology

Guided by the hypothesis that *"Improving demand for sanitation facilities and proper use leads to increased construction and sustainable behavioural use"*, the general question of this research component is to investigate the main constraints for household demand and behaviour towards improved sanitation. It aims to develop psychosocial interventions targeting two focal areas: (i) demand stimulation and (ii) improved behaviour to ensure sustainable use and cleanliness of the facilities. The main objectives of specific research are to:

- Understand the main psychological determinants of the current sanitation situation in urban slum communities.
- Develop, test and evaluate psychosocial interventions based on the above findings to assess their effects on increasing sanitation demand and sustainable behavioural use of the facilities.

The findings from this investigation will contribute to the international debate on ways to achieve sustainable urban sanitation that will hopefully lead to a better understanding of the key factors influencing household sanitation behaviour, especially by tenants. We also

plan on developing guidelines and tools using psychosocial techniques to promote behavioural change in future sanitation research and project planning.

Development economics

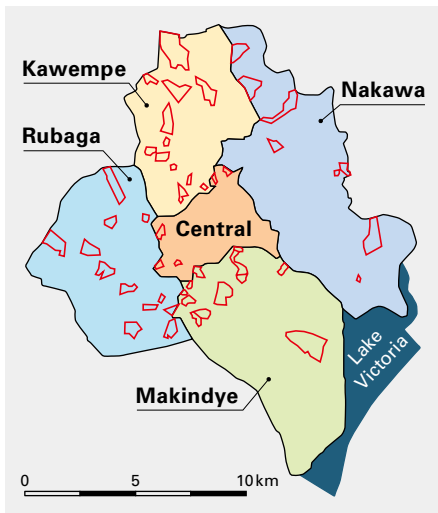
The economic component of this sanitation research aims at identifying and analysing the key economic constraints as well as the sanitation preferences of poor households that underlie the persistent low private investment in sanitation facilities in poor urban settlements. Based on different user and financing arrangements, this research component will analyse the urban poor's willingness to pay for improved sanitation. Analysis of the baseline survey will lead to designing demand-led financing options to sustainably improve the sanitation uptake rate among the urban poor. These financing options will be tested and

implemented in a randomised pilot project in coordination with a local NGO in Kampala. Based on a follow-up survey of all initially interviewed households, it will be possible to conduct a comprehensive evaluation on the effectiveness of the financing options to improve the uptake and access to improved on-site sanitation facilities of Kampala's poor.

To our knowledge, this is the first empirical research on sanitation demand and economic aspects conducted in a poor urban context. It has direct development relevance, as potential economic solutions will not only be theoretically analysed, but also empirically evaluated. This study will therefore not only yield new insights on how to tackle urban sanitation in Uganda from an economic perspective, but our insights will also be of interest to other sub-Saharan African countries.



Photo 1: New double stance shared toilet facilities built in 2012 using targeted subsidies.



Map 1: Randomly selected low-income areas in Kampala from a list of 304 slum communities.

Preliminary results

The research team conducted a joint baseline survey in October and November 2010 to learn about the current sanitation situation in Kampala's low-income areas and answer some of our research questions. The survey, which covered 50 randomly selected slums from the five divisions (equivalent to districts) of Kampala city, interviewed 1500 randomly selected households (Map 1).

Analysis of the baseline survey revealed the following key findings:

- Over 99% of the respondents report to have access to sanitation facilities. However, the majority (84%) of the respondents share their facility with a large number of other households.
- About 70% of the sanitation facilities are simple pit latrines.
- Only 47% of the respondents have clean facilities.
- The majority (70%) of Kampala's slum dwellers are tenants.
- While house owners have higher long-term wealth in terms of asset ownership, the per capita income of house owners and tenants does not differ significantly.
- The cost of an improved and lined on-site sanitation facility in Kampala is high, i.e. about USD500 for a single stance VIP.
- Slightly over half (51.7%) of the respondents were not satisfied with their sanitation facilities – the majority of the dissatisfied respondents (65.9%) are users of shared facilities.
- A vast majority of the respondents (85%) had a rather negative attitude

towards sharing toilets with their neighbours.

- About 61% had used the facilities for <5 years, and around one fifth of the respondents had changed their facilities due to full pits.

More findings on our policy brief *"Where do Kampala's poor go? Urban sanitation conditions in Kampala's low-income areas"* can be downloaded from www.sandec.ch/sesp.

Interventions

Based on the survey findings, the issues of key importance relate to a lack of improved sanitation access due to high user numbers, unsatisfactory cleanliness, low demand, and the role of rental status for private investment in sanitation, including the high cost of a sanitation facility. The interdisciplinary nature of the research will allow us to address the above issues through different interventions.

Psychological interventions

Cleanliness is a constraint mainly among users of shared sanitation facilities. A set of two psychosocial interventions will therefore be piloted in 2012. The first intervention will focus on developing behavioural change techniques related to cleaning of shared toilets by tenant users. The second intervention will focus on the cost of the facilities based on persuasive arguments, such as how the "cost is not a cost", if sanitation merits are put into proper perspective. This will include the expressed demand factors from the tenants and landlords. In all the interventions, (pre-intervention, mid-term and final intervention), surveys will be conducted to assess their effectiveness.

Economic interventions

Based on the results of the baseline survey, the team responsible for the economic research aspects has designed demand-oriented financing options aiming at sustainably improving the sanitation uptake among Kampala's urban poor, and exploring the role of subsidies for increased sanitation coverage in urban slums. The implementation of these financing options, addressing about 1200 poor households, is currently on-going in 40 randomised slum areas. Once finalised and evaluated, it will be possible to determine how sanitation demand changes with price and financing arrangements.

Research relevance to Uganda

This research project will contribute to Uganda's overall sector development by:

- Providing information on the state of sanitation and potential policy-related interventions and planning options of sustainable sanitation – especially by piloting possible interventions at different scales. Most sector review reports lack information on slum sanitation. Our documentation and information sharing (e.g. policy briefs) will allow the data obtained to be shared with all sector players.
- Providing direct benefits to the participating communities. These benefits cut across the knowledge cues on the importance to invest and use improved sanitation facilities (Photo 1), on subsidies to house owners and landlords to purchase toilets and on enhancing collective sustainable use of the toilet facilities by the tenants in informal urban settlements.

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Towards a Wide-Scale Replication Scenario for Small-Scale Sanitation in the Nile Delta, Egypt

In the past few decades, various attempts were made to develop a sustainable sanitation model for the numerous small settlements scattering Egypt's agricultural land. Yet, none of these initiatives turned into an upscalable model. The SECO-funded ESRISS Project (Egyptian-Swiss Research for Innovation in Sustainable Sanitation) seeks to understand why wide-scale replication has not occurred, bridge the gaps and develop an innovative and cost-effective system in partnership with the Egyptian Holding Company for Water and Wastewater (HCWW). Philippe Reymond¹, Christoph Lüthi¹, Rifaat Abdel Wahab², Moustafa Moussa³

The Nile Delta resembles an extremely large peri-urban area, scattered with thousands of compact settlements of various sizes. Only a small percentage of these settlements are served by proper sanitation schemes (Photos 1 and 2). Increasing sanitation coverage in such areas is a central issue in Egypt. A cluster approach has been adopted, focusing on the main urban centres while connecting smaller settlements within a few kilometers distance. However, numerous settlements are located too far to be connected to those large-scale centralised treatment plants in the foreseeable future and need alternative solutions.

So far, no wide-scale replication model is available in Egypt for these smaller settlements. Development of a cost-effective, context-appropriate and wide-scale replicable small-scale sanitation system (i.e. for up to 5000 inhabitants) is the ulti-

mate goal of Sandec's ESRISS project. In a first stage, the results obtained from the project will support the World Bank-funded project ISSIP (Integrated Sanitation and Sewerage Infrastructure Project) and the 30 small settlements expected to be served. Beyond ISSIP, the resulting outcomes have the potential to benefit other large-scale sanitation projects and to support the National Rural Sanitation Strategy currently under revision.

Assessing the small-scale sanitation sector

In a first step, a nation-wide assessment of the rural/peri-urban sanitation sector and existing small-scale initiatives was conducted. Different approaches were applied: (i) interviews with key stakeholders of the sector to identify the initiatives, collect the scattered data, knowledge and experience available; (ii) conduct a literature

review; (iii) select the most prominent initiatives, field visits and detailed assessments with evaluation questionnaires and sample analyses. The evaluation questionnaire was designed in an integrated manner and based on the "Enabling Environment" framework (Fig. 1) [1]. The aim was to assess all the components of the sanitation systems, from the technical parameters to the management scheme, financial sustainability and social acceptance.

Individual trials vs. wide-scale replication

This assessment reveals that isolation of existing initiatives and lack of commitment by government agencies are the main factors preventing wide-scale replication. None of the approaches has been institutionalised. Furthermore, entirely community-based approaches do not appear to work in the Egyptian context. It is consequently clear that the Utility (HCWW and Affiliates) must play a pivotal role in the development and management of small-scale sanitation. So far, the sector finds itself in a vicious circle, as isolated initiatives remain prototypes and, as such, are not cost-effective, do not receive the attention required, are considered too expensive and/or prone to failure, and therefore not replicated.

Development of a model for wide-scale replication requires a clear governmental strategy heading in this direction. The situation could then turn positive, i.e. with a clear strategy, mass-production approaches could be proposed and tried, thereby allowing economies of scale. A model implemented at scale would be significantly cheaper and of better quality than one built on a one-off basis and also allow the Utility to create specialised units in each Affiliate. As such, the interface be-



Photo 1: Typical Nile Delta village (Beheira Governorate).

tween small-scale systems and the Utility (HCWW and Affiliates), including integration of the model in its strategies, forms part of ESRISS' approach.

Advantages of prefabricated units

Use of prefabricated units for part or the entire treatment scheme could control costs and quality as well as reduce overheads. Since it is a commercial product, the price is fixed and the hassle with building contractors avoided in a context where plenty of money is usually spent in the consultant/contractor constellation – mobilisation costs currently carry a big weight in the capital costs of infrastructure in Egypt – and where quality is difficult to control.

Such prefabricated units could easily be manufactured in Egypt and would create a promising new market. The idea, currently under evaluation, is to set up a modular system with several units that can be combined to allow maximum flexibility and adaptability to each village on a case-by-case basis. Such modules could be: (i) anaerobic baffled reactors and up-flow filters; (ii) compact anaerobic and aerobic units for domestic and local industrial wastewater (e.g. cheese factories); (iii) physico-chemical settling and oxidation units. If produced in large quantities, the price of prefabricated units could become highly attractive since the Egyptian market is considerable.

Another advantage of this model is the fact that the companies marketing these prefabricated units can also ensure Operation & Maintenance (O&M) on a public-private partnership (PPP) or private basis. A specialised O&M company contracted

by the Utility could also be created. Development of a strong private sector niche for small-scale sanitation would alleviate government agencies, which have to handle large-scale infrastructural projects.

Creating a baseline for planners and designers

Sector assessment also revealed a lack of baseline data characterising sanitation in rural villages (practices, water consumption, wastewater production, flows, loads), leading to mis-dimensioned infrastructures relating to the actual wastewater characteristics and sometimes even resulting in system failure. Designers do not have the available context-specific values accounting for the various factors influencing quantity and characteristics of the wastewater to be treated.

ESRISS is strengthening the understanding of the specific characteristics of sanitation in the Nile Delta villages by developing such a baseline, including tools and methodologies to rapidly quantify and characterise the wastewater to be treated on a site-specific basis and according to the sanitation-related flow model (Material Flow Analysis).

Rural settlements are highly heterogeneous in nature and differ considerably from urban contexts. Concentrations have to be taken into account, as they are usually far higher due to the lower water consumption and extra loads, such as the liquid part of animal manure. Inflows are extremely variable in time and quantity and lack a buffer effect, such as in large urban treatment plants. The characteristics of each settlement should be described on a case-by-case basis through targeted sampling campaigns, observations of local practices and interviews with key stakeholders (e.g. local authorities, households, farmers, sanitation service providers).

The way forward

In the coming months, ESRISS will be supporting the ISSIP project during implementation of the small-scale component, investigating the potential use of prefabricated wastewater treatment units and completing the village assessment tools by applying them to villages selected by ISSIP. The project will team up with partners to develop the design elements and strengthen the exchange of experience on prefabrication. In parallel, advocacy and awareness raising will be conducted at all levels to favour institutionalisation of the approach. "Strategic niche manage-

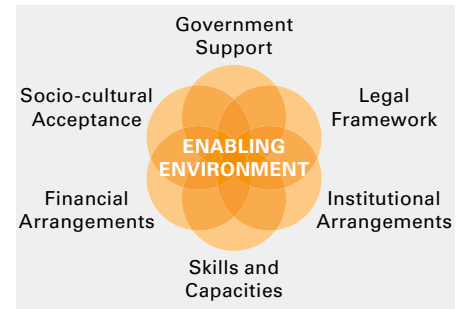


Figure 1: "Enabling Environment" framework [1].

ment" [2] may be used as a tool to structure and analyse the wide-scale replication strategy.

Transparency and dissemination of lessons learned are crucial, even if they are not apparent in this context. ESRISS has an important role to play in gathering the available data, filling the existing knowledge gaps, disseminating the results, and supporting a sound development of the small-scale sanitation sector in Egypt.

For several years, Egypt has been a focus country of SECO's economic cooperation and development programme. In the frame of its new programme phases for the years 2013 – 2016, SECO is intensifying its activities in North Africa and setting up a Swiss Programme Office in Cairo together with other federal offices.

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Photo 2: Nile Delta village drain receiving an array of different waste.

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

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Assessing Willingness to Pay for Improved Sanitation in Vietnam

Information on willingness to pay for improved sanitation facilities can be useful for designers and planners when assessing the economic viability of projects, setting affordable tariffs, evaluating policy alternatives, assessing financial sustainability, and designing socially equitable subsidies. Our study in Vietnam reveals that people are willing to pay USD 800 to have a combined bathroom and toilet to improve their sanitation facility. Hoang Van Minh^{1,2}, Nguyen Viet Hung^{3,4,5}, Nguyen Hoang Thanh², Jui-Chen Yang⁶

Lack of information on willingness to pay and sanitation situation

Many people in developing countries have no access to improved sanitation [1],[2], since the governments in these countries cannot afford to provide heavily subsidised improved sanitation to all or even to the majority of their populations. Improvements of the sanitation situation in developing countries rely heavily on the financial contributions by the households and depend not only on households' willingness to pay (WTP), but also on their ability to pay for the improved sanitation services.

Similar to other developing countries, coverage of improved sanitation in Vietnam remains low [3]. Water-borne diseases are a key issue in Vietnam, with inadequate water supply and sanitation listed as major causes [4]. However, information on household demand for improved sanitation in Vietnam was scarce at the time of the study. The aims of the study were to assess the households' WTP for construction of bathrooms with a septic tank in a rural community of Vietnam and to examine the effects of socio-economic factors on the willingness to pay.

Study in Hanam province, Vietnam

The study was conducted in March and July 2011 in the Kim Bang district of Hanam province, 60 kilometres south of Vietnam's capital, Hanoi. The Kim Bang district was chosen as it is considered typical for a rural community in northern Vietnam. This study applies the contingent valuation method and the iterative bidding game technique to elicit households' WTP, which include a sequence of dichotomous choice questions (i.e., yes or no to the bid offered in each question) followed by a final open-ended question. 370 households devoid of a toilet were selected for this study. Respondents of the questionnaire were the main income earners and decision-makers of the households.



Photo 1: A typical combination of bathroom and toilet in a rural and peri-urban Vietnamese household.

People want to pay for a better sanitation facility

The outcome of the study revealed that 62.1 % of the respondents are willing to pay for an improved service. The mean WTP amounts to VND 15.6 million or USD 780.0 (range: VND 2.0–45.0 million). WTP was significantly correlated with: 1) Gender of the head of household; 2) Age of the head of household; 3) Economic status of household; 4) Type of current toilet; 5) Satisfaction with existing toilet; and 6) Knowledge of health effects of poor sanitation. The mean determinants of WTP are: 1) Geographic location; 2) Economic status of household.

The study conclusively reveals that households in the study area are willing to pay for an improvement of their current sanitation arrangement (Photo 1). To expand coverage of improved sanitation in the area, microeconomic supports, such as government subsidies, low-interest loans and microfinance schemes, as well as public health education, including extensive sanitation modules are required.

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The Challenge of Reinventing the Toilet

Cutting edge technology developed for informal settlements of the Global South not only requires technical expertise, but also socio-cultural and socio-economic considerations at the early design phase. This is particularly important when developing an everyday object like a toilet, which is the aim of Eawag's "Reinvent the Toilet" project. Ulrike Messmer¹, Christoph Lüthi¹

The competition "Reinvent the Toilet" was initiated by the Bill and Melinda Gates Foundation to boost technology research for innovative toilet systems entirely free of utility connections and affordable to the Bottom Billion living on USD 1 per day and capita. In collaboration with the Austrian designers EOOS, Eawag is taking part in the first phase of the competition (August 2011 – July 2012) with an interdisciplinary project team whose objective is to develop a holistic sanitation system.

The system, designed for dense informal settlements in developing countries, comprises the following five parts:

1. A user-friendly source separation toilet.
2. A Gravity-Driven Membrane (GDM) for water recovery to allow anal cleansing, hand washing and toilet cleaning.
3. A logistic concept for excreta transport.
4. A semi-centralised resource recovery plant to treat the excreta of 500 inhabitants.
5. A viable business model.

While parts 2 and 4 include technical elements, parts 1, 3 and 5 also need to focus on socio-cultural and socio-economic aspects, such as assessment of the target group's unmet needs and desires, their everyday life, culturally acceptable innovations, and the question of affordability and willingness to pay. Therefore, a reality check was conducted covering several key activities (see box).

Reality check activities

- Literature review mainly on:
 - Urban sanitation conditions in low-income areas.
 - Requirements of disabled, children, elderly.
 - Gender requirements.
 - Religious requirements.
- Consulting with European sanitation experts to determine design and technology options.
- Workshop in Kampala, Uganda:
 - Workshop with sanitation experts of Makerere University.
 - Transect walks in Kampala's slums, including qualitative interviews with slum residents and key informants.
 - Presenting and discussing a mock-up model in a participatory workshop with slum residents (Photo 1).
 - Subsequent focus group discussions aiming at developing a logistics and service concept (Photo 2).

Main assessment results of the target group

- Typical conditions in an informal settlement: high population density, space restrictions, high fluctuation rates, lack of property rights discouraging private investment in sanitation, heavy rains and floods complicating transport on the already poor infrastructure, water constraints, and a high number of persons sharing one toilet and thus leading to unhygienic conditions.
- Socio-economic aspects: monthly income of USD 36–39 per capita, unsteady income, high ethnic and religious heterogeneity, 1 room = 1 family of 5 people.
- Cultural and behavioural aspects: unwillingness to transport own excreta in sealed containers; "washers" use water for anal cleansing and "wipers" mainly old newspapers; possible additional ablution rituals; Muslims require a high water quality exhibiting no colour, smell or taste; for lack of washing facilities, many slum residents wash themselves outdoors at night; water is valuable and often reused several times mainly to wash dishes, then clothes and finally the floor.
- Needs and desires: although an overall wish for clean toilets prevails, most of the existing toilets exhibit a hygienically poor condition or are no longer functioning. This is mainly attributed to the high number of users and the resulting lack of responsibility for maintaining the toilets.



Photo 2: Focus group discussions aiming at developing a logistics and service concept.

The results of the reality check clearly reveal the need for a movable toilet – a challenge for designers, as our system requires the addition of the GDM water recovery unit. Movable toilets allow for a flexible set up either in existing toilet superstructures or in-house – an important advantage in dense settlements. A rental system of movable toilets could be the solution to the problem of low private investment in sanitation, as no upfront investment is required and the toilets can be returned in the event of land eviction. Moreover, small rental payments, corresponding to the users' existing consumption patterns, are more likely endorsed. A logistics concept for a service system was developed to account for the target group's unwillingness to transport its own excreta. Such an excreta collection service has implications on the design of the toilet's storage containers, as these have to be accessible for the collector when toilet users are absent during the day.

Reality check activities, particularly personal contact with representatives of the target group (Photos 1 and 2), which improved compatibility of our concept with the group's lifestyle, are the key to successful design, especially when developing everyday objects.



Photo 1: Discussing a mock-up model in a participatory workshop with slum residents.

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How to Achieve Evidence-Based Behavioural Change

Practitioners are increasingly aware of the fact that providing for example drinking water disinfection technologies, improved toilets or handwashing facilities will fail to lead to the desired health effects if used inadequately or not at all. Evidence-based behavioural change must therefore be a major component of any mitigation effort. Hans-Joachim Mosler¹, Alexandra Huber¹, Jennifer Inauen¹, Robert Tobias¹

Introduction

Practitioners throughout the world report of unused or misused toilets (e.g. used as storage rooms), abandoned newly constructed wells or inadequate hygiene practices. Providing target populations in developing countries with hygiene, sanitation and water “hardware” must be accompanied by so-called “software” programmes to achieve behavioural change. As behaviour is the product of psychological processes, public awareness campaigns must be conducted to change the factors influencing the outcome of these processes. It is thus necessary to determine the key factors responsible for changing a behaviour, and to implement behavioural change techniques that most effectively change these factors.

A general protocol for behavioural change is outlined containing the following steps:

- Defining the behaviour to be changed of the target population.
- Determining the factors steering the target behaviour.
- Selecting and designing behavioural change techniques (BCTs) to alter crucial behavioural factors.
- Evaluating short-term and long-term effects and the effectiveness of behavioural change techniques.

Defining the behaviour to be changed of the target population

For optimal resource allocation and to attain the objective of a campaign, the specific behaviour of the target population requiring a change must be determined. To characterise critical behaviours, a closer look at everyday behaviour patterns is necessary. At this stage, discussions with experts and in-depth interviews with a small number of people from the target population should be conducted to identify the existing barriers and to facilitate conditions leading to the desired behaviour.

Determining the factors steering the target behaviour

A theoretical framework of potential behaviour-influencing factors should be used to identify the factors determining a specific target behaviour. The factors can then be measured in the target population, and key determinants steering the behaviour identified by statistical analyses. The RANAS Model [1], as a theoretical framework of factors, is herewith shortly introduced (Fig. 1).

Factors of behavioural change: The RANAS Model

The RANAS Model (R(isk), A(ttitudes), N(orms), A(bilities), and S(elf-Regulation) includes several theories from social and health psychology [1]. The model comprises three distinctive components: (1) the factor blocks grouping the behavioural factors, (2) the target behaviours and (3) interventions or BCTs corresponding to the factor blocks.

The psychological factors comprise all possible drivers of health behavioural

change. *Risk factors* are divided into perceived vulnerability (a person’s subjective perception of his or her risk of contracting a disease), and perceived severity (a person’s perception of the seriousness of the consequences of contracting a disease). Additionally, a person should have an understanding (factual knowledge) of how he or she could be affected by a disease through environmental conditions. *Attitudinal factors* include cost/benefit (e.g. how time-consuming is the behaviour) and affective evaluations (e.g. taste and temperature of the treated drinking water). *Normative factors* comprise the descriptive norm (perceptions of those behaviours that are typically performed by others) and the injunctive norm (perceptions of those behaviours that are typically approved or disapproved by important others). *Ability factors* characterise self-efficacy, i.e. the belief in one’s capabilities to organise and take the appropriate actions, and the action knowledge, i.e. knowing how to perform the behaviour. Finally, *self-regulation factors* refer to aspects of putting a be-

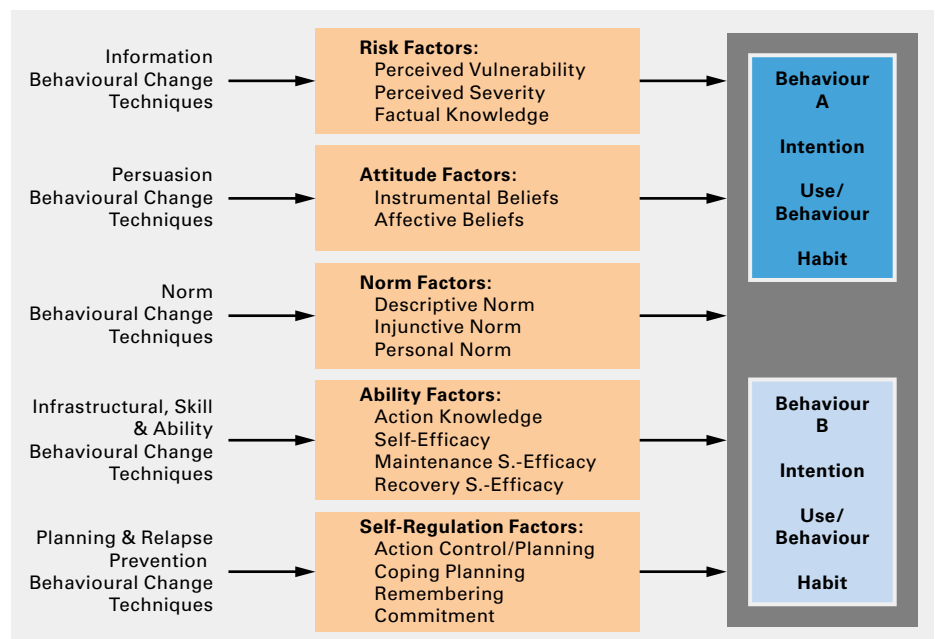


Figure 1: The RANAS model (R(isk), A(ttitudes), N(orms), A(bilities), and S(elf-Regulation) of behavioural change.

Risk Factors	Informational BCTs
Factual knowledge Vulnerability Severity	Presentation of facts/knowledge transfer Personal risk information Showing scenarios Fear arousal
Attitudinal Factors	Persuasion BCTs
Instrumental beliefs	Persuasive arguments Persuasive means Talking to others
Affective beliefs	Affective persuasion
Normative Factors	Normative BCTs
Descriptive norm Injunctive norm Personal Norm	Highlighting norms Informing about others' approval/disapproval Public commitment Anticipated regret
Ability Factors	Infrastructural, Skill & Ability BCTs
Action knowledge (skills)	Provide instruction
Self-efficacy	Guided practice Facilitating resources (financing) Social help Modelling Reattribution of past successes and failures
Maintenance (Coping) self-efficacy	Coping with barriers
Recovery self-efficacy	Coping with relapse
Self-Regulation Factors	Planning & Relapse Prevention BCTs
Action control Coping planning Remembering Commitment	Daily routine planning Outcome feedback Stimulus control Forming implementation intentions Prompts

Table 1: Factor blocks, behavioural factors and corresponding behavioural change techniques (BCTs).

behaviour into practice and maintaining it. Coping with planning includes arrangements plans to cope with barriers. Also to consistently practice a behaviour, the person has to be committed to doing so, and the behaviour has to be remembered at critical moments. A more detailed description of the behavioural factors is given in Mosler [1].

Not only the target behaviour, but also the alternative behaviour has to be taken into account. For example, not only drinking safe water (Behaviour A), but also drinking contaminated water (Behaviour B) has to be tackled. Furthermore, intentions and habits of both behaviours have to be considered.

To measure the incidence of each behavioural factor amongst the population, a questionnaire will have to be developed with questions used as indicators for the corresponding factors. Intensive training of the interviewer team is crucial, as the interviewers have to understand the questionnaire and the interview situation has to be trained.

A large enough number of households should be interviewed and selected according to a predefined scheme. This selection is usually conducted randomly to avoid a biased representation of the population (e.g. questioning only easily reached households).

A comparison of the mean results is the simplest way to determine the most

promising factors to be targeted by BCTs. Any factor whose mean result greatly differs from the optimal result (e.g. any evaluation of the desired behaviour whose result is far from optimal) is a candidate to be targeted. Particularly promising are factors with significant differences in the mean results obtained from persons already practising the desired behaviour and from those not practising it sufficiently enough. For more in-depth analyses (e.g. regression analyses), experts should be consulted (cf. [1] for a short description).

Selecting and designing BCTs to alter crucial behavioural factors

This step allocates the BCTs to the factor blocks of the RANAS Model. BCTs and factor blocks do not necessarily correspond on a one-to-one basis, as many of the BCTs tackle more than one factor. Table 1 contains the BCTs corresponding to each factor block.

A detailed description of the BCTs is given in Mosler [1]. The BCTs are spread via communication channels, comprising mass media and interpersonal channels. Numerous investigations have revealed that interpersonal dissemination is more effective than use of mass media, yet more people can be reached by mass media. The channel chosen for a behavioural change campaign will also depend on availability, resources and on the type of channel people are used to.

Evaluating short-term and long-term effects and the effectiveness

This evaluation will reveal how effective BCTs bring about behavioural change, and also how the BCTs affect the psychological factors. A campaign should comprise at least three surveys: (1) A baseline survey to be conducted before the BCTs are implemented; (2) intermediate surveys to be conducted 1–2 months after implementation of BCTs; (3) the final survey to be conducted 6–12 months after the last BCT is implemented. These surveys are panel surveys, i.e. the same persons are interviewed in all the surveys to identify the changes occurring within the persons.

The baseline survey should be used to define the BCTs (e.g. the BCTs can be tailored to specific subgroups of the population). In intermediate surveys, it is important to also ask about the BCTs, i.e. whether the persons were in contact with promotion material and its impact. It is also good practice to enquire about special events that may have influenced behaviour (e.g. special climatic events or competing campaigns conducted by other organisations). A final survey is vital to evaluate the long-term effects of BCTs. This questionnaire should specifically focus on assessing whether and why people have stopped practising the new behaviour.

For a simple analysis, a comparison can be conducted of the changes in the mean results obtained from groups who received different BCTs. The mean results of the desired behaviour show the effectiveness of the different measures or of the campaign as a whole. The mean results of the psychological factors inform on the reasons for the effect or lack of effect and can be used to improve future campaigns.

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¹ Eawag/Sandec, Switzerland

A more detailed behavioural change protocol can be found on www.eawag.ch/forschung/siam/schwerpunkte/soziale_systeme/index_EN

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Recovery of Industrial Waste Heat for Faecal Sludge Drying

Use of waste heat from industries could enhance the faecal sludge drying process and minimise the treatment footprint. Stefan Diener¹, Josef Cyril Reiser¹, Ashley Murray², Mbaye Mbéguéré³, Linda Strande¹

In Africa and Asia, 65–100% of urban residents use on-site sanitation systems, such as septic tanks or latrines [1]. These systems are typically emptied with suction trucks or by manual labour. Faecal sludge (FS) is most commonly dumped directly into the environment or disposed of in a treatment plant if one is available. This practice has its origin in the common perception that FS is a waste product without any value. Yet, faecal sludge not only contains nutrients (N, P, K) for use as agricultural fertilisers, but it can also replace fossil fuel to produce heat in industrial processes.

Alternative fuel used in the cement industry

Use of alternative fuel in industrial kilns and boilers is a recent trend driven by increasing fossil fuel costs. Alternative fuels, such as tires, animal meal, sewage sludge, and waste oil have to meet certain criteria, not only as regards their energy potential, but also their physical characteristics. Solid fuels are, for example, most often fed into kilns by airflows and, therefore, require a minimum degree of dryness ($\geq 90\%$ DM). FS passively dried on filter beds can achieve a dryness of 60–80% [2] and would need to undergo an additional drying process. A possible option for an energy efficient approach to eliminate excess moisture is the use of waste heat from the clinker production process in cement factories. The SPLASH-funded FaME project (www.sandec.ch/fame) aims at evaluating the waste heat recovery potential from a cement factory in Dakar, Senegal.

Clinker production process

In a typical dry rotary kiln system (Fig. 1), raw material (e.g. crushed limestone, iron, silica) is preheated and precalcined (i.e. CaCO_3 decomposed to CaO and CO_2) before it is fed into the kiln. The rotary kiln itself is a lined tube of max. 6 m in diameter generating a temperature of $\sim 1500^\circ\text{C}$. It is generally inclined at a $3\text{--}3.5^\circ$ angle and rotates 1–2 times per minute.

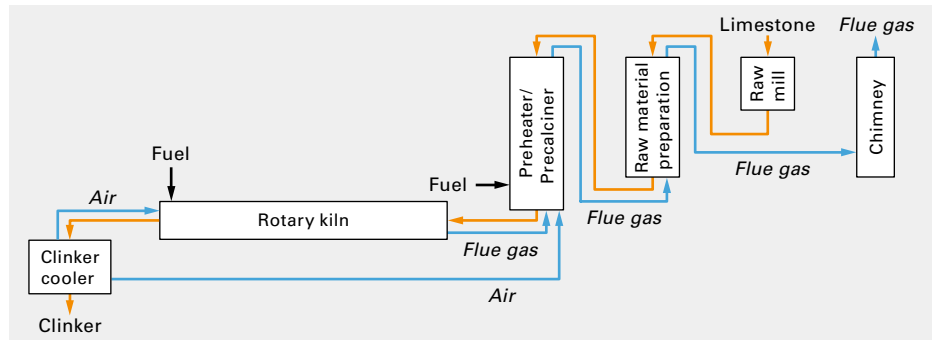


Figure 1: Overview of the clinker production process.

Waste heat recovery and reuse

Two sources of waste heat are generally available in a clinker production line: i) recovery of hot gases and ii) radiant heat loss from the kiln's surface. In this case, the flue gas from the kiln was already used directly in the preheater and for drying the raw material, leaving the flue gas from the chimney as the only hot gas stream available for recovery. The temperature of the flue gas amounts to $115\text{--}140^\circ\text{C}$ and the airflow stream to $450\,000\text{--}500\,000\text{ Nm}^3/\text{h}$. Its heat transfer rate is 2.8MW, which would be sufficient to evaporate 2.5–3.1 tons of water per hour. In Dakar, $6\,000\text{ m}^3$ of faecal sludge (DM0.4%) is collected daily. If the faecal sludge is dewatered on filter beds to 80% solids content, the waste heat could be harnessed to achieve a 90% dry solids content, resulting in 26.7 tons of dried faecal sludge. The flue gas heat recovery technology has already been successfully implemented in drying sewage sludge in Jiangyin, China [3], where some 100 tons of sewage sludge are dried daily to $<30\%$ moisture content. Use of the radiant heat loss from the rotary kiln has also been suggested recently as an energy recovery method. Up to 15% of total energy input is lost through radiation and convection from the kiln surface [4]. High investment costs and limited access to the rotary shell for monitoring and maintenance of the heavy new equipment are major obstacles to the implementation of this technology.

Logistics considerations

Transport costs are a key factor in FS management, as the water weight involved is extremely costly to transport. Besides the energy potential of the waste heat, the economic feasibility of waste heat recovery for FS drying is therefore also determined by site specific and logistic FS transport factors.

A combination of the two waste sources – FS and waste heat – can create an alternative to industrial fossil fuel use. This valorisation process will enhance motivation of FS collection and alleviate the financial pressure on households.

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Institutional Framework for Faecal Sludge Collection and Transport in Burkina Faso

ONEA, the Burkina Faso National Utility for Water and Sanitation collaborates with Sandec to improve faecal sludge management by strengthening stakeholder capacity and designing an institutional framework. Magalie Bassan¹, Linda Strande¹

Need for an institutional framework

The current sanitation policy in Burkina Faso comprises four main components:

- The environmental code [1] specifies proper disposal of urban waste.
- A decree regulates urban waste storage, collection & transport (C&T), treatment and disposal, and requires faecal sludge (FS) to be transported to authorised sites.
- The discharge standard sets limits for pollutants released into air, water and soil.
- The public hygiene code appoints municipalities to manage urban waste and sanitation services.

Yet, no document defines responsibilities and quality standards for the FS supply chain. Due to the long distances to illegal discharge areas and harassment by the police and the population, the mechanical emptiers face difficulties in disposing of FS. To alleviate this situation, ONEA plans to build three FS treatment plants (FSTPs) in Ouagadougou.

Since emptiers are not involved in urban planning programmes, they do not benefit from government assistance and have poor business management skills [2]. On account of financial difficulties, only 60% of the emptiers surveyed in 2007 were active in 2010 [3]. Thus, strengthening the organisation of emptiers and involving them in the planning process is a priority.

Emptiers involvement

Meetings with emptiers have revealed significant weaknesses in their professional

association and financial management skills. Workshops were held to raise their awareness about the benefits of a new institutional organisation. The meetings gradually built up trust, and task groups developed regulatory texts for FS management considering emptiers' constraints.

Participative process outputs

The following four documents were created to organise and professionalise the sector (Fig. 1):

1. A decree on FS C&T regulating:
 - Type of FS and obligation to discharge at authorised sites.
 - Provision of an official address for businesses and payment of discharge fees at FSTPs.
 - Required safety and health measures.
 - Right of emptiers to establish their service price.
2. A municipal licence authorising emptiers who adhere to this decree to deliver C&T services for three years.
3. A partnership agreement between ONEA and the municipality defining their responsibilities to raise awareness of the population, establish discharge and treatment sites, enforce the regulatory texts, and assist the emptiers.
4. Guidelines informing the emptiers about on-site sanitation, safety, hygiene, and financial management.

Perspectives

The emptiers are key stakeholders. Involving them in developing the required regulations guarantees their appropriateness. To ensure the success of this institutional setup, several measures are needed:

- The Emptiers Association needs to be strengthened to become a strong interlocutor for the authorities, to improve working conditions of the employees and to optimise their financial balance.
- Access to FSTPs and official discharge sites require good roads, reasonable opening times and discharge fees.
- ONEA and the authorities should be committed to strengthening the emptiers' capacities, to involving them in sanitation programmes and informing the population on the management of on-site sanitation.
- Financial mechanisms should be developed to ensure viability of the entire system.
- Frequent meetings should be held for ongoing evaluation and optimisation of the sector.

This participative process has initiated a collaboration with the emptiers – often not considered in urban planning – and provided other stakeholders insight into their difficulties. This is crucial, as it improves recognition of the essential public services the emptiers provide. The exchange between authorities, sanitation experts and emptiers improves the quality standard of these services in terms of hygiene, safety and environmental protection. Both the participative process and the resulting documents may readily be adapted to other countries and contribute to appropriate FS management.

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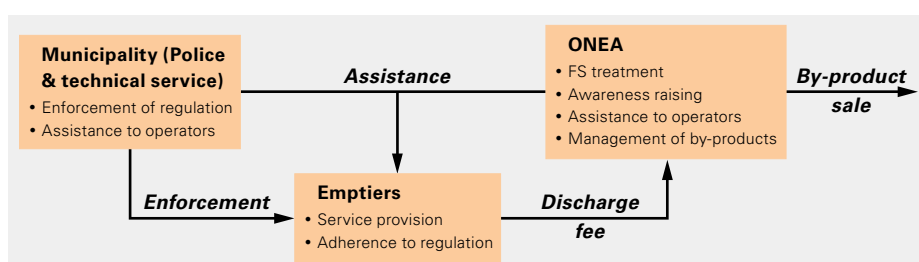


Figure 1: Stakeholders' responsibilities and their relationships.

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Diarrhoeal Disease Related to Agricultural Wastewater and Excreta Use in Vietnam

The incidence of diarrhoea was monitored and the risk factors for diarrhoea were identified in the rural community of Hanam, Vietnam, over a period of one year. Compared to adults without direct contact to wastewater and excreta during their agricultural activities, those in direct contact had a higher incidence of diarrhoea. Phuc Pham Duc^{1,2,3,4}, Hung Nguyen-Viet^{2,3,4}, Jan Hattendorf³, Jakob Zinsstag³, Chris Zurbrugg², Phung Dac Cam⁴, Peter Odermatt³

Epidemiological study in an agricultural community using wastewater and excreta

Vietnam has a long history of agricultural use of human and animal excreta, including wastewater as fertilisers. While this practice provides many benefits to the farmers (e.g. increased crop yields and reduced use of artificial fertilisers), it also involves potential health risks if excreta and wastewater are not properly managed [1], [2]. We conducted a study to determine diarrhoeal incidence and associated risk factors amongst an adult population exposed to agricultural use of wastewater and excreta in Vietnam.

The study was conducted in the two communes of Nhat Tan and Hoang Tay, in the Hanam province located some 60 km south of Hanoi. Sanitation facilities at household and community level are poor in this area. The Nhue River water, containing Hanoi's untreated wastewater from households, industry and hospitals, is intensively used for crop irrigation in these two communes (Photo 2).

An open cohort of 867 adults aged 16–65 years actively working in agriculture was monitored weekly for 12 months to



Photo 1: Excreta storage heap used as fertiliser for agricultural production in Hoang Tay and Nhat Tan communes.

determine the incidence of diarrhoea. A nested case-control study was also used to assess the risk of diarrhoeal diseases [3]. Two hundred and thirty-two pairs of cases and controls were identified, and exposure information related to wastewater, human and animal excreta, personal hygiene practices, including food and water consumption, was collected.

Incidence of diarrhoea and risk factors

The diarrhoeal incidence rate measured revealed 0.28 episodes per person/years at risk (pppy). The lowest diarrhoeal incidence was found amongst participants aged 36–55 years (0.25 episodes pppy), followed by those aged 16–35 years (0.28 episodes pppy) and those aged 56–65 years (0.40 episodes pppy). No difference in diarrhoeal incidence rates between males and females was detected (risk ratio [RR]=0.83). The study also showed a seasonal trend in monthly incidence, with a difference in diarrhoeal disease rates between the dry season (from October to March) and the rainy season (from April to September) (RR=0.77). The peak

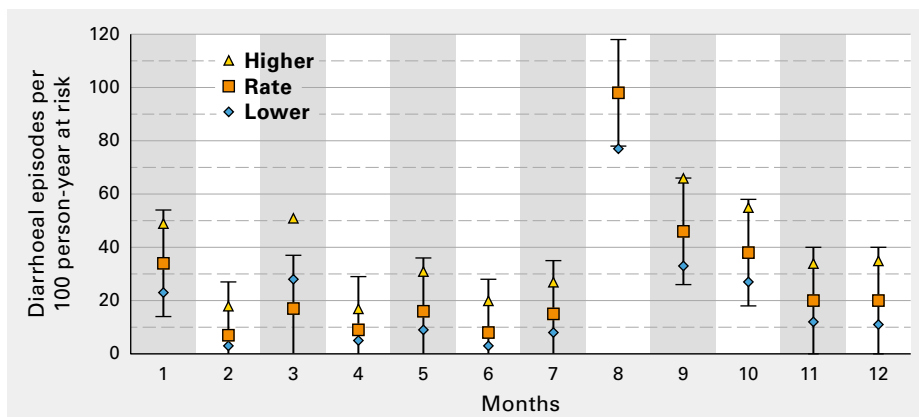


Figure 1: Monthly incidence of diarrhoea in 867 adults recorded from 299 222 persons-day at risk in Hanam, 2009 – 2010.

Definitions

Odds ratio (OR) is the ratio, used particularly in case-control studies, estimating the chances of a particular event from occurring in one population in relation to its rate of occurrence in another population.

Attributable fraction (AF) is the proportion of disease cases in a population attributable to certain risk factors.



Photo 2: Nhue River water used for field irrigation.

of diarrhoeal incidence was observed in August upon launching our monitoring programme (Fig. 1).

The risk factors for diarrhoeal diseases (Fig. 2) include direct contact with Nhue River water (odds ratio [OR]=2.4, attributable fraction [AF] 27%, cf. box for definition of OR and AF), local pond water (OR=2.3, AF 14%), composting of human excreta for a period of less than three months (OR=2.4, AF 51%), handling human excreta during fieldwork (OR=5.4, AF 7%), handling animal excreta in fieldwork (OR=3.3, AF 36%),

lack of protective measures while working (OR=6.9, AF 78%), never washing hands with soap (OR=3.3, AF 51%), use of rainwater for drinking (OR=5.4, AF 77%), and eating raw vegetables the day before (OR=2.4, AF 12%).

Conclusions and outlook

According to our study, direct contact with polluted water from the Nhue River and local ponds, handling practices of human excreta as fertilisers, poor personal hygiene practices, and unsafe food and water consumption are associated with the risk of

diarrhoeal diseases in adults. In agricultural settings, where wastewater and excreta are commonly used, efforts should be made to reduce public health risks by applying protective measures during fieldwork and safety measures when composting human excreta (Photo 1). Health and hygiene education programmes should also be given increased attention to enhance hygiene behaviour.

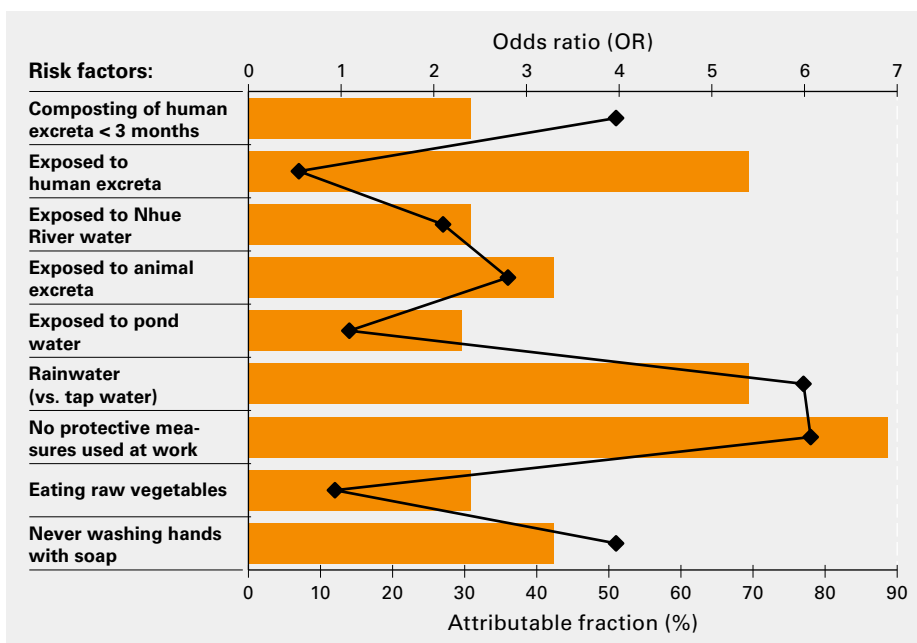


Figure 2: Risk factors of diarrhoeal diseases in 232 adult cases and 232 controls in Hanam province, Vietnam (multivariate conditional logistic regression analysis adjusted for age group and sex). Columns = OR, lines = AF values.

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Building a Better Filter – Combining Research and Design

Engineers, designers and end users contributed to the development of a new generation household water treatment filters. Richard Johnston¹, Selina Derksen-Müller¹, Maryna Peter-Varbanets¹, Wouter Pronk¹, Michael Krohn²

Background

Gravity driven membrane (GDM) filtration is an emerging, easily maintained, energy and chemical free water treatment system for pathogen removal from drinking water [1]. In GDM filtration, a biofilm is allowed to develop on the surface of ultrafiltration membranes. This biological activity prevents complete fouling of the membrane, and the low but stable water flux ($4\text{--}10\text{ L h}^{-1}\text{ m}^{-2}$) reached after several days of operation can be maintained for many years. In 2011, Eawag worked with the Kenya Water for Health Organisation (KWAHO) to distribute two dozen 1st generation prototypes of household GDM filters. The sites selected exhibited different water qualities and the households differed in socio-economic and cultural backgrounds.

After a year of monitoring, 22 out of 24 filters were still in use and performing well – two had been abandoned by their owners due to lack of interest or shortage of water. Monitoring showed general satisfaction with the filters, but also highlighted areas where filter design needed improvement, especially with regard to overflow of the raw water container and intrusion of untreated water into the clean water reservoir.

Partnership with the Zurich University of the Arts

To improve design and usability of the filters, Eawag sought out expertise from the Zurich University of the Arts, Department of Design. A recent graduate from the University's Master of Arts in Design



Photo 1: Survey respondents ranking filter colours.

programme travelled to Kenya with an Eawag team to meet with the women and men using the prototypes. Respondents were asked to rank a series of cards from least preferred to most preferred, to indicate their favourite shapes, colours, patterns, and materials (Photo 1). The goal was to formulate recommendations on the most appropriate design to meet the daily needs, water management practices, cultural values, and aesthetic tastes of the target group. This user-centred design forms part of the design research conducted at the Zurich University of the Arts.

Survey respondents most commonly chose the cubic and cylindrical shapes, as they were perceived to be stable, familiar and not take up too much space. Base of pyramid respondents were more concerned about storage capacity, while middle-class users had more defined preferences for different shapes. Regardless of wealth, respondents overwhelmingly chose blue over other colours. Complex patterns, including traditional African prints, were not as well liked as solid colours.

Besides information on filter appearance, the design team gathered user feedback on ways to improve the filters for daily use. Two consistent recommendations dealt with securing the clean water tank to prevent untreated water from accidentally entering the container, and to increase the water flow through the tap.

Second-generation filters

Information from these field surveys was used to develop a Design Brief, which served as the basis for three conceptual models for 2nd generation filters. Each of these minimises the risk of dirty water entering the clean water reservoir and accounts for size, colour and pattern preference of the Kenyan respondents. The three concepts have important differences in terms of shape (cubic or cylindrical), location and orientation of the membrane module and packing size. In some versions, the filtered water tank is easily accessible for cleaning, but the



Photo 2: One of the three models for evaluation.

risk of overflow and potential inadvertent contamination is increased. In other versions, access to the filter tank is more restricted. A working model of each concept was produced using rapid prototyping technology. Simultaneously, Eawag researchers met with different commercial European producers of ultrafiltration membranes and membrane modules to develop ultrafiltration modules to fit in the new housing units (Photo 2).

The models will be tested in Eawag's laboratories from May to August, and focus group discussions will be held with our Kenyan counterparts to decide on final design of the 2nd generation prototypes. A silicone mould will be cast around a master design pattern and used for plastic injection moulding. Silicone moulds are far less expensive than aluminium or steel moulds, but less durable: each mould can only produce about 30–50 filters before the silicone wears out. The 2nd generation prototypes will be field-tested in Kenya and Uganda through the end of 2012 before deciding on a final design and beginning production of the filter units at scale.

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Mitigating Geogenic Contamination in Drinking Water

This year, the interdisciplinary Eawag research team Water Resource Quality (WRQ) will release useful tools to help mitigate arsenic and fluoride contamination in drinking water. Annette Johnson and the WRQ team¹

Groundwater has long been used for the provision of drinking water for urban and rural populations. The second half of the 20th century has seen a rapid growth in groundwater use since the introduction of mechanised pumping. Indeed, the Millennium Development Goal 7c, aiming to halve the number of people without access to safe drinking water by 2015, could not have been achieved in 2012 without its use. Even though groundwater can supply safe drinking water free from pathogens, its quality can be affected by natural or geogenic contaminants leached from the aquifer's rocks and sediments. Arsenic and fluoride pose the most serious health threat. To date, an estimated 200 million people worldwide, or roughly 5 % of those using groundwater for drinking, are known to be affected. With currently over half the world's population relying on groundwater as a drinking water source, and with increasing pressure on water resources, this number is likely to rise.

In poor urban and rural settings, the provision of drinking water free from geogenic contamination proves to be a real challenge. Provision of water from alternative sources, precluding the need to treat the water for geogenic contaminants, is a preferred option, both by government agencies and consumers, though treatment for microbial contamination may still be necessary. Such a policy can also make use of existing governance structures. However, water treatment for geo-

genic contaminants cannot be avoided in some cases. While centralised water treatment is cost-effective, both in terms of infrastructure, maintenance and staffing, it is not always feasible, particularly for rural communities.

The WRQ research project

Together with local partners, the trans-disciplinary water research team "Water Resource Quality" (WRQ) at Eawag has worked on arsenic mitigation in Bangladesh and fluoride mitigation in the Ethiopian Rift Valley. It has developed tools for both regional assessments, i.e. location and extent of the contamination, and mitigation assessments. It provides potential contamination maps and webtools for users to develop their own maps, as well as practical guidance to water sampling and analysis presented in a manual targeting practitioners.

The mitigation framework consists of a set of tools to identify, plan and implement mitigation measures to combat geogenic contamination in drinking water (Fig. 1). Central to the framework is the integration of expertise from the social and natural sciences. The framework is divided into two parts that complement and interact with each other.

- Regional assessment and planning are essential steps to identify priority regions, the presence of possible alternative water resources, the regional risk of geogenic contamination of drinking

water and even the possibility of alternative dietary sources. It is aimed at the needs of government agencies and international NGOs with trained staff or funds for consultants.

- On a local scale, where water treatment is being considered, it is necessary to assess the different options not only in technical terms, such as costs, efficiency, simplicity, electricity requirements, availability of materials and know-how etc., but also in terms of institutional support and local acceptance. Potential users are local authorities, NGOs and communities interested in solving their specific small-scale problem, e.g. a contaminated water supply in their town or village. Here the level of required detail is more crucial, and guidance for cost-effective and socially acceptable mitigation measures necessary.

The products

An important task of the project has been the development of modelling methods to predict areas with a high probability of groundwater contamination by arsenic or fluoride. We have developed an on-line geodatabase where users can visualise our arsenic and fluoride contamination maps, including a range of other data layers. Registered users will have the possibility to upload their own data to the system and generate probability maps of their region of interest (www.wrq.eawag.ch).

For more localised problems, useful information has been compiled on how to deal with geogenic contamination in a handbook for practitioners. It includes guidelines on water sampling, available treatment technologies and highlights the necessity of initiating behavioural change in affected communities. The manual will be available in digital format, including relevant weblinks and attached resources.

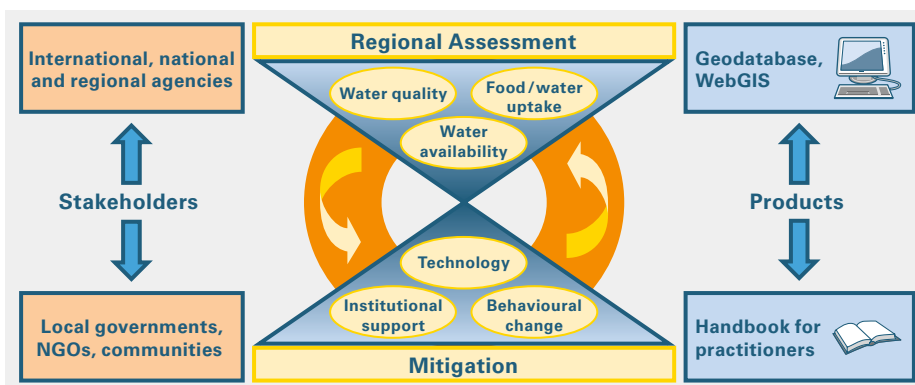


Figure 1: Elements of the mitigation framework.

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Health Impact of Exposure to Arsenic-Contaminated Drinking Water in Vietnam

The public health situation of the population of Hanam Province in Vietnam is of great concern, as it is exposed daily to arsenic-contaminated drinking water. Optimising arsenic (As) removal efficiency of current sand filters at household level or switching to cleaner or As-free water sources is crucial to prevent or reduce community health risks. Tung Bui-Huy^{1,2}, Tuyet-Hanh Tran Thi², Nhung Nguyen Hong², Hung Nguyen-Viet^{2,3,4}

Drinking water from tubewells in Hanam Province

The history of tubewell water use for drinking purposes dates back to the 1980s, when UNICEF introduced and provided tubewells to the rural areas of Vietnam and to the Hanam Province, located some 60 km south of Hanoi. Use of tubewells has widely spread with the introduction of electricity, as it facilitates extraction of groundwater from tubewells by electric instead of manual pumps. The Chuyen Ngoai commune in the Duy Tien district of Hanam is a lowland area near the Red River. It is located in an area where flooding occurs practically every year and the population therefore prefers to draw its water from tubewells rather than from deep wells, now almost entirely contaminated and filled up. The commune does not dispose of any waterworks or water supply. The inhabitants can only use rainwater and tubewell water for drinking and

daily activities. Rainwater is used mainly for drinking and tubewell water for other purposes like bathing, washing and watering. 61.3% of the households use both water sources for drinking, while 38.7% use tubewell water throughout the year. The majority of households use tubewell water for drinking in January, February, November, and December when rainwater is scarce.

Arsenic contamination and weak removal efficiency with sand filters

We collected 150 tubewell water samples from the same households before and 150 water samples after sand filtration to determine As concentration by atomic absorption spectrometer. The results revealed that 98.7% of the water samples before filtration were heavily contaminated with As. The As concentrations in water prior to filtration ranged

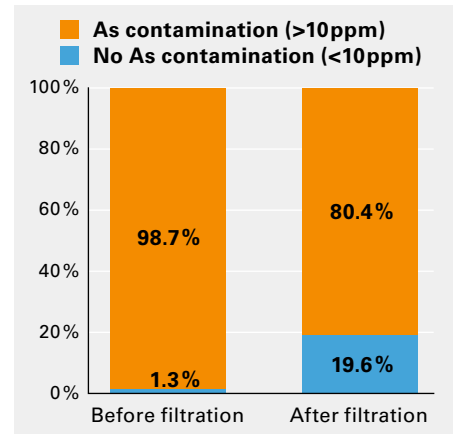


Figure 2: As concentration in tubewell water before and after sand filtration.

from 8–579ppb (mean: 301 ppb), thereby exceeding the limit of 10ppb for drinking water (Figs. 1 and 2). Since the majority of households design and build their own sand filters (Photo 1), the filters usually do not meet the standard for As removal. For example, 95.3% of the sand filters do not meet the required thickness, or 66.9% of the households do not adhere to the time required to replace/clean the filters and 90.5% do not conform to the aeration standard. Average As concentration in water after filtration amounted to 26.5ppb, which is still higher than the limit for drinking water for 80.4% of the surveyed households (Fig. 2). Although As contamination distribution was heterogeneous amongst villages in the Chuyen Ngoai commune (Fig. 1), no difference in As concentration before filtration was observed amongst the villages or between the areas.

Health risks caused by As contamination

Assessment of the health risks was conducted by the Australian Environmental Health Risk Assessment Framework combined with analysis of As accumulated in

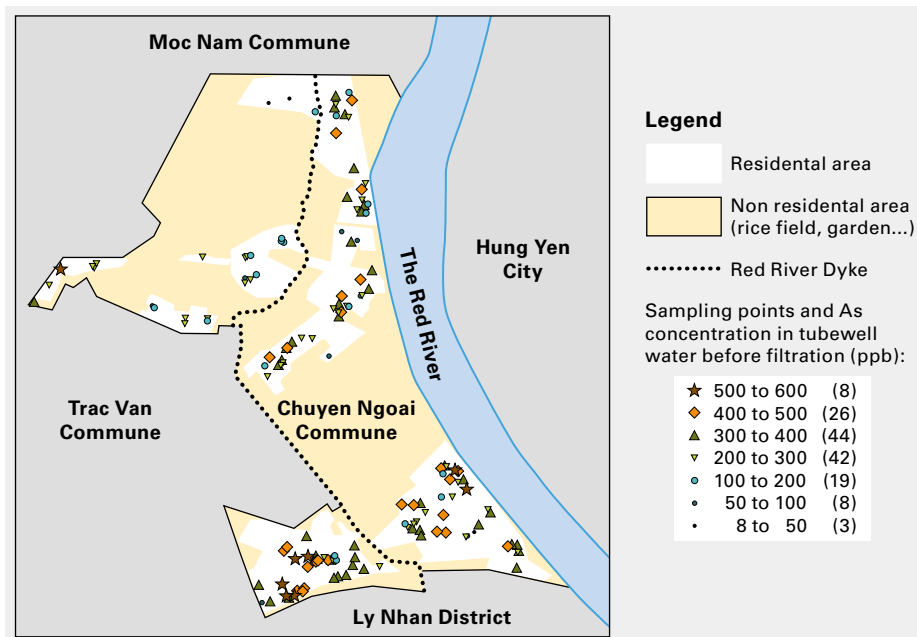


Figure 1: Sampling site and As contamination (before filtration) in the Chuyen Ngoai commune.



Photo 1: Sand filter with tubewell in Chuyen Ngoai, Hanam.

hair samples of 150 persons. Exposure was determined not only by measuring As concentrations in tubewell water samples as aforementioned, but also by estimating the water volume consumed as drinking water by 150 interviewed households. This provided data on the daily consumption volume via the oral route. As arsenic enters the body through the oral route, other exposure pathways, such as bathing and washing, were not considered. The health risk was characterised by comparing the As levels in water with the national technical regulations on drinking water quality, and by comparing the daily consumption dose with the Tolerable Daily Intake (TDI) value established by WHO. Finally, the cancer risk of people exposed to

As-contaminated water sources through eating and drinking was estimated by applying the Cancer Slope Factor index and lifetime average daily dose.

Twenty-four hair samples (16 %) had As levels exceeding the limit of 0.57 mg/kg, of which 6 samples (4 %) revealed an As concentration higher than 0.8mg/kg and corresponding to the standard diagnosis of chronic arsenic toxicity. Arsenic levels in hair were statistically significant to be correlated with As concentration in tubewell water after filtration.

Daily consumption of As amongst 40 % of adults was higher than the TDI level ($1 \mu\text{g}/\text{kg}/\text{day}$). The average cancer risk in adults from drinking filtered tubewell water amounted to 24×10^{-5} . In other words, based on a population of 100 000 people consuming As-contaminated water, 24 persons are prone to have or develop cancer. This cancer risk would be 1.2 and 1.5 times higher after 5 and 10 years of drinking filtered water, respectively. By using filtered tubewell water over 70 years, the average cancer risk level amounts to 204×10^{-5} . If tubewell water is used without filtering, the risk of cancer is 11.3 times higher. Different cancer risk scenarios are presented in Fig. 3.

current drinking water sources (e.g. by rain water, clean piped water etc) are recommended to prevent health risks of the local population. Risk awareness among the population, and especially amongst health workers, should be raised to prevent and mitigate the daily health effects posed by As contamination.

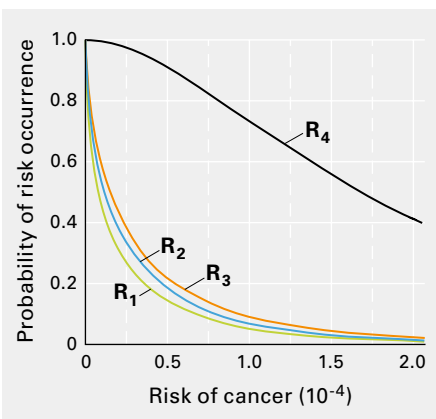


Figure 3: Estimated risk of cancer due to As-contaminated water. R1: Current consumption of filtered water, R2 and R3: Risk after 5 and 10 years of drinking filtered water, respectively, R4: Risk of consuming filtered water over a lifetime.

Towards prevention and mitigation of health risks

Our study revealed a high As contamination level in tubewell water in Hanam, and a high risk of exposure to using As-contaminated water for drinking. Improved filtration measures or replacement of the

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Using Logistic Regression to Model Arsenic Risk in Dhaka City, Bangladesh

Four geostatistical risk models were developed to assess the current risk of arsenic contamination in shallow groundwater of Dhaka city. Jannatul Ferdous¹, Kazi Matin Ahmed¹, Sarmin Sultana¹, Manouchehr Amini², Michael Berg², Richard Johnston²

Introduction

In Dhaka, the capital of Bangladesh, some 15 million people rely on groundwater for most of their water supply. Due to high demand and insufficient recharge, groundwater levels have been declining 2–3 meters per year over the last few years. Groundwater elevation contour maps show a number of cones of depressions at heavy abstraction areas where regional groundwater flows are converging from all sides. Though the Pleistocene aquifers underlying Dhaka are historically free from As, shallow groundwater in young Holocene aquifers in the surrounding areas contain high concentrations of geogenic As. Heavy abstraction in Dhaka creates a risk of encroachment of arsenic-enriched water to Dhaka city shallow aquifers.

Methods

Different geospatial data were collected from within Dhaka city and its immediate surroundings: As measurements from 227 wells, lithologic information from 47 drilling logs and a GIS coverage of surface geology. With data from the drilling logs, two-dimensional subsurface geology maps were interpolated at 5-m depth intervals from 0–100m below the earth's surface and 10-m intervals from 100–150m. Four geostatistical risk models were developed using different combinations of surface geology, subsurface hydrostratigraphy and

well depth as independent variable. Pixel-wise logistic regression was then applied for each depth layer using a binary coding of As (above the WHO provisional guideline value of 10 µg/L) as the dependent variable. The goodness of fit of the models was checked using receiver operating characteristic (ROC) curves. The area under the curve (AUC) represents the likelihood that the model correctly predicts the actual risk, and an AUC of 70 % or higher is taken to be a good result. Finally, depth-wise risk maps were integrated to produce a summary map of As risk (Fig. 1).

Results

In the study area, seven hydrostratigraphic units (three aquifers and four aquitards) were identified from the borelogs. The uppermost aquifer correlates with the Holocene epoch Bashabo Formation, while the two deeper aquifers are older, i.e. from the Pleistocene Madhupur Formation. Arsenic levels exceeding 10 µg/L were most frequently found in moderately shallow depths of about 25m below ground. Arsenic levels were negligible between 0 and 10m, and decreased with depth below 25m. As was rarely found at more than 100m below surface.

All four geostatistical models concurred well with the data obtained. The model using only earth's surface information yielded an AUC of 76 %, which increased

to merely 77 % when well depth was added. When subsurface geology was included (without surface geology), AUC was higher than 80 %, and the best fit of 85 % was reached using both subsurface and surface geology. Well depth was not significant in this model.

26 depth-wise As risk maps were produced and revealed very low risks of As in any area more than 100m below surface. The highest risk was found in the Holocene sediments within the 20–40-m depth range. This unit is found mainly outside Dhaka, but also extends into the eastern and southeastern parts of the city.

Conclusions

The different geostatistical logistic regression models produced maps of high and low risk zones matching available data well and allowing prediction of risk in areas lacking sufficient data. The simplest model, using only surface geology, gave results that were nearly as good as the more complicated models using subsurface geology. Preparing subsurface geology maps was time-intensive and required detailed drilling logs that were not always available. In the absence of such data, simple surface geology models are more practical and also yield good results. Well depth is normally available when As concentrations are measured. Model performance was slightly better when depth is included as an independent variable.

The models confirm that As risk is low in Dhaka city and suggest that the rapidly declining groundwater levels in Pleistocene aquifers have not resulted in As migration from surrounding Holocene aquifers. Yet, Holocene sediments found in the southeastern reaches of the city, are at relatively high risk of As contamination. Since few As data were available from these zones, future investigations should target these areas for water quality monitoring.

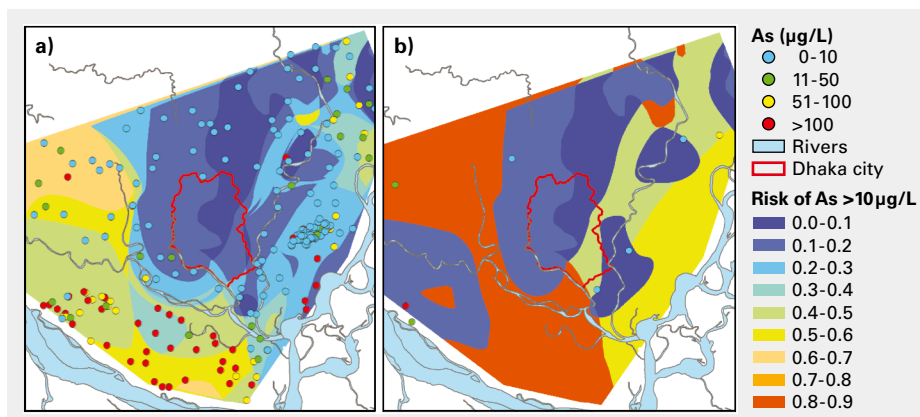


Figure 1: Results from model including surface and subsurface geology: (a) depth-integrated risk map and (b) risk map at 35 m below surface. Dhaka city corporation outlined in red.

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Risk Assessment of Fluorosis in Rural Villages of the Ethiopian Rift Valley

High levels of fluoride in groundwater in the Ethiopian Rift Valley have raised concern among scientists in the past. Most studies to date have focused on investigating the distribution and concentration of fluoride in groundwater, but intake from food can also contribute to dental and skeletal fluorosis. Feleke Zewge¹, Tesfaye Emiru¹, Pawan Labhasetwar², Richard Johnston³, Annette Johnson³

Introduction

Health impacts of fluoride intake, such as dental, skeletal and systemic fluorosis, depend on intensity and duration of exposure, as well as on the age of the individual. To mitigate fluorosis in an integrated manner, it is important to understand the level of fluoride exposure from water and other sources, exposure level of specific age groups, health and economic impacts, dietary patterns, and nutritional status of the endemic communities. The purpose of this study was to assess the health impacts in terms of disability adjusted life years (DALYs) from fluoride in endemic communities, using a Quantitative Chemical Risk Assessment (QCRA) tool [1].

Methodology

Surveys were carried out in eight villages in the Ethiopian Rift Valley where fluoride is known to exceed national standards (1.5 mg/L) in drinking water. Dental fluorosis was assessed using Dean's Index [2], and skeletal fluorosis was evaluated on the basis of a physical exercise method developed and field tested in India [3]. Daily fluoride intake was assessed by a questionnaire survey, including sampling and analysis [4] of foods.

Dental and skeletal fluorosis prevalence was converted into DALYs for each village. Since fluorosis is not fatal, DALYs

are equivalent to years lived with disability, which were calculated using weighting factors of 0.003 and 0.24, for dental and skeletal fluorosis, respectively [5]. The duration of disability for skeletal fluorosis was taken as twenty years [6], while that for dental fluorosis was established at four years, signifying the duration of mineralisation.

Results

Fluoride levels in drinking water in surveyed villages ranged from 3–11 mg/L, with a resulting exposure of 3.7 to 20 mg/day from water (Fig. 1a). The contribution of food to fluoride intake ranged from 4 to nearly 15 mg/day. There is suggestive evidence of skeletal fluorosis at total fluoride intakes above about 6 mg/day, and clear excess risk when total intake exceeds 14 mg/day [7]. All of the surveyed villages exceeded the first threshold (6 mg/day), and five exceeded the second (14 mg/day).

In Miskan and Kulfo, where fluoride levels in water were lowest, food was the dominant exposure route. In the other six villages, water was the most important source of total daily intake of fluoride. Skeletal fluorosis contributed 98% of the total DALY burden in the villages, so in Miskan, Kulfo and Dibisa, where no skeletal fluorosis was detected, DALY burdens

were low. Two villages had a high fluorosis burden, while in three villages, where water contained more than 10 mg/L fluoride, the DALY burden was extremely high. Water was the main exposure route in all villages exhibiting skeletal fluorosis.

Conclusions

In all the studied villages, the daily fluoride intake and disease burden was found to be much higher than the recommended levels, but with significant variation at the individual level. Drinking water is the principal contributor of fluorosis, and DALYs are a useful tool for the continuous monitoring of success interventions. The survey reveals the importance of providing fluoride-free drinking water. Skeletal fluorosis could be significantly reduced with this measure alone.

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- [4] Malde, M.K., Zerihun, L., Julshamn, K., Bjorvatn, K. (2003): Fluoride intake in children living in a high-fluoride area in Ethiopia – Intake through beverages. *International Journal of Paediatric Dentistry*, 13(1), 27–34.
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- [6] UNICEF/NEERI (2007): *Integrated fluorosis mitigation: guidance manual*, Nagpur, India.
- [7] WHO (2011): *Guidelines for drinking-water quality*, 4th edition, WHO, Geneva.

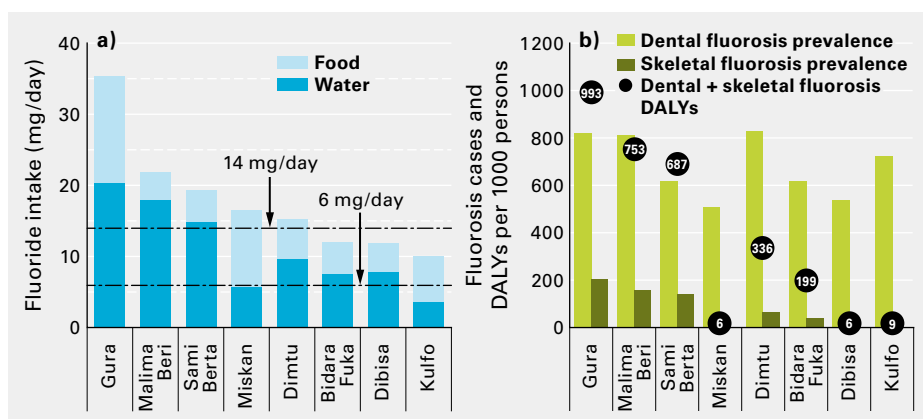


Figure 1: Fluoride intake from food and water (a); and fluorosis burden (b).

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Organic Waste in Indonesia – Diversifying Markets with Innovative Products

Sandec is currently finalising negotiations on an organic waste management research project in Indonesian cities. This project will link to an on-going infrastructural project focussing on emission reduction in cities through improved solid waste management, funded by the Indonesian government via the Ministry of Public Works and assisted by the German Development Bank and the Swiss State Secretariat for Economic Affairs (SECO).

Designing treatment for value rather than treatment for disposal is at the core of this research project. Biogas or biochar as fuel, protein as fishmeal, compost as soil amendment or fertiliser are just examples of products which can be derived from organic waste processing. Assessment of the local market potential and demand will help choose the most viable treatment options from a business and sustainability viewpoint. Sidoarjo and Pekalongan, on the island of Java in Indonesia, are the selected research sites.

Treatment technologies will be studied and piloted taking into account a robust organisational and institutional setup. The research will be conducted in close collaboration with the Gadjadara University (based in Yogyakarta) for the engineering component, the Islamic State University (based in Jakarta) for the economic and institutional component, the Research Centre of Public Works (based in Bandung) for the dissemination and training aspects, and the University of Applied Sciences in Berlin for logistics modelling and spatial analysis. Its main goals are to:

- Foster a business approach to boost employment opportunities in organic solid waste recycling.
- Push for private sector and community-oriented solutions.
- Explore innovative technical and managerial approaches for organic waste processing to broaden market penetration for products derived from waste treatment.



Partnership Between Eawag and Helvetas Swiss Intercooperation

The SODIS Reference Centre at Eawag/Sandec has been supporting the promotion of Solar Water Disinfection (SODIS) for more than 10 years. As a result, the method is currently being used by some five million people in more than 20 countries. In November 2011, the efforts to promote SODIS and other methods of household water treatment paved the way for a new collaboration:

Eawag entered into a formal partnership with Helvetas Swiss Intercoopera-

tion (www.helvetas.org) to strengthen the promotion of household water treatment methods, particularly the SODIS method.

The partnership combines Sandec's research capacities and the competences of Helvetas Swiss Intercooperation in development cooperation. It aims at using the different complementary skills of each partner to optimise the individual efforts and efficiency in providing safe water to developing countries. Moreover, the partnership also opens new collaboration

opportunities in fields such as sanitation or geological contamination of drinking water.

Helvetas Swiss Intercooperation, an experienced Swiss NGO active in the water sector in 30 countries, will be responsible for implementing household water treatment projects, policy dialogue and advocacy work at country level. Sandec's activities will centre on research, technical backstopping and advocacy at international level.

Forthcoming Event

GeoGen2013 – International Conference: Towards sustainable safe drinking water supply in developing countries: The challenges of geogenic contaminants and mitigation measures
5–7 February 2013 in Addis Ababa, Ethiopia

The sustainable supply of contaminant-free drinking water (focussing on arsenic and fluoride) requires a multifaceted approach. Conference topics will include:

- Health challenges for mitigation
- Policy
- Fluoride and arsenic mitigation options
- Behavioural change / acceptance
- Private-public partnership

Two-page abstracts on one of the main conference topics can be used for oral or poster presentations. For submission deadline and further details see our website www.eawag.ch/geogen2013



Call for Information

Comparing Costs of On-Site Sanitation Infrastructure in Asia & Sub-Saharan Africa (see article on page 7)

What do on-site sanitation facilities cost in your country? How are material, transport and construction costs allocated? Do you know interesting examples of high or low-cost installations? What and how much material is used at what price?

We would greatly appreciate receiving your information on the cost figures of on-site sanitation infrastructure.

Please share your data (ideally broken down into bills of quantities) by sending us an email at lukas.ulrich@eawag.ch.

New Faces

Magalie Bassan, MSc

in Environmental Engineering from EPFL, is specialised in sanitation. She has been working at Sandec since 2009, where she is responsible for managing our project in Burkina Faso in close collaboration with the National Utility. Her activities focus on optimising operation and maintenance of wastewater and faecal sludge treatment, organising stakeholder consultation and training, as well as disseminating information. She has coordinated several studies on faecal sludge, including characterisation, financial flows, byproduct valorisation, and management schemes incorporating stakeholder participation.



Selina Derksen-Müller, BSc

in Environmental Sciences, is currently completing her Masters in Environmental Engineering at the ETHZ. She joined Sandec in March 2010 as an Intern in the Gravity-Driven Membrane (GDM) Filtration project. In September 2011, she started working as a Project Officer in the Drinking Water group. Her current field studies focus on the performance of the first generation prototypes of GDM filters in Kenya and on design of the second filter suitable for large-scale production at an affordable price.



Christian Riu Lohri,

completed his MSc in Environmental Sciences at Wageningen University in The Netherlands. He has already conducted various Sandec projects on anaerobic digestion of organic solid waste in Tanzania, Nepal and Ethiopia before joining the Sandec group in March 2012. His tasks as a Project Officer in the Solid Waste Management group comprise research on innovative solutions in organic waste management, including development and testing of new technical approaches, decision-support tools for technology selection and promising business models for successful operation and maintenance of biowaste valorisation technologies.



Anne Matter holds a

MSc in International Relations from IHEID Geneva. She joined Sandec as Research Associate in December 2011 during her last semester of postgraduate studies in Development and Cooperation at Nadel ETH in Zurich. In 2011 she worked in Bangladesh and conducted a research on solid waste management and on the role of the informal recycling sector. She wrote a publication on this topic (in print). Currently, she is updating and developing the Sandec Training Tool.



Martin Affentranger,

MSc in Geography, joined Sandec in March 2012 as a temporary administrative employee working primarily in the Solid Waste Management group. His main tasks at Sandec currently comprise graphic illustration of the Biogas Handbook for Developing Countries, optimising tables and photos, compiling factsheets of case studies, and layout activities in general. Labelling the Sandec photos in the E-Pix database and updating the Sandec website also belong to his support activities.



Lars Schöbitz, Env.

Engineer from Germany, will start at Sandec in August 2012 with our Resource Recovery and Reuse (RRR) project in the faecal sludge management sector. Lars has an Engineer's degree from the University of Applied Sciences Giessen-Friedberg. He worked previously with the Pollution Research Group at the University of KwaZulu-Natal in South Africa. Lars will be developing metrics and indicators of business models, evaluating market demand and conducting environmental and human health impact assessments.



The Sandec Team



From left to right:

Standing: Fumbi Crescent, Chris Zurbrügg, Matthias Saladin, Caterina Dalla Torre, Selina Derksen-Müller, Maryna Peter, Bastian Etter, Sämi Luzi, Rahel Künzle, Philippe Reymond, Yvonne Vögeli, Ulrike Messmer, Jennifer McConville, Regula Meierhofer, Stefan Diener, Fabian Suter, Christoph Lüthi

Kneeling: Hung Nguyen, Magalie Bassan, Lukas Ulrich, Christian Riu Lohri, Amalia Gallardo, Innocent Tumwebaze, Rick Johnston

Missing on photo: Linda Strande, Sylvie Peter, Monika Tobler, Martin Affentranger, Anne Matter, Carina Flückiger

Associated doctoral students: Jean Birane Gning, Ebenezer Soh Kengne, Parfait Koffi Kouame, El Hadji Mamadou Sonko, Amadou Gueye, Alsane Seck, Tu Vu Van, Achara Taweesan

On the Bookshelf

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

Water and Sanitation

WASHCost Briefing Note 1a, Life-cycle costs approach – Costing sustainable services

Estimating the true cost of extending sustainable WASH services to poor households is an on-going problem for WASH service providers. How can we achieve the most while spending the least? WASHCost addresses this challenge by developing and testing the life cycle cost approach in rural and peri-urban areas of developing countries. Using the life cycle cost approach enables service providers to consider a wide range of costs. The life cycle approach compares effectively the different WASH delivery systems within a district, country or region. The approach can therefore be tailored to specific needs and critical issues in different countries.

By Fonseca, C. et al., IRC Int. Water & San. Centre, Nov. 2011, 40 pages, Available as pdf download (481.2 KB) from www.washcost.info/page/1557

Sanitation financing models for the urban poor (Thematic overview paper 25)

This Thematic Overview Paper attempts to search for pro-poor financing models that can facilitate the urban poor's access to complete sanitation services. It catalogues existing financing models and examines each based on an analytical framework that comprises six criteria. It offers a recommendation for mixing financing mechanisms to meet the urban poor's needs, and makes a plea for developing poor-specific and full-cycle specific plans for sanitation.

By Christine Sijbesma, IRC Int. Water & San. Centre, Nov. 2011, 124 pages. Available as pdf download (3.6 MB) from www.source.irc.nl/page/68618

GLAAS 2012 Report, UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water – The challenge of extending and sustaining services

This second UN-Water GLAAS report presents data received from 74 developing countries, covering all the Millennium Development Goal regions, and from 24 external support agencies, representing approximately 90 % of official development assistance for sanitation and drinking water. Sections 1 and 2 of the report describe the efforts of countries to be accountable and to plan and coordinate effectively. Section 3 presents data on financial flows. Section 4 examines the adequacy of the human resource base to implement WASH interventions and highlights the gaps in data. Section 5 describes the successes and constraints to extending WASH coverage in an equitable way. Section 6 describes priority setting, targeting of development aid, and the coordination and alignment of assistance with country programmes. Section 7 focuses on sanitation, hygiene and drinking water in schools and health-care facilities, reporting on access to WASH services in these public institutions.

By WHO, 2012, 112 pages, ISBN 978-92-4-150336-5, Available in English and French as pdf download from www.who.int/water_sanitation_health/publications/glaas_report_2012/en/index.html

Compilation of 13 factsheets on key sustainable sanitation topics

This factsheet book is a compilation of 13 thematic factsheets produced by the eleven SuSanA working groups. What makes these factsheets special is that they are multi-authored by people from different organisations and by free-lance consultants. The factsheets were developed in a long process involving many discussions and review loops which were mostly carried out in public, e.g. at working group meetings, with the working group mailing lists or, since July 2011, also in the open SuSanA discussion forum (<http://forum.susana.org/forum/categories/6-susana-working-groups>). The target audience for this document includes practitioners, programme managers, engineers, students, researchers, lecturers, journalists, local government staff members, policy makers and their advisers or entrepreneurs. The emphasis of this document is on developing countries and countries in transition.

By von Münch, E., Ingle, R., Mbalo, D., Kappauf, L. (eds.), Sustainable Sanitation Alliance (SuSanA) and GIZ, Germany, 2012, 116 pages. Available as full pdf download (5.48 MB) from www.susana.org/lang-en/library/rm-susana-publications?view=ccbkttypeitem&type=2&id=1229

On the Right Track – Good practices in realizing the rights to water and sanitation

The UN Special Rapporteur on the human rights to safe drinking water and sanitation, Ms Catarina de Albuquerque, carries out thematic research, undertakes country missions, collects good practices, and works with development practitioners on the implementation of the rights to water and sanitation. In 2011 she reported on good practices for the implementation of the rights to water and sanitation of a range of stakeholders, including State bodies, international agencies, service providers, nongovernmental organizations and civil society. Her reports cover many approaches to realizing the rights to water and sanitation, including legislation, planning, service delivery, advocacy and capacity-building, monitoring and litigation. Through her research she found more experiences than could be included in her formal reports, and she decided to publish a book of good practices as an opportunity to examine the practices more deeply, include more practices and attempt to address some of the more thorny questions.

By Catarina de Albuquerque and Virginia Roaf, February 2012, 223 pages, ISBN 978-989-8360-09-0. Available as pdf download (3.3 MB) from www.ohchr.org/Documents/Issues/Water/BookonGoodPractices_en.pdf

Excreta and Wastewater Management

Capital and Operating Costs of Full-Scale Fecal Sludge Management and Wastewater Treatment Systems in Dakar, Senegal

This article provides a financial comparison of a parallel sewer based (SB) system with activated sludge, and a faecal sludge management (FSM) system with on-site septic tanks, collection and transport (C&T) trucks, and drying beds conducted in Dakar, Senegal. The results of the

study illustrate that in low-income countries, vast improvements in sanitation can be affordable when employing FSM, whereas SB systems are prohibitively expensive.

By Dodane, P.-H. et al., Environ. Sci. Technol., March 13, 2012, 46 (7), pp 3705–3711. DOI: 10.1021/es2045234. Available as a downloadable open source article from <http://pubs.acs.org/doi/abs/10.1021/es2045234>

Wastewater Irrigation and Health – Assessing and Mitigating Risk in Low-Income Countries

Edited by Drechsel P. et al., 2010, 433 pages, Earthscan/IWMI/IDRC, ISBN 978-1-84407-795-3. This book, which we recommended in your Sandec News No. 11, 2010, is now available also as a French document titled: Irrigation avec des eaux usées et santé – Évaluer et atténuer les risques dans les pays à faible revenu.

By Presses de l'Université du Québec and IDRC, 2011, 488 pages, D3160, ISBN 978-2-7605-3160-4. Available as hardback for \$ 35 or as a 1-page summary from www.puq.ca/catalogue/livres/irrigation-avec-des-eaux-usees-sante-13497.html

Solid Waste Management

Collection of Municipal Solid Waste – Key Issues for Decision-makers in Developing Countries

Solid waste collection faces a range of challenges, and the difficulties faced by one city can be very different from those experienced by another. The aim of this booklet is to assist the reader to find help for the array of different challenges. The first chapter presents some basic principles of good solid waste collection. Chapter 2 summarises the challenges that commonly face decision-makers and suggests strategies for improving the effectiveness, efficiency and acceptability of solid waste collection services. Chapter 3 suggests key points on decision-making. The booklet is written for decision-makers in the fields of local politics, management and technical issues who are concerned to upgrade the solid waste collection service for which they are responsible. By UN-HABITAT, 2011, 38 pages, ISBN 978-92-1-132385-6, HS/094/11E. Available as pdf download (2143 KB) from www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3231

What a Waste: A Global Review of Solid Waste Management

This book illustrates the current and expected (by 2025) global solid waste management situation. It also highlights the enormous budgetary deficit the cities are experiencing in the solid waste sector. Global municipal solid waste production, currently 1.3 billion tonnes per year, is projected to reach 2.2 billion tonnes/year by 2025.

By the World Bank, Urban Development Series, March 2012, No. 15, 98 pages. Available as a full pdf document (8 MB) or chapter-wise from <http://go.worldbank.org/BCQEP0TMOO>