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Water research is an essential part of finding solutions to the challenges faced by the Global South.

2023 has been an exciting year for Sandec! A three-member Eawag delegation took part in the UN Water Conference, which took place 22–24 March at the UN Headquarters in New York City. This was the second such conference in more than 50 years. Over 10,000 delegates from 150-member states, civil society, academia, the private sector, NGOs and other stakeholder groups gathered to discuss water and its related challenges and opportunities in five-themed dialogues and over 400 side events. The main outcome of the conference was the adoption of the *Water Action Agenda*, compiling 700+ voluntary commitments of countries and stakeholders to meet the global water-related goals and targets of the Sustainable Development Goals. Eawag was involved in co-organising more than five sessions, and its representatives were speakers in 15 sessions, including high-level interactive dialogues and side events on topics ranging from planning tools to financing WASH. Two Sandec members were part of the Eawag team.

This year, we have hired a dedicated knowledge broker who will strengthen the transfer and dissemination, and ultimately the uptake of Sandec's main research findings. Dr. George Wainaina will work to ensure that our key research and documents (e.g. the upcoming Water Compendium) reach the wider audience of development practitioners (SDC, other bi- and multilateral IDAs, development NGOs, implementation practitioners, and decision and policy makers). He will also ensure that practitioners have opportunities to shape our research for wider societal impact by gathering their input and knowledge. This new position was made possible through generous funding by the Swiss Agency for Development and Cooperation (SDC).

Finally, since 1 January 2023, Eawag has a new Director: Professor Martin Ackermann. Martin studied biology at the University of Basel, where he obtained his doctorate in 2002. Martin joined Eawag in 2007. He knows Eawag inside out because he led the Environmental Microbiology research department, one of the global leaders in aquatic microbiology. He is well known in Switzerland, as he was the Vice-President of the Swiss National COVID-19 Science Task Force that advised the government on evidence-based measures dealing with the coronavirus in April 2020 and the Task Force President from August 2020 to August 2021. "Water research is an essential part of finding solutions to the challenges faced by the Global South", says Ackermann. "Climate change mitigation and adaptation and sustainable rural-urban landscapes, for instance, are important Eawag research themes, and both have a strong impact on people and the environment".

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

Best regards –
Christoph Lüthi, Director Sandec

Photographer: Alessandro Della Bella

Municipal Solid Waste Management

Municipal solid waste management is one of the major environmental challenges of urbanisation. Together with local partners, Sandec's Municipal Solid Waste Management group research focuses on developing innovative concepts and appropriate solid waste management solutions with a strong emphasis on recycling approaches. Special consideration is given to:

- Researching how to treat biodegradable (i.e. organic) municipal waste and using appropriate technologies to derive products of value, thus, generating incentives and business opportunities in waste management.
- Assisting decision-makers with tools to apply sustainable and integrated waste management approaches, including financial mechanisms for cost recovery and cash flow, and evaluation of strategic alternatives.

Photo The waste collection area of a Black Soldier Fly facility in Kampala, Uganda, run by Marula Proteen.

Photo by Stefan Diener.

Macro-plastic Pollution – A Case Study From Egypt

Poor municipal solid waste management services contribute greatly to macro-plastic leakage into the environment. Although estimating the amount of pollution is a challenging, this information is crucial for planning improvements.

Amira El Manadely[1,2], Dorian Tosi Robinson[1], Mustafa Elkhedr[3], Capucine Dupont[2], Maria Kennedy[2], Christian Zurbrügg[1]

Introduction

The Waste Flow Diagram (WFD) is an open-source tool that enables assessments of macro-plastic pollution. Developed in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, University of Leeds, Wasteaware and Eawag, the WFD tool helps map and visualise the material flows within a municipal solid waste management (MSWM) system, and quantifies the amounts, sources and fates of plastic leakage into the environment.

With the support from the Eawag Partnership Programme (EPP) and in collaboration with IHE Delft Institute for Water Education, this case study applied and validated the WFD tool in Sheikh Zayed City, Egypt. The overall objective was to improve the waste management system by providing data for evidence-based decision-making and to check the user friendliness and applicability of the WFD tool [1].

Approach

Interviews with stakeholders gave insight into the existing MSWM services and detailed observations disclosed the state of waste services at each stage of the service chain. Expert judgement of leakage factors based on leakage influencers and fates of leakage – as proposed by the WFD methodology – allowed for a first approximation of total plastic leakage into the environment. Improvement scenarios were then created with the WFD to assess how to reduce plastic pollution.

Results

The municipality provides waste services (34%) in Sheikh Zayed City, as do private companies (66 %). The municipality uses containers that are often old and damaged. Due to low collection frequency, overflowing occurs, resulting in residents disposing of their waste indiscriminately. Collected waste is disposed at a designated disposal site. Waste of value is recovered directly from containers by people in the informal sector and by waste scavengers at the disposal site.

The private sector also uses containers, which are mostly newer and smaller than those of the municipality and emptied daily (except Friday). Because the private companies pay to obtain the waste from the residential areas, their main objective is recovery of value. Collected waste is transported off-site for recovery, recycling and disposal of residues. Although lack of cooperation from the private sector hindered direct observations at these sites, it is assumed that there is a maximum plastic recovery rate of 70% based on studies from other cities and opinions from waste experts.

Based on the results from the WFD tool, our study estimates a total plastic waste leakage of 2.3 % to 2.5 % of the total plastic waste generated. The main point of leakage is the collection stage in areas of the municipal services. Another source of leakage is the disposal site, where there is a lack of environmental control measures (Figure). The fate of this leaked plastic is onto land, as there are no water bodies near the city.

Conclusion

Improvement scenarios were modelled with the WFD tool that took into account their socio-economic feasibility and two scenarios show significant leakage reduction. The first relies on a door-to-door collection service, a material recovery facility (MRF) and an upgraded disposal site, while the second envisages household waste segregation, inclusion of the informal sector and an improved landfill. The first would require high capital and operational costs, which is a barrier to implementation. The second, on the other hand, would require behaviour change by the waste generators to ensure waste segregation and the inclusion of the (existing) informal sector. •

References

[1] El Manadely, A., 'Deficient Solid Waste Management Services – A Source of Plastic Leakage into the Environment? – A Case Study of Sheikh Zayed City, Egypt', Master of Science Thesis (IHE Delft Institute for Water Education, 2023).

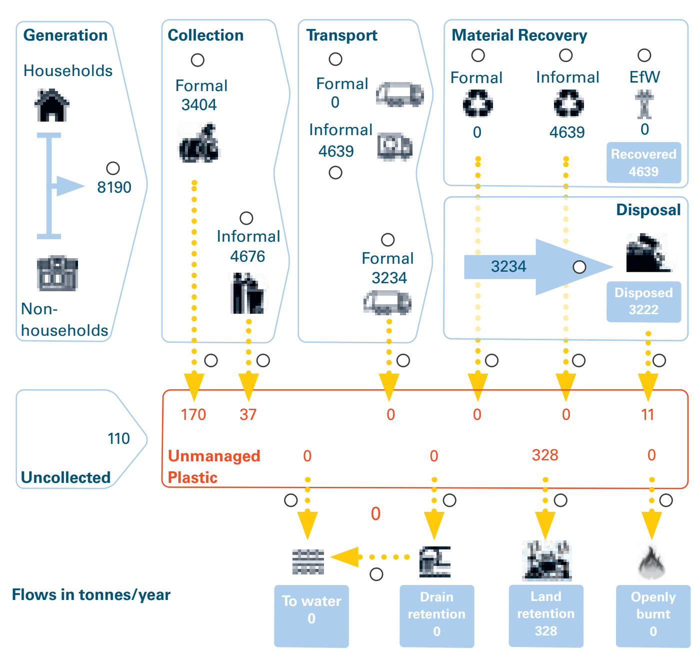

Figure: Baseline flow diagram for the municipal waste services of Sheikh Zayed City.

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The thesis was funded by the Eawag Partnership Programme (EPP) and defended at IHE in April 2023.

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Guidelines for the Safe Disposal of Solid Waste in Humanitarian Contexts

Safe disposal of solid waste in humanitarian contexts is critical to ensure it has limited impact on public health and the environment. Sandec is collaborating with the Geneva Technical Hub to develop and publish the *Guidelines for the Safe Disposal of Solid Waste in Humanitarian Contexts*. Dorian Tosi Robinson[1], Sara Ubbiali[1], Christian Zurbrügg[1]

UNDP

Photo: New landfill in Cox's Bazar refugee camp in 2019 [1].

Solid waste management in humanitarian response

Safe solid waste management is key to limit the environmental and public health impacts of waste. In humanitarian contexts, the risks are even higher as people of concern can be highly exposed to and directly impacted by solid waste mismanagement. This includes: the inhalation of toxic fumes from the open burning of waste, contamination of drinking water and soil, flooding risks due to solid waste clogging drainage systems or increased disease transmission by vectors that proliferate when solid waste is mismanaged. Despite its significant impacts, solid waste management is often not considered a priority in humanitarian responses. Limited funding, lack of service ownership and the reluctance of local governments to provide designated spaces for solid waste treatment or disposal are just some of the reasons for this neglect.

Collaboration with the Geneva Technical Hub

Sandec is contributing to the development of several guidelines and tools to support practitioners on how to improve solid waste management in humanitarian settings. Led by the Geneva Technical Hub (GTH) and the United Nations High Commissioner for Refugees (UNHCR), this initiative is gathering best practices for safe solid waste management during protracted humanitarian crisis. The first output of these efforts will be the *Guidelines for the Safe Disposal of Solid Waste in Humanitarian Contexts*.

The Guidelines

Through an interactive decision tree, the Guidelines support the planning process for new disposal sites and help in analysis of conditions at existing sites, as well as offering targeted improvements. An example of a disposal site from the Cox's Bazar refugee camp in Bangladesh is shown in the Photo. The guide explains what aspects are critical to assess and to enable at disposal sites, thereby developing practitioners' awareness of and knowledge about the key features of a well-functioning disposal site. By using this guide, the target audience – the implementing stakeholders – can identify areas that require upgrades and learn how to achieve them, so that the level of control and management at the disposal site can be improved to ensure proper and safe operations. The guide also provides a complete list of mitigation measures that practitioners must select from according to the context and available resources. Lastly, there is a section that advises the practitioners with regard to key operational tasks and procedures, as well as management principles, e.g. planning and operation of individual cells at a disposal site.

The first version of the *Guidelines for the Safe Disposal of Solid Waste in Humanitarian Contexts* is under review with an envisaged publication date of September 2023. Once published, UNHCR staff and partners will implement it in the field to evaluate its effectiveness. If required and when requested, Sandec can contribute to further capacity building efforts and also support implementing partners on how best to apply the recommendations of the Guidelines.

Conclusion

Final disposal alone cannot solve the challenging problem of solid waste in humanitarian responses. In this sense, this guide is only one part of an integrated approach to solid waste management services. The complete service chain, including generation, collection and transport, treatment, resource recovery and disposal plays an essential role in sustainable service delivery. With this in mind, other guidance documents are being developed in coordination with the GTH that are targeted to humanitarian practitioners, for instance, on how to manage organic waste or the anaerobic digestion of organic waste. •

References

[1] *Standard Operating Procedure (SOPs): External use of the Temporary Solid Waste Facility (TSWF)*, (UNDP, 2020).

[1] Eawag/Sandec, Switzerland
Funding: Swiss Agency for Development and Cooperation (SDC)
Partners: UNHCR
More information: Geneva Technical Hub
Sandec: https://www.eawag.ch/en/department/sandec/projects/sesp/water-sanitation-and-hygiene-in-emergencies/
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Waste Segregation in Vietnam: What Factors Influence Household Behaviour?

Changing behaviour towards waste segregation at source is challenging and cannot be achieved by policies alone. The RANAS approach was applied in the city of Tuy Hoa, Phú Yên Province, to identify how to best design an effective behaviour change intervention. Laura Stocco[1], Thi Hanh Tien Nguyen[2], Jurgita Slekiene[3], Christian Zurbrügg[1]

Laura Stocco

Photo: Administration of questionnaires in Ward 5, Tuy Hoa.

Introduction

Waste segregation to recover valuable resources is an essential part of the movement towards a circular economy and sustainable solid waste management (SWM). Vietnam has taken a significant step towards achieving this by ratifying the Law on Environmental Protection, which requires nationwide waste segregation by 2025. However, while policy changes are essential, understanding the psychosocial drivers that underpin waste management practices in households is equally crucial. There is a gap in research on the driving forces of waste segregation behaviour in Vietnam, making it challenging to design the effective behaviour change interventions needed to achieve the new national goals. This study investigated current household waste management practices in Vietnam and sought to identify the key behavioural drivers influencing these practices using the RANAS approach [1]. The aim is to design effective and lasting behaviour change interventions in Vietnam and encourage the use of a systematic approach to foster waste segregation.

Context

Phú Yên Province, located in South Central Vietnam, is known for its exceptional natural heritage and is a popular tourist destination. Phú Yên's provincial capital, Tuy Hoa, has a high level of economic activity and a growing population (156,600 inhabitants in 2022). It generates a large amount of solid waste that is a challenge to the current waste management system and services.

The SWM system in Tuy Hoa City is structured as shown in the Figure. The Phú Yên Town Environment Joint Stock Company (URENCO) collects mixed waste, while the informal sector plays a crucial role in recyclables collection, comprised mainly of plastic bottles, metals, paper, and cardboard. Specifically, junk buyers (locally known as "Nhôm nhựa", literally "aluminium and plastics") purchase or collect recyclables from households and commercial units, while waste pickers extract the remaining recyclables from waste storage sites (public places, disposal sites, etc.). The recyclables are traded to junk shops, which further sell them to other intermediaries and finally to recycling facilities.

The city disposal site (landfill) has almost reached its full capacity. Given the challenges of finding a new disposal site, the provincial authorities support pilot initiatives to increase waste reduction and recycling by the World Wildlife Fund (WWF) and our project partners GreenHub (a local Non-governmental organisation) and IDE-E (the non-profit Institute for Development, Environment and Energy). To enhance the recycling efforts, EAWAG in partnership with Pheenika University in Vietnam is engaging in applied research using the RANAS approach [1, 2], to better understand the behavioural factors that influence waste segregation by households.

Method

A qualitative pre-survey was conducted in 30 households to identify the actions involved in solid waste segregation practices. This was complemented by focus group discussions. Pre-survey results allowed for the identification of a spectrum of segregation practices in the selected neighbourhoods. A standardised RANAS questionnaire was then developed, following the RANAS methodology, and implemented in KOBO toolbox. It consisted of question sets corresponding to the following psychosocial factors: Risk, Attitude, Norm, Abilities and Self-regulation. The team of researchers and Vietnamese students discussed and translated the questionnaire. After undergoing three days of training, the Vietnamese students administered the survey to more than 515 people over the entire study area, resulting in 450 valid interviews.

The survey was conducted after coordination with street leaders and comprised face-to-face interviews at community centres (Photo). The collected data was analysed in SPSS to identify the relevant and key psychological factors influencing waste segregation behaviour. Specifically, the answers of those who already practised the behaviour (*doers*) were compared to those who did not (*non-doers*).

Results

The results show that women were predominately responsible for waste management segregation at home. The most frequently segregated materials were non-organic recyclables, e.g. aluminium cans, pet bottles, cardboard and paper, which were typically sold or given to junk buyers. Low value plastics (Polypropolene or Polystyrene) were not of interest to the junk buyers and were typically not separated. People felt that their separation efforts were futile because no incentives existed for the informal sector to collect the

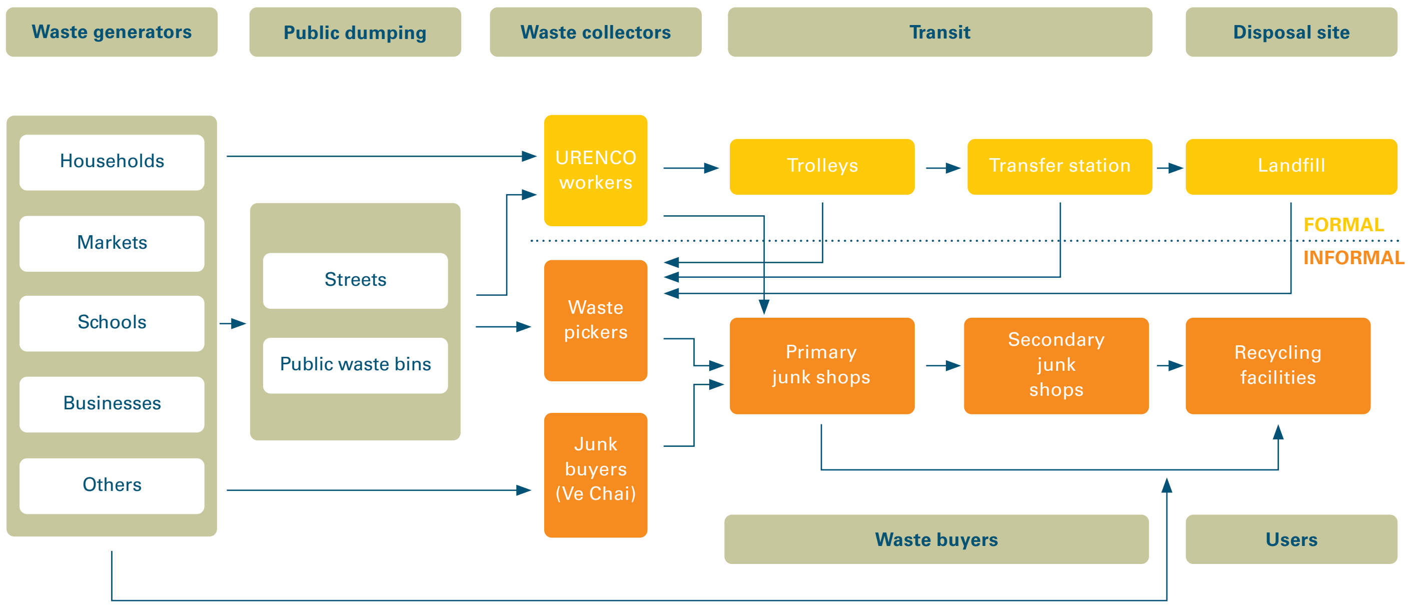

Figure: Simplified waste management system in Tuy Hoa City. The formal sector activities are in yellow; the informal sector activities, focused on non-organic recyclables, are in red. Adapted from [3] by Vincent Decroocq, IDE-e.

materials and this led to a lack of motivation to segregate the waste. Many households in the city commonly kept food waste separate to give for free to neighbouring farmers and pig owners as animal feed.

Doers were defined as individuals who segregated their recyclables as a matter of "habit" and who reported a firm "intention" to segregate waste. There were significant differences in the responses of doers versus *non-doers* and this allowed for the identification of the relevant behavioural drivers that motivated people to either segregate their waste or not to do so. Some of the common factors identified were: knowledge of how to segregate waste and why, different feelings associated with waste, i.e. disgust, shame, pride, satisfaction, and care, feelings of personal importance, such as obligation and guilt, confidence in performance, and commitment. These findings will be covered in more detail in Stocco, L. et al. 2023 [4].

Conclusion

The study results provide valuable insights into waste management practices and the psychosocial factors driving non-organic recyclables segregation. For example, asking people to segregate recyclables that currently have no perceived value to the informal sector remains challenging. This highlights the need of authorities and policymakers to more actively engage and involve the informal sector in waste segregation and to use the existing stakeholders and structures to strengthen resource recovery value chains at the regional and national levels. Based on these systematic findings, targeted behaviour change interventions are being developed for implementation in late 2023. •

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[4] Stocco, L. et al., 'What drives household segregation of recyclables in Vietnam?', (2023), In preparation.

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The opinions, findings and conclusions or recommendations expressed herein are those of the Author(s) and do not necessarily reflect those of the funding organizations.

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The Waste Flow Diagram – Mainstreaming its Application

The Waste Flow Diagram toolkit helps map and visualise municipal solid waste management system material flows to quantify amounts, sources and fates of waste leakage into the environment. New training videos on how to use it and an online portal for data upload are now available. Christian Zurbrügg[1], Dorian Tosi Robinson[1], Andrew Whiteman[2], Maya Zaatar[2], Steffen Blume[3]

Background

The Waste Flow Diagram (WFD) toolkit was developed in a collaboration between Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, University of Leeds, Swiss Federal Institute of Aquatic Science and Technology (Eawag) and RWA-Wasteaware to help city authorities assess the quantities and fates of unmanaged municipal solid waste (MSW) released into the environment. It maps the waste flows using a Material Flow Analysis (MFA), covering all stages of the solid waste management (SWM) system from generation to collection, transport, treatment/recovery, and disposal. This assessment can be the basis for informed decision-making at city level to improve the solid waste service and infrastructure system. Scenarios of improvements can also be run through the WFD to assess how a proposed intervention may affect the system and reduce plastic pollution into the environment.

Figure: Screen shot of the Training Teaser Video for WFD, available on YouTube.

Need for mainstreaming

The WFD relies on a rapid assessment, mostly through direct observation, to generate a first-level approximation of plastic leakage. The reliability of these results depends on a variety of factors, for instance, the skill and determination of the WFD assessor to obtain results that are representative of the city, and the quality and reliability of data, including whether primary data was freshly collected or not. Training and support resources for users contribute not only to the quality of the assessment, but can incentivise local authorities to collect the baseline data required to understand the weaknesses of the solid waste management system and to decide on key solutions. Using the WFD has been proven to facilitate engagement with stakeholders, build a sense of ownership for the SWM system and assist in the development of mitigation activities that suit local circumstances. To-date, over 100 WFD assessments have been implemented globally under a range of different initiatives with a variety of different objectives. The majority have been prepared by waste management consultants and practitioners, and in a few cases have been implemented by city/ municipal waste managers with training and backstopping support.

Learning to apply the WFD

To build on the practical experience of the many WFD assessments carried out thus far and to support future applications, the WFD team developed further resources to support and facilitate application of the WFD tool, and to provide a central hub for storage and analysis of results.

A comprehensive application support and training package can be accessed at: https://wfd.rwm.global

- The excel-based WFD tool
- A user manual accompanying the WFD tool
- Two general videos for decision makers: a) Intro explaining the WFD approach, key function and data requirements, and b) Application example explaining how the WFD quantifies plastic leakage and determines its fate in the environment
- Three video courses for learning how to apply the WFD tool
- Train the trainer course for consultants that implement WFDs

WFD data portal and compendium

To facilitate WFD assessments, to show data and to foster data sharing, a WFD data portal has been developed. It features full WFD computations, as well as a graphic generator for the Waste Flow and Sankey diagrams, and also integrates with the Waste Wise Cities Tool (WaCT: https://unh.rwm.global/Welcome/Resources) and its data portal. The WFD portal also includes general information about the WFD, a repository of case studies, a blog, tutorial videos, training material and a marine litter data catalogue. Furthermore, it allows for peer-to-peer exchange and support through a forum.

With a growing repository of case studies, it is now possible for people to apply data analytics and, for instance, categorise case studies along key parameters, which could assist in finding suitable measures of improvement for SWM systems based on their city profile. In addition, general lessons from two years of WFD applications and the results of 50 case studies were published in a compendium covering a wide range of realities of solid waste management and cultural practices [1]. •

Reference

[1] Whiteman, A. et al., *The Waste Flow Diagram: Identifying Leakages from Municipal Waste Management Systems – Compendium of Case Studies* (Bonn: GIZ, 2023).

[1] Eawag/Sandec, Switzerland
[2] Resources and Waste Advisory Group (RWA GROUP), RWA-Wasteaware
[3] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Compendium of Case Studies:
https://wfd.rwm.global/wp-content/uploads/2023/05/en-giz-wfd-compendium-2023.pdf

Waste Flow Diagram (WFD): Training Teaser Video:
https://www.youtube.com/watch?v=3lDs9TsMVKw

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The Sustainable Waste-based Insect Farming Technologies Project

A new transdisciplinary project on Black Soldier Flies and the transformation of organic waste has received three-years of funding from the "Solution Oriented Research For Development" (SOR4D) Programme of the Swiss Government. Christian Zurbrügg[1], Stefan Diener[1], Daniela Peguero[1], Konstantin von Hoerner[1]

Background

In waste management, the need for improved practices remains highly relevant. Waste is still seen as a challenge rather than a resource to be utilised. Improper waste methods, such as dumping and open burning, contribute to greenhouse gas emissions and pose significant health and environmental threats. To address these issues, waste-based Black Soldier Flies (BSF) insect farming offers an economically attractive alternative. With increasing food uncertainty and population growth, this organic waste processing approach can produce animal feed, helping to increase the resilience of smallholder farmers and strengthening food production for local markets. In Sub-Saharan Africa, poultry, pig and fish husbandry are the fastest growing agricultural sectors, but are unable to realise their full potential due to high feed costs. Waste-based BSF insect farming aims at alleviating the challenges of food security, job and livelihood creation, and environmental protection.

Objective

SWIFT's objective is to enable and foster adoption of waste-based BSF insect farming technologies by smallholder farmers and small and medium enterprises. The project's location is in Uganda and Malawi.

Approach

Waste-based BSF insect farming involves adult fly and egg production and the growing of BSF larvae using waste substrates. Grown larvae are harvested for use as animal feed, while the residue and insect manure (frass) that remain can be used as an ideal soil amendment (Figure). The use of wastes as a substrate to create value incentivises recycling and reduces the environmental impact associated with improper waste disposal. Farms can develop this as a side activity or a small and medium business, and provide a new livelihood opportunity for women and youth farmers or entrepreneurs.

This transdisciplinary project is based on the Livelihood Platforms Approach and the concept of technology adoption and innovation platforms, and addresses specific research gaps. It consists of four thematic research work packages (WPs) and crosscutting activities:

WP1 looks at waste substrates with the aim to strengthen the knowledge base of development partners and practitioners regarding the challenges and suitability of waste-based BSF insect farming. Research will assess waste practices, quantities and qualities, and waste suitability for insect farming at two locations (Jinja, Uganda; Mzuzu, Malawi), using field sampling, observation, interviews, surveys and multi-criteria analysis.

WP2 centres on co-development of insect farming design, equipment and operations to establish adaptable blueprints and implement pilots in each country. The pilots will serve as demonstration and training sites.

WP3 focuses on insect products and markets and emphasises market entry and financial feasibility of farming operations. It involves market surveys, perception assessment, and extension work with farmers. A cost-revenue model will be developed based on primary data from the pilot units with the objective to develop business models and assess their financial viability and the socio-economic impacts of different organisational setups.

WP4 evaluates how communities and institutions impact insect farming, comprising studies of institutional, legislative and economic enabling conditions. This includes analysing the potential of carbon trading as a financing mechanism and assessing legislative and institutional barriers and opportunities using research methods, such as interviews, focus group discussions and multi-stakeholder dialogues.

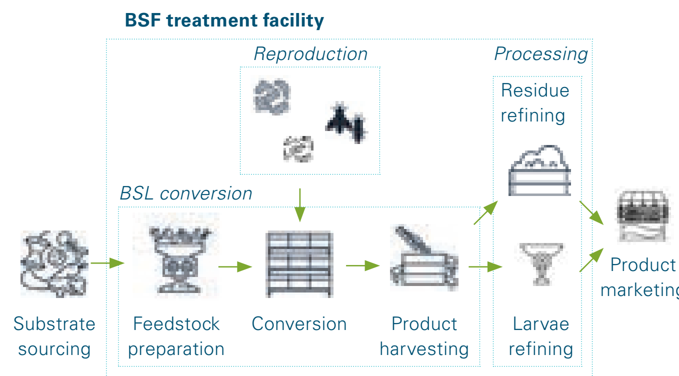

Figure: Different units of a waste-based BSF insect farming system.

All work packages rely on participatory methods and close interaction with a wide range of stakeholders in all research phases. In this regard, innovation platforms and a science-policy-practice dialogue will be established involving all stakeholder groups.

Funding and partnerships

The Municipal Solid Waste Group at Eawag-Sandec and its partners in Uganda and Malawi will receive close to 1,000,000 CHF funding for three years. The project team consists of research partners Frank Mnthambala at Mzuzu University in Malawi and Allan John Komakech at Makerere University in Uganda. The development partners are Esther Lupafya of Soil Food and Healthy Communities in Malawi and Sheila von Hoerner at Bioconvision in Uganda. SWIFT's objective is to better understand which elements of an enabling environment can foster an innovative approach to better mainstream BSF-insect farming in these two countries and beyond. Contact us directly to be on our mailing list and receive updates and to join the community of practice of waste-based insect farming with Black Soldier Flies. •

[1] Eawag/Sandec, Switzerland

Acknowledgments: The project is funded by the Swiss National Science Foundation (SNSF) and Swiss Agency for Development and Cooperation (SDC) through the Solutions Oriented Research for Development (SOR4D) programme.

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Black Soldier Fly Larvae Generate Heat – Can We Make Use Of It?

While feeding on waste, larvae of the Black Soldier Fly generate heat and increase temperature levels in the substrate up to 47 °C. Can this energy be captured and used for another purpose? A bench scale experiment provides the first results. Stefan Diener[1], Luca Heinrich[1], Riccardo Zaghi[2], Christian Zurbrügg[1]

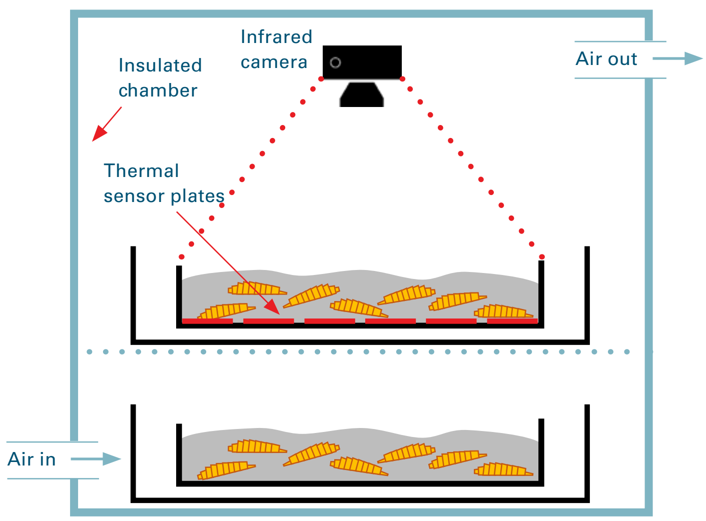

Figure 1: Experimental set-up with the two larval trays within the climate chamber (left) and the modified tray with the temperature sensor plates, the IR-camera and the RaspberryPi 4 (right)

Background

Waste processing by Black Soldier Fly (BSF) larvae is considered a promising organic waste treatment technology, due to the high waste reduction potential, while producing valuable products. Young BSF larvae are placed on organic waste where they feed for about two weeks, reducing the biomass by up to 70%. The grown larvae are harvested and sold as animal feed for fish, poultry or pets. Operating BSF facilities, thus, allows for the establishment of inclusive business models, fosters job creation and contributes to a circular economy.

BSF facilities control and accelerate the natural life cycle of BSF to treat waste and produce marketable products. While the reproduction of the young larvae requires expertise, the actual stage of waste treatment by larvae is relatively simple. If the larvae have enough waste to feed on and can benefit from suitable environmental conditions, the process is straightforward. When operating in closed settings (shipping containers or closed storage rooms), favourable environmental conditions can be ensured using off-the-shelf equipment to control the system as needed. This becomes especially relevant in climatic areas with seasonal climatic variations or with strongly fluctuating temperatures between day and night (e.g. Nairobi, Addis Ababa or the Andean region).

BSF larvae usually feed in aggregations. This maggot-mass effect, also observed in blowflies and carrion beetles can result in significantly higher "inner bunch" temperatures of up to 10–30 °C above ambient air temperature. Although the cause of this effect remains unclear, assumptions are that it is due to microbial activity, larval exothermic digestive processes, or a result of the frenetic movements of the larvae. However, there is currently no clear evidence supporting any of these hypotheses [1]. Especially when operated at a large scale, the energy produced by the BSF larvae may even lead to overheating of the treatment area, which then reduces their feeding performance or even leads to mass exodus of the larvae. It is, therefore, desirable to extract this excess heat. Ideally, such excess energy could be reused for other BSF process units, for example, to preheat the air for the waste treatment unit. This saving of energy costs is particularly interesting in temperate climates or in areas with strong day-night temperature fluctuations.

But what is the potential for recovering the heat generated by the larval activity? This was evaluated in a bench-scale experiment.

Methodology

Two containers filled with five-day-old larvae were placed in a heat-insulated chamber (V = 240 litres). Each container (39 x 26 x 10 cm) received 5,070 larvae (5 larvae/cm^2), which were fed with moist poultry feed (UFA 625, 75 % dry matter). Larvae were obtained from the BSF research colony at Eawag (Dübendorf, Switzerland). The larvae hatched within 24 h and were first fed ad libitum with poultry feed (UFA 625, 75 % H_2O) for five days. The mean dry weight at experimental start was 0.75 mg/larva. Feed portions for the feeding experiment were based on a feeding rate of 40 mg TS/larva/day and a feeding time of 12 days. Feeding took place on the first day (1/3 of total feed) and day four (2/3 of total feed) using poultry feed at 75 % H_2O. Ten larvae were removed daily from both containers to determine the development of growth. The experiment was terminated after 18 days.

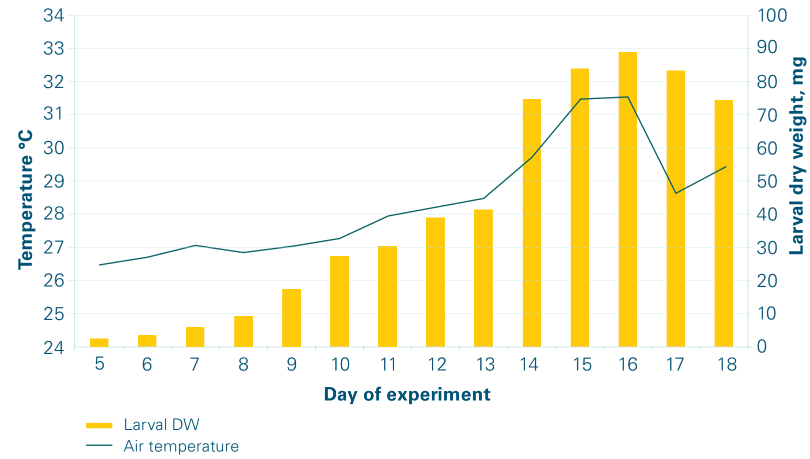

Figure 3: Daily average temperature in the climate chamber and larval dry weight (temperature drop at day 17 caused by a cold external environment on that particular day).

Two temperature sensors and two humidity sensors (Aosong, AM 2315) were used to measure incoming and outgoing air. For one container, an infrared camera (Melexis, MLX90640 32 x 24 IR array) was used to measure the surface temperature of the material (Figure 1). To measure the substrate temperature, one of the two plastic containers was fitted with 20 aluminium plates, which were equipped with temperature sensors (Maxim integrated, DS18B20). Single-board computers (Raspberry Pi 4) were used to record and store the measurement data.

Results

The larval activity produced a maximum temperature in the substrate of up to 47 °C (Figure 2). Much of this heat is generated when a strong weight gain of the larvae is also evident. The temperature decreased after day 16, either due to the limited availability of nutrients in the substrate or due to the transformation of the larvae into prepupae. At that time, when their feeding stops, the larvae use up part of their energy reserves, which is reflected in a loss of weight (Figure 3).

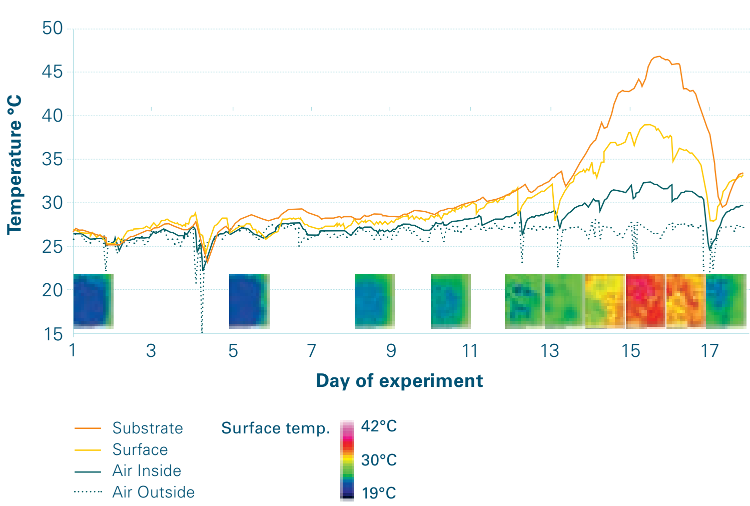

Figure 2: Temperature of outside air and of different media inside the climate chamber.

A limited share of the heat in the substrate can be measured and visualised at the surface of the substrate. The infrared camera recordings show constantly shifting hotspots, depicting a very dynamic larval activity. Some of the energy is transferred from the substrate to the air, and can increase the air temperature by a maximum of 5.5 °C. In the substrate, however, temperature variations can reach up to 20 °C. These results are consistent with other studies of larvae that feed in aggregations, such as maggots of the sheep blowfly *Lucilia cuprina* [2].

Conclusion

Over the entire larvae development period, the average temperature difference between incoming and outgoing air from the climate chamber was only 1.42 °C. However, depending on the climatic conditions (cold nights, rainy season, etc.), heating up the outside air with a heat exchanger could be an interesting option; even an additional 1.4 °C could help to reduce electricity consumption when fresh air going into the facility has to be pre-heated. Furthermore, one must bear in mind that these results relate to 10,000 larvae. If applied to a scale of a 20' shipping container as a corresponding climate chamber, the number of larvae would be around 5 – 7 million. A next step is to estimate to what extent our results will scale, and at which size (number of larvae) the use of a heat exchanger might become interesting, and to calculate the possible energy savings when using a heat exchanger to preheat the inflowing air. •

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Management of Excreta, Wastewater and Sludge

Globally, sustainable solutions that are equitable and safe are required for urban sanitation. Access to safely managed sanitation can be achieved through implementation of a range of appropriate technologies tailored to the realities of climate change and rapidly growing cities, with integrated combinations of sewered and non-sewered, and onsite, decentralised, and centralised technologies. Sandec's Management of Excreta, Wastewater and Sludge research in this area includes:

- **Collaborative research:** Conduct applied research to develop the fundamental knowledge required for integrated management and technology solutions.
- **Technology innovation:** Research the development of safe and effective management of excreta, wastewater and sludge to meet treatment and resource recovery goals with industrial and implementation partners.
- **Facilitating sustainable implementation:** Uptake of research by integration of knowledge into policy through dissemination and strategic partnerships.

Photo Suzan Atim transporting barrels of fecal sludge in Kampala, Uganda. She is the Director of Perfect Emptiers Uganda SMC Ltd., General Secretary of Gulper Association Uganda Ltd., and was the African Pit Emptying Champion 2020/2021.

Photo by Shafic Katumba.

Vermifiltration: Optimising and Scaling-up for Domestic Wastewater Treatment

Vermifiltration is an economic, robust, and sustainable non-sewered sanitation technology for domestic wastewater treatment. This four-year research project aims to address current knowledge gaps in vermifiltration research related to optimisation and scaling-up. Kayla Coppens[1], Serge Stoll[1], Linda Strande[2]

Introduction

Vermifiltration (VF) is a non-sewered sanitation (NSS) technology that harnesses the symbiotic relationship between earthworms and microorganisms. Earthworms break down solids, aerate the compost via tunnelling, and enhance the microbial community with the addition of their own gut microorganisms and enzymes [1]. Microorganisms biologically degrade pollutants common to wastewater and fecal sludge, such as organics and nitrogen [1].

VF offers several advantages that make it an attractive global solution, including: cost-efficiency, robustness, minimal energy requirements, use of local materials, and creation of value-added by-products (e.g. compost) [2]. The utilisation of VF effluent for irrigation provides sustainable sources of nutrients (N, P, K) and closes the current linear cycles (water, nutrients) [2]. Limitations of VF include its sensitivity to temperature (optimal temperatures from 20 to 35 °C) and its large space requirements [2].

VF has been implemented on a full-scale in various countries, including China, Germany, France, India, Rwanda, the USA and Switzerland, where more than 10 VF systems are in use. Despite this widespread use, 'Vermifilter' remains a vague term for which an optimised treatment model has yet to be scientifically defined. Although available literature focuses on optimal design, operating parameters and treatment mechanisms of VF, research on the effects of scaling-up and the long-term performance of full-scale vermifilters is lacking [3].

Targets

In February 2022, a four-year research project began that aims to overcome the following knowledge gaps: **1)** Functioning of VF on a full-scale and scaling-up of laboratory models, **2)** Greenhouse gas emissions from VF, **3)** Fate of micropollutants during VF and **4)** Use of VF effluent for fertigation.

Equilibre

Photo: Vermifilter installation at the housing cooperative, Equilibre, in Geneva, Switzerland. The installation is located underground in the yard of the apartment building and covered by a wooden terrace upon which children play and adults stop to chat.

Methods

The project's first step was a preliminary study that evaluated the treatment performance of a full-scale vermifilter, constructed in 2017 by the housing cooperative Equilibre in Geneva, Switzerland (Photo). It took place between November 2022 to January 2023 (Figure). 24-hour flow-proportional samples were collected monthly after each treatment step and various quality parameters were analysed (temperature (T), dissolved oxygen (DO), pH, conductivity, COD, TN, NH_4-N, NO_3-N, TP and PO_4-P, TSS, TOC, DOC, and common domestic micropollutants).

Results

Results from the preliminary study show that the effluent quality meets European [4] and Swiss standards [5] for wastewater discharge (Table). Despite hourly fluctuations in the hydraulic loading rate, the effluent quality remains stable. It is thought that the long hydraulic retention time (estimated to be 10–15 days) smooths out the effects of the varying loading rates. The removal rates of the analysed parameters were calculated for the BW and GW vermifilters, as well as for the entire treatment installation (Table). In general, the observed removal rates of the vermifilters in Geneva are high when compared to what has been observed in the literature [3], which is likely due to the over-dimensioning of the vermifilters, resulting in smaller loading rates and longer retention times.

The treatment processes taking place throughout the vermifilter are thought to be: **filtration** (86 % TSS removal in the BW compost layer); **microbial degradation** (93 % COD removal in BW and 98 % in GW vermifilters); **nitrification** (primarily in charcoal layer of vermifilters, where 44 % of the total nitrogen is in the form of nitrate for BW, and 95 % for GW); and **mineralisation** (62 % PO_4-P increase despite 46 % TP decrease in BW compost layer) [1]. The concentration in dissolved oxygen increases throughout the BW (+ 5.18 mg/L) and GW (+ 6.40 mg/L) vermifilters, which supports the assumed treatment processes listed above, as most are aerobic.

Additionally, it was observed that the vermifilter buffers outdoor temperatures (median outdoor T during the study: 3.7 °C, effluent T: 7.8 ± 3.8 °C warmer). This buffering capacity may explain how VF can function well despite the colder climate.

Conclusion

The preliminary results demonstrate that vermifiltration can successfully be scaled-up and function in colder climates. Additionally, the system requires little maintenance (no skilled labour) and allows for a decrease in potable water needs (47 % of total water use is re-circulated treated wastewater and average potable water consumption: 55 L/P/D (average Swiss habitant uses 142 L/P/D).

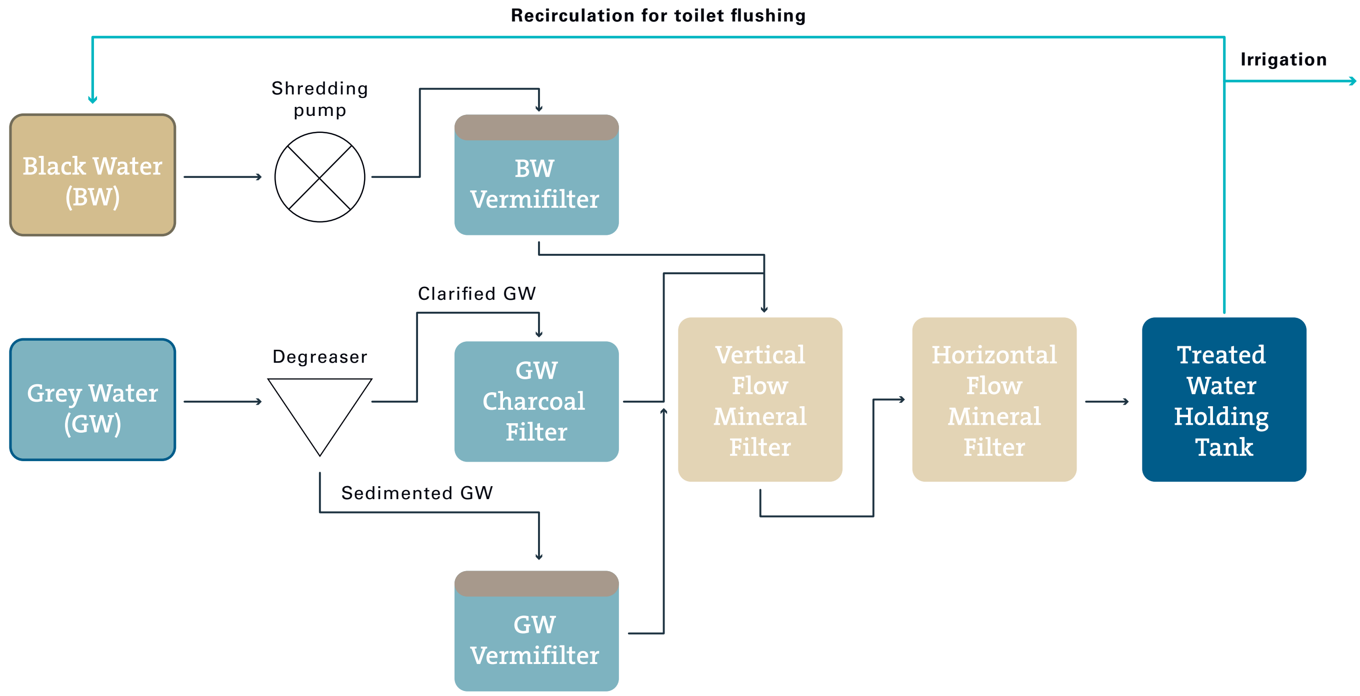

Figure: Diagram of the decentralised treatment installation used for the scoping study. The installation, designed for 112 people, treats 6.2 m^3 of domestic wastewaters daily. Sedimented greywater from the degreaser and blackwater are treated separately via vermifiltration. Clarified greywater is treated by a charcoal filter. The composition of both VFs is (top to bottom): 0.2 m vermicompost with Eisenia fetida and Dendrobaena veneta, 0.1 m fine charcoal, 0.6 m coarse charcoal. After post-treatment by two subsequent mineral filters, the effluent is used for on-site irrigation and toilet flushing.

	Removal Rates (%)					Effluent Quality (mg/L)		
Parameter	Literature VF RRs [3]	BW Vermifilter	GW Vermifilter	Full treatment installation at Equilibre	WWTP*	Full treatment installation at Equilibre	WWTP*	Swiss Standards [5]
Biological Oxygen Demand (BOD5)	50–96%	93%	98%	100%	94%	2.1	10	20
Chemical Oxygen Demand (COD)	50–90%	88%	77%	99%	89%	22.2	36	60
Dissolved Organic Carbon (DOC)	–	31%	92%	98%	88%	7.5	–	10
Total Phosphorus (TP)	10–98%	45%	32%	64%	87%	8.9	1.23	–
Total Nitrogen (TN)	–	21%	-8%	66%	–	54.2	–	–
Ammonium Nitrogen (NH4-N)	10–86%	46%	93%	100%	89%	0.1	2.3	3
Total Suspended Solids (TSS)	55–90%	98%	91%	99%	–	5.5	12	20

Table: *Removal Rates (RR):* The range of removal rates observed in available literature [3], median removal rates for blackwater and greywater vermifilters, and the full decentralised treatment installation at Equilibre in Geneva (n = 3) and at the centralised wastewater treatment plant (WWTP) in Geneva (Aïre) in 2022. *Effluent Quality:* Average effluent water quality (n = 29) for the full treatment installation at Equilibre (effluent of horizontal flow mineral filter), the effluent of the WWTP Aïre in Geneva, and the Swiss standards for discharge into surface waters.

This ongoing project will also analyse greenhouse gas emissions, micropollutant treatment, nitrogen and phosphorus fates and the use of the effluent for irrigation. The main goal is to develop an optimised design and operation model so that VF can be efficiently and safely scaled-up as an effective worldwide NSS solution. •

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Evaluating Metrics to Determine Levels of Stabilisation in Fecal Sludge

Stabilisation of fecal sludge lacks universally agreed-upon metrics and direct comparisons of metrics used in other organic waste management fields is challenging. MEWS is developing potential fecal sludge stabilisation metrics.

S.B. Sam[1,2], K. Kapanda[3], N. Maqbool[4], N. Andriessen[1], B.J. Ward[1,2], J. Tembo[3], S.J. Khan[4], E. Morgenroth[1,2], L. Strande[1]

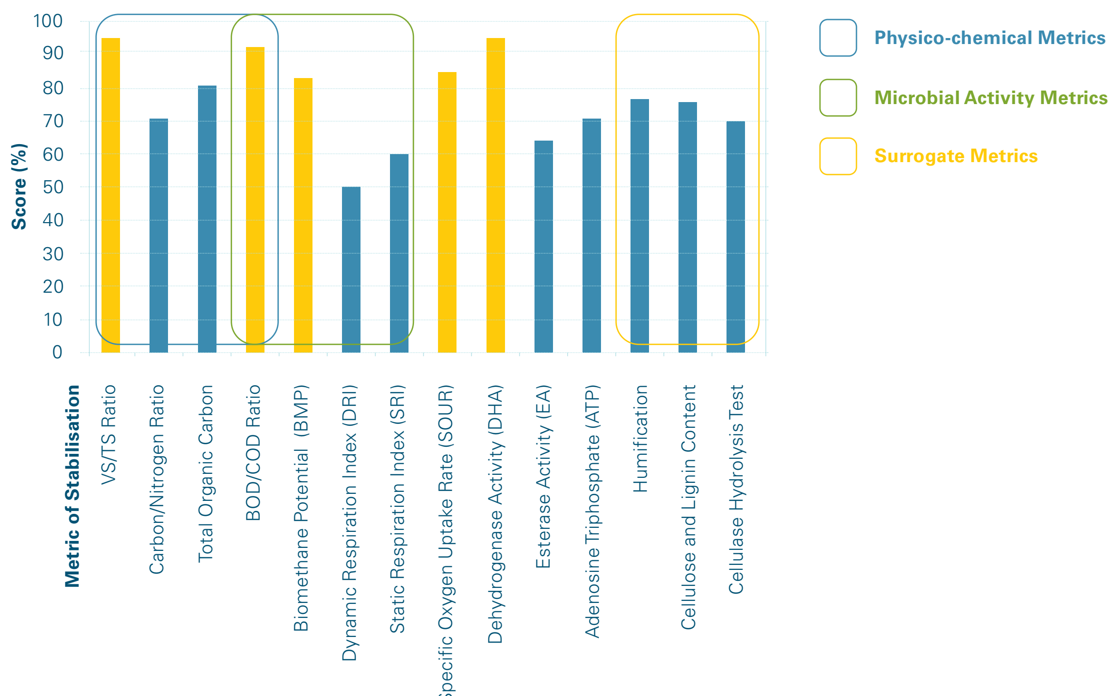

Figure: Stabilisation metrics grouped by type; the resulting score on the y-axis (score %) are based on a weighted criteria for use in Lusaka. Orange bars are the methods selected for evaluation in the laboratory [2].

Importance of stabilisation

Knowledge of the levels and mechanisms of the biodegradation of organic matter, or the 'stabilisation' processes, that take place during onsite storage of fecal sludge is lacking. The composition of fecal sludge is complex, and in laboratory experiments replicating degradation during storage, stabilisation has been observed to plateau after one week [1]. Stabilisation of supernatant following dewatering is an important step prior to discharge into the environment to mitigate the adverse environmental effects caused by readily degradable organic content. For solids fractions, it facilitates resource recovery opportunities related to calorific value or biogas generation. Additionally, there is a positive correlation between levels of stabilisation and the dewatering performance of fecal sludge [1]. Furthermore, the presence of small particles in fecal sludge leads to clogging of drying bed filters, which deteriorates dewatering performance. The process of stabilisation, which reduces these small particles, limits clogging and enhances the overall dewatering performance.

Metrics of stabilisation could be used to predict dewatering performance and other process control variables at fecal sludge treatment plants. However, unlike the management of other organic waste streams, such as municipal wastewater, composts and solid waste at landfills, metrics of stabilisation have not yet been established for fecal sludge. To develop this, the MEWS group has been evaluating metrics of stabilisation in relation to treatment performance.

Current state of knowledge

Kapanda Kapanda recently completed a two-year Master's degree at the University of Zambia focused on metrics of stabilisation. Based on a comprehensive literature survey, Kapanda identified existing metrics that are used in wastewater and compost processes, and ranked them for fecal sludge analysis based on robustness, simplicity, cost, reproducibility, and availability of materials in different settings. Identification of the methods was based on microbial activity, physico-chemical properties, and surrogates consisting of more stable compounds. Microbial activity metrics utilise the activity of microorganisms and enzymes to quantify remaining fractions of biodegradable organic substrates, whereas physico-chemical metrics are proxies that quantify total pools of organic matter. The surrogate methods, which are quicker, easier and less expensive, quantify amounts of more stabilised compounds as proxies of stabilisation. The Figure illustrates the metrics identified during the literature review and those identified for further laboratory scale testing [2].

Based on our research evaluating relationships within quantities and qualities of fecal sludge (See Andriessen's article on p. 23), the volatile solids to total solids ratio (VS/TS) of 1,206 fecal sludge field

Stanley Sam

Photo: Nida Maqbool conducting biomethane potential tests at Eawag to evaluate the rates of degradation of readily biodegradable (sCOD, polysaccharides) and slowly biodegradable organics in fresh and stored fecal sludge and food waste.

samples from 13 countries followed a consistent relationship with a VS/TS of 0.49 (R^2 = 0.88) [3]. The VS are organic matter, quantified as the fraction of TS that are combustible at 550 °C, and for fecal sludge VS/TS is lower than reported for primary wastewater sludge (0.60 – 0.80) or waste activated sludge (0.59 – 0.88). However, as stabilisation metrics, the values cannot be directly compared. The VS in fecal sludge comprise a wide range of readily to slowly or non-biodegradable organics, whereas primary wastewater sludge comprise settled solids from wastewater that have not been stored in containment (versus fecal sludge), and activated sludge is mainly biomass generated during aerobic digestion of wastewater. In addition, TS of fecal sludge contains larger, varying amounts of inert material from soil or non-biodegradable wastes than wastewater, which also commonly undergoes grit removal.

Nida Maqbool's recent study (Photo) that evaluated metrics of stabilisation for prediction of biogas potential, confirmed that VS/TS and Carbon/Nitrogen were not predictors of the bioavailability of organic matter in fecal sludge that had been stored in containment [4]. However, VS/TS were reliable predictors for fresh feces, fecal sludge and food waste that had not been stored prior to treatment.

In both the Maqbool and Kapanda studies, metrics that were specifically based on biological activity were the most promising. These included biomethane potential (BMP), specific oxygen utilisation rate (SOUR), and biochemical oxygen demand (BOD) or BOD/COD. However, the BMP test needs 21 days for analysis, and BOD five days, whereas SOUR two hours. Other chemical metrics that generally indicate readily biodegradable organic matter were also promising, such as soluble COD and polysaccharide concentrations. Establishing optimal metrics for sector wide usage will require more analysis, and will also depend on the intended use. For example, rapid results are needed for process control decisions, whereas general waste flow characterisation can be more in-depth and utilise longer-term methods.

Conclusion

Although VS/TS and C/N can be used to monitor how the stabilisation of compost piles changes with time, or to compare relatively similar organic streams, i.e. primary or waste activated sludge and fresh feedstocks, they are not applicable to fecal sludge that has been stored in containment. Fecal sludge is so highly variable that using VS/TS and C/N, which provide information on similar pools of organic matter, is like 'comparing apples and oranges'. Metrics of the actual biological availability will be more useful, i.e. biological methods BMP, SOUR, and BOD and such chemical methods as sCOD and polysaccharides. •

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Can Next-Generation Sequencing Unravel Anaerobic Pathways in Containments?

The contribution of microorganisms towards stabilising fecal sludge and generating gasses, which could be captured for recovery or harm the environment, remains unknown. Applying sequencing techniques could help quantify these relationships. Kelsey Shaw[1,2], Caetano Dorea[2], Linda Strande[1]

Introduction

Onsite sanitation technologies, particularly non-sewered sanitation systems (NSS), can be an improved form of sanitation. However, research on NSS technologies has lagged behind conventional wastewater treatment, resulting in a lack of operational practices and management solutions. To maximise the potential of NSS technologies, understanding biodegradation mechanisms and quantifying climate impacts, including greenhouse gas emissions, is crucial [1]. Knowledge of organic substrate degradation pathways is vital for sustainable sanitation planning and climate mitigation policies. Within onsite containments, it is typically thought that there are distinct layers. The bottom layer is anaerobic, while the upper layer may demonstrate facultative and aerobic reactions. The anaerobic degradation process in these systems is a complex biological process that relies on a diverse microbial community. The process's stability depends on various factors, i.e. bioavailability of organic matter, key operational parameters, such as emptying frequency and loadings, and such inhibitory conditions as temperature, pH, and ammonia concentration. Newly accessible tools can help us confirm assumptions about the dominant pathway of acetoclastic degradation (i.e. acetate as energy source) [2].

Overview of Next Generation Sequencing Tools

Culture-dependent techniques have identified some microbial populations, but many unculturable archaea remain unidentified. This difficulty in the observation of dynamic microbial changes throughout the anaerobic process can be addressed by the increasing applicability of culture-independent techniques in NSS containments, aided by decreasing costs. The Table highlights the value (performance and challenges) of three types of culture-independent molecular methods, including marker gene sequencing (16S rRNA amplicon sequencing) and the meta-omics approaches of metagenomics and metatranscriptomics. These techniques offer valuable insights into microbial community structure, function, and activity. Combining these methods provides a unique opportunity to understand active metabolic pathways and optimise NSS performance.

Current and future applications

Culture-independent techniques are valuable for studying microbial communities in NSS storage, but few studies focus on methanogens. A recent study by Sam et al. used marker gene analysis on fecal sludge samples from 135 onsite containments. Paired with in situ gas measurements, these tools offer insight into degradation kinetics. To develop climate-resilient sanitation systems, practitioners need to identify key microbial communities in the system that can affect the quality of outputs and their response to environmental changes. Additionally, measuring GHG emissions and identifying potential sources of emissions can allow for targeted interventions to reduce the climate impact. Investigating community composition and structure alone are not sufficient, as it does not give insight into the metabolic pathways, how these organisms interact with their environment, and how it can be harnessed or mitigated for beneficial purposes, which is why a combination of NGS techniques is necessary. To improve our understanding of the microbiome in the containment of NSS, efforts should be made to control factors and develop accessible methods (i.e. open-source data). The costs for NGS are decreasing, with marker gene analysis being the most affordable, while the other two remain costly. However, these methods generate large data sets, and openly sharing data can facilitate other researchers to continue analysis, which could result in further insights into different trends and relationships. •

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Tool	Objective	Performance Metrics (i.e., Cost, Simplicity, Robustness)[1]	Examples of limitations /challenges
Marker Gene	Community Composition	1	Amplification errors (i.e. false reads from sample DNA sequences leading to incorrect identification)
Metagenomics	Community Physiology	2	Compositionality errors (i.e. issues with quantification of total amount of DNA extracted leading incorrect conclusions about the relative abundance of different microorganisms in the sample)
Metatranscriptomics	Community Activity	3	Organisms with high transcription rates (i.e. organisms that are more actively expressing their genes are overrepresented compared to lower abundance but still important organisms).

Notes: [1]Author interpretation based on published peer-reviewed literature – Rankings: 1= lowest (i.e., cheapest, most simple, and least robust) to 4 = highest (most expensive, most complex, and most robust).

Table: Comparison of NGS tools for evaluating microbial communities in NSS.

Determining Fecal Sludge Quantities and Qualities During a Pandemic

During the Covid-19 pandemic, when no international travel was possible, eight institutions collaborated to understand local and global trends of fecal sludge quantities and qualities. This article highlights the most important learnings.

Nienke Andriessen[1], Eugene Appiah-Effah[2], Shirley Browne[3], Rita al Jahjah[4], Joel Kabika[5], Joel Kinobe[6], Naomi Korir[7], Pius Nishimwe[3], Charles Niwagaba[6], Rohini Pradeep[8], Prerna Prasad[8], James Tembo[5], Andruga William[3], Benjamin Ambuehl[9], Linda Strande[1]

Joel Kinobe & Kizito Andrew

Photo: Measuring fecal sludge volume with a Volaser in a septic tank in Uganda.

Introduction

When designing fecal sludge management solutions, it is essential to understand the expected quantities and qualities (Q&Q) of fecal sludge that need to be managed. Because these are highly variable, however, it is difficult to make these projections. In 2021, a new methodology developed to make improved, localised estimations of Q&Qs was published [1]. During the Covid-19 pandemic, the MEWS group and research partners worked together to implement the Q&Q methodology, and field test the Volaser (Photo), a measuring device that can measure volumes of fecal sludge and onsite sanitation systems in situ [2]. 204 samples were collected from onsite sanitation systems in seven countries. The findings and full dataset are available in an open access scientific journal paper [3].

Methodology

Field testing took place in Ghana, India, Lebanon, Kenya, Sierra Leone, Uganda, and Zambia. Each collaborator made a local sampling plan to sample approximately 30 onsite sanitation containments, following the Q&Q methodology described in [2]. Samples were taken with a pit or core sampler and the quality parameters (pH, conductivity, total solids, volatile solids, and chemical oxygen demand) were determined in a local laboratory. Quantities were measured with a Volaser. To ensure datacomparability across locations, it was paramount to have a rigorous quality assurance and quality control strategy. All exchange between collaborators was digital; no in-person meetings took place during the project period. At the end of the project, an external evaluation assessed the pandemic's effect on the collaboration and people's experiences using the Volaser.

Lessons learned

The main takeaways are:

- An empirical relationship was found between volatile solids and total solids of 0.49 ($R^2 = 0.88$), based on 1,206 data points from this study and other published open-source data. Establishing such relationships for fecal sludge is important, as they are different than in wastewater (e.g. volatile solids in faecal sludge are less biodegradable [4]). Such general trends can be useful for city-wide planning or overall modelling approaches.
- The strongest predictor of accumulation rate was containment type.
- Terminology used for onsite sanitation containments (e.g. "pit latrine" or "septic tank") has different meanings across the world, and does not always reflect real conditions. Therefore, their physical characteristics (e.g. fully lined, unlined, with outflow, no outflow, etc.) should be carefully defined before sampling starts.
- Everyone liked using the Volaser, though trouble shooting was impaired in very specific cases due to the purely digital nature of the collaboration.
- Having an established network of international experts was extremely valuable for the success of the project during the pandemic. It meant that there was a mutual level of trust and understanding of capacities, which could be capitalised on.
- You can now construct a Volaser yourself with the videos and manual [2] on our website (www.sandec.ch/volaser)! •

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Towards Low-footprint Dewatering of Fecal Sludge in Dense Urban Areas

Enhanced dewatering of fecal sludge with conditioners can enable low-footprint fecal sludge treatment in dense-urban areas. The Management of Excreta and Wastewater group is researching the knowledge gaps hindering full-scale implementation of this treatment solution. Michael Vogel[1], Nienke Andriessen[1], Maxwell Bergström[1], Julian Fritzsche[1], Benjamin Morath[1], Eberhard Morgenroth[2], Linda Strande[1]

Introduction

Fecal sludge generally consists of more than 95% water. This water needs to be transported to a treatment facility and treated to protect human health and the environment. In non-sewered sanitation systems, this problem burdens the entire service chain, as service providers often struggle to access the fecal sludge containments to empty them due to traffic jams or being located in densely built areas. At conventional treatment facilities, dewatering technologies, such as settling-thickening and drying beds, require a large footprint and have an unpredictable performance. To facilitate the transport and treatment of liquid fecal sludge, approaches are needed that enable low-footprint dewatering closer to the fecal sludge onsite storage containments. Conditioners (i.e. coagulants and flocculants) are widely applied in drinking water and wastewater treatment to remove small particles and condition the wastewater sludge for faster dewatering to higher cake solids. Although the Management of Excreta, Wastewater and Sludge (MEWS) group's research has shown that conditioners reduce chemical oxygen demand and total suspended solids by more than 55% after settling [1, 2], there are research gaps needing to be addressed before low-footprint dewatering can be implemented.

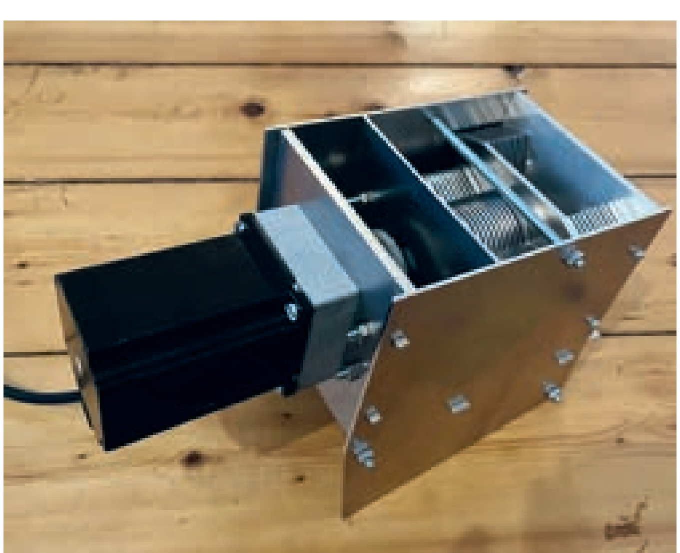
Inorganic and synthetic vs. biological conditioners

Today, most conditioners applied in wastewater or drinking water treatment come from non-renewable sources, such as inorganic minerals (e.g. alum or ferric chloride) or synthetic organic polymers (e.g. polyacrylamide or polyacrylic acid) synthesised from crude oil [3]. The effect of these substances on human and environmental health when released uncontrolled into the environment is unknown. In recent years, conditioners have been produced from renewable biological sources, such as tannins from bark, chitin from shrimp shells, or starch from potatoes [3]. Bio-conditioners can remove as many particles as the non-renewable sourced conditioners if shear exposure is low, for example, with settling-thickening [2].

Supply chain issues are one major reason for the failure of fecal sludge treatment plants because replacement parts and the chemicals required for operation are in short supply. Bio-based conditioners could be locally produced for treatment facilities, which would create a steady supply of conditioners and jobs. Achieving this, however, requires developing and implementing community-based business models that would assess the economics and ecological sustainability of bio-based conditioners for fecal sludge treatment. Technical research on how a stable quality of these conditioners can be achieved from different biological waste streams is also needed.

Floc characteristics

If shear exposure is high, flocs formed after flocculation can break apart. Shear forces are generated during treatment with pumping, changes in flow pattern, and mechanical dewatering processes (e.g. centrifuge or screw presses). Once the flocs fall apart, the small particles in the liquid fraction reduce dewatering efficiency or clog filters, which eventually leads to complete failure of the dewatering technology. Therefore, when selecting a dewatering technology, it is important to consider the requirements for floc characteristics, such as shear resistance and the size of the flocs. A simple test with a stirrer and a beaker can demonstrate how flocs formed with different conditioners hold up to shear exposure. For the test in the Figure, conditioned blackwater (a mixture of excreta, toilet paper and water) was stirred in a beaker with baffles for 30 minutes. During the test, supernatant turbidity was measured every five minutes by stopping the mixing for one minute.



Benjamin Morath

Photo 1: Small-scale, low-cost screw press.

Michael Vogel

Photo 2: Fruit press tested to dewater conditioned faecal sludge.

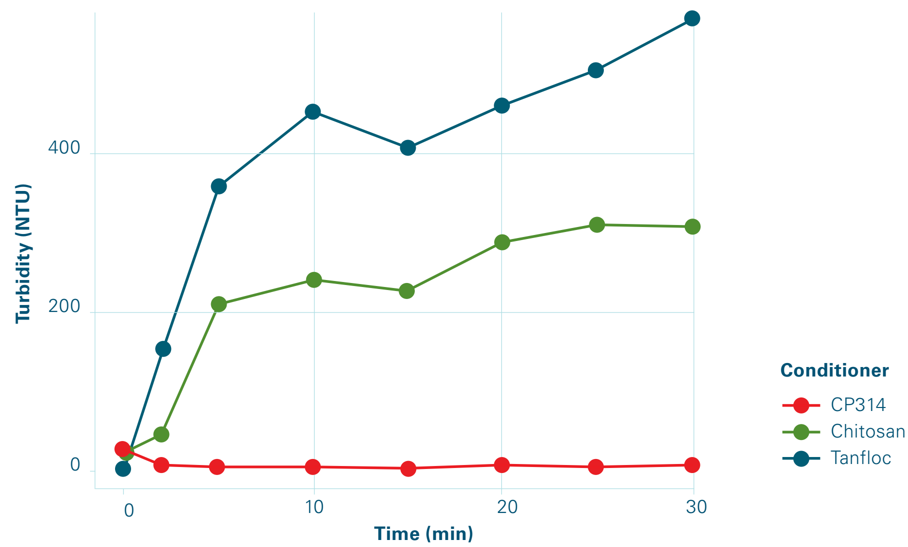


Figure: Turbidity measurements of supernatant over time after inducing shear forces on flocculated blackwater with CP314, Chitosan and Tanfloc.

The supernatant turbidity of the bio-based conditioners tanfloc (tannin-based) and chitosan (chitin based) rapidly increased when compared to CP314 (poly-acrylamide), indicating that flocs from tanfloc and chitosan were clearly weaker. How these results translate to actual dewatering technologies in the field requires more empirical evidence.

Not only does the type of conditioner determine the floc characteristics, but also the dosing amount. Under-dosing causes insufficient floc formation and in the worst cases downstream treatment failure by the clogging of the dewatering technology. Over-dosing can lead to flocs breaking up due to charge-inversion, excess polymers in the supernatant, and increased costs due to inflated conditioner demand. Currently, the MEWS team is testing different sensors in order to accurately predict dosing based on real-time solids, density measurements, turbidity, colour sensors and photos. Our latest results indicate that because of the high variability of fecal sludge characteristics, there will not be one conditioner solution. However, rough estimates of dosing might be possible even with low cost turbidity sensors. Pilot applications must be done to confirm the results and enable full-scale implementation.

Mechanical dewatering technologies

Mechanical dewatering technologies, such as screw or filter presses, greatly reduce the space required for fecal sludge treatment and can achieve higher cake solids than with settling-thickening, but require conditioners to perform as needed. Many mechanical dewatering technologies used in centralised wastewater treatment plants are expensive, complex to operate and difficult to repair. In addition, they are typically dimensioned for much larger centralised treatment facilities and are larger than the size needed for community-scale systems. For the non-sewered sanitation context, one solution could be locally manufactured and even manually operated dewatering technologies. For example, the MEWS team built a prototype screw press for less than 1,000 USD in material costs, which is able to dewater conditioned blackwater up to 25% cake solids (Photo 1). A commercially available fruit juice press with a nylon filter cloth was also tested with the same dewatering performance (Photo 2). Although these results are promising, pilot scale tests are needed to assess how these technologies perform on a larger scale.

Conclusion

Our results confirm that the use of conditioners and the mechanical dewatering of fecal sludge can be an efficient option for low-footprint treatment. However, scaling-up and addressing the identified knowledge gaps require further research and in-field piloting. Technology transfer is not a standalone solution. Many innovations in the software and hardware fields came from community-driven and open-source approaches. The MEWS team would like to foster these methods in the sector to enable the creation of innovative local solutions for fecal sludge technologies, and develop implementation partnerships for adaptive management and technical backstopping. Follow MEWS research regarding the full-scale implementation of conditioners for low-footprint fecal sludge dewatering in our publications and Sandec's social media channels. •

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Strategic Environmental Sanitation Planning

As the world becomes progressively more urban, and humanitarian needs are on the rise, the challenge to provide safe and effective sanitary arrangements becomes even greater. Sandec's Strategic Environmental Sanitation Planning research aims to address the complexity of urban sanitation systematically. Our research combines aspects of engineering with planning methods and social science approaches and includes four fields of activity:

- Developing and validating comprehensive approaches for planning Citywide Inclusive Sanitation that includes a variety of technologies and service delivery mechanisms.
- Exploring the governance and enabling environments necessary for sustainable local service delivery (including financial, technological, socio-cultural and institutional issues).
- Validating appropriate, cost-effective sanitation systems in peri-urban, slum, small town and refugee camp settings.
- Providing backstopping services to humanitarian aid partners on water, sanitation and hygiene in emergencies.

Photo Public toilets in Kakooge Town, Uganda.

Photo by Abishek Narayan.

Lighthouse Initiatives for Decentralised Urban Water Management

Decentralised urban water treatment and reuse systems improve the flexibility, resilience and circularity of water and sanitation infrastructure and, thus, play a key role in developing sustainable cities. The Lighthouse Project assessed highly promising examples from around the world. Vasco Schelbert[1], Christian Binz[2], Christoph Lüthi[1]

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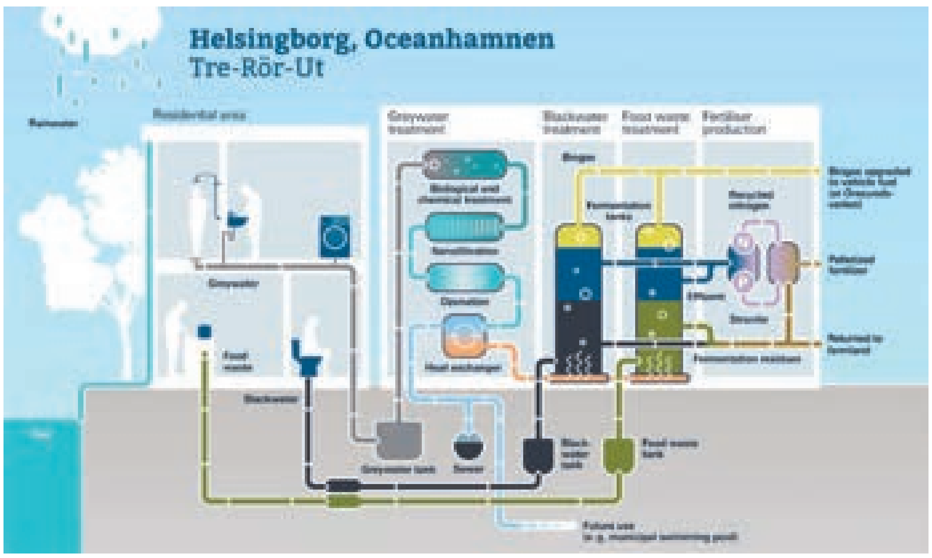

Figure 1: Schematic overview of the 'Tre-Rör-Ut' system implemented in Helsingborg, Sweden. The system recovers biogas for vehicle fuel, nutrients for fertiliser production, concentrated sludge for agricultural application, and greywater for reuse water.
(Own illustration based on www.recolab.se/utvecklingsanlaggning/)

Introduction

Urban water and wastewater management needs to be deeply transformed, away from end-of-pipe to more circular designs. Actors around the world have started developing decentralised urban water treatment and reuse systems (DUWTRS) that create various sustainability related co-benefits for urban communities. DUWTRS treat and recycle water and recover resources (heat, energy, nutrients) locally in closed-loop systems. They increasingly include source-separation, i.e. divide various 'waste flows', such as greywater, blackwater, rainwater or kitchen waste, and convey them to separate treatment processes (Figure 1), which promises efficient treatment and targeted resource recovery.

Despite the high potential of DUWTRS in solving multiple urban development challenges at once, their implementation is confronted with strong barriers. DUWTRS transcend traditional institutional and regulative boundaries between the waste, water and energy sectors, as well as between the public and private spheres. In effect, only a few cities worldwide have successfully implemented innovative approaches at scale. Well-documented templates and best practices of successful DUWTRS implementations are lacking. The Lighthouse Project (LH) assessed key DUWTRS case studies, which can serve as 'templates' and inspire other cities around the world [1].

Research Strategy

To generate practice-oriented lessons, projects at different scales (city-wide vs. neighbourhood) in different contexts (high-income vs. low-/middle-income) and using different technological set-ups were compared. Five criteria were developed to identify potential LH initiatives[1] and four neighbourhood-scale and two city-scale projects were selected for analysis, equally distributed across high- and low-/middle income contexts (Figure 2).

Data was collected between November 2021 and August 2022 through an extensive literature review and semi-structured key-informant interviews. Interviewees were selected from relevant stakeholder groups, i.e. planning, implementation and operation. On average, 20 interviews were conducted for each case, resulting in more than 100 interviews that (combined with an expansive secondary literature review) informed the data analysis. An integrative assessment framework was developed and applied and qualitative analysis tools used to derive the key success conditions for DUWTRS implementations.

Results

Innovative DUWTRS solutions are systemic, cross-sectoral innovations that not only challenge the concept of end-of-pipe infrastructure, but also how it is currently planned, operated and maintained. Our case studies identified three generic models of successful DUWTRS implementation.

[1] They must have all four LH characteristics (cover the entire service chain; long-term perspective; broad-scale adoption; visibility and impact beyond immediate context [2]); include resource recovery (e.g. water, energy, heat, nutrients, etc.); implement a fully developed service chain from collection to disposal/reuse; serve a minimum of 300 residential units; and be in operation for a minimum of two years.

	High-Income Context	Low-/Middle Income Context
City-wide Scale	**Case 1: San Francisco, California, USA** Since 2015, mandatory requirement for new developments above 23,225 m^2 (250,000 ft^2) gross floor area to install and operate an onsite water reuse system.	**Case 4: Bengaluru, Karnataka, India** Since 2004, buildings with 50+ residential units/5,000+ m^2 in unsewered areas must install onsite treatment plants and reuse 100 % of the treated water.
Neighbourhood Scale	**Case 2: Jenfelder Au, Hamburg, Germany** Blackwater, greywater and rainwater separation. Vacuum collection system, biogas and heat production. Serves 630 (uo to 835) residential units, in operation since 2017.	**Case 5: Nirvana Country, Gurugram, India** Treated water from small-scale treatment plant is used for horticulture. Serves 400 residential units, in operation since 2020.
	Case 3: H+, Helsingborg, Sweden Blackwater, greywater and organic waste separation. Vacuum collection system, biogas and fertilizer production. Serves 320 residential units, in operation since 2020.	**Case 6: M3M Merlin, Gurugram, India** Treated water is used for horticulture and toilet flushing. Serves 760 residential units, in operation since 2018.

Figure 2: Overview of selected and assessed Lighthouse Initiatives.

First, San Francisco and Bengaluru exemplify a policy-induced and networked/market-based model, which is arguably the most transformative model. With onsite DUWTRS implemented in various buildings city-wide, key responsibilities shift from public service providers (utilities) to private entities (developers, firms, owners and residents). In this model, private actors plan, implement, operate and maintain DUWTRS, which are permitted and indirectly supervised and sanctioned by the public authorities. The role of the utility shifts from full-fledged top-down control to network facilitation and system intermediation.

Second, neighbourhood-scale solutions, such as Hamburg and Helsingborg, have advanced resource recovery systems and follow a more conventional utility-based model. The public utility still largely covers water and sanitation services, and this is occasionally complemented with private sector involvement if or where allowed or required. However, this model transcends the traditional institutional and regulatory boundaries between the waste, water and energy sectors, as well as between public and private spheres, because it applies advanced source separation and recovery solutions. It requires substantive innovation, which transforms the work of the utilities and related stakeholder groups.

Gurugram illustrates a hybrid model, in-between the two above types. Here, the DUWTRS solution is installed at a district scale, but still mostly managed by private actors and the local RWA's. Many similar hybrid systems can be envisioned that offer 'distributed' or 'cluster' solutions.

Conclusion

Cross comparison analysis of the case studies led to the identification of 10 key ingredients for successful DUWTRS implementation. They need **(1)** a dedicated system integrator who coordinates and aligns the large number of stakeholders and the stakeholders need to be pro-actively connected through formal and informal exchanges. A dense and transdisciplinary stakeholder network **(2)** is essential; this creates joint solutions that transcend boundaries between sectors (water, sanitation, energy, etc.) and between the public and private spheres. Given the long implementation timeframes, DUWTRS need **(3)** stable political and policy support, and receive adequate human and financial resources. DUWTRS implementation is usually confronted by major legal and regulatory barriers and, consequently, **(4)** legal and regulatory arrangements are needed that are adapted to their specific requirements. Legal and regulatory frameworks lead to sustainable outcomes only when combined with an effective approval procedure that clearly outlines the responsibilities of all involved authorities. Thus, **(5)** a well-defined permitting pathway, water quality monitoring and enforcement systems are indispensable.

Since DUWTRS offer a unique opportunity to turn sanitation from a 'waste management' problem into a business opportunity, **(6)** this requires business models and markets for the generated products. A design-build-operate business model that makes the same firm responsible for all the parts requires the design of well-adapted systems, which increase regulatory compliance, robustness, longevity, and, ultimately, economic viability. To support market formation, **(7)** industry-internal standardisation, certified trainings and information sharing are key. Given the 'yuck factor' connected to the smells of wastewater, creating legitimacy for DUWTRS is not an easy task. Therefore, **(8)** an active communication and public outreach strategy that builds awareness is required. To support this, **(9)** publicly accessible pilot- and demonstration projects were key for public legitimation and technology development. Because DUWTRS have high costs, especially when compared to conventional (and often highly subsidised) centralised solutions, **(10)** finding financially and economically viable system designs (in a full system and infrastructure lifecycle perspective) is necessary for any local authority implementing DUWTRS. •

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SaniChoice: Sanitation Technology Choices for Development and Emergencies

SaniChoice is a sanitation technology and system selection tool that builds on the Compendium of Sanitation Systems and Technologies and an advanced technology selection and system builder tool developed at ETH Zürich. After testing in Nepal, it is now freely available online. Dorothee Spuhler[1], Basile Weber[1], Mingma Sherpa[2], Andreas Scheidegger[1], Christoph Lüthi[1]

Basile Weber

Photo 1: Changunarayan Municipality in Nepal.

The selection of a locally appropriate and sustainable sanitation technology and system configuration is a complex multi-criteria decision-making problem. It involves an increasing number of technologies and often-differing stakeholders' preferences. In sanitation planning, experts usually handle the initial technology selection, but often lack the knowledge and data to consider a broad range of options and selection criteria systematically [1]. However, the final technology choice can only be as good as the set of options available.

To fill this gap, a model was developed that draws from methods of Multi-criteria Decision Analysis (MCDA) and substance flow modelling. It can assess the appropriateness of technologies for a given context, find all viable system configurations, from the toilet to the final use and/or disposal, and quantify the performance of the system regarding financial requirements and resource recovery (nutrients, water, organics, or energy). However, the model lacked a user-friendly control panel, which led to the development of SaniChoice.

SaniChoice in a nutshell

SaniChoice is an open-source online tool for capacity development and decision support. The aim is to make sanitation technology and system selection more evidence based. It consists of a sanitation technology and system selection web-application, tutorial videos, a practitioners' guide, and a training package with presentations and exercises.

The application contains information organised as factsheets on more than 90 technologies [2, 3, 4] with technologies requirement data [1]. The specific case settings can be defined by 28 criteria related to geo-physical, technical, socio-cultural, legal, financial and management aspects. This allows for computing an appropriateness score for each technology to assess its fit to the local context. The technologies are compared on a dashboard, where unwanted options can be removed. For the remaining technologies, SaniChoice then provides the most appropriate system configurations. The user can further narrow down the options by including or excluding certain types of systems (wet, dry, biomass or urine diversion), or the degree of centralisation (onsite, decentralised, centralised or hybrid). The dashboard provides the key parameters of the technologies, as well as a system overview, which permits comparisons of the most appropriate options based on an appropriateness score, resource recovery potentials (phosphorus, nitrogen, total solids, and water), financial requirements, technical maturity, and system complexity – all specifically evaluated based on the provided local context.

Planning with SaniChoice

WASH practitioners are the main target group of SaniChoice, including consultants, and community-based or non-governmental organisations. A step-by-step guide for practitioners was developed to show how SaniChoice integrates with any urban sanitation planning framework (e.g. CLUES [5], or CWIS [6]). It provides information on how to collect data using a multi-stakeholder participatory approach with various experts or stakeholder workshops. The SaniChoice beta version and a draft of the practitioners' guide were piloted in Changunarayan, Nepal, (Photo 1) in 2022 in a process led by the WASH task force of the municipality supported by our partner 500B Solutions. The process was based on a draft CWIS (Citywide Inclusive Sanitation) Guide for Nepal recently published by the Ministry of Water Supply. To account for the spatial and socio-economic diversity within the municipality, the project team developed a typology of zone types: densely populated without slope, moderately populated with/without slope, sparely populated with/without slope, and flood prone area. SaniChoice was applied to each zone type and the most appropriate system options were presented to the municipality. The stakeholders discussed the advantages of the different systems, and this led to the prioritisation of three systems: upgraded onsite sanitation (twin-pits, septic tanks, vermi-composting), decentralised systems (simplified sewerage with anaerobic baffled reactor and constructed wetland), and faecal sludge collection and centralised treatment (Photo 2). Currently, these options have been complemented by the local project team with a detailed feasibility analysis, and design and financing options (part of the CWIS plan for the municipality).

Adding the humanitarian component

Currently, we are adding technologies (e.g. lime treatment) and criteria (e.g. speed of implementation) specifically relevant for humanitarian contexts to SaniChoice. The Compendium of Sanitation Technologies in Emergencies and a series of key expert interviews from 2021 provide the necessary information for the development of a special filter for SaniChoice to select technologies applicable for immediate response, the stabilisation phase, or recovery and development. With this, SaniChoice can help humanitarian practitioners and sensitise them for a nexus approach from emergency to development.


Basile Weber

Photo 2: Focus group discussions in Nepal in June 2022.

Conclusion

SaniChoice assesses different technology options based on their performance data in the light of local conditions. It provides a systematic list of criteria to make the process transparent, helps to open up the option space by including novel technologies and enforces the consideration of the entire sanitation value chain. SaniChoice is currently online and can be used for urban sanitation planning projects. There are tutorial videos and the practitioners' guide to assist people in using SaniChoice as part of the planning process. •

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Closing the Gap: Delivering Safe Sanitation for All in the Pan-European Region

This article summarises a WHO report about the situation of sanitation and wastewater management in the pan-European region. It describes current and emerging issues in ensuring access to safe and sustainable sanitation services and proposes key action areas to strengthen sanitation governance. Sital Uprety[1], Sara Marks[1], Christoph Lüthi[1]

Introduction

Access to sanitation is a fundamental determinant of human health and well-being and is essential for protecting the environment and enabling economic and social development. Safe sanitation is associated with improvements in health, including the prevention of infectious diseases, reduction of antimicrobial resistance, and maintaining mental health and dignity.

Regrettably, the provision of safe sanitation is still not a reality in many countries in the pan-European region. Over 271 million people lack the most basic sanitation services (Figure 1). This poses a considerable risk to human health and the environment. At the current rate of progress, the region is not on track to deliver universal and equitable access to safe sanitation by 2030. In addition, only 67% of domestic wastewater in the pan-European region is collected and safely treated, and significant urban/rural differences exist in terms of connections to centralised sewerage. While wastewater reuse is well established in some countries in the region because of its recognised benefits, the limited data available indicate that in most countries there are low rates of reuse. In addition, the uptake of risk-based approaches in sanitation management – such as sanitation safety plans (SSPs) – in legislation and practice is limited across the pan-European region.

Key sanitation challenges in the region – Health and environmental impacts of unsafe sanitation

A comprehensive overview of the sanitation-related disease burden in the pan-European region is not available. This is due to the limited capacity of public health surveillance of sanitation services and associated health outcomes in this area. Poorly managed sanitation and discharge of untreated and insufficiently treated wastewater and sludge to water bodies cause environmental damages.

Climate change

The effects of climate variability and change pose risks to the functioning of sanitation systems and exacerbate associated health risks and environmental contamination.

Antimicrobial resistance

The discharge of untreated and treated wastewater and sludge is a pathway for the spread of antimicrobial resistance in the environment, posing a risk to human health.

Human migration and demographics

Human migration and changing demographics can pose challenges for sanitation service providers, as well as for migrants and refugees who may face barriers to accessing sanitation services.

Ageing and maintenance of sanitation infrastructure

Ageing of infrastructure has adverse impacts on sanitation and wastewater system efficiency and service quality, and presents health and environmental risks.

Small-scale sanitation systems

A considerable proportion of the population in the pan-European region relies on small-scale sanitation systems. However, insufficient regulations, standards, coordination and surveillance capacities hinder the provision of safe and sustainable services.

Areas for Action – Closing the gap in delivering safe sanitation for all

National and local governments should prioritise ensuring equitable access to at least basic sanitation services for all people in all settings. Incremental improvements are needed, starting by ending open defecation where it is still practised and making sure that all people have access to basic sanitation services – particularly in countries with low coverage of such services in rural areas.

Strengthen national policies and regulatory framework

Good governance of sanitation is vital for expanding and maintaining access to safe services. Policies and their implementation at the local level should be transparent; it should be possible to hold those responsible for policy formulation and implementation accountable. Devolution of decision-making to the local level would help to create transparency and accountability, but it must be adequately resourced.

Improve surveillance systems for evidence-informed interventions

To ensure safe sanitation, it is essential to manage health risks systematically along the entire service chain. Governments should establish legal requirements and regulations to adopt risk-based management principles for sanitation services – such as the sanitation safety plan approach recommended by WHO – and scale-up their implementation. The health sector should fulfil core functions for safe sanitation to protect public health. Sanitation should be integrated as an essential component in public health surveillance systems to ensure that resources are targeted at settings with a high disease burden. Such functions require long-term resource allocation. More reliable data on sanitation and wastewater, and on associated disease and environmental contamination, should receive enhanced policy attention and be used in public health decision-making.

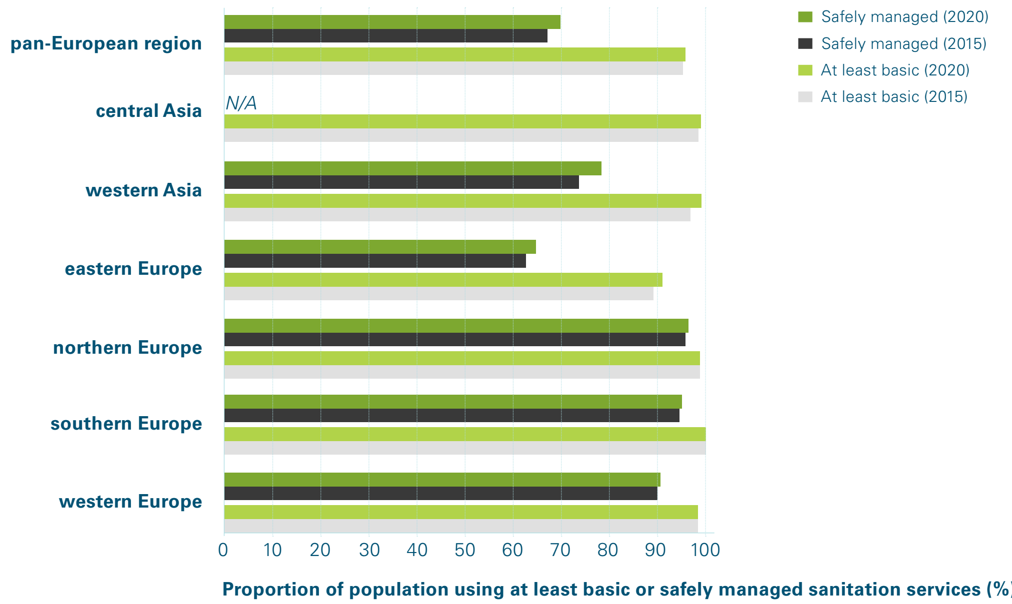

Figure 1: Population-weighted averages in subregions (Figure adapted from WHO report).

Making use of appropriate and innovative sanitation solutions

Reuse of treated wastewater should be promoted, with a regulatory framework in place at national and local levels to ensure safety. Wastewater reuse promotes the transition to a wider circular economy, aids adaptation to climate change and water scarcity, and has direct climate benefits. Sanitation is vital to community resilience, but may be vulnerable to the effects of climate change. Sanitation should be integrated into national adaptation plans and nationally determined contributions, and investment should be made in building the resilience of services. Ensuring the systematic collection of data on sanitation and wastewater management is critical for addressing the persistent data gap. This requires national monitoring and the strengthening of information system capacity and scaling-up of country participation in the global instruments for monitoring sanitation-related SDG targets. This should include consideration of different onsite and sewered technology options, with choices made using transparent and accountable processes.

Improving and sustaining financing for sanitation

Sustainable and resilient sanitation needs financing. It is important that governments establish dedicated budget lines and develop realistic financing plans for the delivery of safe sanitation services. Equity, climate resilience and sustainability aspects should be integrated into investment plans. National sanitation asset registers and asset management plans, integrating current and future climate threats and scenarios, should form the basis for expansion, rehabilitation and replacement planning.

Developing capacity for sanitation and wastewater management

A human resources strategy for sanitation – looking at skills and grades of staff, remuneration, career pathways and professional development – is critical to attract and retain a strong and knowledgeable workforce in both governments and service providers.

Conclusion

The WHO report (Figure 2) was produced to support countries in the region in identifying priorities tailored to their specific country needs. It recommended improvement actions from the policy, institutional, financial, technology and monitoring perspectives, including consideration of increasing resilience to climate change. It also supports public health and environment authorities, surveillance agencies, sanitation service providers and other relevant stakeholders and partners in engaging and contributing to the shared goal of delivering safe sanitation services to all people in the region. •

This article was adapted from: *Delivering safe sanitation for all: areas for action to improve the situation in the pan-European region* (Copenhagen: WHO Regional Office for Europe; 2022).

Figure 2: Cover page of the report, *Delivering Safe Sanitation For All: Areas For Action To Improve The Situation in the Pan-European Region*, published by WHO-Europe.

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The report can be found here:
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Research Integrating Water, Sanitation and Solid Waste for Development

The WABES programme will research how to integrate water supply, sanitation and solid waste management services in small towns. This article shines light on the research process of bringing different groups together and working closely with local partners. Abishek S Narayan[1], Charles Niwagaba[2], Ronald Sakaya[2], Christoph Lüthi[1]

Introduction

Water, sanitation, and solid waste management are closely interconnected in their physical service chains. Despite this, their planning and management are often isolated from each other, leading to negative interlinkages, such as solid waste entering pit latrines and faecal contamination in drinking water [1]. Opportunities for positive interlinkages, however, are possible, such as the reuse of treated wastewater and co-digestion of faecal and organic waste, leading to nutrient recovery. Sandec has been conducting research in these three fields over the last five decades and disseminating findings that benefit each of these sectors. However, in order to test if a joint approach to water, sanitation and waste service provision is possible and in fact beneficial, a new transdisciplinary programme was developed.

WABES (Water, Behaviour Change and Environmental Sanitation) is a four-year transdisciplinary programme that builds on current research to investigate, validate and disseminate knowledge targeting the outcome of integrated planning for water, sanitation and waste services in two small towns in Uganda. In addition to the research on integration, which focuses on two small towns in Uganda, there are several other research projects on improved and equitable access to safely managed water and environmental sanitation and how to create knowledge outputs to foster capacity improvement. The time period of WABES is 2022–2026 and it is co-financed by Eawag and the Swiss Agency for Development and Cooperation (SDC). Sandec's five research groups and its Digital Learning team, as well as the Contaminant Hydrology group from Eawag's Water Resources & Drinking Water department are involved in WABES. The College of Engineering, Design, Arts and Technology (CEDAT) at Makerere University in Kampala is our local research partner in Uganda.

The earlier cited review article provides a basis for understanding the integration of these three sectors [1]. A key research objective of WABES is how to plan for sustainable integrated services, which requires doing an integrated baseline assessment as the first step. However, since no planning frameworks exist that can provide such an integrated baseline assessment (IBA), a research design process was needed to create an IBA. Two essential components were identified as essential for a research design process to become truly transdisciplinary: integration of research groups and equitable partnerships with local partners, which are explained below.

Designing research towards integration

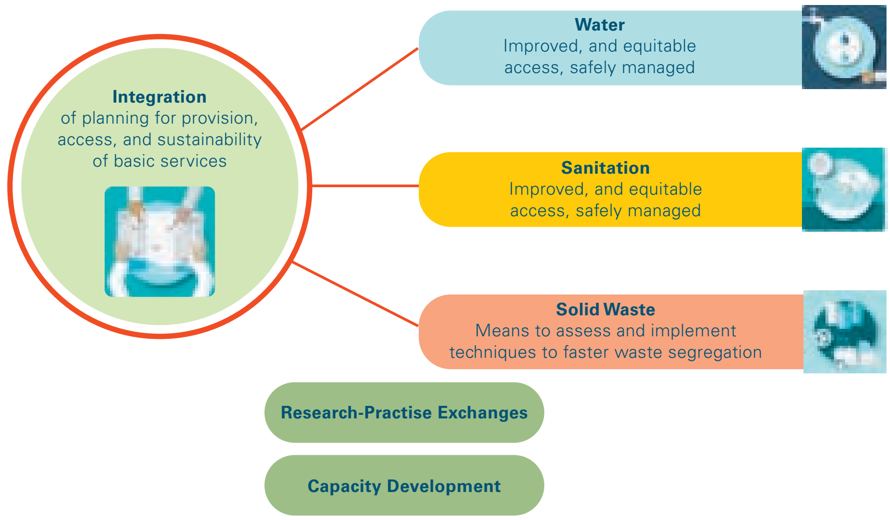
In order to co-create the integrated baseline assessment (IBA), a series of research design seminars were conceptualised and carried out over six months (Photo 1). The following were the objectives of the individual research design seminars:

1. Understand data requirements and collection means of individual sectors and classify these data points as necessary, important and optional.
2. Identify all possible interlinkages between the three sectors and the means to identify, qualify or quantify them.
3. Identify the levels of data collection – town level, survey level, and detailed level as sub-sets of each and define scale.
4. Create an IBA framework to unify the data collection means (e.g. data points classified between the three service chains and the enabling environment).
5. Finalise the envelope of data points and the corresponding methods to collect them. Design the methodology to empirically show value addition of IBA compared to conventional siloed assessment methods.

In addition to the research design seminars, a smaller group of Project Officers from each sector met to synthesise the outcomes and produce a robust assessment package, that includes such activities as household surveys, key informant interviews, observations, and water, faecal and municipal waste characterisation.

Abishek Narayan

Photo 1: Research design seminars bring different groups together to co-create integrated knowledge products.



George Wainaina

Figure: The WABES programme integrates water, sanitation and waste sectors through research, capacity development and research to practice exchanges.

Designing research towards equitable partnerships

Development research by definition has to be equitable to all partners involved. The Swiss Commission for Research Partnerships with Developing Countries (KFPE) has created a set of 11 principles for transboundary research partnerships [2]. These were reviewed and incorporated into WABES. For example, the Ugandan project partners are thoroughly integrated into the everyday work and there is a constant exchange of information, as well as regularly scheduled meetings. A common platform is used for the database management system and all relevant documentation is available on it.

A funded PhD position was created at Makerere University exclusively for WABES that is jointly supervised by Eawag Sandec scientists. The doctoral researcher is also embedded at Sandec and has research stays through the Eawag Partnership Programme (EPP). Local government officials are also involved through collaboration during the fieldwork process and through knowledge exchange. They will also benefit from the knowledge outputs produced, such as the detailed GIS maps of the administrative zones and services available. The results from the IBA will also be shared with the local governments. Lastly, the Ugandan Ministry of Water and Environment is involved in WABES and exchange on its progress and plans take place regularly.

Way forward

The field campaign for the IBA takes place in the summer of 2023 (Photo 2). Based on these findings, a portfolio of modular research projects will likely be developed to implement in the two towns in the coming years. An integrated planning methodology is also planned to be conceptualised and validated in a manner similar to the IBA process in 2025. The political economy of integration in Uganda and globally is also being analysed, which will help inform future programme directions.

Ultimately, the aim of WABES is to not only conduct research on innovative mechanisms of integrated service provision, but also to catalyse investments for these services in the towns worked in. Therefore, the programme has the objective to closely involve stakeholders from the relevant ministries, national NGOs, regional development banks, and other international development agencies to foster this development. •

Abishek Narayan

Photo 2: Prof. Charles Niwagaba and PhD student Ronald Sakaya from Makerere University during their visit to the Town Council of Wobulenzi where WABES fieldwork will take place.

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CAS WASH: An On-the Job Online and In-person Training Programme

WASH interventions in low- and middle-income countries are very challenging. Doing this work requires specific design, planning and implementation skills and knowledge. Recognition of this led to the development of the CAS WASH course programme. Sara Ubbiali[1], Claudio Valsangiacamo[2], Ellen Milnes[3], Christoph Lüthi[1]

Claudio Valsangiacomo

Photo 1: ***CAS WASH 2022 class – From left to right – Front row:*** Marie-Louise Vogt, Akmal Akbarov, Khairul Bashar, Anne-Lize Hertgers, Alessandra Riva, Sergio Cozar Gafia.
2nd row: Lorenzo Fontana, Paul Patrick Onyango, Kh. Shafiur Rahaman, Veronica Soldati, Angelo Nahavitatsara, Abdisalam Ibrahim Hussein, Marc Rusterholz, Andreas Peter, Romal Omari.
All of the students successfully obtained the diploma.

Swiss academia meets the NEXUS agenda

The NEXUS agenda, which was an outcome of the 2016 World Humanitarian Summit, was developed to strengthen the interconnection between humanitarian, development, and peace activities, and has gained in prominence in the sector in recent years [1]. This approach recognizes that the sector's efforts are closely connected and must be coordinated to achieve sustainable and long-lasting outcomes when responding to complex humanitarian crises. Capacity development activities, such as the Certificate of Advanced Studies in Water Sanitation and Hygiene for humanitarian and developing contexts (CAS WASH), are critical to ensure that individuals and organisations have the necessary skills, knowledge and resources to effectively work together in a coordinated manner when responding to emergencies. These reasons triggered the collaboration between the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), the Swiss Federal Institute of Aquatic Science and Technology (Eawag) and the University of Neuchâtel (Uni-NE) to develop and offer the state-of-the-art CAS WASH course programme.

Knowledge into action

CAS WASH is a one-year on-the-job programme with four modules: online public health, environmental sanitation, and sustainable water supply courses, and an in-person fieldwork session in Switzerland. The current class includes 16 students from 10 different countries (Photo 1). It is now in its fourth year and there are 37 alumni from 17 countries.

The three online courses are delivered on Teams, providing participants with the flexibility to learn at their own pace and from anywhere in the world, and to maintain their life/work balance. There are live sessions a few hours each week to ensure attendance where learners can engage with their peers and course experts. The online lectures are delivered using a variety of formats, including videos, group work in break-out rooms, and case studies.

The fieldwork module allows the course participants to put into practice a direct link between theory and realities on the ground (Photo 2). They put their knowledge into action, observing each other's work and discussing results and/or decisions after each activity. This module adds great value because after a year of online interaction the people can work with and learn from each other in-person. It also facilitates networking and knowledge sharing among the participants who come from different parts of the world and have different backgrounds.

Conclusion

Given the rapidly evolving nature of humanitarian, development and peace work, it is essential to further customise CAS WASH, according to the learners' backgrounds and the latest cutting-edge developments and technologies. Course instructors plan how to best meet the educational needs of the learners who apply for the programme. The aim is to keep course content always up-to-date and ensure that it deals with real world challenges and problems. •

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Unknown

Photo 2: Students of the CAS WASH 2021/2022 running a pumping test.

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Sandec's Participation at the UN Water Conference

Sandec had a strong presence at this year's UN Water Conference, which took place in New York City, from 22–24 March 2023. Laura Stocco, Abishek Narayan and Dorothee Spuhler gave presentations and co-organised four sessions, a side event and a Swiss apéro, where the Joint Swiss Commitment was launched (https://sdgs.un.org/partnerships/know-your-water-action-oriented-partnerships-interface-between-science-politics-and). Here are some of the highlights!

Unknown

Photo 1: Eawag's Delegation of Laura Stocco, Abishek Narayan, Dorothee Spuhler (Sandec), and Joel Podorski (WS&T).

A. Zysset

Photo 2: The Swiss Consul General Niculin Jäger speaking at the Swiss Apéro organised after the side event at the International House.

Unknown

Photo 3: Sandec representatives with key partners at the meeting of the Sustainable Sanitation Alliance (SuSanA) at Columbia University.

Barnard College Team

Photo 4: The side-event "Water we waiting for?" that was jointly organised by IHE Delft, Barnard College, ETH Zürich and Eawag.

Marie Claire Graf

Photo 5: Abishek Narayan providing an interview to the UN SDG Media on the Global Youth Movement for Water.


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Water Supply and Treatment

A safe and reliable drinking water supply is a foundation of health and well-being. Sandec's Water Supply and Treatment group examines treatment technologies, monitoring systems and training tools in support of extending and sustaining access to safe drinking water. Current projects focus on:

- Implementing passive chlorination technologies at scale.
- Strengthening water testing laboratories in remote rural areas.
- Understanding how extreme natural events impact WASH infrastructure.
- Identifying the social and technical factors that contribute to water system functionality over time.

Photo A drinking water kiosk in Kitui County, Kenya.

Photo by Jackline Muturi.

Fit-for-Purpose Labs to Assess Drinking Water Quality in Rural Nepal

Rural labs in Nepal have enabled regular monitoring of drinking water quality and identification of major risk factors and mitigation strategies. Communicating results with water users positively impacted users' attitudes and water handling practices. Donat Crippa[1], Marisa Boller[1], Bal Mukunda Kunwar[2], Jackline Muturi[1], Sital Uprety[1], Madan Bhatta[2], Sara Marks[1]

Ariane Schertenleib

Photo 1: Example of a fit-for-purpose lab.

Donat Crippa

Photo 2: Local staff taking water samples.

Introduction

Between 1990 and 2015, 2.6 billion people worldwide gained access to an improved drinking water source. In Nepal, where most people live in rural areas, 90% of households now use improved water sources, such as boreholes, protected springs or gravity-fed piped schemes. However, the drinking water is often contaminated with faeces, with only around 10% of the household stored water containers from untreated supplies meeting the WHO guidelines for microbial safety (<1 *E. coli* CFU/100ml) [1]. A risk-based water safety framework is necessary to mitigate widespread health risks, such as diarrhoea and intestinal parasitic infections.

Scoping activities

In 2017, Eawag and Helvetas-Nepal initiated a study in collaboration with the REACH programme to understand the water sector's needs for an effective water safety framework. It revealed a lack of a well-defined, coordinated strategy for water quality monitoring in rural Nepal. Even though the government's water supply department provided field test kits to regional laboratories for sampling, the kits are hardly used due to malfunctioning materials, insufficient training and lack of dedicated staff to do the water quality testing. Moreover, the Nepal Water Sector's Development Plan for 2016–2030 highlights the lack of an effective drinking water monitoring strategy as a barrier to implement National Drinking Water Quality Standards [2]. Regular monitoring of drinking water quality – across schemes, within a scheme (source, reservoir, tap, household), and across seasons – allows for identification of contamination risks and mitigation methods, and has been shown to encourage water treatment practices, such as filtering or boiling, among households [3].

Project preparation and results

Rural "fit-for-purpose" laboratories (Photo 1) are designed to meet local operational monitoring needs, and are typically equipped to analyse basic water quality parameters (*E. coli*, pH, free residual chlorine, and turbidity). REACH installed seven such laboratories in the Karnali Province of Mid-Western Nepal, where Helvetas-Nepal has established gravity-fed piped drinking water systems between 2011 and 2017 (Figure). An additional lab was installed in the neighbouring Sudurpashchim Province, demonstrating the potential of scale-up to other regions. Long-term implementation of these labs requires low-cost equipment, stable inland supply chains, local staff training and integration into existing monitoring structures.

Equipment and supply chains

Lab testing requires incubators to culture countable colonies from water samples. As an alternative to commercially produced, expensive incubators that require a reliable electricity grid, a mobile and affordable solar-powered incubator was designed and constructed using readily available components, following a construction manual [4]. Most of the material for this low-cost incubator can be purchased in Nepal and India and its total cost is less than US$300. The incubator is effective under ambient temperatures ranging from 3.5 °C to 39 °C, with a temperature variation of less than 3 °C over a 24-hour period. Compact dry plates, used for selective culturing of faecal bacteria, however, still have to be imported. During the Covid pandemic, delays in importing these plates led to interruptions in the monitoring process. To bypass such dependencies and decrease the purchasing costs, manually poured

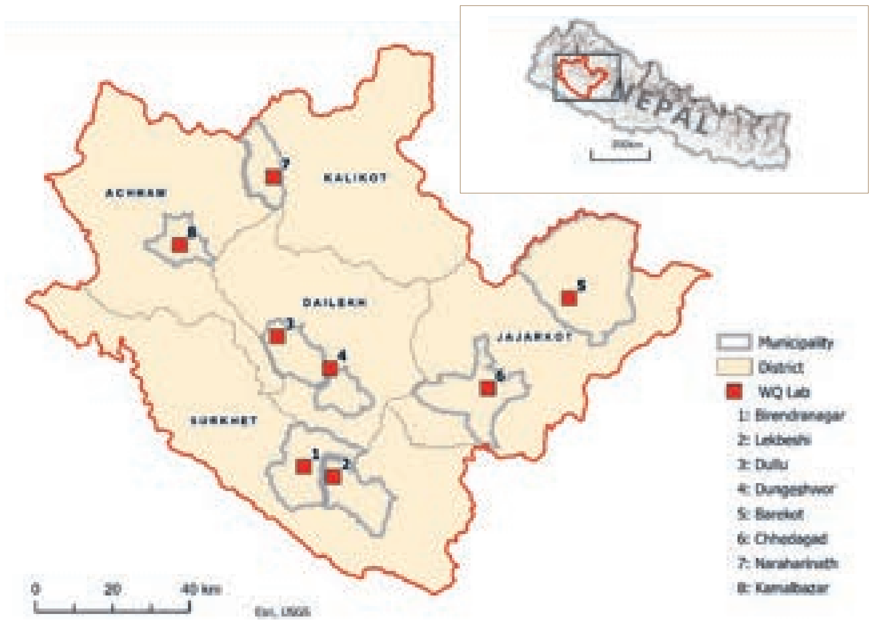

Figure: Map of Nepal showing the locations of the fit-for-purpose labs (WQ lab) implemented under the REACH programme.

plates using a locally available agar powder are being tested as an alternative.

Local staff and lab operations

The eight labs are located at schools, health centres, the offices of the water users committees and Helvetas-Nepal. Water quality testing is done by staff of the host institution, municipality staff or local staff from the water schemes who have received training (Photo 2). Microbial and basic physicochemical analyses are performed three times a year in the fit-for-purpose labs for most schemes, and can be enhanced depending on specific needs. Although collected data is currently stored in a hard copy register, a plan to integrate the labs with the national WASH (NWASH) platform (nwash.mows.gov.np) is under development.

Monitoring results and impact

Regular water quality monitoring has shown that schemes with chlorination were the most successful at minimising the risks of exposure to faecal contamination [5]. However, insufficient monitoring of free residual chlorine could lead to overdosing or unreliable chlorination via manually operated batch chlorination. Therefore, it is crucial to regularly monitor the chlorine dosing, as well as the chlorine levels throughout the schemes. Helvetas-Nepal staff are developing protocols for the reliable management of chlorine dosing technologies.

Integration into existing structures

While the municipalities involved in the REACH programme have shown interest in the fit-for-purpose labs, their focus has been mainly on the construction of water schemes rather than on water quality monitoring. This highlights the need to promote water safety as a key component of water supply development, along with strengthening the capacity of municipalities to achieve monitoring objectives. Additionally, addressing the challenge of lab staffing is crucial in many municipalities to ensure the sustainability of the labs.

Conclusion

The fit-for-purpose labs have proven to be an effective solution for enabling regular drinking water monitoring, demonstrating that they can play an integral role in risk management of piped supplies in rural communities. The labs will continue to play a crucial role since future work on system-level chlorination in the study area will require regular monitoring to ensure proper dosing. The success of the labs in the REACH study area suggests that similar labs could also be successfully implemented in rural areas across Nepal and beyond. To this end, the research team has initiated a three-country study (Nepal, Kenya and Bangladesh) to identify the enablers of and barriers to establishing fit-for-purpose labs to accelerate their implementation at scale. •

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Passive In-Line Chlorination Challenges in Rural Guatemala

Drinking water safety in rural communities is a global challenge. This project evaluated an artisanal passive chlorination device, analysed the challenges, considering the different stakeholders involved, community acceptance and governance practices. Jael M. Locher[1], Dorian T. Robinson[1], Eunice N. Canú[2], Giezy Sanchez[2], Mario Muj[3], Sara Marks[1]

RU'K'UX YA', Helvetas

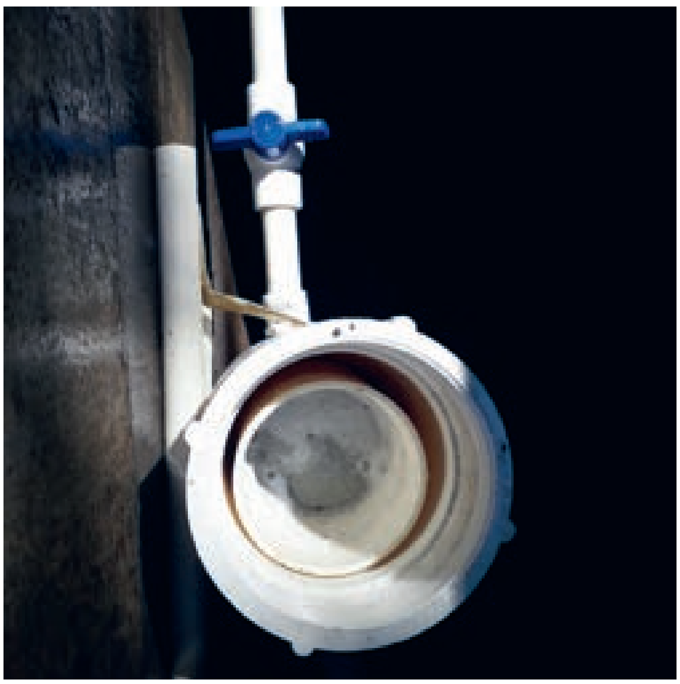

Photo 1: View of the A'Jín chlorinator in use.

RU'K'UX YA', Helvetas

Photo 2: Measuring free residual chlorine concentration after installation of the chlorinator in collaboration with water committee members, the Health Ministry, the Municipality and Helvetas Guatemala.

Introduction

Meeting the ambitious Sustainable Development Goal Target 6.1, to deliver "universal and equitable access to safe and affordable drinking water for all", continues to be a major challenge worldwide. In rural Guatemala, there is near universal access (90%) to basic water services [1]. However, water systems face unreliable water availability, inconsistent treatment and monitoring, and vulnerability to faecal contamination. Guatemala has among the highest rates of chronic malnutrition and child morbidity in Latin America [2]. Providing safe drinking water is key as contaminated drinking water is closely linked to child health due to the transmission of waterborne diseases [3]. Sandec and Helvetas Guatemala assessed the applicability and performance of the A'Jín chlorinator in Sololá, Guatemala, to inform rural water supply upgrading efforts through passive chlorination in similar rural settings.

A'Jín chlorinator

Chlorination is the most common drinking water disinfection approach worldwide because it is low-cost and provides residual protection from recontamination. Consistent dosing of chlorine is essential for this treatment to perform well. Passive in-line chlorination is particularly promising for rural areas as the device is capable of providing chlorine dosing at system scale without the need for electricity. The passive chlorinator A'Jín designed by Helvetas Guatemala uses calcium hypochlorite tablets that slowly dissolve, providing a continuous chlorine dose into the water reservoir tank (Photo 1). This low-cost device can be locally produced with PVC pipe parts widely available in rural communities.

Research context and methods

In the Lake Atitlán region, Helvetas Guatemala implements the RU'K'UX YA' programme that focuses on improving water, sanitation and hygiene in rural communities. The programme planned the roll out of chlorination interventions, which presented a unique opportunity for a rigorous evaluation of the A'Jín chlorinator. Funded by an ETH4D research challenge grant, a partnership between Sandec and Helvetas conducted the research with the support of the Ministry of Health and Social Assistance of Guatemala, as well as the water committee members and users of 15 water distribution systems. The team collected water samples at tap and consumption points to determine the bacterial contamination and residual chlorine concentrations (Photo 2). Moreover, the team conducted a household survey assessing treatment acceptance, water management and health indices.

Chlorination framework – local setting

Water is transported from a protected spring intake to water tanks via the water distribution system (WDS), using either gravity or mechanical pumps for abstraction (Figure). The water tanks are located mostly outside the villages, in the forest, and accessible only by foot.

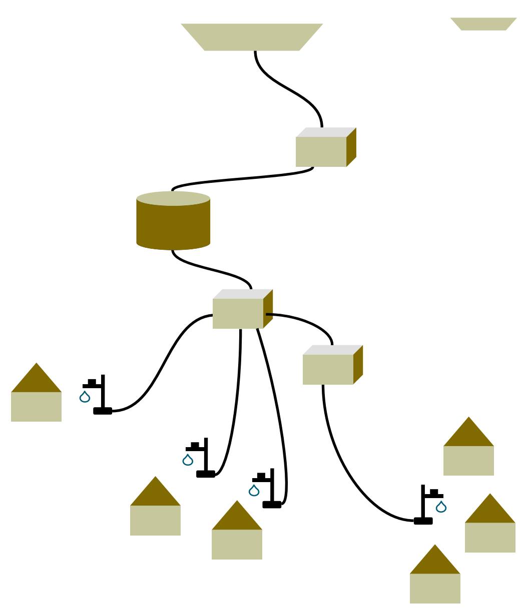

Figure: Schematic of a typical gravity-fed piped WDS.
The A'Jín chlorinator is installed at the inlet of the reservoir tank [4].

The user community owns the WDS and and the weekly users' assembly makes all decisions about it. The user community elects or appoints a water committee to act as the managing entity responsible for the good functioning of the WDS and any necessary repair work. The committee members are appointed for a duration of three to five years and are not remunerated. The water committee has, according to Guatemalan legislation, the responsibility to provide clean and disinfected water to their users. However, the water is often found to be contaminated and no system-level disinfection treatment is in place in most WDSs. Rural health technicians from the Health Ministry regularly monitor the bacterial contamination of the water in the WDS and promote hygiene and water disinfection through chlorination within the communities.

Preliminary observations during fieldwork

Chlorination acceptance

In rural Guatemala, it is generally challenging to implement chlorination projects. Most local stakeholders report that users are very sensitive to chlorine's taste and odour. An often-mentioned reason is that too high dosing during past projects has turned public opinion against chlorine. Among the study participants, most had a very traditional way of living and were sceptical of novel technologies. The majority preferred to continue with the household level treatment they were used to, mostly ceramic filters, disinfection by boiling or no treatment at all. Awareness of the importance of drinking water disinfection for avoiding waterborne illnesses was not present in all the households. This low acceptance of chlorine imposed a difficult barrier to overcome. Out of the six communities that had initially opted to install the A'Jín chlorinator, five had successful installations, although only three actually put it into use. For two WDSs, the users' assembly decided to reject chlorination during the research timeframe.

Governance practice

Communities are well organised and local governance bodies have a central role in their development. As mentioned previously, the user assembly has the decision-making power over the WDS. Due to the low chlorine acceptance, the willingness to install and adopt the A'Jín chlorinator was very low, even if the RU'K'UX YA' programme covered all the costs. If the majority of the users did not support chlorination in their WDS, then the assembly would not approve it. Proactive water committee members tried to promote water disinfection with chlorine within their communities. However, as it represented an additional effort to their already numerous tasks, the subject was neglected. The Health Ministry tried to promote chlorination, but has little authority in rural communities as they are used to managing their own WDS without governmental support.

Operation and maintenance

During the installation period of the A'Jín chlorinators, the calibration and proper operation of the chlorinator were very time-consuming for the committee members. During the first few weeks, it was necessary to monitor the free residual chlorine (FRC) concentration in different households and adapt the dosage iteratively. Other technical challenges included difficulties with precise dosing due to the use of basic valves, which had to be slightly opened to achieve a drop-by-drop dosing rate, resulting in frequent clogging of the device. Daily maintenance visits were required to unclog the valves, refill hypochlorite tablets and monitor FRC. Because the tanks were located outside of the village and only accessible by foot, the maintenance required for the A'Jín to work correctly was a non-negligible additional workload for the committee members. •

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State of Affairs of Open Defecation Free Status in Southern Nepal

Despite Nepal being declared Open Defecation Free in 2019, our study identified that more than 21 % of the households in the study region still lack adequate sanitation facilities. Moreover, 35 % of the sanitation infrastructures in the households had been affected by flooding. Sital Uprety[1], Abhinay Man Shrestha[1], Anjil Adhikari[2], Sanjeena Sainju[1], Sara Marks[1]

Sital Uprety

Photo 1: Enumerators conducting a survey about the sanitation situation in the Terai region of Nepal, which faces an increase in flooding events.

Introduction

The history of sanitation promotion campaigns in Nepal dates back to the 1980s. However, the extensive work in the sanitation sector did not start until 2011, when the Sanitation and Hygiene Master Plan (SHMP) was developed by the Government of Nepal (GON) and put into action [1]. The plan primarily focused on building universal toilets and promoting the proper use of toilets in urban and rural areas by 2016/17 [2]. The effective implementation of the plan and intensive work from WASH (Water, Sanitation, and Hygiene) stakeholders pushed the national sanitation coverage from 6 % in 1990 to 87.3 % in 2016 [3]. Nepal was officially declared an Open Defecation Free (ODF) zone in a declaration ceremony held on the 30th of September 2019, in Kathmandu [4]. Unfortunately, after only four years of being declared an ODF zone, there are already concerns regarding possible slippage nationwide in sanitation coverage. For example, a study found that the decrease in households using improved sanitation facilities was as high as 16 % in Madesh Pradesh [5].

However, the impact of annual flooding in Madesh Pradesh on these toilets and people's behaviour is unknown. To address this knowledge gap, Eawag and Oxfam conducted an assessment of ODF toilets in the flood-affected regions of Madesh Pradesh, focusing on four districts: Siraha, Saptari, Rautahat, and Sarlahi (Figure 1). They were chosen because annual flooding was prominent in these areas (they were categorised as highly flood-affected in 2017). The goal was to understand how ODF toilets have been operating, what should be done further to reduce slippage in their use and move towards the national goal of total sanitation.

Methods

Two Municipalities and one Rural Municipality from each district were selected to obtain a holistic sanitation scenario, ranging from urban to rural contexts. Key Informant Interviews (KIIs) and Household (HH) Surveys were conducted to collect first-hand data from these sites (Photo 1). Water samples were also collected from all the surveyed HHs from containers stored inside the home and were analysed for *E. coli* concentrations using standard methods for water and wastewater at the government laboratory facility in Janakpur.

Results

The surveys showed that 21 % of the HHs did not have any toilets on the premises (Figure 2). Among the HHs reporting having a toilet, 75 % had a private toilet, and 4 % depended on shared toilets. Among HHs that did not have a toilet, the practice of Open Defecation (OD) was reportedly higher during the dry season than the rainy season. In the rainy season, people preferred to use shared toilets to avoid flood hazards. Moreover, 35 % of the HHs with toilets were affected by flooding during heavy rains, which would potentially force people to practice OD. During the monsoon season, 27 % of the toilets affected by floods were inaccessible as they were filled with water. The floods also washed away 8% of the toilets or made them unusable due to excreta gushing on the surface.

The study found that those who practised OD were mainly from households with poor financial conditions (88 % of HHs) or lacked proper space to build a toilet (49 % of HHs). It also showed that the reduced usability of toilets would easily push people back to alternative and unsafe defecation practices. People in 68 % of the HHs with toilets stated that they had to defecate openly if their own toilet became dysfunctional. This indicates that HHs with poorly structured toilets are prone to inundate in the rainy season (Photo 2), and that HHs lacking the means to keep their toilets clean are on the verge of returning to OD status. Additionally, people in 18 % of the HHs with toilets reported practising open defecation.

Sital Uprety

Photo 2: A toilet without a proper structure in Sarlahi, Nepal.

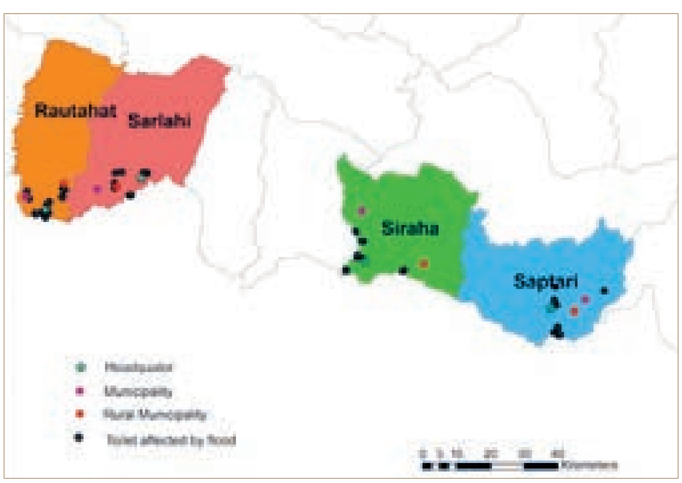

Figure 1: Study districts showing the HHs surveyed.

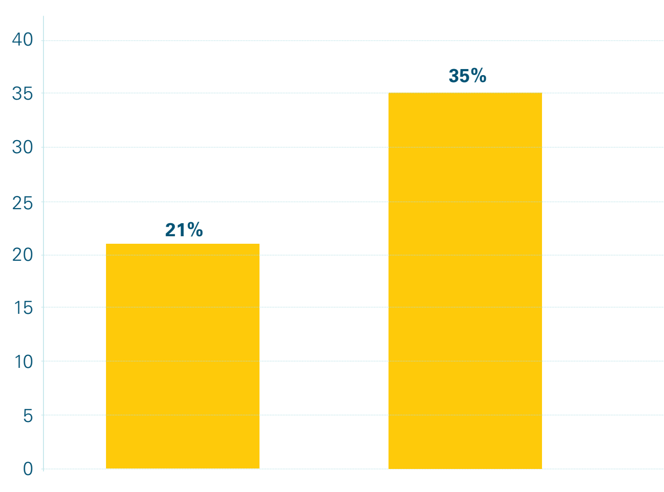

Figure 2: Results for the 1,000 HHs surveyed.

Water Quality

The microbial water quality data of HHs stored water containers were categorised into four tiers per WHO guidelines: <1 colony forming units (CFU)/mL = no risk; 1–10 CFU/100 mL = low risk; 11–100 CFU/100 mL = moderate risk; and >100 CFU/100 mL = high-risk [6]. Overall, 78 % of the samples were free from *E. coli* contamination, while 8 % were at high risk. Chi-square and Spearman correlation tests did not reveal a statistically significant relationship between drinking water quality and sanitation aspects (presence of toilet facility, containment type, leakage around the toilet area, etc.). This could be due to the fact that most of the HHs relied on groundwater sources obtained from boreholes dug as far as 100 ft underground. In addition, the surveys were conducted during the dry season (Nov-Dec); therefore, the sub-surface water level could have even been lower, further reducing the chances of contamination.

Conclusion

This study revealed that a household toilet that is less functional and lacking cleanliness saw less usage. A structurally stable, clean toilet that is easily accessible during flooding is considered a functional toilet and was used more effectively. However, a functional toilet far from the house was used less than the one near the house. Families with lower education profiles were found to practise open defecation more than families with higher education profiles. It was also found that older toilets were used more consistently than newer ones. This indicates that if there is a toilet in the house, households will gradually use it consistently. Notably, the choice to consistently use a toilet is also linked to the financial status of the HHs. It was observed that people in HHs with higher spending ability chose septic tank toilets over single pit toilets, while people in HHs with lower spending ability intentionally used their toilets inconsistently to avoid the costs associated with desludging. •

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Community Based Participatory Action Research: An Indo-Swiss Project

Improving a research project's sustainability requires engaging communities. This article analyses the application of the community based participatory action research framework in an interdisciplinary shared water infrastructure project. Benjamin Ambuehl[1,2], Bharat Kumar Singh[3], Manoj Kumar[3], Ashok K. Ghosh[4,5], Sara J. Marks[1], Jennifer Inauen[2]

Introduction

As important as the Sustainable Development Goals (SDGs) are, their specific means of implementation (MoI) are often neglected in the public discourse [1]. For example, the MoI of SDG 6, which aims to "ensure availability and sustainable management of water and sanitation for all", contain:

- "Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes ..." (MoI 6.a)
- "Support and strengthen the participation of local communities in improving water and sanitation management." (MoI 6.b)

To align with the SDG 6 MoI and ensure comprehensive outcomes, research projects should identify participatory strategies that effectively engage communities in targeted and meaningful ways, while simultaneously building local capacity. One promising approach to doing this is to follow the principles of community-based participatory action research (CBPAR).

Community-based Participatory Action Research

CBPAR is a research framework that focuses on actively involving community members in the research process [2]. It is a way of creating community ownership [3] because it integrates communities by identifying and prioritising issues that are relevant to them, involving all relevant stakeholders and the community in decision-making and the conduct of research, and offering equitable opportunities for community members to develop context-specific actions to achieve social change. It happens in six phases (Figure) and the main focus of each phase relies on the resources and strengths of the community.

Our research project PACT (Participatory Action for Long-term Arsenic Safe Water Infrastructure) investigated two key concepts and their impact on the adoption and use of new safe water infrastructure: psychological ownership (the feeling that something is "mine" or "ours", [4]) and habit (to automatically associate water-collection with safe water infrastructure, [5]). A Cluster-Randomized Control Trial (C-RCT) was done in Bihar, India, [6] that used the CBPAR framework to ensure the context specificity of interventions. The six phases of CBPAR in context of the project PACT are explained below.

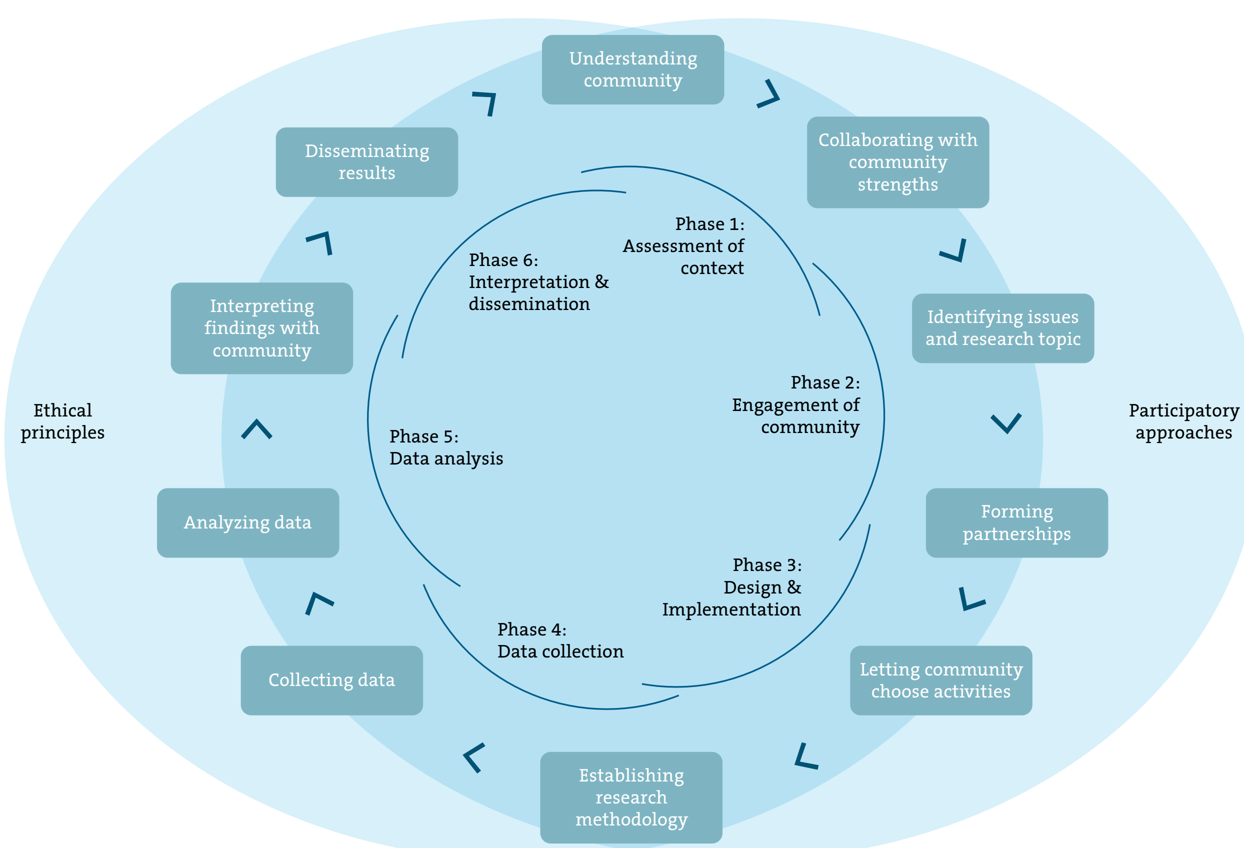

Figure: ACBPAR methodology over the lifecycle of a research project (adapted from Vivona & Wolfgram, 2021).

"Community participation is recognised as an old tradition at many levels in the communities, for example, through Mahatma Gandhi's use of Gram Swaraj in Indian society. But, at present, many communities are found to be divided and community participation is missing a lot. After our intervention, people were found remembering the sense of community ownership similar to as in the old social system."

– Bharat Kumar Singh (Research officer at Paridhi, Bhagalpur)

Phase – 1: Assessment of context

We actively engaged with researchers, experts and practitioners from diverse disciplines and established connections with both international and local organisations to identify joint interests and potential partners to conduct research on psychological aspects of safe water infrastructure in India. This was followed by discussions of and agreements on principles (e.g. work ethics and methods, salary, responsibilities, and deliverables). Fieldwork was initiated and the collaboration details tested and if necessary modified. During the preliminary qualitative study, we identified relevant insights into the psychological aspects of community-based shared water infrastructure. The research question was collectively defined with the community.

Phase – 2: Engagement of community

Work with traditional power structures (i.e. local politicians and community organisations) was based on the principle of equal partnerships. Informal local knowledge collection methods (mapping, photo, GPS) were used to foster community knowledge about the research topic. By assigning a team of facilitators to certain communities who then accompanied the same community over the entire lifespan of the research project and led community visits by the research team, we aimed to create trust and a stable relationship.

Phase – 3: Design & Implementation

Together with the communities, we explored how to foster relevant constructs and co-design a study to test the effectiveness of an intervention campaign. This included preparing a guideline for the implementation of interventions that allowed for tailoring to the specific context of each community. In workshops, interventions were developed to align community interests and needs and international standards (WHO quality of water supply infrastructure) with the intervention manual. Communities also proposed useful activities as interventions. This process aimed at fostering the communities' sense of ownership and involved offering choices; communities could decide how to implement and what to contribute to interventions.

Phase – 4: Data collection & Phase – 5: Data analysis

Although these are the only phases requiring expert work, data collection relied on working with enumerators who were familiar with the communities and the culture of the villages. Data analyses were done by expert scientists according to preregistration. However, the project team dealt with iteration to assess the needs of the population.

Phase – 6: Interpretation & dissemination

Because data does not speak for itself, local dissemination took place by way of joint workshops to make sense of the results and interpret the meaning of the statistics. The conclusions were shared in street dramas developed together with the communities, and through leaflets comprising simple language and graphics.

Discussion

By actively involving the community in the decision-making, we ensured that the scope and content of the research project were shaped by their priorities. This also enhanced the uptake of our research findings in the local policy-making and in the education of government engineers. However, this type of research is not easy to do because it demands more resources (time, discussions, compromises on work ethics, etc.) compared to traditional approaches. In addition, there is the tension between scientific rigour and community-based flexibility requiring constant balancing of interests and iterative decision-making. Yet, if successfully implemented, this approach results in more relevant and specific, impactful project outcomes for the communities. In our case, implementing CBPAR led to increased use of the safe water infrastructure, increased caretaking attitudes and improved infrastructure quality. Yet, it is important to note that we did not observe any effects on water quality, which may indicate the need for expert level support when using complex technologies.

Conclusion

Through CBPAR, we fostered a collaborative and equitable research endeavour that placed community knowledge and needs at the forefront. CBPAR, thus, contributes to an effective implementation of a global research agenda of sustainable development, by focusing on the priorities and empowerment of the most vulnerable populations of our common planet. •

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Safe Water Promotion

About 1.8 billion people use a source of water that is unsafe and large disparities in access to water exist between rural and urban areas and among different regions worldwide. Sandec's research on Safe Water Promotion is developing and evaluating appropriate solutions to strengthen the access to and enhance the consumption of safe drinking water in vulnerable households in low-income countries. Research activities focus on:

- Laboratory and field-level performance evaluation of innovative methods for drinking water treatment and safe storage in low-income areas.
- Assessment of effective and sustainable safe water interventions, strategies and programmes.
- Impact evaluations of improved access to safe drinking water.

Photo The Safe Water Promotion Group is evaluating strategies to assure that drinking water stays safe between the point of collection and consumption. The photo shows people at a bono in Dulecha Tibirako, Ethiopia, collecting water to take home.

Photo by Anna Wettlauffer.

How Much Would You Pay for an Improved Water Container?

Improved water containers can reduce recontamination of previously safe drinking water during transport and storage at the household level. This project evaluated the market potential of such containers in rural and urban Uganda.

Lukas Bouman[1], Regula Meierhofer[1]

Introduction

Drinking water in low-income countries is often collected at community-based water taps in neighbourhoods. After collection, people transport the water in water containers, which are stored at the household level. If a water connection is available in the household, but the water supply is irregular and unreliable, people also store their water in containers. The containers available for water transport and storage are largely inadequate because they have small openings that do not allow for proper cleaning. This can lead to the formation of biofilms and because biofilms protect and nourish pathogens, they are an important source of water recontamination [1, 2].

The goal of this study was to evaluate the market potential of improved water containers. We assessed the demand for the improved containers among potential customers from different socio-economic backgrounds and their willingness-to-pay (WTP). At the same time, the study analysed people's preferences regarding different design features of improved containers.

Methodology

Quantitative and qualitative face-to-face interviews were conducted in Central and Eastern Uganda with lower income households in rural areas and higher income households in urban areas (Photo). The quantitative interviews assessed WTP for improved containers in single bound dichotomous choice experiments and open questions. Discussions about different design preferences also took place. Illustrations of improved containers, designed by the Zurich University of the Arts, were used as visual aids during the interviews. The qualitative interviews were conducted with two village chairmen, four water kiosk operators, six shop managers and four NGO and government workers about their awareness of drinking water recontamination and the potential challenges of promoting improved containers.

In addition to the interviews in Uganda, online interviews were conducted with staff of 14 international and local organisations working in the water sector in Asia, Central America and Africa. The topics covered were: are employees and customers aware of

Thierry Mounir

Photo: An interviewer explaining the benefits of improved containers to a household member.

ZHdK

Figure: Illustration of an improved water container.

recontamination in water containers, the use of safe water containers in their projects, as well as their market potential, important design features and WTP for improved containers. In addition, a short online survey was created with questions about the key features of a safe water container, improved containers, and the optimal size and WTP for improved containers. It was shared with the country offices of two Swiss-based international organisations (Helvetas and HEKS) and among members of the Rural Water Supply Network.

Results of the quantitative household interviews

The quantitative interviews revealed that people perceived a strong need for an improved safe water container on the basis of challenges faced with the current containers (too heavy, difficult to clean, formation of dirt inside the containers and small opening). The respondents also liked the proposed features of the improved containers, which include a large opening, an improved tap, a handle for carrying and a stand (Figure).

The WTP for an improved container strongly depended upon the socio-economic status of the households. The online interviews and surveys showed that higher income households from urban areas (~ 1/3 of the interviewed households) expressed a WTP of approximately 12 USD, while lower income, rural households expressed a significantly lower WTP of approximately 6 USD. The dichotomous WTP choice experiment revealed that 39 % of all the households were not willing to pay more than 5.25 USD, 26.4 % were willing to pay 6.60 USD to 7.90 USD and 34.4 % were willing to pay 10.55 USD to 13.15 USD.

The design evaluations indicated that people mostly liked colours they are familiar with (yellow and transparent), followed by dark blue. The preferred volume was 20 litres, but at the same time, some interviewees complained that the weight of 20 litre containers was too heavy. The preferred height of the stand was around 1m because this would prevent children from messing around with the container. Also, people liked round shapes because the cleaning of round containers is easier.

Results of qualitative stakeholder interviews

In rural Uganda, the stakeholders questioned in the qualitative interviews were confident that improved containers would help solve the recontamination problem. Taps and larger openings were seen as the most important container features. WTP for improved containers was estimated between 1.29 CHF to 5.14 CHF, depending on the village. With an affordable price and a convincing communication strategy, the interviewees were confident that they could sell the containers to 50 % of their customers.

In urban Uganda, the shop managers interviewed thought that people would be interested in a new improved safe water container. In Busia, WTP was evaluated at 7.71 USD to 12.86 USD, while in Kampala, the shop managers thought that people would be willing to pay even more. Currently, standard water containers can be bought from 1.54 USD (20 L) to 18 USD (210 L). Some shops already sell improved safe water containers with taps and handles.

In contrast, the experts from local organisations in different African, Central-American and Asian countries and from international organisations were sceptical about the market potential of an improved safe water container. Most of the organisations emphasised the need for such a container, but thought that the water users would not pay more for an improved container than for the containers they currently use (commonly 1 – 3 USD maximum 5 USD. In the online survey, 29 participants out of 35 estimated that WTP was less than 5 CHF. The experts also mentioned that the most relevant features of the improved containers were: "easy to carry", "durable/robust", "(robust) tap", "easy to ship/transport" and "large openings/easy to clean", while respondents of the online survey mentioned "lid", "a large opening" and "durable".

Conclusion

According to the stakeholder interviews conducted in Uganda, there is a high demand for an improved water container. Urban, higher-income households expressed a significantly higher WTP compared to rural, lower-income households. Whereas kiosk operators, NGO staff and village chairmen in the rural area estimated a WTP lower than that expressed by people in the rural households, shop managers in the urban areas estimated a WTP similar to that expressed by the people in the rural households. In contrast, experts from international and local organisations did not believe that the WTP for an improved container would be higher than for a typical container. To obtain a more accurate understanding of the actual WTP, real market experiments are needed and are currently being planned.

As highlighted by staff of many NGOs and by local stakeholders working in the water sector, a key challenge will be to convince customers about the added value and functionality of a new product. They believed that introducing and promoting improved water containers would require a strong and effective marketing promotional campaign. And they also felt that these marketing campaigns should include promotional activities, such as exhibitions, communication outreach and behaviour change trainings. •

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WASH, Nutrition and Child Health During the Covid-19 Pandemic in Nepal

Our study documented significant changes in water management and hygiene practices in Nepal during the Covid-19 pandemic, which were associated with a reduction in infectious diseases among children. At the same time, household income and children's nutritional status decreased. Regula Meierhofer[1], Bal Mukund Kunwar[2], Akina Shrestha[3]

Introduction

Access to safe and sufficient water, adequate sanitation, hygiene and nutrition are essential preconditions for healthy children. However, despite the clear association between WASH and health, WASH interventions do not always yield the expected results. Improvements in child health can only be achieved with significant reductions of the pathogen load in the household environment, which depend on the efficacy of treatment technologies and consistency in applying them. Past WASH promotion efforts have shown though that establishing a consistent behaviour change in this field is challenging [1].

Several WASH studies conducted during epidemics indicate that a pending epidemic threat coupled with an intensified dissemination of WASH promotion messages might enhance risk awareness, impact social norms and be more effective in achieving WASH-related behaviour change than promotion activities that take place during normal times [2]. Our study's goal was to contribute additional evidence to the understanding of WASH-related behaviour change during epidemics and their association with child health by analysing longitudinal data that had been collected before and during the Covid-19 pandemic in the Surkhet, Accham and Dailekh Districts in Mid-Western Nepal in 2019 [3, 4].

Methodology

The longitudinal, cross-sectional study was conducted in areas with piped water supply schemes. Households were randomly selected to be included if they had at least one child between 6 months and 10 years present at the time of baseline data collection during spring 2018. The same households and children (490 in Dailekh and Accham and 589 in Surkhet) were interviewed and examined during the second data collection, three years after the baseline data collection. The interventions consisted of adequate WASH, infrastructure improvement and hygiene trainings. Water safety interventions, including scheme-level chlorination and household water treatment, were partially promoted in all project sites. During the pandemic, various media channels and community health workers promoted hygiene measures.

In spring 2021, a second round of data collection was conducted in Surkhet during a recession of the pandemic. It took place before new lockdowns occurred due to a high infection rate of the Delta variant of the SARS-CoV-2 virus. In Dailekh and Accham, endline data were collected during November and December 2021. Quantitative data on water management and hygiene practices, the nutrition provided to children, information received on protective measures against Covid-19 and corresponding behaviour recommendations, and child health, e.g. fever, respiratory infections and diarrhoea, were collected during household interviews. Certified medical assistants did anthropometric measurements of the children (height, weight and mid-upper arm circumference) and examined them for clinical signs of nutritional deficiencies. A fresh morning stool sample of the participating child was analysed for parasitic infection. Drinking water quality was evaluated at the source and at the point of consumption using membrane filtration of 100 ml water samples to detect *E.coli*.

The statistical analysis done included frequency statistics, logistic regression, the McNemar Test for binary variables and the Wilcoxon signed rank test for continuous variables to assess the significance of the difference between variables at baseline and endline. Generalized Estimating Equation with binary logistic distribution, independent

	Surkhet				**Accham Dailekh**			
	Baseline %	**Endline %**	**Δ prevalence %**	**p *value*** McNemar Test	**Baseline %**	**Endline %**	**Δ prevalence %**	**p *value*** McNemar Test
Water Management								
Piped water at the home	40.6	52.6	12.0	<0.001	0.8	1.4	0.6	0.549
Water source sometimes chlorinated during the past 2 years	0	39.6	**39.6**	**<0.001**	0.0	5.8	5.8	n/a
Kettle for water boiling available	2	8.3	6.3	<0.001	0.7	29.8	**29.1**	**<0.001**
Ceramic water filter available	12.2	34.8	**22.6**	**<0.001**	7.8	18.9	**11.1**	**<0.001**
Water transport container is clean	81.3	90.8	**9.5**	<0.001	73.9	77.3	3.4	0.21
Hygiene & Nutrition								
Toilet is clean	56.3	77.9	**21.6**	**<0.001**	42.4	60.5	**18.1**	**<0.001**
Kitchen drying rack available	60.3	69.4	9.1	0.001	24.5	36.8	12.3	<0.001
Type of floor in the house (cement vs earth)	27.3	47.4	**20.1**	**<0.001**	4.7	8.0	3.3	0.002
Presence of handwashing facility	62.8	98.1	**35.3**	**<0.001**	17.9	64	**46.1**	**<0.001**
	[mean (SD)]	**[mean (SD)]**	**Δ prevalence**	**p *value***	**[mean (SD)]**	**[mean (SD)]**	**Δ prevalence**	
Frequency meat, fish*	3.23 (1.2)	2.59 (1.0)	-0.65 (1.6)	<0.001	2.8 (1.4)	2.5 (1.2)	-0.33 (1.7)	<0.001
Frequency eggs*	1.93 (1.7)	2.30 (1.2)	0.35 (2.0)	<0.001	1.2 (1.1)	2.3 (1.2)	1.1 (1.6)	<0.001
Frequency leafy green vegetables*	4.27 (2.2)	2.57 (1.5)	-1.7 (2.7)	<0.001	5.1 (2.1)	4.0 (1.6)	-1.1 (2.6)	<0.001

**Categories: three times per day (7), twice per day (6), once per day (5), every 2nd day (4), two times per week (3), once per week (2), less than once per week (1), not at all (0)*

Table 1: Changes in Water, Sanitation, Hygiene and Nutrition before and during the Covid-19 pandemic.

	Surkhet				Accham and Dailekh			
	Baseline %	**Endline %**	**Δ pre-valence %**	***p value*** McNemar Test	**Baseline %**	**Endline %**	**Δ preva-lence %**	***p value*** McNemar Test
Parasitic infections								
Soil transmitted helminths	26.4	21.2	-5.2	<0.001	24.4	20.1	-4.3	**<0.001**
Hymenolepsis nana	1.6	0	-1.6	<0.001	8	1.3	-6.7	0.45
Giardia lamblia	13.6	2.9	**-10.7**	**<0.001**	34.2	6.5	**-27.7**	**<0.001**
Infectious diseases in the past 7 days								
Fever	37.9	16	**-21.9**	**<0.001**	41.1	16.8	**-24.3**	**<0.001**
Cough	40.2	19.6	**-20.6**	**<0.001**	36.9	14.4	**-22.5**	**<0.001**
Respiratory difficulties	16.1	5.8	**-10.3**	**<0.001**	14.3	4.3	**-10.0**	0.002
Diarrhoea	13.8	4.4	**-9.4**	**<0.001**	19.6	9.5	**-10.1**	**<0.001**
Growth (HAZ, WAZ scores)								
Medium stunting (HAZ)	24.5	20.9	-3.6	0.15	28.3	17.8	-10.5	0.01
Severe stunting (HAZ)	11.8	10.4	-1.4	0.15	26.6	**48.5**	**21.9**	**0.01**
Wasting (WAZ)	11.3	15.9	4.6	<0.001	19	**54.9**	**35.9**	**0.01**
Clinical signs of malnutrition								
Pale conjunctiva (Iron deficit)	24.8	15.3	**-9.5**	**<0.001**	47	63.3	**16.3**	**0.01**
Loss of hair pigments (Protein deficit)	9.5	0.4	**-9.1**	**<0.001**	13.3	41.4	**28.1**	**0.01**
Bitots spots (Vitamin A deficit)	13.1	18.7	**5.6**	**<0.001**	26.7	40.2	**13.5**	**0.01**
Spongy bleeding gums (Vitamin A deficit)	14.3	18.5	4.2	<0.001	17.8	66.7	**48.9**	**0.01**

Table 2: Child health before and during the Covid-19 pandemic.

correlation, and robust variance estimation accounting for repeated measures with random intercepts at the individual level was used to assess the association of health outcomes with longitudinal changes in WASH-related risk factors.

Results

Interventions prior and during the Covid-19 pandemic effectively reached the population in the study areas; 94 – 98.5 % of the households received information on Covid-19. In May 2021, only 7 % of interviewees in Surkhet reported a Covid-19 case in the household. In December 2021, 96 % of households in Accham and Dailekh reported at least one case of Covid-19 in the family and 12 % reported mortality. Significant changes occurred in water management and hygiene in all districts. Table 1 summarises the most significant changes in WASH and nutrition. Particularly remarkable was the increased frequency of handwashing and construction of handwashing stations by the households. We hypothesize that people were particularly motivated to improve hand hygiene after receiving numerous handwashing instructions due to the threat of contracting Covid-19.

In all districts, there was a strong and significant reduction in the incidence of infectious diseases and in parasitic infections. Table 2 presents details of infectious diseases among children before and during the Covid-19 pandemic. The analysis of risk factors and child health revealed that changes in WASH in Surkhet were associated with improved child health. Four main WASHrelated risk factors were identified: **(a)** the chlorination of piped water supply schemes, **(b)** handwashing with soap, **(c)** the cleanliness of the container used for the transport of drinking water and **(d)** the type of floor in the household [3]. In Surkhet District, various indicators of malnutrition decreased, including stunting among children. However, wasting in Surkhet significantly increased, which could indicate a short-term reduction of nutrition provided to children. In Accham and Dailekh districts, household income declined due to lockdowns and migrant workers returning during the pandemic. Concurrently, nutrition provided to children decreased. The already high prevalence of malnutrition (stunting and wasting) among children in these areas further increased particularly in Accham and Dailekh during the pandemic, while most clinical signs of malnutrition significantly increased.

Conclusion

Our findings support evidence that people are more likely to improve hygiene behaviour and WASH infrastructure during epidemics. The perception of increased risk and higher vulnerability during an epidemic seems to assist the behaviour change process to improve hygiene practices and more consistent safe water management. However, despite improved hygiene behaviour and associated reduction of infections among children in the study areas, the pandemic lockdowns led to a decline in household income, less nutrition provided to children and an increase in already high levels of malnutrition. This shows that mitigation measures for the prevention of epidemics have to be carefully evaluated. While some interventions were very effective and contributed to improving child health beyond the prevention of the pandemic, others produced substantial social, financial, and health-related problems and challenges. •

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Piloting the Water Flow Diagram in Santa Maria, Bulacan, Philippines

The Water Flow Diagram was tested to assess the water cycle from source to discharge and the interrelationships among various water uses, drinking and wastewater treatment, and storm water management. Multi-stakeholder engagements and participatory approaches were part of the process. Aman Melad[1], Lukas Bouman[2], Dorothee Spuhler[2]

Background

According to the World Bank data for the Philippines of 2020, most of Philippines's population has at least basic drinking water services (94 %) and basic sanitation services (82 %). However, the shares of the population that use safely managed sanitation services (61 %) and safely managed drinking water services (47 %) are low. The Philippine Development Plan (PDP) 2023 to 2028 [1] highlights the challenges facing the country's water resources, including: **(i)** weak and fragmented institutional setup, **(ii)** hydrologic variability, **(iii)** inadequacy in water-related data collection, **(iv)** changing and competing priorities of water infrastructure, and **(v)** required overhaul or redesign of existing irrigation infrastructure facilities. To visualise the challenges and opportunities in urban water management for the city of Santa Maria, Bulacan, a Water Flow Diagram (WFD) was conductedfor the area. The WFD is a simple and easy-to-understand tool developed at Sandec to better visualise urban water usage and assist in advocating for holistic and sustainable water management [2]. The goals were to test the WFD methodology in an Asian context and to guide local stakeholders in the Philippines on the key steps required to generate a WFD.

Methodology

To collect data and develop a WFD with multi-stakeholder engagements, four steps were used:

1. Review of national and local policies, plans, strategies, and legal documents with a focus on water sanitation and hygiene (WASH) and related sectors (e.g., economic and environmental sectors).
2. High-level stakeholder meetings with the officials and representatives of the National Economic and Development Authority (NEDA), Philippine Association of Water Districts Inc. (PAWD), and the United States Agency for International Development (USAID) from August to September 2022.
3. Interviews with the municipal local government unit (MLGU) of Santa Maria, Bulacan, seven public water district and private water concessionaires, and expert consultation with the Maynilad Water Academy from October 2022 to February 2023.
4. Stakeholder consultation with the Integrated Safe Water, Sanitation, and Hygiene (iWASH) Council and Technical Working Group (TWG) of Santa Maria, Bulacan, in January 2023.

Aman Melad

Photo 1: Photo opportunity during the stakeholders' consultation with the members of the Santa Maria iWASH Council and TWG.

What did we learn?

The Figure shows the WFD for Santa Maria, Bulacan, for 2022. A total of 50 million cubic meter of water is used per year, consisting of 42% groundwater, 41% precipitation and 17% surface water. Most of the water is used for domestic purposes (41%), followed by agricultural use (35 %), losses (12 %), industrial utilisation (12 %), and public institutions' water consumption (less than 1%). For the drinking water, the groundwater and surface water extracted from the municipality's environment are treated using chlorination and distributed via a piped network. Overall, agriculture accounted for over 60 % of the water use. However, two-thirds of the water used for agricultural purposes is sourced directly from precipitation and utilised in rainfed agriculture.

There is no sewer system or faecal sludge or wastewater treatment facility for the 14 million m^3/y of wastewater in the municipality. While sludge is generally emptied by a vacuum truck and exported to another municipality, it could not be confirmed if there is no leakage of contaminated wastewater from onsite sanitation into the surroundings. Open channels, locally known as *kanals/esteros*, drain approximately 3 % of the wastewater (0.5 million m^3/y) into surface waters. The iWASH Council and the government's TWG are aware of this situation and intend to prioritise the installation of wastewater facilities.

There is leakage of contaminated wastewater from pit latrines and septic tanks into the surroundings. Also, losses from the piped water in-filtrate into the groundwater. Approximately 20 % of the water used for agriculture are also infiltrated. Another 10 % of the water used in agriculture flows into surface waters, together with the water from the open channels *(esteros)*. A large proportion (ca. 60 %) of the water used in agriculture evaporates and 10 % is exported in agricultural products. To our knowledge, there was no reuse or recycling.

The blue boxes located on the left-hand side in the WFD Figure represent the estimated renewable water resources available in Santa Maria, Bulacan. The volume of water being utilised is lower than the renewable water available within the defined system boundaries. As the renewable volumes of surface or groundwater are not being fully exploited, the likelihood of overexploitation of water resources in the area is low.

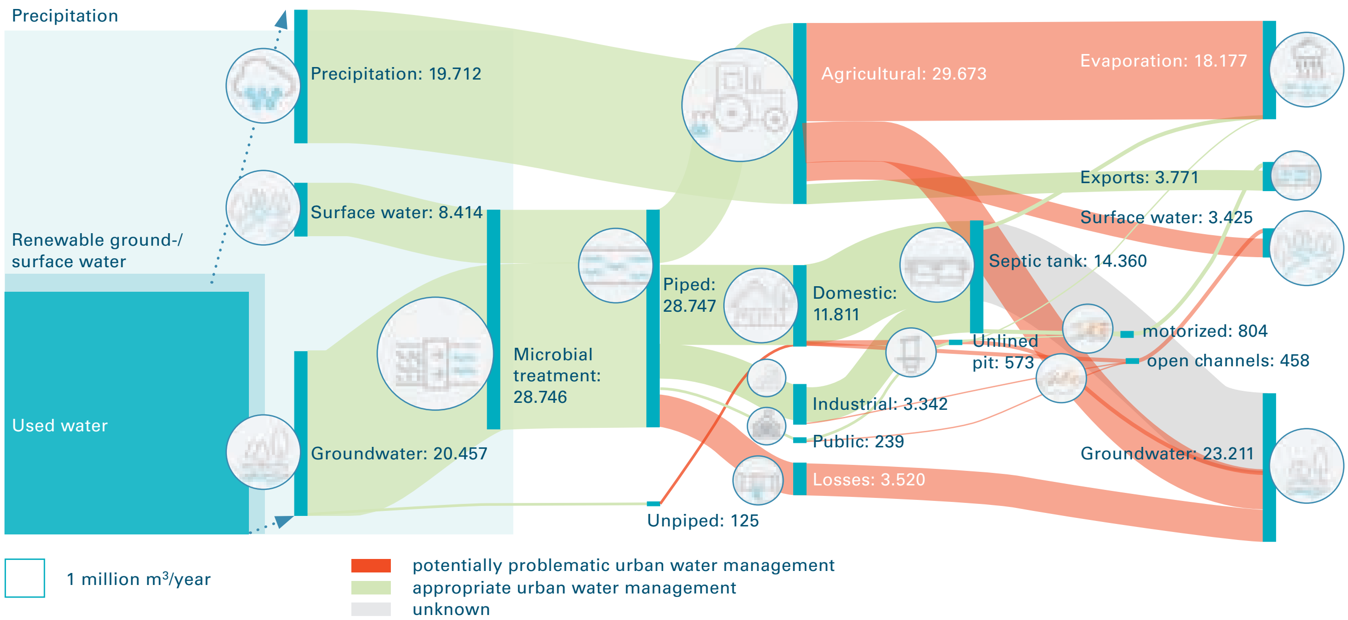

Figure: 2022 WFD for Santa Maria, Bulacan in the Philippines as of February 2023.

Conclusion

The WFD of Santa Maria, Bulacan, identified three main areas of potential improvement related to the WASH sector of the municipality:

1. **Mainstreaming integrated data management system**
   While the WFD for Santa Maria, Bulacan, was generated with strong local support, some of the data was not available and had to be estimated, which limited its accuracy. Thus, there is a need for the iWASH Council and TWG to work with public and private organisations to improve an integrated data management system on WASH-related indicators.
2. **Intensifying septage and sewerage management**
   With the lack of septage management and the absence of sewerage-related technologies in Santa Maria, Bulacan, the iWASH Council and TWG should heighten the MLGU's efforts to invest in the appropriate septage and sewerage management.
3. **Possible recycling of water**
   Interventions to recycle water for potable and non-potable reuse were not observed. As water is not scarce, recycling of water is also not a priority at the moment. However, with population growth and/or climate change water might become scarce in the future. Therefore, it could be helpful to introduce the recycling of water (e.g., rainwater harvesting or greywater reuse) especially in densely populated areas.

The Santa Maria, Bulacan, MLGU emphasised the need to prioritise the upgrading and expansion of water infrastructure in the area by matching the infrastructure needs with potential financing from various sources. The WFD was useful to foster collaboration with local stakeholders and water right holders and will assist in efforts to upscale sustainable water management initiatives. •

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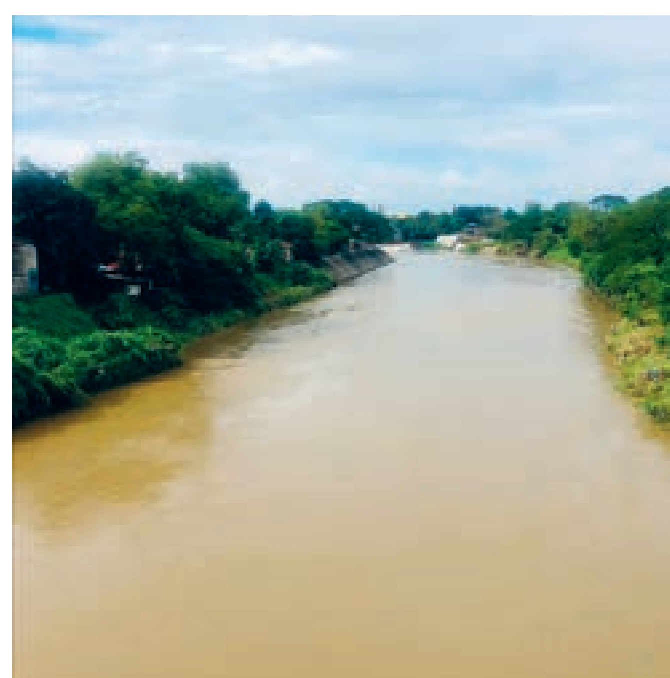
[2] Bouman, L. et al., "Enabling a More Holistic Urban Water Management", *Sandec News*, No 23 (2022), 50–51.



Aman Melad

Photo 2: The Santa Maria River in Santa Maria, Bulacan, a major tributary and water source of the city.

[1] IHE Delft Institute for Water Education, Netherlands & De La Salle University, Philippines

[2] Eawag/Sandec, Switzerland

For the detailed study report and more information on the Water Flow Diagram.

Contact: lukas.bouman@eawag.ch or www.sandec.ch/wfd


ACQUEDOTTO
DI MENDRISIO

Education and Training

Sandec aims at reducing the global WASH capacity gap by offering a wide range of education and training initiatives. These cover face-to-face, blended and online learning formats, as well as fellowships. Five of our main focus areas are:

- Offering free online education at scale with the MOOC series "Sanitation, Water and Solid Waste for Development".
- Fostering capacity development collaborations with partner institutions in Africa, Asia and Latin America.
- Conducting research on digital learning in the WASH sector.
- Teaching Master's courses on Sanitary Engineering at EPFL Lausanne and ETH Zürich.
- Hosting Master's and PhD students and visiting scientists from low- and middle-income countries who receive Eawag Partnership Programme Fellowships.

Photo Site visit in Mendrisio, Switzerland, of the students enrolled in the Certificate of Advanced Studies in Water, Sanitation and Hygiene for humanitarian and developing contexts (CAS WASH) course.

Photo by Claudio Valsangiacomo.

Joint Online Training for WASH Professionals in Somalia

Somalia's Ministry of Health and Sandec are jointly conducting an online WASH training of professionals from government, academia and NGOs. It combines self-paced online learning, online learning sessions with Sandec researchers and onsite learning activities. Sara Ubbiali[1], Abdisalam Ibrahim Hussein[2], Zakariye Abdi Hashi[2] and Fabian Suter[1]

Introduction

Somalia is one of the world's most fragile states, facing multiple challenges, such as drought, hunger, disease and economic pressure. These issues have further exacerbated the country's humanitarian aid and development situation, especially regarding access to WASH services. According to the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), approximately 8 million people (47% of the population) in Somalia will need life-saving WASH assistance in 2023, a 25 % increase from 2022. Additionally, the ongoing conflict between various factions in the country has resulted in the displacement of populations, increased poverty, and limited access to basic services [1]. Despite this dire situation, Somalia's Ministry of Health (MoH) has initiated a number of initiatives. Among them, in collaboration with Sandec, is a learning journey for WASH practitioners who are actively engaged in building a more resilient future for Somalia.

Personal contact as starting point

In summer 2022, Abdisalam Ibrahim Hussein, Head of the WASH and Environmental Health Unit at the MoH in Somalia, proposed a training collaboration with Sandec to strengthen the capacity of his team at the Ministry. This was during a CAS WASH organised by SUPSI, Eawag and UniNE [2]. A consultation with key WASH actors in the country revealed that demand was also high among other institutions. Hence, access to the training was expanded to Somali WASH professionals from government, academia and NGOs.

Creating a tailored training with the WASH MOOCs

Based on the request to get a full-fledged WASH education, the training was built around the MOOC series "Sanitation, Water and Solid Waste for Development" [3]. Learners complete each of the four courses within two months and have the flexibility to learn anytime, individually or in a group (Photo). The courses are complemented with live online sessions jointly organised by Sandec and the MoH, and an online question box has been set up to facilitate communication. The self-paced MOOC learning is embedded into an engaging environment, where topics are being thematically introduced and learners can directly interact with Sandec content experts. Having the live online sessions helps to limit learner isolation, and the MoH can prioritise information of particular relevance for the Somali context [4, 5].

About the learners

27 people are enrolled (10 female and 17 male learners), all of whom have professional experience in the WASH sector. The average age is 33 years, and all hold a Bachelor's or Master's degree. While the majority have experience with online courses, it is new for about one-third of the learners. Participants can attend the training for free and will earn a Statement of Accomplishment at the end jointly issued by Sandec and the MoH.

Ministry of Health of Somalia

Photo: Introduction to the Household Water Treatment and Safe Storage MOOC in Somalia.

Conclusion

Although the training is ongoing, some preliminary conclusions can be drawn: personal contact was essential for the joint design and implementation of the training, taking two months to complete a MOOC seems to be suitable for practitioners working full-time, and the leadership and collaborative spirit of an in-country partner, such as the MoH, is crucial for the conversion of the MOOC series into a contextualised learning experience. There are promising signs that this training is making a relevant contribution to increasing the capacity of the WASH sector in Somalia and can become a role model for Sandec's capacity development collaborations with partners in other countries. •

References

[1] *Humanitarian Needs Overview* (OCHA, 2023).

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[5] Grünewald, F. et al., 'Designing MOOCs for the Support of Multiple Learning Styles', Presented at the European conference on technology enhanced learning, (2013) 371 – 382.

[1] Eawag/Sandec, Switzerland

[2] Ministry of Health, Somalia

More information about Sandec's capacity development collaborations:
https://www.eawag.ch/en/department/sandec/digital-learning/collaboration/

Contact: fabian.suter@eawag.ch; sara.ubbiali@eawag.ch;
Abdisalam Ibrahim Hussein: wash@moh.gov.so

Building Capacity on Solid Waste Management for Humanitarian Responses

During humanitarian responses, waste management requires particular consideration. To support field practitioners in integrated and safe solid waste management, Sandec trained 17 humanitarian WASH specialists in 2022.

Dorian Tosi Robinson[1], Sara Ubbiali[1], Christian Zurbrügg[1]

SDC

Photo 1: A participant presenting solid waste flows for a group exercise.

SDC

Photo 2: Participants analysing a case study in a group work.

Introduction

Solid waste management (SWM) is essential to protect public health and the environment and should be prioritised during humanitarian responses or protracted crises. Yet, many constraints impede the provision of safe waste management services when these occur. To equip field professionals with the knowledge to improve solid waste management in humanitarian responses, Sandec, in partnership with the Swiss Humanitarian Aid Unit (SHA), developed and implemented a five-day training course for 17 WASH specialists who had different backgrounds and expertise.

Solid waste management training

How to improve waste management with limited human and financial resources, in a constantly changing environment, while also considering urgent problems? These are some of the issues covered in the training, which juxtaposed textbook theory with practical realities and how to find the best applicable solutions to SWM challenges. The training curriculum was based on the Integrated Sustainable Waste Management (ISWM) framework and covered all the stages of the solid waste management service chain, such as waste collection, transportation, treatment and disposal. Throughout the training, special emphasis was given to deal with governance challenges – including the role of host communities and their existing waste systems.

Although the training took place at a pristine Swiss location, learning by doing was strengthened through group exercises using existing case studies that dealt with refugee camp settings from Zimbabwe and Bangladesh. Participants had to analyse the different solid waste flows and discuss the needs and challenges of each stage of waste management in these settings (Photo 1). The case of Cox's Bazar refugee camps in Bangladesh was given special attention, due to its well-established local coordination structure among humanitarian actors, and the already ample baseline data available from recent initiatives implemented to improve and foster safe solutions for waste management. Particular attention was also given to innovations dealing with the concept of circular economy, comprising behaviour change training to improve source segregation, separate collection of recyclables, recycling innovations, as well as integration of the informal sector.

External contributions

Besides contributions by Sandec and the participants themselves, humanitarian experts of the United Nations High Commissioner for Refugees (UNHCR) shared their experiences and the main challenges related to SWM that they faced during humanitarian responses through interactive sessions and case studies. Additionally, in line with the NEXUS agenda of the Swiss Agency for Development and Cooperation (SDC), SHA and Sandec; the governance unit of the SDC was invited to share its expertise and to highlight the linkages between governance in development and in the humanitarian sector. The participants worked to put into practice what they learned and developed strategies and solutions that merged development cooperation and humanitarian aid responses for a case study dealing with armed conflict (Photo 2).

Conclusion

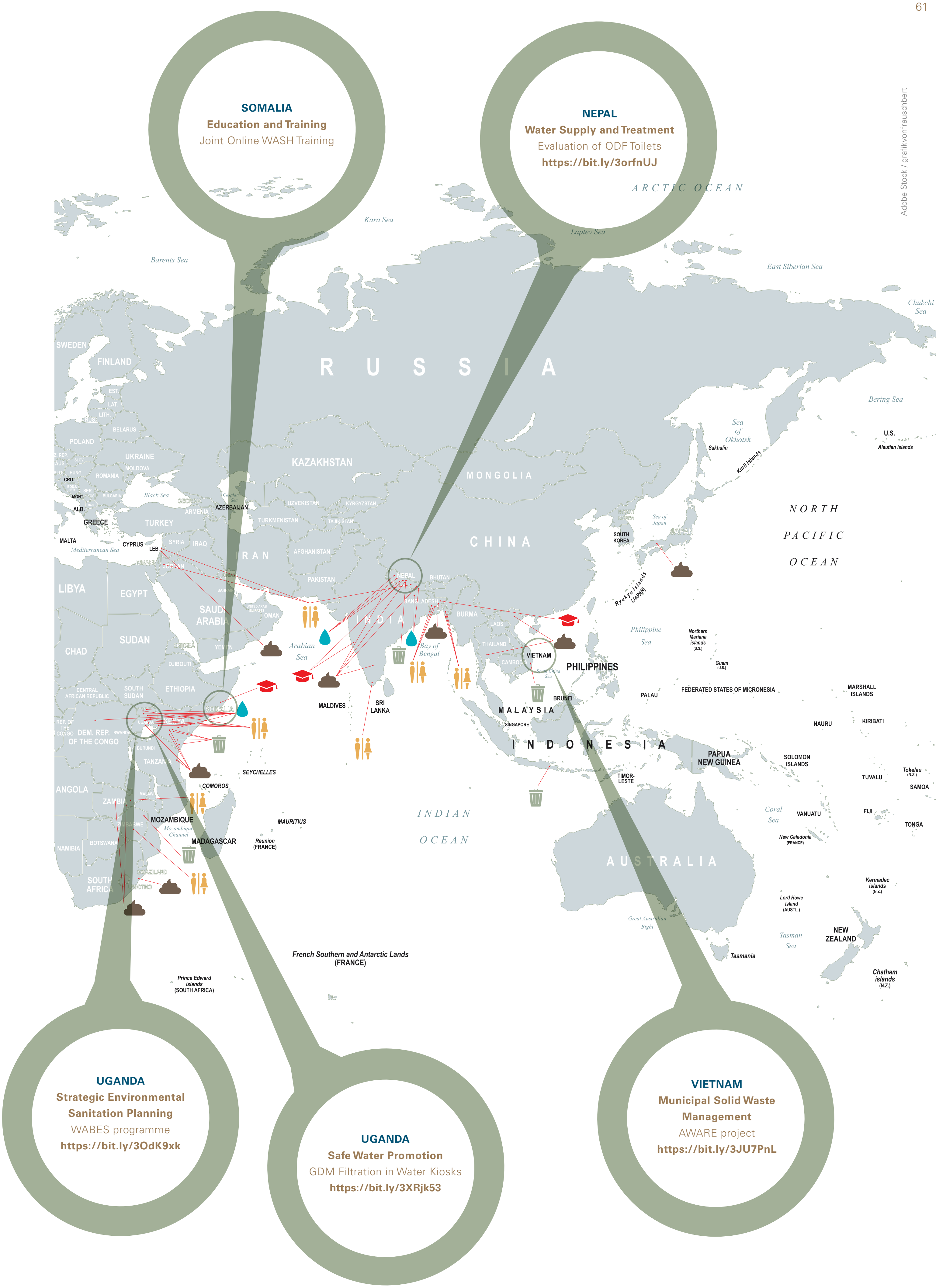
Although more and more people in the sector acknowledge that solid waste management is important to address, knowledge of SWM is not yet widespread among many humanitarian actors. Targeted training helps practitioners understand key concepts and how to apply existing tools to better assess and plan for the safe management of solid waste in humanitarian contexts. The ISWM framework is an ideal entry point to start with in order to teach about the design, implementation and operation of a SWM service that safeguards public health and the environment and protects the most vulnerable in humanitarian crises. •

[1] Eawag/Sandec, Switzerland
Funding: Swiss Agency for Development and Cooperation
More information: www.sandec.ch/swm
Contact: dorian.tosirobinson@eawag.ch

Global Research Projects and Partners Map

Legend:

- Strategic Environmental Sanitation Planning
- Municipal Solid Waste Management
- Management of Excreta, Wastewater and Sludge
- Water Supply and Treatment & Safe Water Promotion
- Education and Training


SOMALIA
Education and Training
Joint Online WASH Training
NEPAL
Water Supply and Treatment
Evaluation of ODF Toilets
https://bit.ly/3orfnUJ
UGANDA
Strategic Environmental Sanitation Planning
WABES programme
https://bit.ly/3OdK9xk
UGANDA
Safe Water Promotion
GDM Filtration in Water Kiosks
https://bit.ly/3XRjk53
VIETNAM
Municipal Solid Waste Management
AWARE project
https://bit.ly/3JU7PnL
ARCTIC OCEAN
Kara Sea
Laptev Sea
Barents Sea
East Siberian Sea
Chukchi Sea
Bering Sea
RUSSIA
SWEDEN
FINLAND
POLAND
BELARUS
UKRAINE
ROMANIA
KAZAKHSTAN
MONGOLIA
CHINA
GREECE
TURKEY
MALTA
CYPRUS
Mediterranean Sea
Black Sea
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DJIBOUTI
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CENTRAL AFRICAN REPUBLIC
DEM. REP. OF THE CONGO
SOMALIA
KENYA
TANZANIA
ANGOLA
ZAMBIA
MOZAMBIQUE
MADAGASCAR
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BOTSWANA
SOUTH AFRICA
COMOROS
SEYCHELLES
MAURITIUS
Reunion (FRANCE)
MALDIVES
SRI LANKA
Arabian Sea
Bay of Bengal
INDIAN OCEAN
French Southern and Antarctic Lands (FRANCE)
Prince Edward islands (SOUTH AFRICA)
SOUTH KOREA
JAPAN
Sea of Japan
Sea of Okhotsk
Sakhalin
Kuril Islands
Ryukyu Islands (JAPAN)
NORTH PACIFIC OCEAN
U.S.
Aleutian islands
Philippine Sea
Northern Mariana islands (U.S.)
Guam (U.S.)
PALAU
FEDERATED STATES OF MICRONESIA
MARSHALL ISLANDS
NAURU
KIRIBATI
PAPUA NEW GUINEA
SOLOMON ISLANDS
TUVALU
Tokelau (N.Z.)
SAMOA
TIMOR-LESTE
Coral Sea
VANUATU
FIJI
TONGA
New Caledonia (FRANCE)
AUSTRALIA
Great Australian Bight
Kermadec islands (N.Z.)
Lord Howe Island (AUSTL.)
Tasman Sea
NEW ZEALAND
Tasmania
Chatham islands (N.Z.)

Monika Tobler – Cocoa Sustainability Manager, Lindt & Sprüngli

Unknown

Monika Tobler is from Switzerland and has a Master's of Science in Biology from ETH Zürich.

Photo: Exchange with cocoa farmer on honey production as an additional income generation opportunity.

What did you study and where did you do your university degrees?

I am a biologist by training and specialised in ecosystems and taxonomy. For my MSc at ETH Zurich, I studied the drought resistance of native and invasive species in the Seychelles. Working in international cooperation, additional topics became important and, thus, I later completed advanced studies in coaching, organisational development and change leadership.

How did you find out about Eawag-Sandec?

I already knew of Eawag from my studies, having attended a number of Eawag lectures. In 2008, my assignment with FAO in Burkina Faso came to an end and I was looking for my next professional adventure. While I had mainly worked on sustainable agriculture in Burkina Faso, the lack of access to clean drinking water and sanitation was omnipresent for most Burkinabé. Therefore, I was very excited to join Sandec as a project manager for drinking water projects.

What work did you do at Eawag-Sandec?

I managed projects in several Sub-Saharan African countries to disseminate methods for household water treatment and safe storage, as well as measures to improve hygiene. I supported partner organisations in the planning, implementation and scientific evaluation of these projects, as well as their advocacy efforts, and their participation in policy dialogues. Of course, fundraising was equally part of the job and I was also responsible for the SODIS website.

How was Eawag-Sandec beneficial to your career?

Managing development projects in a research environment has been extremely inspiring and has given me a good understanding of the challenges faced when translating research results into meaningful applications that truly benefit people in the Global South. Moreover, to meet today's challenges, international cooperation needs to learn much faster how to address them. Research has a key role to play in this learning process. Based on this experience, I have always attached great importance to learning throughout my career.

What are you presently doing?

To achieve its goal of creating decent and resilient livelihoods for cocoa farmers and their families today and in the future, Lindt & Sprüngli deploys its own sustainability program. As a Cocoa Sustainability Manager, I am responsible for the implementation of the Farming Program in Madagascar and Papua New Guinea. In my role as the Global Lead for Monitoring, Evaluation and Learning, I support partners on their way to collect meaningful data that is translated into more effective and efficient strategies. Collaboration with research is a key pillar in my work. •

Contact: mtobler@gmx.net

Amplifying the Impact of Research on Society

How to amplify the impact of research on society is a ripe area of opportunity for researchers. To deliver "science that matters", research, practice and funding activities have to be aligned in resolving society's grand challenges. Sandec is enhancing this through scientific knowledge brokerage in line with its water, sanitation and solid waste research themes.

Knowledge brokerage fosters synthesis, translation and dissemination of research to practitioners. In doing so, it supports the learning of practitioners. And this work incorporates feedback from practitioners into current research questions and outputs.

Brokerage amplifies research's societal impact by exploiting synergistic opportunities between researchers and practitioners. It enhances the adoption of research outputs by practitioners and provides early opportunities for practitioners and users to shape research questions in line with actual needs.

My name is George Wainaina. In collaboration with colleagues at Sandec, I lead scientific knowledge brokering and encourage practitioners, funders and researchers to reach out for collaborations.

Robert Tjalondo

Photo: George Wainaina.

Eawag-Sandec Becomes a Member of the Global WASH Cluster

The Global WASH Cluster (GWC) is the largest humanitarian WASH stakeholder platform worldwide, with more than 90 actors coordinating water, sanitation and hygiene (WASH) interventions in humanitarian aid operations. It is led by UNICEF and operates on the principles of coordinated partnership and accountable humanitarian WASH coordination that is equitable and people-centred. At the global level, the GWC supports the cluster approach by strengthening the system-wide preparedness and coordination of response capacity in humanitarian crises. At the country level, the GWC supports national coordination platforms to strengthen partnerships, and the predictability and accountability of humanitarian action, by improving prioritisation and clearly defining the roles and responsibilities of humanitarian organisations. Eawag-Sandec is one of only a few research institutions participating in the GWC and contributed to its Strategic Plan 2022–2025.

To find out more about the Global WASH Cluster, visit: www.washcluster.net

The Sandec Team

From left to right – Front row: Lukas Bouman, Ariane Schertenleib, Daniela Peguero, Jasmine Segginger und Nala, Elizabeth Tilley, Laura Stocco, Linda Strande, Dorian Tosi Robinson, Paul Donahue
2nd row: Zie Coulibaly, Abihek Narayan, Stefan Diener, Fabian Suter, Nienke Andriessen, Sara Marks, Regula Meierhofer, Adeline Mertenat, Sara Ubbiali, Dorothee Spuhler, Franziska Genter, Anne Nakagiri, George Wainaina
3rd row: Christoph Lüthi, Navarro Ferronato, Maxwell Bergström, Philippe Reymond, Vasco Schelbert, Christopher Friedrich, Michael Vogel, Caterina Dalla Torre
Missing in photo: Chris Zurbrügg, Sital Uprety, Laura Baquedano, Stanley Sam, Kelsey Shaw

New Faces at Sandec

Ednah Kemboi has an MSc in Sanitary Engineering from IHE Delft Institute for Water Education and a BSc in Civil and Structural Engineering from Moi University, Kenya. She is a Wastewater Treatment and Faecal Sludge Management expert with more than 10 years of experience in academia and industry and has taught water and sanitation courses at Moi University for the past seven years. She is currently a PhD student in Sandec's MEWS group.

Marisa Boller holds an MSc in Environmental Engineering from EPFL with a specialization in water resources and treatment. She has gained valuable experience in the field of WASH in low- and middle-income countries through projects conducted during her studies and she shows a passion for addressing water, sanitation and hygiene challenges. Currently, she is a Project Officer in the WST group at Sandec.

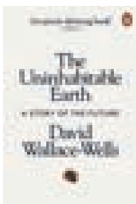
George Wainaina holds a Ph.D. in Sustainability Transitions and Innovation Management for basic service provision from Utrecht University. He has over five years of international experience consulting for and implementing water and sanitation projects in urban and drought contexts. He is currently the Scientific Knowledge Broker at Sandec.

Nabin Bogati holds a MSc. in Sanitation Technology and a B.Tech. in Biotechnology from Kathmandu University. He has experience working as Research Assistant in various project related to Biotechnology and has more than three years of experience as a WASH consultant in Nepal. Currently, he is a PhD student in Sandec's MEWS group.

Kayla Coppens, MSc in Environmental Sciences from the University of Geneva, is doing a PhD at UNG in collaboration with Eawag Sandec, specialising in vermifiltration for decentralised domestic wastewater treatment. She is a founding and active member of aneco, an association implementing decentralised wastewater treatment in Switzerland, and of VaLoo, the Swiss umbrella association for circular sanitation.

On the Bookshelf

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



The Uninhabitable Earth: A Story of the Future

This book is a ruthless portrait of climate change and its impact on our future lives on Earth. It explores what to expect in the coming decades if humanity does not change course fast and describes the effects of accelerating climate change as 'all-encompassing and all-transforming'. Written for a non-scientific audience, it aims at galvanizing public action and politics before it is too late.

By: David Wallace-Wells
Penguin Books, 2019
320 pages
ISBN: 9780141988870

Safe Water Promotion

Rural Community Water Supply: Sustainable Services for All

The book addresses the factors that need to come together to make rural water supply truly available to everyone. Sustainable water supply for all requires sound stewardship of water resources, good quality physical infrastructure and management and financing arrangements that are fit-for-purpose. In many countries, systemic change is needed.

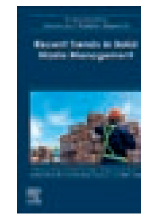
By: Richard C. Carter
Practical Action Publishing 2021
206 pages
ISBN: 1788531655

Water Supply and Treatment

The Three Ages of Water: Prehistoric Past, Imperiled Present, and a Hope for the Future

This book guides the reader through the long, fraught history of our relationship to water, the resource central to existence on Earth. Humanity's achievements made possible by water have also brought about consequences, i.e. ecological destruction and climate change, which threaten us. It charts a path toward a sustainable future for water and the planet.

By: Peter Gleick
Public Affairs, 2023, 368 pages
ISBN: 1541702298



Municipal Solid Waste Management

Recent Trends in Solid Waste Management

Presenting comprehensive information on recent advances in solid waste treatment and management, readers will learn about up-to-date/background information on global annual solid waste generation and effective waste management strategies (recycle, reuse, remediate). It will assist both the academic and industrial communities.

By: Balasubramani Ravindran (ed.) et al.
Elsevier, 2023
450 pages
ISBN: 9780443152061

On the YouTube Channel

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

Assembling the Volaser

This video shows you how to assemble the Volaser, a measuring device developed to measure in situ volumes (quantities) of fecal sludge. Understanding both quantities and qualities is essential when designing treatment facilities, emptying programmes and for sound fecal sludge management planning. The *Operating the Volaser* video will also soon be up on our YouTube channel.

Produced by: the Management of Excreta, Wastewater and Sludge group at Sandec/Eawag
Filmed by: Paul Donahue, Sandec/Eawag
Edited: Paul Donahue, Sandec/Eawag, 2023, 13:25
It can be seen at: https://youtu.be/5vv_BZPrpHk

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Eawag: Swiss Federal Institute of Aquatic Science and Technology

Cover Photo: Sampling for a waste characterisation study in Thu Voc landfill, Tuy Hoa, Vietnam.

Cover Photo by: Dorian Tosi Robinson

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