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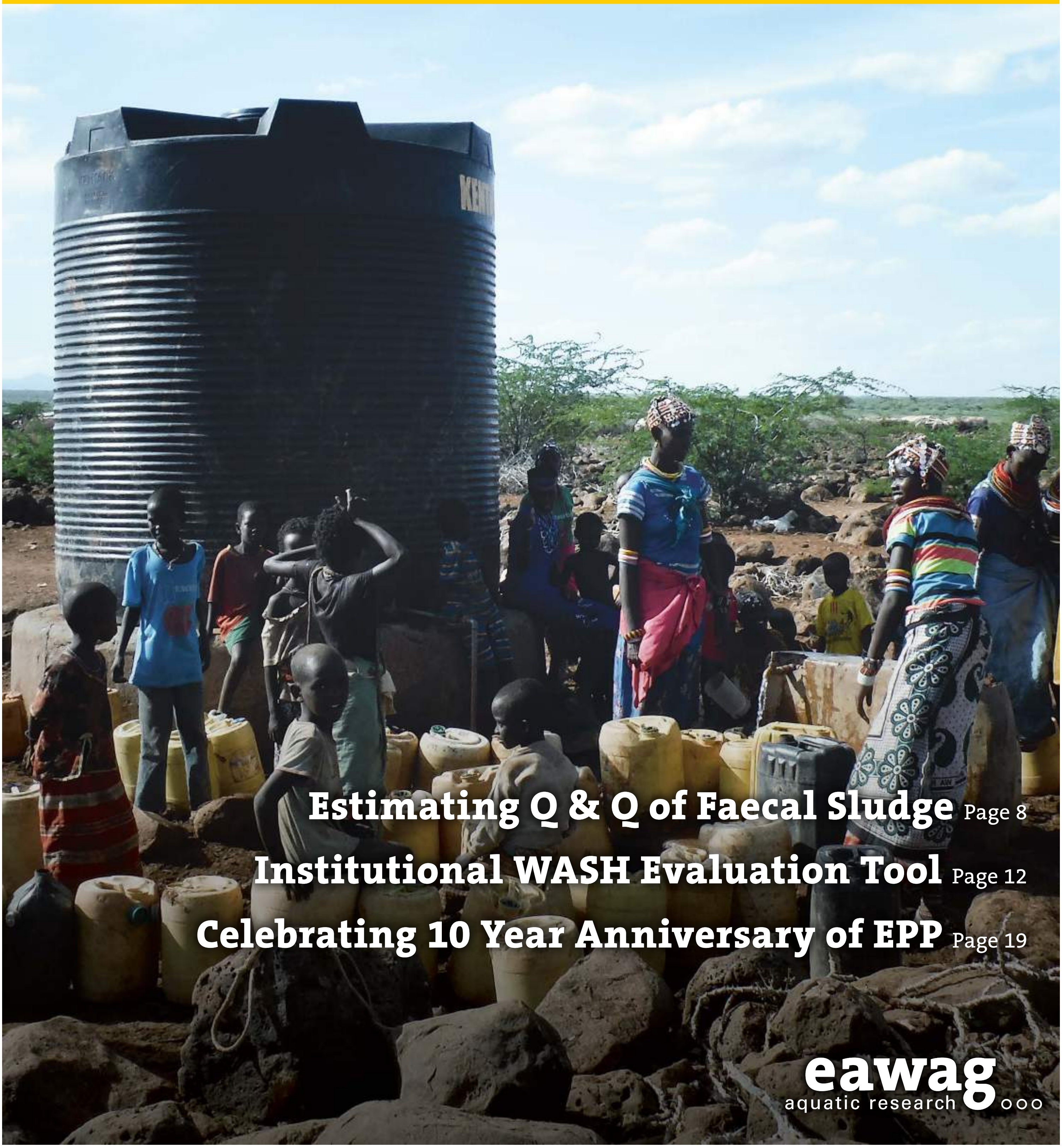
sandec news



eawag aquatic research

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Sandec
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Capacity Development in the WASH Sector

“Better human resources and capable, trained staff hold the key to accelerating access to water and environmental sanitation in the coming decades.”

Sandec has always attached great importance to capacity development and knowledge transfer in the WASH sector. Better human resources and capable, trained staff hold the key to accelerating access to water and environmental sanitation in the coming decades. According to a recent study by the International Water Association, more than 3.3 million sectoral staff will need to be trained in the coming years to meet the enormous demand for expertise.

Capacity development takes many forms and I would like to highlight some recent innovations we have developed with our partners. Our MOOC course series “Sanitation, Water and Solid Waste for Development” now spans five courses of five weeks each and continues to attract over 300 new learners each week, more than half of whom are from the global South. Furthermore, we look forward to delivering the $10\,000^{\text{th}}$ Statement of Accomplishment later this year.

With seed funding from Eawag we are testing a new blended learning approach to upgrade and enhance the quality of educational activities at three universities in Africa and Asia: the University of Malawi, the University of Kathmandu, and Birla Institute of Technology and Science, Goa. This new approach shows promise, as it combines on-line with on-campus learning in a variety of different academic settings.

Increasingly, we are also active in multi-country capacity development initiatives funded by some of our long-standing funding partners, such as SDC, or most recently, the Bill & Melinda Gates Foundation. With the Foundation and local implementing partners we are developing a six-country initiative to strengthen the capacity of the private sector in urban sanitation and faecal sludge management. This new initiative is set to kick-off in September this year.

2018 also marks the tenth year of Eawag’s Partnership Program (EPP) – a flagship fellowship programme that offers MSc and PhD students a research stay of three to four months at an Eawag research department. We have welcomed 85 EPP fellows in the past ten years, some of whom have moved on to important leadership positions.

Last, but not least, Sandec continues to further its communication and social media efforts. Begun more than four years ago, our Facebook site has an ever-growing number of followers. Sandec uses this channel to communicate about new published articles, new funding awards and news about its research.

Besides our capacity development initiatives, Sandec remains heavily engaged in applied research with local partners on a wide range of WASH topics. On pages 8–9, we present faecal sludge management research, and on pages 13–15, the results from a two-year landscape study of small-scale sanitation systems in India. Finally, a report on the newly published Emergency Compendium can be found on page 30.

We hope you enjoy this overview of our research and capacity development efforts and look forward to keeping in touch via Facebook, Twitter and LinkedIn!

Christoph Lüthi
Director Sandec

Cost Modelling of Waste Management – Assessing Alternatives in Bolivia

Waste collection and disposal use are a large part of the municipal budget in low- and middle-income countries. Costs are, however, seldom evaluated systematically. A cost model was developed for a Bolivian municipality to evaluate the status-quo and possible future waste collection scenarios. A. Mertenat[1], M. R. Landaeta[2], Ch. Zurbrügg[1]

Introduction

Poor solid waste management (SWM) threatens local residents and their environment, especially in low- and middle-income settings where limited financial resources and inefficiencies are often the cause of limited service delivery. Interestingly though, many municipalities do not have accurate data on SWM service costs in their municipal budgets. This limits their capacity to assess inefficiencies and is a major barrier to strategic planning and improvements. Although SWM cost-models exist in literature, they are setup for high-income settings containing technical solutions inappropriate for lower-income settings [1]. A simple Excel-based cost modelling tool was developed to assist local authorities, and applied to a Bolivian municipality to help evaluate their current collection service costs and assess alternative waste collection scenarios.

Methodology

Total cost and revenues of current SWM service were assessed by observations, document review and interviewing key stakeholders. The aim was to identify each SWM service work unit and related operating and administrative costs, including: workforce salaries, equipment (Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) considered) and consumables. The data was put into an Excel cost-model developed in previous studies and a model developed by CSD Ingénieurs. The costs were split by four work units: 1) Collection, 2) Transfer station and treatment, 3) Transport and 4) Final disposal. For the collection work unit, cost calculations were based on waste generated per kilometre of road, allowing for estimations of number of vehicles required, route distances and travel time, number of trips and kilometres travelled.

With the cost model in place, four different scenarios were assessed: 1) Baseline scenario – a simplified and optimised mixed waste collection scheme based on the current door-to-door collection service, with transfer stations and subsequent transport to the municipal sanitary landfill; 2) Same as baseline scenario but without transfer stations; 3) A mixed waste collection scheme relying on a self-delivered system to neighbourhood containers; and 4) A two-fraction segregated waste self-delivered system with neighbourhood containers and a central composting facility for the organics. All scenarios were based on similar administrative costs.

Results

The Bolivian study confirmed the knowledge gap at the municipal level about the true total service costs. Only 55 % of the real costs were in the municipal SWM budget; the rest were hidden in expenditures of other municipal departments. The financial analysis revealed that only 4 % of the total expenditures are covered by the current tariff systems and respective user fees.

Modelling of scenarios shows that a transfer station reduces total costs by 14 % (Figure 1), comparing scenarios 1 and 2. This is mainly because fewer vehicles and fuel and less workforce is needed as collection is done by bigger transport trucks that go to the landfill. Scenario 3, waste collection in containers, would decrease total costs by up to 15 %. Here, the improved collection efficiency in terms of decreasing waste collection time, vehicles and workforce needed, outweighs the need for additional container equipment costs. Finally, scenario 4, waste segregation at source and a separate collection with organic waste composting at the transfer station, results in a 19 % cost reduction compared to the baseline. The cost of the various work units shifts, increasing for collection and treatment, and decreasing for transport and disposal due to organic waste diversion from the landfill.

Conclusion

Our study shows that analysing the costs of SWM services systematically can be an eye-opener and activator for local authorities. Knowing the true status quo costs allows them to evaluate cost efficiency and even implement easy improvements. The estimates from our analysis can support decision makers with strategic planning when considering alternative systems and services. It is, however, important to remember that cost modelling shows only one part – the financial aspects – of the complex solid waste management system. Financial modelling and assessments for evaluating service alternatives must always be accompanied by evaluations of social acceptance and environmental impact.

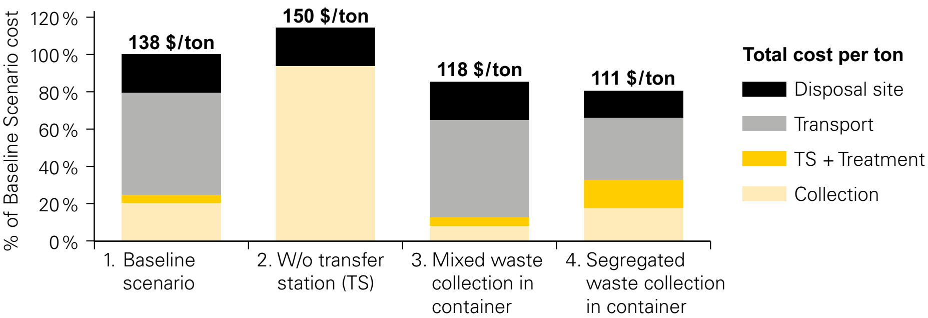

Figure 1: Total cost and cost distribution of different waste collection and transportation scenarios.

[1] Parthan, S. R., et al. (2012): Cost estimation for solid waste management in industrialising regions – Precedents, problems and prospects. Waste Management *32 (3)*, 584–594.

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We would like to thank Pascal Blunier from CSD Ingénieurs, Martín del Castillo from HELVETAS-Bolivia and EPSA Manchaco Social for their support during the field work in Bolivia, as well as SDC for funding this research.

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Combining Biowaste Treatment Technologies to Extract Value Products

A simple spreadsheet-based model can help predict the resource extraction potential of a given amount of biowaste, using a combination of two or more biowaste treatment technologies. The aim is to motivate waste managers to reconsider the multiple resource values of biowastes. Imanol Zabaleta[1], Hildemar Mendez[2], Christian Zurbrügg[1]

	FEEDSTOCK			1st Technology: Anaerobic digestion						2nd Technology: Vermicomposting									
				RANGES (%)			DIGESTATE			RANGES (%)			DEWATERED DIGESTATE				VERMICOMPOST		
	%	kg	-	Min	Max	Alert	%	kg	-	Min	Max	Alert	%	kg	-	Alert	%	kg	-
Mass (ww)*	-	300	-	-	-	-	-	290.8	-	-	-	-	-	20.1	-	-	-	8.6	-
TS	5.0	15	-	5	29		2.0	5.8	-	19	65		28.7	5.8	-		51.7	4.4	-
VS	78.0	12	-	31	91		85.4	4.9	-	12	78		69.2	4.0	-		60.0	2.7	-
TN	3.1	0	-	1	18		6.8	0.4	-	0.2	3.1		2.9	0.2	-		2.1	0.1	-
TP	0.4	0	-	0.2	1		1.1	0.06	-	0.1	0.3		0.7	0.04	-		0.9	0.0	-
TC	43.0	6	-	3	49		47.5	2.7	-	7	80		38.5	2.2	-		33.3	1.5	-
C:N	-	-	25	3	45		-	-	7	25	57		-	-	30		-	-	16
pH	-	-	7	4	7		-	-	7	6	9		-	-	7		-	-	7
Value products							*Biogas (m^3)***	3.6 – 6									*N° worms:* *kg worms:*		*3075* *1.6*

*: ww: wet weight, **: Assuming a biogas yield of 300 – 500 L / kg VS

Table 1: Model results from combining anaerobic digestion and vermicomposting.

Introduction

Biowaste, the main waste fraction in low- and middle-income settings, typically is an unused resource. Many biowaste treatments create products of value and generate residual materials that may contain recoverable resources. A simple spreadsheet-based model developed by Hildemar Mendez during her Master's thesis evaluates mass and substance flows when combining different organic waste treatment technologies, i.e. composting, vermicomposting, anaerobic digestion (AD), black soldier fly processing and slow pyrolysis. It can help decide how to extract maximum value from the same biowaste.

Model description

The MS Excel-based spreadsheet model allows for the combination of two different treatment technologies. Parameters describing the feedstock (blue cells in Table 1) i.e. mass (kg), total solids (%), volatile solids (% of TS), total nitrogen, phosphorus and carbon concentrations (% of TS), Carbon-Nitrogen ratio and pH, are the input values.

The spreadsheet first evaluates if the input values for each parameter meet the requirements of the first selected technology (yellow cells in Table 1). If the values of the input parameters are within the accepted range, the spreadsheet highlights it in green. Otherwise, an alert appears in red. Using transfer coefficients and equations developed based on literature and case studies, the model calculates the mass for the different output products of the technology and respective parameter values (orange cells in Table 1). The obtained mass flows are the input for the next technology.

Combining anaerobic digestion and vermicomposting

Table 1 shows the scenario of treating 300 kg of manure by AD to produce biogas and digestate, and then using the digestate for vermicomposting to obtain worms and vermicompost. All feedstock parameters for manure are suitable for AD (no red alerts). The spreadsheet calculates the expected output amounts of biogas (around 3.6 – 6 m^3) and of digestate with its respective parameters (first orange column in Table 1). The digestate is then evaluated as feedstock for the second technology, vermicomposting, and the spreadsheet alerts the user that certain digestate parameters are outside the suitable range for vermicomposting (marked in red). The user can now consider a treatment step for the digestate, e.g. dewatering or addition of another feedstock. Based on this treatment, the only parameter that remains out of range is total phosphorus (which is in excess), but this would not hinder the treatment process. The model calculates that around 685 worms (0.4 kg) are needed to treat this amount of dewatered digestate and estimates the amounts and parameters of the vermicompost output product.

Conclusion

This tool can quickly assess the potential resources to be obtained by combining different biowaste treatment technologies. Because several assumptions underlie the calculations, the tool outcomes should be considered as rough estimates, not accurate values. Using more case studies with real data to test the model will help refine it. We are confident that such simple models can motivate waste managers to reconsider the multiple resource values of biowastes.

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Monitoring Waste SDGs in Kathmandu: A Need for Standardised Methods

Cities in the global south suffer from poor and unreliable waste data. This has severe consequences on investment plans. By agreeing to fulfil the SDGs, countries need to report on their waste situation. However, robust methodologies to obtain this data are currently lacking. Imanol Zabaleta[1], Eriko Shrestha[2], Christian Zurbrügg[1]

Introduction

Municipal solid waste (MSW) management is key to the Sustainable Development Goals (SDGs) and several indicators relate to waste management. This exercise assessed and compared our own data with data from 2012 provided by the authorities of Kathmandu Metropolitan City (KMC) for indicators 11.6 (city collection and disposal rates) and 12.5 (national recycling rate).

Waste management in KMC

KMC, with a population of 1 003 285 [1], has unsystematic and unsustainable collection and disposal methods. An estimate of the total generated MSW is based on a domestic waste survey conducted with 200 households on a single day. The average generation rate of domestic waste is 233.2 g/d/cap, which amounts to a total generation of 233.1 t/d in the city [2]. KMC authorities assume that this represents 50 % of the total MSW, and commercial and institutional waste comprises the remaining 50 %. The authorities claim that the city generates 466 tons/day of MSW, with a collection rate of 87 % and a 20 % recycling rate [3].

The transfer station receives around 295 t/d from the public waste collection service; 110 t/d and around 108 t/d is transported to the landfill by a door-to-door service and private haulers repectively, and around 1.7 t/d of biowaste is composted. Approximately 114 t/d of recyclable materials is recovered by 660 informal scrap dealers [4]. This amount is not included in the KMC waste collection data.

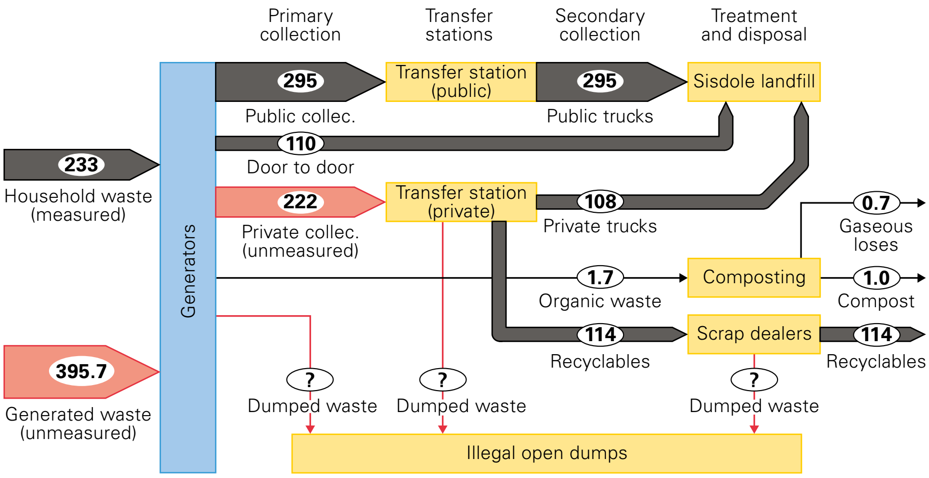

Figure 1: Material flow analysis of waste in KMC.

The material flow analysis (MFA) (Figure 1) shows the waste flows with those partially measured or unmeasured flows depicted in red. Based on the MFA and a mass balance approach, the total generated MSW in KMC is roughly 630 tons/day, 35 % higher than the officially reported number. This, however, is a low estimate as littering and illegal dumping is not included.

Table 1 shows how the SDG indicators 11.6 and 12.5 would change if, based on our estimates, other waste generation amounts are used. Scenario A shows the mass flows as shown in Figure 1, and Scenario B assumes a 10 % higher waste generation amount to account for waste littering and dumping (before collection). As shown in Table 1, the total generation rate estimated by KMC is most likely too low, mainly due to not considering the informal recycling and ignoring littering. Scenario B most likely provides a more realistic picture, although the exact amounts littered and dumped remain unknown.

Conclusion

SDG performance depends on sound data, but methods to obtain city waste data are lacking. In addition, using unreliable data is problematic as it impacts investment plans. We promote the development of methodologies for measuring waste related SDG indicators, such as a systematic MFA. This would also allow for comparable assessments over time to show improvements in performance, as well as comparisons between cities and countries.

		Scenario A		Scenario B		Official figures	
		Tons	*Rate (%)*	*Tons*	*Rate (%)*	*Tons*	*Rate (%)*
Total MSW generation		628.7		691.6		466.0	
Indicator	***Sub-indicator***						
SDG 11.6	Collection	628.7	100 %	628.7	91 %	405.0	87 %
	Safe disposal	513.0	82 %	513.0	74 %	513.0	110 %
SDG 12.5	Recycling	115.7	18 %	115.7	17 %	?	20 %

Table 1: SDG indicator scoring and its variations per scenario.

[1] Statistical Yearbook of Nepal (2013).
[2] Magar et al. (2012): Report of SWM Baseline Study in Kathmandu Municipality.
[3] Asian Development Bank (2013): SWM in Nepal: Current Status and Policy Recommendations.
[4] Pathak, D. R. (2013): Recycled Materials from Solid Waste Stream in Kathmandu Valley.

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Long-term Acceptability of UDDTs: A Case Study in Rural Malawi

People's positive perception of human manure use in agriculture and of diarrhoea reduction due to using UDDTs likely motivated them to continuously use these toilets. Urine usage for agriculture was not so positively perceived; proper understanding of its impact could promote its use. Hidenori Harada[1], Doris A. Mchwampaka[1], Shigeo Fujii[1]

Introduction

To increase sanitation coverage, urine-diverting dry toilets (UDDTs) have been promoted in developing countries since at least 1990 [1]. UDDTs hygienically separate human urine and faeces, closing the loop between sanitation and agriculture by easily facilitating the use of their nutrients in agriculture [2]. UDDT usage is gaining attention; studies reveal that UDDT acceptance is influenced by prevailing conditions where they are introduced [3]. To better understand their use, we studied long-term UDDT acceptability in rural Malawi in terms of diarrhoea, agriculture, and water in 2017.

Methodology

A non-profit organisation, Nippon International Cooperation for Community Development, introduced 1 052 UDDTs in rural Malawi from 2007–2014. Before this, people practiced open defecation or used pit latrines. We investigated 277 of the project's beneficiaries (individual households) in Nkhotakota and Dowa districts. The following data were collected through interviews and observations: 1) household demographics, 2) physical conditions of UDDTs, 3) frequency of UDDT use for faeces/urine, and 4) perceptions on present cleanliness of drinking water, faeces/urine effect on agriculture, and diarrhoea frequency reduction after UDDT use.

Results

221 of the 277 households (80 %) were still using UDDTs. Those not using them stated this was due to their collapsing from heavy rains and/or strong winds (13 %). 98 % of the 221 households perceived a yield increase in agriculture due to the use of human faeces, and 96 % believed there to be a reduction in diarrhoea frequency from using the UDDTs. In contrast, 44 % perceived an agricultural yield increase due to urine use. Only 36 % still used urine as liquid fertiliser, while 44 % had never used urine. Using a Wilcoxon rank sum test, we determined that respondents perceived the yield increase due to human excreta use (average: 4.6 out of 5 levels) to be significantly higher than that from urine use (2.5 out of 5) ($p<0.001$). Comparing urine use between households (79 using, 142 not using), the urine-users had a significantly higher belief in increased crop yields (3.6 out of 5) than the non-urine users (1.8 out of 5) ($p<0.001$). According to a logistic regression analysis, continuous use of urine was associated with positive perception of the yield effect and of cleaner drinking water. However, it was negatively associated with the perception of diarrhoea reduction (Table 1).

Conclusion

Most UDDTs were still in use five to nine years after installation. Beliefs that human excreta positively affect agricultural yields and that UDDT use reduces diarrhoea frequency likely contributed to this. Since physical damage was a primary reason for their non-use, more durable design and construction, and training on how to repair them, should be done to maintain high use levels. Using human faeces was remarkably well accepted, while urine use was less accepted, implying that how people perceive urine's effects could improve the acceptability of its use. The perception that diarrhoea can be reduced seemed to have a negative impact on urine use and might be due to health concerns people had. Proper understanding of the agricultural effect and health risks of urine use could improve its acceptability.

Hidenori Harada

Photo 1: The inside of a UDDT.

	Estimate	S.E.	Z value	Odds Ratio
(Intercept)	-3.183	1.897	-1.68	0.04 [0.00–1.57]
Perception of urine use effect (1–5)	1.129**	0.159	7.08	3.09 [2.30–4.32]
Perception of manure use effect (1–5)	0.051	0.291	0.17	1.05 [0.61–1.90]
Perception of present cleanness of drinking water (Y/N)	1.494**	0.450	3.32	4.46 [1.90–11.17]
Perception of diarrhoea reduction (1–5)	-0.645*	0.248	-2.60	0.52 [0.32–0.84]
Fertilizer demand (1 000 kg)	-0.070	0.050	-1.40	0.93 [0.83–1.02]
Education level (1–5)	0.245	0.217	1.13	1.28 [0.84–1.98]
Monthly income (1–5)	0.146	0.152	0.96	1.16 [0.86–1.57]
*: p<0.01, **: p<0.001				

Table 1: Logistic regression results on the continuous use of urine.

[1] Langereraber, G. and Muellegger, E. (2015): Ecological sanitation – away to solve global sanitation problems? Environment International, *31 (3)*, 433–444.
[2] Esrey, S. A. (1997): Ecosan – closing the loop in wastewater management and sanitation. British Food Journal, *99*, 207–211.
[3] Uddin, S. M. N., Muhandiki, V. S., Fukuda, J., Nakamura, M. and Sakai, M. (2012): Assessment of social acceptance and scope of scaling up urine diversion dehydration toilets in Kenya. Journal of Water, Sanitation, and Hygiene for Development, *2 (3)*, 182–189.

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Acknowledgements: The authors appreciate the suggestions given by Dr Elizabeth Tilley.
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Method to Estimate Quantities and Qualities of Faecal Sludge

The design of appropriate management and treatment solutions for faecal sludge depends on knowing its quantities and qualities. Previously there has been no method to determine reasonable estimates of quantities and qualities; however, Sandec's research is addressing this need. Miriam Englund[1], Juan Pablo Carbajal[2], Linda Strande[1]

Introduction

Reasonably accurate estimations of quantities and qualities (Q&Q) of faecal sludge are very important for the design of appropriate management solutions. For example, under-designing faecal sludge treatment plants will result in risks to public health, and over-designing them will waste financial resources. Determining Q&Q of faecal sludge in a city is like counting fish in a lake. It is complex and difficult and hidden under water (fish) or the ground (faecal sludge), but it is possible to make reasonable estimations. Doing so, however, requires prior knowledge, research and structured approaches to make sure that the assumptions reflect the reality.

Determining Q&Q of faecal sludge is much more complicated than with sewer-based sanitation, where wastewater is relatively homogenised during transport in the sewer. There is a huge diversity observed at the level of each individual toilet. The Q&Q method provides a way to make weighted averages for an entire area, versus trying to predict what is happening in individual containments of faecal sludge.

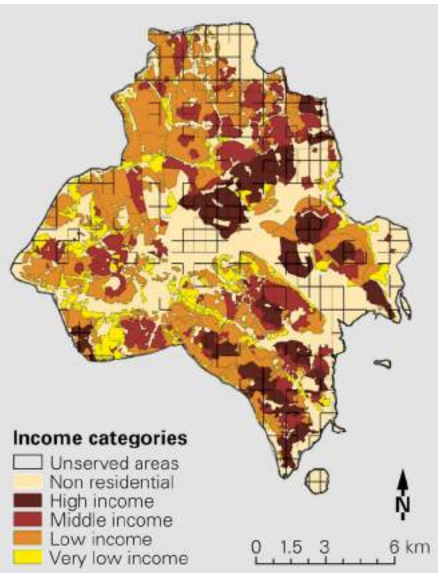

Figure 1: Income categories and areas without service provision is an example of SPA-DET that can be used as predictors of faecal sludge Q&Q [2].

The Q&Q method is an approach to data collection to make practical estimates at a reasonable cost. Further development and use of standard methods in the faecal sludge management field will result in more comparable and accurate results. The method has evolved with time, from basic Sludge Production or Sludge Collection methods [1] and will continue to change to meet the demands of this rapidly growing sector. It was developed and then field-tested in Kampala, Uganda, Hanoi, Vietnam, and Dar es Salaam, Tanzania, with more field-trials in India and Nepal planned for the coming year. The method is appropriate for any scale, from small communities to entire cities, and is applicable worldwide.

Method for data collection

The method for data collection is based on the hypothesis that types of demographic, environmental and technical (DET) data that can be spatially analysed (SPA), can be used as predictors of faecal sludge Q&Q. It is important to note these are correlations, not necessarily causation, but if consistent relations are observed, they can be used as predictors. An example of SPA-DET is income level, shown in Figure 1 for Kampala. Overall, statistical relationships have the power to increase the accuracy of the estimations, while reducing or making efficient use of costs. Figure 2 is an overview of the steps employed in the method summarised in Figure 1.

Set objectives

First, it is necessary to define clear objectives for the study, as planning for different management solutions could require different forms of data collection. For example, one scenario could be planning for the design of a treatment plant in a city with no previous existing treatment, or planning to implement a regular interval desludging program for a community. For the treatment plant, estimates are needed for the total volume and strength of faecal sludge influent that is expected upon commission, in addition to projecting future growth. For the

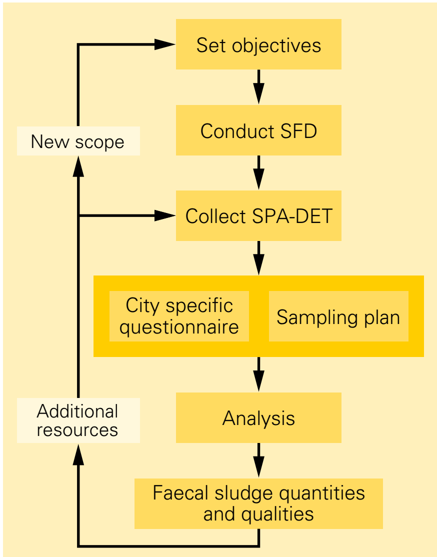

Figure 2: Schematic of the iterative steps in the method to determine quantities and qualities (Q&Q) of faecal sludge.

desludging program, however, estimates are needed for the rates of faecal sludge accumulation, emptying frequencies and "pumpability" of sludge.

Conduct a SFD (Shit Flow Diagram)

The excreta flow diagram or SFD estimates safely or unsafely managed fractions of excreta flows in a neighbourhood or city to understand the current sanitation situation [3]. The method provides fractions of total excreta, but does not estimate actual flows or quantities of faecal sludge. Prior to planning sanitation solutions, it is imperative to have a solid understanding of the current situation. In addition, implementing the SFD makes one familiar with the types of SPA-DET data that is available to use in the Q&Q method.

Collect SPA-DET

Types of DET data include: demographic (e.g. income level, number of users, housing density, family size, and patterns of urban development – building type, property usage, informal settlement, industrial, commercial or markets); environmental (soil characteristics, elevation, groundwater and hydrology); and technical information (access to piped water or type of onsite containment). This information can be obtained from research institutes, national bureaus of statistics, government bodies, water authorities, desludging businesses, NGOs, and other stakeholders in faecal sludge management.

City specific questionnaire

Following collection of SPA-DET data, a context specific questionnaire is developed based on the study objectives and available information. The questionnaire will be used to interview customers and service providers during both emptying operations and sludge delivery, and treatment plant operators. Examples of collected data include: containment information (containment technology, lined or unlined, number of users and volume); user behaviour (e.g. cleansing method, water usage, solid waste, etc.); and emptying operation (manual or mechanical emptying, emptying frequency, truck size, fully emptied, etc.).

Sampling plan

The number of samples collected during the study will depend on available resources. Ideally, adequate samples can be collected to ensure statistical significance. Even if this is not possible, however, collecting data as outlined in the methodology increases the power of conclusions that can be made from it. Once the sample size is determined, then a sampling plan needs to be designed to ensure adequate representation of all types of intended SPA-DET that representatively covers the entire study area.

Analysis

It is recommended to use the laboratory methods presented in the forthcoming book for sample analysis (Figure 3) [4]. The possibilities for analysis of the collected data will depend on resources and capacities, from straightforward predictions to complicated modelling approaches. One of the most important conclusions is that faecal sludge Q&Q should not be assumed to follow symmetrical, normal distributions. This means that another type of summary statistics other than means and standard deviation needs to be considered, in contrast to the current status quo in the field.

Additional resources and/or new scope

As additional resources become available, the sample size could be increased and further sampling and data collection can be conducted. As additional information is obtained, the possibility to develop models that reliably predict actual conditions increases. The entire method should be revisited as new or modified objectives are developed. Sustainable long-term planning requires adaptive planning for population growth and increased infrastructure.

Conclusion

Types of SPA-DET data were found to be predictors for faecal sludge Q&Q in Kampala, Hanoi, and Dar es Salaam. In Kampala, high-income areas had lower TS concentration (7* g TS/L faecal sludge) than low-income areas (29* g TS/L faecal sludge) [5]. The actual reasons for this could be many, i.e. water connections, quality of construction of faecal sludge containment, or types of waste streams going into containment. Other observed predictors were water connection, black water only, solid waste, number of users, containment volume, emptying frequency and truck size.
In addition, correlations can be observed amongst types of characteristics. In Kampala, this correlation between COD and TS was $COD = 0.88 \cdot TS + 3.3$ with an R^2 of 0.86 [5]. A correlation between COD and TS were also confirmed in a neighbourhood in Dar es Salam. Once established, these relationships could be used to extrapolate COD based on TS analysis, thereby reducing analytical costs and resources.
Further, data from Hanoi and Kampala were used to build a mathematical model to predict TS and emptying frequencies from SPA-DET data (in preparation). The model's accuracy was improved by splitting into two different models for septic tanks or pit latrines. This is a first attempt at developing city-wide and multiple city models, and the approach will continue to be refined with further research.

* Median value

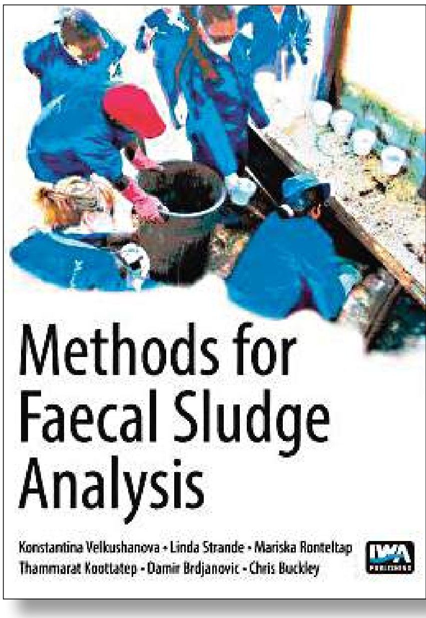

Figure 3: Cover page of forthcoming book, Methods for Faecal Sludge Analysis.

[1] Strande, L., Ronteltap, M., Brdjanovic, D. (2014): Faecal Sludge Management - Systems Approach for Implementation and Operation. IWA Publishing, London.

[2] Schoebitz, L., Bischoff, F., Lohri, C. R., Niwagaba, C. B., Siber, R., Strande, L. (2017): GIS analysis and optimisation of faecal sludge logistics at city-wide scale in Kampala, Uganda. Sustainability *9 (2),* 194.

[3] SuSanA. (2015): SFD Promotion Initiative (Shit Flow Diagram). http://sfd.susana.org/. (accessed 30 April 2018)

[4] Velkushanova, K., Strande, L., Ronteltap, M., Koottatep, T., Brdjanovic, D., Buckley, C., (in prep). Methods for Faecal Sludge Analyses. IWA publishing.

[5] Strande, L., Schoebitz, L., Bischoff, F., Ddiba, D., Okello, F., Englund, M., Ward, B. J., Niwagaba, C. B. (2018): Methods to Reliably Estimate Faecal Sludge Quanti-ties and Qualities for the Design of Treatment Technologies and Management Solutions. Environmental Management.

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Research Priorities and Progress in Faecal Sludge Dewatering

Difficulties in dewatering of faecal sludge are a crucial barrier to implementation of effective faecal sludge management. This article focuses on progress with locally available conditioners and the next steps toward implementing high-throughput, low-footprint dewatering technologies. B. J. Ward[1,2], S. Sam[1,2], N. Andriessen[1], E. Morgenroth[1,2], L. Strande[1]

Introduction

Faecal sludge, the waste collected in onsite sanitation systems, such as septic tanks and pit latrines, is typically more than 95 % water. Solid-liquid separation is necessary for faecal sludge treatment and safe disposal or resource recovery. The option to dewater faecal sludge at decentralised facilities would improve collection and transport logistics in traffic congested cities and high density slum areas that are not accessible to vacuum trucks. However, the existing dewatering methods for faecal sludge, for example, unplanted drying beds and settling-thickening tanks, require large land areas and are time-intensive. Residence times in settling-thickening tanks and on drying beds are on the order of weeks to months, limiting capacity at centralised faecal sludge treatment plants. The large footprint required for drying beds also makes them challenging to implement in dense urban environments where land is expensive and scarce. In order to expand sanitation coverage in urban areas, high-throughput and low-footprint technologies need to be adapted for faecal sludge.

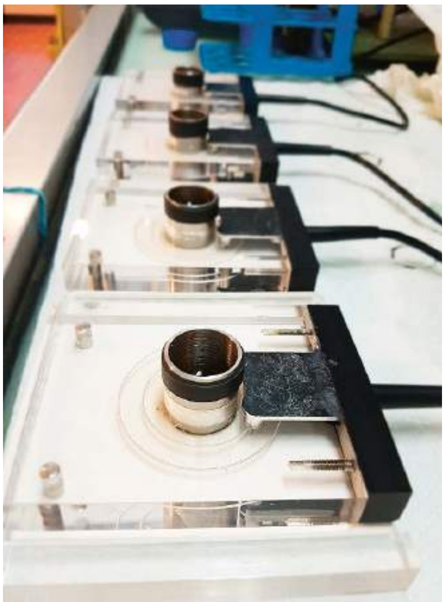
The case for conditioners

Conditioners are chemicals that facilitate rapid coagulation and flocculation of particles, which induce more complete settling and faster dewatering. Introducing conditioners has the potential to revolutionise the management of faecal sludge, if it can be determined how to use them reliably. Furthermore, this can lead to improvements in the effluent quality from settling-thickening tanks and reduce dewatering and drying time on drying beds, which can increase the treatment capacity of existing facilities. Conditioners are necessary for many low-footprint dewatering technologies. For example, mechanical dewatering technologies, such as belt and filter presses, and passive dewatering technologies, e.g. geotextile bags that rely on filtration to separate solids from liquids, only work with the addition of conditioners. Without conditioning, small colloidal particles within the sludge quickly clog the filter and dewatering cannot proceed.

Barbara Jeanne Ward

Photo 1: Settling tests on conditioned faecal sludge in Dakar, Senegal.

Many previous trials with geotextiles and mechanical dewatering technologies have been unsuccessful due to difficulties in reliably conditioning faecal sludge. In order to form strong flocs and bind colloidal particles, the appropriate conditioner must be determined and added at a correct dose. Conditioner selection and dose depend on physical and chemical properties of the sludge (e.g., TSS, pH, salinity and surface charge), which can vary by orders of magnitude with each batch of influent sludge.



Barbara Jeanne Ward

Photo 2: Capillary suction time tests to measure filtration speed of faecal sludge.

Lab-scale and pilot conditioner research

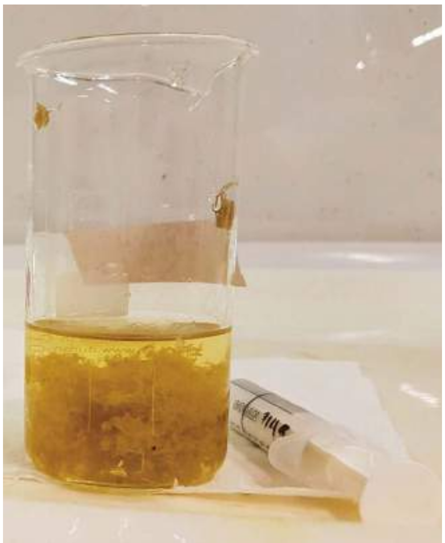
To improve the understanding of the performance and optimal dosage of a range of conditioners for faecal sludge, bench-scale trials were performed in Dakar, Senegal [1]. Locally available natural conditioners chitosan and *Moringa oleifera* showed settling and dewatering performance similar to standard polymer conditioners used for wastewater treatment. However, *M. oleifera* required very high doses to reach optimal performance, which contributed to increased COD and nutrient loading in the effluent. In contrast, chitosan required much lower optimal doses to achieve the same performance as *M. oleifera* (Table 1).
Due to their relative success in laboratory trials, the performance of chitosan and *M. oleifera* were analysed at pilot scale with unplanted drying beds in Dar es Salaam, Tanzania [2]. Despite differences in faecal sludge between the cities, optimal doses of the conditioners were comparable (Table 1). This is significant, as it is the first step in comparing the performance of single conditioners across a variety of faecal sludge samples. Conditioning with chitosan reduced dewatering and drying times on drying beds by 53 % and 13–18 %, respectively, compared to unconditioned sludge. Adding chitosan did not measurably influence the effluent quality, measured by TSS removal in the effluent from the drying beds; 99 % removal was observed in trials with and without conditioning.
Our research has identified chitosan as a high performing conditioner for faecal sludge on drying beds, but optimising conditioning with chitosan requires better understanding of appropriate dosing. Currently, the optimal doses of conditioners have to be determined individually for each batch of sludge with trial and error. However, this method is too time and labour intensive for practical application. The key question to answer is: how can we translate our research results with conditioners, which have worked well for different faecal sludges, to progress to rapid online process control on a larger scale?

Conclusion

In 2018, B. J. Ward and Stanley Sam began PhD research projects to further investigate the improvement of faecal sludge dewatering. Their research will focus on identifying the underlying mechanisms governing settling and dewatering behaviour in faecal sludge. The influence of faecal sludge microorganisms and their degradation and production of biopolymers, along with the effects of particle properties, surface charge, and solution properties, will be examined in order to develop a unified theory of faecal sludge dewatering behaviour. Once the controlling mechanisms have been identified, rapid or online measurements for practical use can be determined that link back to fundamental behaviour. The hopeful outcome of this research will be a model based on rapid influent sludge characterisation to predict conditioner dosage in real-time. Collaborations with partners throughout Asia and Africa to validate the model and improve trials with drying beds, settling-thickening tanks, and low-footprint dewatering technologies will continue.

Barbara Jeanne Ward

Photo 3: Preparing for microbial community analysis of faecal sludge. Future work will investigate the link between dewatering performance and bacterial populations.



Barbara Jeanne Ward

Photo 4: Faecal sludge after conditioning with polymer flocculant. Distinct flocs are visible and the supernatant turbidity is reduced.

	Optimal conditioner dose (kg/tonne TS)	
	Chitosan	***Moringa oleifera***
Dakar	1.5–3.8	400–500
Dar es Salaam	2.5–3.0	250–750

Table 1: Optimal conditioner dose for faecal sludge samples from Dakar and Dar es Salaam for locally available conditioners chitosan and *M. oleifera.*

[1] Gold, M., Dayer, P., Faye, M., Clair, G., Seck, A., Niange, S., Morgenroth, E., Strande, L. (2016): Locally produced natural conditioners for dewatering of faecal sludge. Environmental Technology *37 (21),* 2802–2814.
[2] Moto, N., Esanju, M., Andriessen, N., Kimwaga, R., Strande, L. (2018): Use of chitosan and Moringa oleifera as conditioners for improved dewatering of faecal sludge. 41st WEDC International Conference, Nakuru, Kenya.

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The Facility Evaluation Tool for WASH in Institutions (FACET)

Sustainable Development Goals 4 and 6 include the monitoring of institutional WASH services in schools and health care facilities. Developed by Sandec and Terre des hommes, the Facility Evaluation Tool (FACET) supports this monitoring task and is an easy to use mobile data collection tool. Samuel Renggli[1], Vasco Schelbert[1], John Brogan[2]

Introduction

Adequate WASH delivery services in health care facilities (HCFs) and schools are essential to maintain the health of patients and students and to enable the sustainable provision of health and education services. Without the provision of gender-sensitive basic WASH infrastructure and services, the risk of infection and/or disease transmission in HCFs is drastically increased. In schools, inadequate WASH facilities pose a public health hazard to (vulnerable) children and teaching staff, while female students might not be able to attend classes because adequate WASH equipment is missing, preventing them from basic menstrual hygiene management [1].
Including WASH parameters for HCFs and schools in the SDGs monitoring framework will allow for the development of a more precise picture of the global WASH situation [2]. In order to support the monitoring of the SDGs, FACET was jointly developed by Terre des hommes, Eawag and CartONG with support from the UNICEF/WHO Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP). FACET is based on globally recognised indicators developed by the Joint Monitoring Programme (JMP) for WASH HCF Global Task Team for monitoring [3].

FACET

FACET offers state-of-the-art on- and offline mobile data collection in Kobo Toolbox [4], an open source platform. Surveys for HCF and school contexts are available two ways: a core version (short assessment of the JMP core indicators) and an expanded version (extended assessment including additional indicators). The four service areas monitored are: water supply, sanitation, hand hygiene and healthcare waste management for outpatient areas. A section for delivery rooms is planned following the issuance of new JMP indicators. The surveys (available in English and French) can be downloaded on any mobile device using the Android operating system.
The FACET manual (available in English and French) explains the monitoring process and the content of the FACET tool, and provides informative insights from field experience, material for enumerators and survey trainings, as well as report templates (Figure 1). Customised on- and offline tools allow for data analysis and visualisation (dashboards). All products are available for free and can be downloaded from the FACET homepage [5].

Field-application of FACET

FACET is a tool intended to be used by field practitioners for project development, monitoring and evaluation and to be complementary to participatory implementation methods, such as WASH FIT (WHO/UNICEF) and others [6]. Based on the results, more thorough assessments can be done that include corrective action planning. The results of core questions are displayed immediately on the mobile device at the end of the survey and can be shared. Structured along the JMP laddered approach, FACET encourages institutions to climb the service monitoring ladder step by step.
Testing of FACET was undertaken in seven different countries in Africa and Asia and it has proven its applicability. Presented below are the results from an assessment of 123 HCFs in Bangladesh that was part of a Terre des hommes project (Figure 1).

Conclusion

FACET offers an easy to use complete survey package for mobile monitoring of WASH delivery services in HCFs and schools. The immediate display of results increases the transparency and credibility of the monitoring process. A key factor for success is the proper training of the enumerators who collect the data. To foster accountability and enhance progress, the data can be shared with regional authorities or the responsible persons for WASH in the respective institutions. The survey and reporting process help to set priority areas for investment and advocacy.

REGION 1

	WATER		SANITATION		HAND HYGIENE		WASTE MGMT	
Basic	40	83 %	1	2 %	10	21 %	0	0 %
Limited	5	10 %	40	83 %	35	73 %	35	73 %
No service	3	6 %	7	15 %	3	6 %	13	27 %

REGION 2

	WATER		SANITATION		HAND HYGIENE		WASTE MGMT	
Basic	40	53 %	0	0 %	8	11 %	0	0 %
Limited	19	25 %	60	80 %	58	77 %	62	83 %
No service	16	21 %	15	20 %	9	12 %	13	17 %

Figure 1: Sample graphic of core indicator results comparison for health care facilities (FACET Analyser).

[1] World Health Organization and UNICEF (2015): Water, sanitation and hygiene in health care facilities: status in low and middle-income countries and way forward. Geneva.
[2] https://washdata.org/monitoring
[3] https://www.washinhcf.org/home/
[4] www.kobotoolbox.org/
[5] Eawag and Terre des hommes (2018): Facility Evaluation Tool WASH in Institutions (FACET). Zürich.
[6] World Health Organization. (2017): Water and Sanitation for Health Facility Improvement Tool (WASH FIT): a practical guide for improving quality of care through water, sanitation and hygiene in health care facilities.

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How to Sustainably Scale up Small-Scale Sanitation in India?

The project "Small-Scale Sanitation Scaling-up (4S)" reaches completion after 2.5 years and provides a systematic assessment of small-scale sanitation in South Asia. This article highlights our research findings with a focus on India, and presents the main recommendations. Lukas Ulrich[1], Marius Klinger[1], Christoph Lüthi[1], Philippe Reymond[2]

Introduction

Since 2006, there has been a remarkable growth in the number of small sewage treatment plants (SSTPs) in India's rapidly expanding urban areas, typically serving 10–1 000 households. This is mostly due to policies that require on-site wastewater treatment and reuse for new, large buildings. More than 20 000 such small-scale sanitation (SSS) systems are estimated to be in operation in India today, providing an alternative to conventional, large-scale systems and an opportunity for water reuse. However, a majority of these systems are underperforming due to poor design, operation and maintenance (O&M), and monitoring. The 4S study was initiated with the endorsement of the Indian government in order to find out what can be done to ensure sustainable use of SSS systems.

Due to increasing demand for SSTPs, hundreds of private companies operate across the country (300+ were found). They offer consultancy, design, turnkey solutions, as well as O&M services. A wide variety of technologies are available on the market, ranging from energy-saving anaerobic and soil-based systems to common activated sludge and even membrane bioreactors.

There is no comprehensive database of SSTPs, their capacity, operational status and performance. As part of 4S, 9 500 systems in India were catalogued from various sources and 279 were visited for qualitative assessments.

Rohan Sunny

Photo 1: Basic assessment visit of a small-scale sewage treatment plant in Chennai, India.

Detailed water quality analyses were undertaken for 40 (35 in India, 5 in Nepal). These formed the basis for detailed studies on technical aspects. In parallel, interviews, policy review and data collation with stakeholders allowed for the analysis of governance and financial aspects.

Results

Technical performance

Performance analysis (Figure 1) shows that for biochemical parameters and solids (BOD, COD and TSS), any technology, if combined with the right post-treatment units and operated correctly, has the potential to achieve the stringent discharge standards set by the Central Pollution Control Board (CPCB). The rest of the parameters subject to CPCB standards (e.g. nitrogen), however, are systematically not met. It appears that nutrient removal is more a side-effect than a goal by itself in the assessed SSTPs, as most systems lack nutrient removal processes. Microbial quality is also consistently not met in almost all systems analysed. Systems with disinfection steps (usually chlorination) do not ensure a better removal of faecal coliforms than those without. This indicates low pre-disinfection water quality (e.g. high organic content), as well as poorly operated and/or designed disinfection units. The management of solids (sludge, screenings and scum) is another major issue observed. A majority of the systems studied do not treat and safely dispose of the sludge they produce. With a lack of alternatives, sludge is often disposed of in nearby storm drains, water bodies or land, neutralising the benefits obtained from treating the wastewater.

The analysis of the water reuse practices highlights the good impact of the reuse policies established in the wake of increasing water stress. Reclaimed water from SSTPs is commonly used for toilet flushing and gardening. Unfortunately, a significant fraction of the treated water (typically in the range of 25–70 %) cannot be reused due to the lack of local reuse opportunities.

Sustainability of systems

The factors that influence a system's successful long-term performance were analysed. Such success factors can be found in five different performance-enabling domains (Figure 2). Among them, the following areas of concern are highlighted here:

i. System start-up and hand-over: The period in which ownership and/or responsibility are transferred from the designer/builder to the management entity is crucial, but, unfortunately, often not getting sufficient attention.
ii. Skills and knowledge: Operators and managers often do not sufficiently understand the functioning of SSTPs and the requirements for good performance. Troubleshooting skills are, therefore, generally weak.
iii. Supervision of O&M activities: Operators are often not clearly instructed and supervised, leading to unclear or neglected responsibility and lack of information exchange.
iv. Documentation of O&M activities and financial flows: The absence of systematic archiving of information makes it difficult to monitor, understand and optimise the systems' performance over time.
v. Anticipation of maintenance works: Clear responsibility for organising spare parts, as well as for planning and budgeting scheduled maintenance, is often lacking. As a consequence, there are risks of lasting system failures.

Governance of small-scale sanitation

At the national level, current sanitation policies focus on large-scale centralised systems and faecal sludge management (FSM), without defining the role and scope for SSS. SSS is also not explicitly mentioned in the State Sanitation Strategies and only rarely in City Sanitation Plans (CSPs). Today, SSS systems are driven and funded by the private sector/citizens who have to build and operate them to fulfil building regulations. As such, SSS is not under the responsibility of the government agencies in charge of wastewater management, although it plays a growing role in terms of sanitation coverage.

The capacity of monitoring agencies has not kept up with the rapid expansion of the sector in recent years. Lack of coordination, expertise, human resources and financial means for SSS hamper monitoring processes. Re-

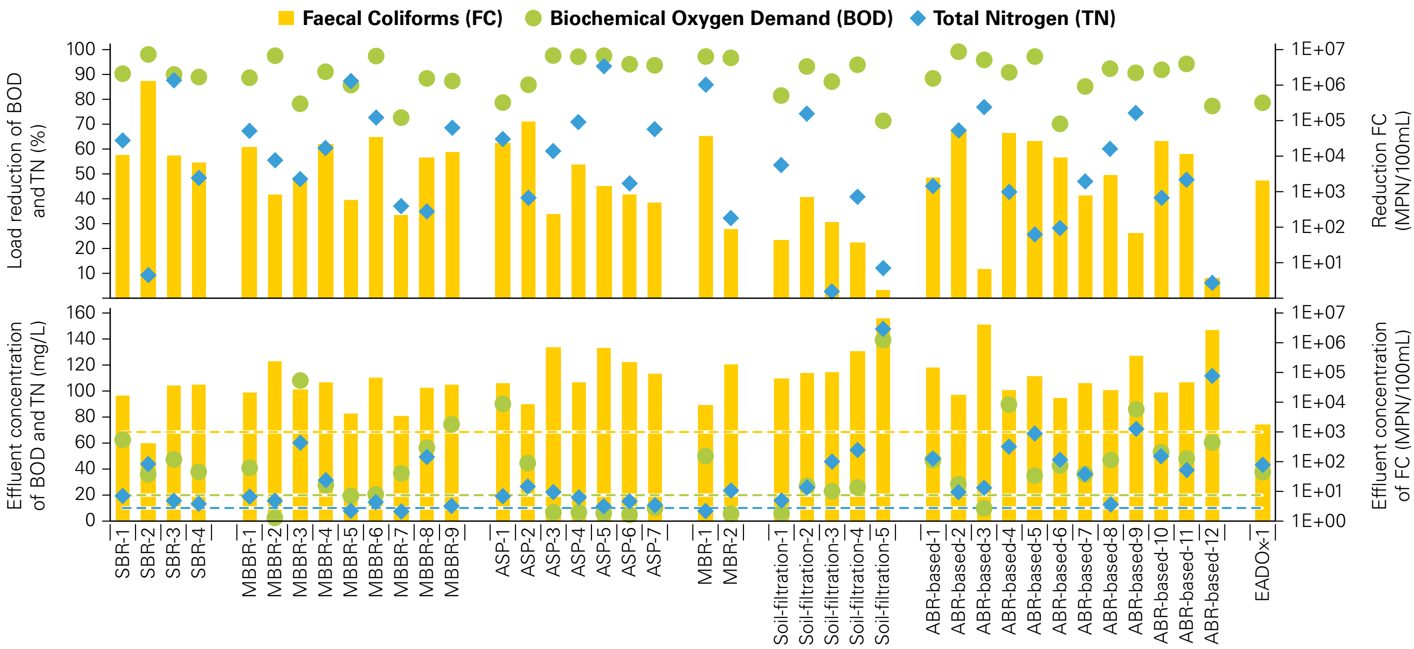

Figure 1: Average removal performance and effluent concentration for key water quality parameters of 40 sampled SSTPs, grouped by technology families. The dashed lines indicate the 2017 CPCB discharge standards for metropolitan cities.

lated loopholes lead to poorly designed and operated plants.

Even where good water reuse policies exist (e.g. requiring the use of treated wastewater on construction sites), there is presently insufficient coordination and regulation to link producers and potential users of reclaimed water. Therefore, much of the water, which cannot be reused onsite, is wasted.

Costs and financial issues

As part of 4S, life-cycle costs (capital, operational and capital maintenance costs) were analysed for different common SSS technologies. The findings show that operational expenditures have a cumulative impact on life-cycle costs, which outstrip the initial investment manifold (2–12 times). Costs vary greatly depending on technology, system size and level of O&M. Hence, an approach to financial sustainability would need to consider entire life-cycle costs at the moment of technology choice. Today, however, technology selection is largely vendor-driven and dominated by the investment and area required, as well as preferences of consultants. Real estate developers seek to minimise their capital expenditures, often leading to high O&M costs on the part of the future users who are not included in the system selection. Therefore, owners and users commonly see SSTPs as financial burdens rather than assets that create value for them. This drives their thinking towards cost reduction rather than system optimisation, unless further incentives are provided.

Main recommendations

Reaching adequate treatment performance

Good effluent quality regarding organic constituents can be achieved by combining measures to ensure proper O&M of systems with efficient monitoring. However, it is not realistic to expect compliance with stringent nutrient standards from most systems. If current standards for nitrogen parameters are to be fulfilled, systems must account for this in their process design. While this could be implemented for newly planned units in the higher capacity size range, it will be necessary to lower the bar for existing and smaller systems. Concerning microbial quality, measures ensuring the correct design and operation of disinfection units, as well as reuse-specific standards, are required for safe reuse.

Arranging for sludge management

The issue of solids management should be addressed strategically by either ensuring appropriate on-site treatment or by providing (semi-) centralised off-site sludge treatment units. Any newly planned treatment infrastructure for sewage sludge, faecal sludge or septage should account for capacity to receive the sludge from existing and future SSTPs nearby.

Standardising handover, operator training and documentation

A clear procedure for the handover of plants from technology providers to long-term owners and operators is required. Systematic transfer of information, including design details, user-friendly and comprehensive manuals and other technology-specific knowledge, should take place to ensure proper operation. Mandatory training and licencing of operators should be established and complemented with technology, design and context-specific requirements. Mandatory documentation of financial and O&M details would allow for the traceability of the systems' operation and upkeep. Analysis of such information should become part of the monitoring procedure. In the long term, online logbooks should be established for all systems.

Improving monitoring through a centralised database

A collated, unified database would foster coordination and harmonisation between agencies, standardise data collection, allow for automated analyses and facilitate SSS progress monitoring at national, state and city levels. First, an online data platform should be created, ideally under the auspices of the Ministry of Environment, Forest and Climate Change or Ministry of Housing and Urban Affairs (MoHUA). State and city authorities must then upload records on locations, system specifications and performance. There needs to be agreement on the merging of existing databases to create a national (or state-based) repository. It is essential that each SSS system can be tagged and given a unique ID. Geo-referencing of all units is necessary to facilitate follow-up and to eventually bring SSS into sanitation plans. There needs to be a clear allocation of the responsibilities for data collection and analysis at the various government levels.

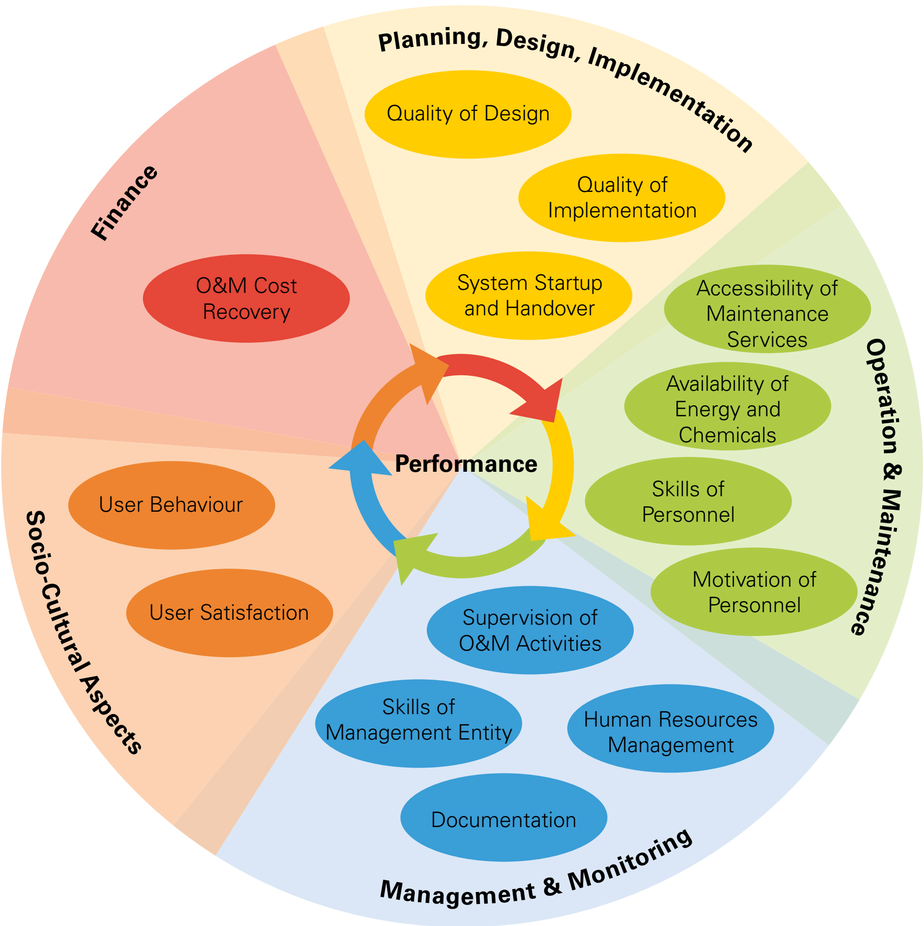

Figure 2: Critical success factors for well-performing SSS systems.

Creating SSS management units
While long-term monitoring should remain with the PCBs, agencies in charge of wastewater management must be given more responsibility. City water utilities and urban local bodies need to create a dedicated SSS planning and management division, consisting of trained professionals. These are the government bodies closest to implementation, with the required technical expertise. In cities with staff shortages, delegating the monitoring to a private company could also be considered as a medium-term measure.

Developing clear policies and design standards
At the national level, the MoHUA should lead the development of a clear policy framework for SSS. Technical specifications and design standards need to be developed, so that funds can be channelled from the national level down to cities. Guidelines for the design and implementation of SSTPs are needed, considering the SSS specificities and the wide variety of technologies now on the market.

Integrating SSS in strategic planning
The role of SSS should be explicitly stated in the State Sanitation Strategies and every CSP. This together with the online database will allow for the making of informed decisions about future investments for sanitation and water usage improvements. Cities should produce and maintain sanitation maps of sewers, SSTPs and FSM infrastructure. This will promote the zoning of areas to be served by SSS, which should be based on the optimal scale of sanitation systems. The latter is a function of availability of funds and space, life-cycle costs, management constraints and the reuse strategy.

Encouraging water reuse
Reuse policies need careful planning based on a good understanding of the situation. Reuse opportunities, space for SSTPs, the feasibility of retrofitting dual plumbing and cost implications are crucial aspects to consider when drafting effective and realistic policies.
The current gap between supply and demand for treated water opens up a potential market opportunity for an Uber-like service, allowing users of treated water to identify suppliers. Also, as users require a certain water quality, operators would be incentivised to maintain a consistent treatment performance.

Incentivising affordable quality systems
Purchasing decisions should be made based on life-cycle costs, not just capital costs. To improve O&M, special funds should be earmarked by developers to cover all costs over a defined period (e.g. 10 years). More sustainable systems could also be achieved by giving builders and technology providers more responsibility in O&M (e.g. build-operate modalities), and through performance-based contracts between owners and operators. Governments should provide incentives for sound SSS systems. Tax incentives would encourage developers to invest in robust premium systems. Well-operated SSTPs should benefit from lower development charges, property taxes or water rates as they save substantial money and work for the government.

Conclusion

Distributed SSS systems offer the opportunity to simultaneously address public health, environmental pollution and water scarcity issues in a targeted way. Current policies in India have enabled the establishment of a capable private sector with technical solutions ready to be scaled up. To cope with increasing water stress, the concerned authorities will be obliged to introduce a systematic and coordinated management approach for the strategic and efficient planning, design, implementation, O&M and monitoring of SSS.
The full potential of SSS can only be successfully tapped if an institutionalised process of continuous analysis, learning and optimisation is established. By studying the current scenarios and experiences on the ground, 4S aimed to start this learning process. Another objective was to provide guidance for decision-makers so that they can devise concrete steps towards creating an ecosystem conducive to a thriving and scaled-up SSS sector. The outputs of this project include policy briefs, factsheets, reports and a technology guide. They will be available at: www.sandec.ch/4S.

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Arsenic Concentrations in Drinking Water and Food in Burkina Faso

Long-term arsenic exposure poses serious health hazards. A 4-year project investigated the extent and magnitude of groundwater arsenic contamination in Burkina Faso. Low-cost arsenic removal filters were also tested and arsenic uptake pathways via food explored. A. Bretzler[1], G. Clair[2], F. Lalanne[3], J. Nikiema[4], K.D. Kienou[5], M. Schirmer[1,6], S. Hug[1], S. Marks[2], Ch. Zurbrügg[2]

Introduction

The Sustainable Development Goal 6, Target 6.1, represents a framework for ensuring safe and affordable drinking water for all, not only free from microbiological contamination, but also from dangerous chemical contaminants such as arsenic. Long-term exposure to arsenic in drinking water greatly increases the risk of developing cancers of the internal organs during one's lifetime [1]. Widespread geogenic (naturally occurring) arsenic contamination of groundwater has been under-investigated in Africa [2], as compared to Asia and South America.

In Burkina Faso, arsenic in groundwater stems from sulphide minerals, such as arsenic-containing pyrite (FeS_2) or arsenopyrite (FeAsS), both of which commonly occur in mineralised zones and are associated with gold ores [3]. In contact with oxygenated groundwater at circum-neutral pH, these minerals are oxidised, releasing arsenic. During the course of a 4-year project supported by the Swiss Agency for Development Cooperation (SDC), a research team from Eawag and from the Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE) in Ouagadougou investigated the extent of groundwater arsenic contamination in Burkina Faso. A major aim of the project was to produce maps that identify priority areas for water quality testing and mitigation. In addition, low-cost arsenic treatment technologies were tested, targeting remote rural areas where water treatment is needed due to a lack of alternative, uncontaminated sources of drinking water. Since arsenic can also be transferred to the human body via other pathways than drinking water, the ingestion of arsenic through food was explored.

Arsenic dataset

Many tens of thousands of tube wells equipped with hand pumps exist throughout Burkina Faso, supplying the rural population with drinking water. We assembled a comprehensive dataset of groundwater arsenic measurements of tube wells from various regions of the country, consisting of already existing data (~1 200) and new samples collected during field trips (~300). About 15 % of the tube wells in this dataset exceeded the WHO guideline value for arsenic in drinking water of 10 µg/L (Burkina Faso has adopted this as its national guideline). However, the high concentrations that are especially harmful to human health (> 50 µg/L) are much less frequent in these regions (2.3 % of all tube wells).

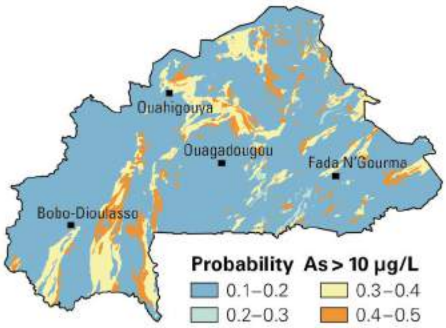


Figure 1: Arsenic hazard map showing the probability that arsenic in groundwater exceeds the guideline.

Arsenic hazard maps

Arsenic analysis should be carried out every time a borehole is drilled or rehabilitated. However, testing all the wells of the country would be unrealistic because it is time-consuming and costly. Maps pinpointing areas where arsenic testing should be prioritised are, therefore, useful and valuable tools for Burkina Faso's water sector. By combining freely available geospatial data of geological and mineralogical parameters (rock types, mineral deposits, fault zones, etc.) with the above mentioned arsenic concentration dataset (separated into calibration and validation data), we computed arsenic prediction maps using multivariate logistic regression. This method allows for the identification of statistically significant parameters that correlate with elevated arsenic in groundwater. Results showed that groundwater in volcano-sedimentary schists and volcanic rocks of the Birimian formation has a three to four times higher probability of containing arsenic > 10 µg/L than in other regions (Figure 1). Figures of population density in these high-risk regions combined with the approximation that one in five tube wells has arsenic > 10 µg/L led to the estimation that ~560 000 people in Burkina Faso (roughly 3 % of the population) are potentially exposed to arsenic concentrations exceeding the guideline value in their drinking water.

Experimenting with low-cost arsenic removal technologies

Arsenic removal by water treatment is challenging for remote rural communities due to the considerable costs and efforts involved. It would, therefore, be preferable to switch to alternative, uncontaminated water sources (e.g. uncontaminated tube well, improved shallow well or treated surface water) if they are available and sustainable throughout the year. Where switching the source is not possible, water treatment remains the only option to reduce households' arsenic exposure. Numerous arsenic treatment technologies exist, but many require sophisticated materials and/or infrastructure that are expensive for small communities and challenging to maintain. In Burkina Faso, we tested the acceptability and effectiveness of low-cost arsenic removal methods based on the design of the SONO filter [5]. This two-bucket

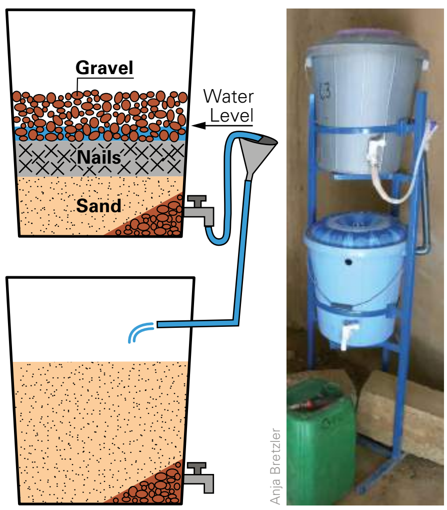
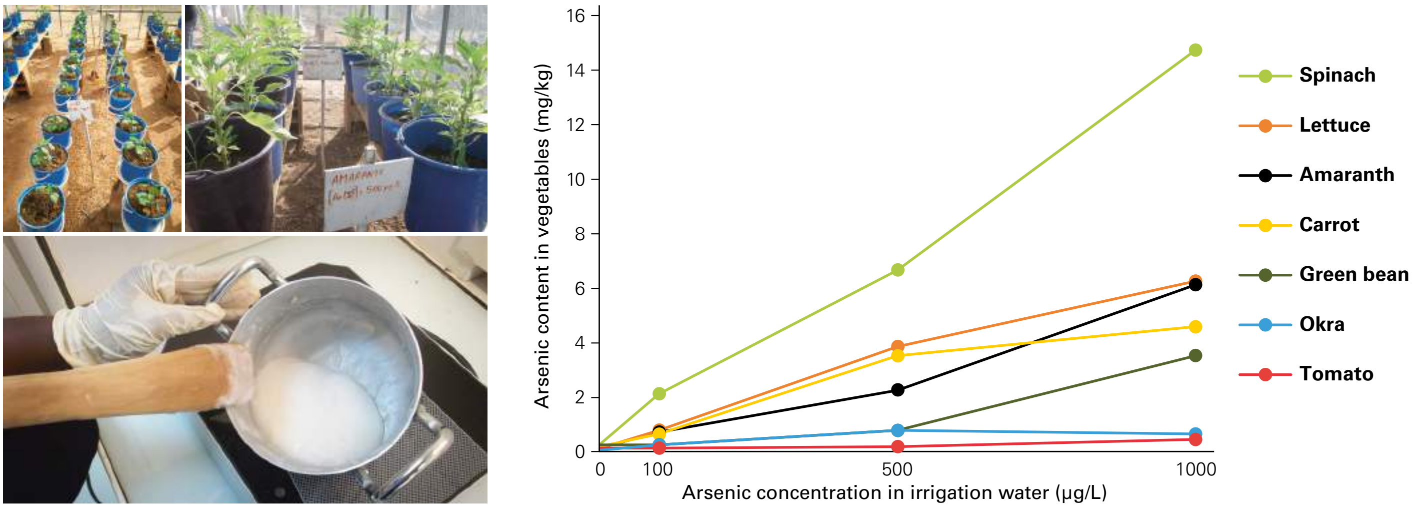


Figure 2: Cross-section of the arsenic removal filter constructed and tested in Burkina Faso.



Guillaume Clair

Figure 3: Vegetables and a dish (tô) irrigated/cooked with arsenic contaminated water (left) and arsenic content in vegetables (right).

household system uses simple and widely available materials, such as sand, scrap iron and brick chips. Arsenic is adsorbed on iron (hydr)oxides produced during the corrosion of scrap iron filings in the filter.

Filter construction and installation

Due to a lack of clean scrap iron filings, we opted for small, widely available iron nails as a source of iron oxides for arsenic removal. Additional filter materials were gravel and sand to stabilise the water flow and to remove residual iron precipitates (Figure 2). Four nail-based filters were tested during the course of one year in a remote village in northern Burkina Faso, where tube well arsenic concentrations were between 450 and 1 350 µg/L. Filters were operated at flow rates of 8–12 L/h, with a total of 60 L filtered per day, providing the daily drinking and cooking water needs for a 6–8 people family.

Filter efficiency

Regular monitoring and sampling by an employee of the partner NGO "Le soleil dans la main" provided insights into the functionality of the filter and arsenic removal efficiency. On average, the filters removed 70–90 % of arsenic, but effluent concentrations still remained above 10 µg/L due to the very high arsenic levels in the influent. Villagers did not report any problems with filter clogging or changes in water taste, and filters required no maintenance during the one-year study period. Due to the cheap raw materials and simple construction, these filters can be rapidly built and employed as a first emergency measure to lower the arsenic exposure of a population. However, more efficient long-term water treatment options are recommended to reliably meet the guideline values.

Uptake of arsenic in food products

Arsenic-contaminated water is also used for cooking and irrigation purposes, posing risks due to the migration of arsenic into food and vegetables. To investigate the transfer of arsenic from cooking water to food, water artificially spiked with arsenic (V) (0, 100, 500 and 1 000 µg/L) was used to prepare five common dishes: rice, "tô", yam, beans and gari. Also, vegetables traditionally cultivated and consumed (green bean, tomato, carrot, lettuce, amaranth, spinach and okra) were irrigated with the same arsenic-spiked water. Food samples (cooked meals, and roots, stems and leaves from plants) were freeze-dried, acid-digested and analysed by ICP-MS to determine their arsenic content.
The arsenic content increases as its concentration increases in irrigation water (Figure 3). Roots had the highest arsenic content, followed by leaves and stems, and then fruits. Spinach had more arsenic than lettuce, amaranth, carrot and green beans, while okra and tomato had the least. Cooking food with a large volume of arsenic-free water reduces the arsenic content in the raw vegetables, while cooking with contaminated water transfers arsenic to the cooked food. Adapting the cooking method could be a solution; for instance, the arsenic transfer is much less if yams or rice are cooked with steam than in boiling water.

Conclusion

This project revealed the extent and magnitude of groundwater arsenic contamination in Burkina Faso, with half a million people potentially exposed to arsenic levels exceeding drinking water guidelines. Further research is necessary and targeted mitigation activities involving stakeholders from the health, water supply and rural development sectors should be developed.

[1] Smith, A. H., et al. (1992): Cancer risks from arsenic in drinking water. Environmental Health Perspectives, *97*, 259–267.

[2] Ahoulé, D., et al. (2015): Arsenic in African Waters: A Review. Water, Air, & Soil Pollution, *226 (9)*, 1–13.

[3] Smedley, P. L., Knudsen, J., and Maiga, D. (2007): Arsenic in groundwater from mineralised Proterozoic basement rocks of Burkina Faso. Applied Geochemistry, *22 (5)*, 1074–1092.

[4] Bretzler, A., et al. (2017): Groundwater arsenic contamination in Burkina Faso, West Africa: Predicting and verifying regions at risk. Science of the Total Environment, *584–585*, 958–970.

[5] Hussam, A. and Munir, A. K. M. (2007): A simple and effective arsenic filter based on composite iron matrix: Development and deployment studies for groundwater of Bangladesh. Journal of Environmental Science and Health – Part A Toxic/Hazardous Substances and Environmental Engineering, *42 (12)*, 1869–1878.

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Evaluating Household Water Treatment Filters in Emergency Contexts

Household water treatment is essential to ensure drinking water safety in humanitarian emergencies. An interdisciplinary team is assessing water treatment devices in emergency contexts to identify filter designs that better meet the needs of vulnerable populations. M. Peter[1], R. Meierhofer[2], J. Affolter[3], F. Ochieng[3], I. Garino[4], M. Caniato[4], M. Verber[4], S. Marks[2]

Introduction

Household water treatment and safe storage (HWTS) devices are essential in humanitarian emergencies to improve drinking water quality and protect health [1, 2]. Their technical efficacy has been well documented through laboratory testing [3]; however, evidence that HWTS products (particularly drinking water filters) are used correctly and consistently in emergency contexts is limited [4]. To improve humanitarian agencies' ability to procure and distribute the most suitable products and to motivate manufacturers to adapt their design for emergency situations, Elrha's Humanitarian Innovation Fund initiated a 1.5 year field study. It is evaluating five HWTS devices: two ceramic filters, two ultrafiltration membranes, and one ceramic filter with bromine-releasing post treatment. Evaluation criteria include technical performance, consistency of correct use, and users' preferred design improvements. These results will be delivered to the filter manufacturers to encourage optimisation of their products.

Study sites and methods

The filters are being tested in three emergency settings: occupied Palestinian territories (oPt), Marsabit County in Northern Kenya, and the Tabelha Settlement in Somalia. Each site is characterised by different humanitarian conditions: in oPt, a man-made protracted emergency; Northern Kenya, a severely drought-affected pastoralist area; and Somalia, an acute crisis with informal refugee camps. The water used by the local population is known to be contaminated at the point of consumption. Cesvi is managing the project in oPt and Somalia, and Caritas in Northern Kenya.

Four to five filter types were distributed to 60 (Somalia) and 150 (oPt and Kenya) households. Filters are being evaluated over nine months through three activities. First, a monthly assessment of technical performance is done, i.e. filter integrity, microbial removal efficiency, microbial recontamination, and volume of treated water. Second, a user-centred evaluation based on structured observations and videography, focus group discussions, semi-structured interviews and a co-design workshop is completed. Third, a multi-criteria decision analysis with partners and relevant international stakeholders is done to allow for final informed choice of filters and their features. Comparative assessment is made possible by delivery of two household water filters sequentially to each household (Figure 1).

Preliminary results and next steps

In oPt and Kenya, the filters were distributed and two monitoring rounds completed (Photo 1). In Kenya, only 15 out of 125 households could assemble the filters correctly and avoid leakage or re-contamination. In general, filters with larger water storage containers were preferred by families. In oPt, the average log removal values (LRVs) for Enterococci bacteria for the two ceramic filters were 2.89 and 3.01, while both membrane filters and the ceramic filter with bromine-based post-treatment acheived average LRVs of 3.96 to 4.29. In oPt and Kenya, the third monitoring period is ongoing. Following filter switching, focus group discussions are planned to comparatively assess each filter type. In Somalia, the eviction of refugees from the informal camps delayed the start of the study, and the baseline will be conducted at a different site.


M. di Paolo and J. Affolter

Photo 1: Filter distribution and use in occupied Palestinian territories and Marsabit County, Kenya.

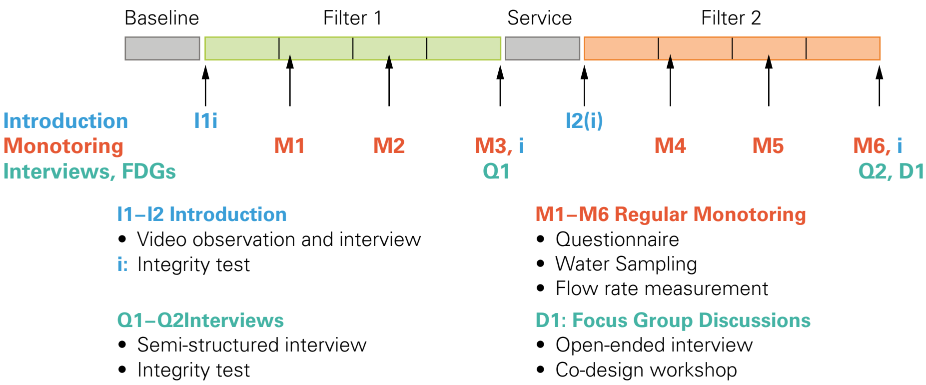

Figure 1: Study design over a 9 month period at each field site.

[1] SPHERE (2012): Humanitarian Charter and Minimum Standards in Disaster Response. The Sphere Project, Geneva.

[2] Latagne, D.S. and Clasen, T.F. (2012): Point-of-use water treatment in emergencies. Waterlines *31 (1–2)*, 30–52.

[3] WHO (2016): Results of Round I of the WHO International Scheme to Evaluate Household Water Treatment Technologies, Geneva.

[4] Latagne, D.S. and Clasen T.F. (2012): Use of household water treatment and safe storage methods in acute emergency response: Case study results from Nepal, Indonesia, Kenya and Haiti. Environ Sci & Tech *46 (20)*, 11352–11360.

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We would like to thank Elrha's Humanitarian Innovation Fund for its funding support.

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Eawag Celebrates 10 Years EPP: The Eawag Partnership Programme

2018 marks the ten-year anniversary of Eawag's EPP Programme, best known for its fellowships to distinguished masters and doctoral students from low- and middle-income countries. Since 2008, 83 Fellows from 28 countries have benefited from Eawag's unique working environment. Christoph Lüthi[1]

Introduction

International research partnerships and capacity development are core areas of Eawag's mandate and the Eawag Directorate decided in 2008 to strengthen research in and with low- and middle-income countries by establishing the Eawag Partnership Programme (EPP). The aim was to strengthen ties with selected academic institutions in the global South and to boost the desperately needed capacity of qualified experts and researchers in Africa, Asia and Latin America. More than 80 masters and doctoral students have benefited from an EPP grant at Eawag. Most students came from Africa (50), followed by Asia (30) and Latin America (3) (Figure 1).

The EPP Fellowship Programme

The EPP Fellowship Programme has two application deadlines: 01 March and 01 September, and up to six to eight students apply each time. An Eawag-internal EPP selection committee chaired by the Sandec department selects the three top qualified candidates. The following selection criteria are critical for a successful application: 1) the research subject must be relevant to the developing country and address critical issues, i.e. water scarcity, environmental sanitation, biodiversity loss, etc., and 2) scientific excellence has to be evident in the submitted research proposal. This outlines the objectives the candidate would like to achieve at Eawag.

What do former EPP Fellows appreciate most regarding their time at Eawag? All EPP Fellows must complete an evaluation form at the end of their stay to provide feedback and suggestions on programme improvements, and the responses received have been mostly positive. Fellows appreciate the open exchange with other researchers and scientists and the advantage of working in an interdisciplinary research environment. They also highlight the access to state-of-the-art facilities (library, labs and NEST), which are rare or non-existent in many of their countries, as well as the face-to-face interaction with their Eawag supervisors when drafting peer-reviewed publications or their masters theses (Figure 2). To quote Alex Ojuka Jalameso, a 2015 EPP Fellow from Uganda: "I appreciated the team spirit, the style of work, the method of collaboration, the friendly atmosphere and the professionalism – these were touching experiences and was great to have. And, I have a task to emulate back home too."

IHE MSc Fellowships and Visiting Scientist Programme

EPP has two other successful programmes that merit mentioning: the IHE MSc Fellowships and the Visiting Scientist Programme.

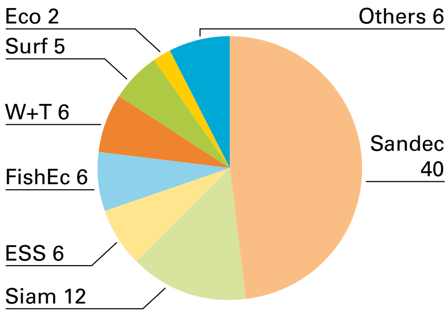

Figure 2: Eawag departments hosting EPP Fellows.

Annually, three IHE MSc students from Africa and Asia visit Eawag to work on their research projects. These students from Delft, Netherlands, benefit from the one-on-one supervision and state-of-the-art research facilities. The Visiting Scientist Programme provides opportunities for senior researchers and teaching staff from the global South to visit Eawag and gain from high-level exchanges with Eawag staff (e.g. by preparing a joint research grant or upgrading their curricula development skills).

Conclusion

Eawag proudly looks back on its past 10 years of the Eawag Partnership Programme and is committed to continuing this support to future experts, researchers and sector leaders in low- and middle-income countries. We are convinced that EPP will continue to strengthen the academic and research competence of its Fellows and assist them in facing the growing demands of a water-challenged world.

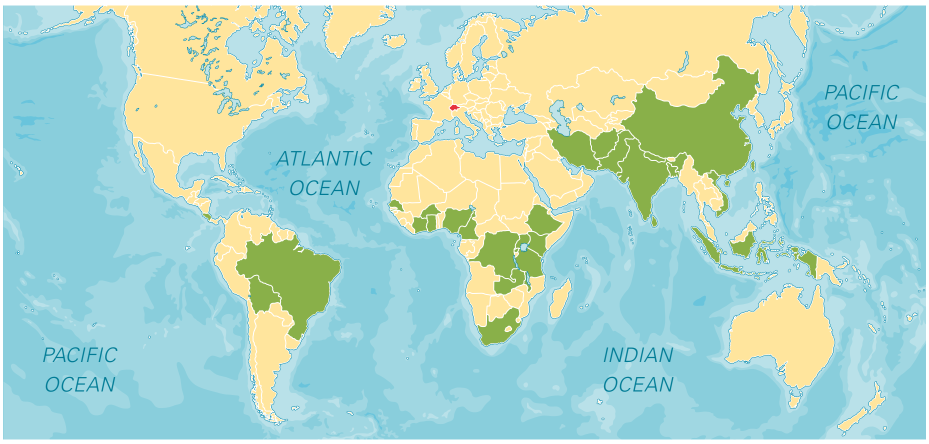

Figure 1: World map with all EPP candidate countries.

[1] Eawag/Sandec, Switzerland

EPP Fellowship Programme in a nutshell:
- 3–4 month research grant at Eawag
- Covers monthly salary, travel, insurance and admin costs
- MSc and PhD students from non-OECD countries qualify
- Application deadlines: 01 March and 01 Sept
- An overview of previous Fellows at Eawag: ...
- For submission details, visit: www.eawag.ch/epp

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Combining the Strengths of MOOCs and Onsite Education

Based on the MOOC series "Sanitation, Water and Solid Waste for Development", Eawag-Sandec has developed a blended learning programme, the Programme of Open Studies. It merges MOOCs with onsite teaching and is being tested at partner universities in Malawi, Nepal and India. Fabian Suter[1], Christoph Lüthi[1]

Introduction

Last year, Eawag-Sandec completed its MOOC series. It has introductory courses on sanitation planning, solid waste management, water treatment and faecal sludge management, and has reached a global audience of 80 000 learners. Most are from low- and middle-income countries, practitioners and 25–44 year old men with at least bachelors degrees. The courses run continuously and attract between 300 and 500 new students each week [1]. The MOOCs' strengths, scalability, affordability and accessibility, and weaknesses, relatively high-dropout rates and lack of degree credits, led to the creation of a blended learning programme.

Programme of Open Studies "Sanitation, Water and Solid Waste for Development"

The Programme of Open Studies merges the MOOCs with face-to-face teaching at partner universities and is open to all interested students, irrespective of their prior education. In the first part, students complete all four MOOC courses, regularly meet to discuss content, and take an onsite exam developed by Eawag and the local university.

Anonymous

Photo 1: Handing over of a certificate for part 1 of the programme at Washted in Malawi.

Successful completion qualifies students for part two: research design training and capstone project work at the university (Photo 1). Students earn credits from the local university, and a certificate from Eawag-Sandec and the university.

Methodology

The 16-month pilot phase began August 2017 with: BITS Pilani in India, Kathmandu University in Nepal and the University of Malawi in Blantyre. During this phase, demand for the programme, the resources required for it, and the different ways of embedding it in university curricula are being analysed. The key question is: can it be replicated or scaled-up? Standardised surveys and semi-structured interviews are used for data collection and analysis of the challenges and success factors.

First results from India, Nepal and Malawi

Each partner approached the programme differently. The Univ. of Malawi started with a relatively high number of 59 students and practitioners. BITS Pilani embedded the programme into their curricula, limiting the first round to 29 students, before opening it to all candidates. Six months since the project's start, BITS Pilani has begun a second round with 58 students to satisfy high internal demand. Kathmandu Univ. applied an approach similar to the Univ. of Malawi and opened it to students and practitioners. They had 26 participants and launched a second round with 33 participants in April 2018.

The instructors at the three institutions support the programme differently. In Nepal, participants mainly received instruction via email. Participants in Malawi could join face-to-face meetings with instructors to discuss course content. In India, field visits to waste and wastewater treatment plants were offered to bridge the gap between the virtual and the real world (Photo 2).

114 students started the programme's first round; 46 successfully completed the MOOC series and passed the onsite exam. According to feedback, students dropped out due to the courses' challenging level, lack of experience with eLearning technologies and underestimation of the required workload. The 40 % completion rate, however, is within the expected range. The work-intensive second phase starts with a motivated and qualified cohort of students.

Srikanth Mutnuri

Photo 2: Students from Bits Pilani visiting a solid waste treatment plant.

Conclusion

After the first phase's completion at the three universities, preliminary conclusions can be drawn. Regular face-to-face contact with instructors during the online phase is key to low dropout rates, and field visits are highly appreciated by students. The two partners show interest and capacity to run the programme continuously by launching a second round. However, the potential for replicability and scalability depends on the more personnel-intensive second phase and can only be assessed at the end of the pilot. The different approaches taken highlight the importance of a standardised programme structure that offers the partners flexibility to implement the courses according to their interests and needs.

[1] www.eawag.ch/mooc

[1] Eawag/Sandec, Switzerland

Further information

Websites:

- MOOC Series "Sanitation, Water and Solid Waste for Development": www.eawag.ch/mooc

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How Can We Make Online Courses More Useful for Practitioners?

Online students want to utilise the knowledge obtained through our MOOCs to impact society by improving current practices, while at the same time strengthening their professional profile and advance their careers. Both require a firm understanding of solid waste management. Christian Zurbrügg[1], Audinisa Fadhila[2], Imanol Zabaleta[1], Fabian Suter[1]

Currently, the MOOC on Municipal Solid Waste Management is structured as a somewhat gentle introduction, applicable to a rather general low- and middle-income country context. How to move from the general course to one that contextualises the content specific to a country or region has become one of our main concerns.

Contextualising content

During a learning event in Indonesia on the topic of "Integrated Urban Biowaste Management", all participants agreed that easy accessible knowledge and training on municipal solid waste issues are still lacking and that filling this gap was considered a key priority. Although the ongoing Eawag/Sandec Solid Waste MOOC was highly appreciated, this Indonesian target audience desired more specific focus on Indonesia. Thanks to funding by the Swiss State Secretariat for Economic Affairs (SECO) and a partnership with the Institute of Technology Bandung (ITB) and the NGO Greeneration Indonesia in 2017, Sandec was able to develop an "Indonesian" version of the MOOC. Besides translation of the existing module subtitles into Indonesian, five additional video modules on the specifics of Indonesia were added. These course modules were prepared and given by Indonesian experts and practitioners, such as Prof. Enri Damanhuri (Teknik Lingkungan ITB), M. Bijaksana Junerosano (Greeneration Foundation) and Audinisa Fadhila (FORWARD project). The modules give a general overview on Indonesian waste governance, cover financial aspects and provide examples of implementation of, as well as opportunities for biowaste management in Indonesia. The target audience of this course are staff working on urban waste in government, private sector, NGOs, academia and educational institutions. The course is available on the ITB website and YouTube and has a current count of around 20 000 viewers, and will soon be available through the Indonesian online learning platform IndonesiaX.

Including practical knowledge

Online courses obviously face challenges when trying to achieve learning in practical fields and specific applications. To overcome this barrier and to add more practical information, we have revised the solid waste course to include new modules. These provide tools and clear recommendations or methods on how to conduct certain tasks in solid waste management. For instance, if you want to know how to conduct a waste generation and characterisation survey, or how to determine waste moisture or estimate carbon-nitrogen ratios, a respective new module will be able to help you. Other practical assistance is given, for instance, by a module on how to operate a Black Soldier Fly biowaste treatment facility, how to upgrade the current dumpsite, or how to decide on the best practicable biowaste treatment option.

Developing blended learning tools

To enhance blended learning – this combines online digital media with traditional classroom methods, i.e. lectures and workshops – in the coming year, we plan to develop exercise templates, which provide ideas and examples for hands-on, experiential waste management curricula that complement the video modules. MOOCs provide knowledge competency and create a new network of potential colleagues. We believe that blending them with practical exercises and context specific details will build practitioner capacity.

Sirajuddin Kurniawan

Photo 1: At the landfill, while recording for the Indonesian online course modules.

Selected new modules
https://www.coursera.org/learn/solid-waste-management
- Waste Collection & Transport
- Measuring Waste Generation and Characteristics
- Overview of Biowaste Treatment Technologies
- Triggering Community Participation with the RANAS behavioural change approach
- Upgrading a Dump Site
- Operating a Black Soldier Fly Waste Treatment Facility

Indonesian online course Municipal Solid Waste Management:
ITB website:
https://ftsl.itb.ac.id/kuliah-online-pengelolaan-sampah-di-indonesia/
Indonesian MSWM YouTube Channel; (search for *Kuliah Online Pengelolaan Sampah di Indonesia):*
https://www.youtube.com/c/KuliahOnlinePengelolaanSampahIndonesia

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Changing Handwashing Behaviour in Schools and Households in Zimbabwe

This study describes a systematic handwashing behaviour change campaign that was implemented and evaluated in a before-after control trial. Handwashing frequency of caregivers at key times increased to 28 %, and caregivers performed up to 7 out of 8 recommended handwashing steps at follow-up. Max Friedrich[1], Hans-Joachim Mosler[1]

Introduction

Domestic handwashing with soap reduces diarrhoea morbidity and mortality considerably. Handwashing with soap at key times, namely after contact with faeces and before contact with food, is being intensively promoted worldwide. However, despite ongoing promotion efforts, handwashing rates around the globe remain low. The main goal of this project was to promote frequent handwashing at key times and effective handwashing technique in areas of high population density in Harare, Zimbabwe. The specific objectives were to assess current handwashing practices and the behavioural factors determining these practices among adults and primary school children and to design, implement, and evaluate systematic behaviour change strategies in households and schools to promote handwashing.

Activities

In the first step, we determined the behavioural factors steering handwashing. To do this, we conducted a baseline survey on handwashing practices and the behavioural determinants of handwashing using the RANAS model [1] with 600 primary school children and their caregivers in June and July 2014 (Photo 1 and Photo 2).

For caregivers, the RANAS behavioural factors influencing handwashing frequency and technique were identified by bivariate correlations. Behavioural factors steering handwashing frequency were *Disgust, Others' behaviour, Others' approval, Confidence in performance and Continuation, Action control, Remembering, and Hindrances*. Additional behavioural factors influencing handwashing technique were *How-to-do knowledge and Action planning* [2]. For children, the behavioural factors influencing handwashing frequency were *Vulnerability, Others' behaviour, Confidence in performance and continuation, Action control, and Remembering*. In most schools, functioning handwashing stations and soap were not available.

Based on these results, we selected behaviour change techniques (BCTs) and designed behaviour change strategies to promote handwashing using the RANAS catalogue of BCTs [3] (See also an illustrated catalogue of BCTs) [4].

For caregivers, six BCTs were selected. These were: (1) *Describe feelings about performing and about consequences of the behaviour (BCT 8)*, (2) *Prompt public commitment (BCT 10)*, (3) *Prompt guided practice (BCT 18)*, (4) *Organize social support (BCT 21)*, (5) *Prompt specific planning (BCT 26)*, and (6) *Prompt self-monitoring of behaviour (BCT 27)*.

For children, six BCTs were selected. These were: (1) *Inform about and assess personal risk (BCT 3)*, (2) *Prompt public commitment (BCT 10)*, (3) *Provide infrastructure (BCT 16)*, (4) *Organize social support (BCT 21)*, (5) *Prompt self-monitoring of behaviour (BCT 27)*, and (6) *Use memory aids and environmental prompts (BCT 34)*.

These BCTs were combined in behaviour change strategies for caregivers and children. For caregivers, the strategies comprised (1) a handwashing exercise to visualise dirt on hands and attach the feeling of disgust to not washing hands with soap at key times, (2) planning when, where and how to wash hands and documentation of plans, (3) filling out a self-monitoring calendar, (4) household discussion of how household members can support each other to wash hands with soap at key times, (5) a handwashing song, detailing critical times and recommended technique for handwashing, and (6) a public commitment ceremony.

For children, the strategies comprised: (1) a handwashing exercise to visualise dirt on hands and highlight risks when not washing hands with soap at key times, (2) installation of handwashing stations in classrooms and planning how children maintain them, (3) a handwashing song, detailing critical times and recommended technique for handwashing, (4) filling out a self-monitoring calendar, and (5) public commitment of classes through a poster.

The behaviour change strategies were then implemented and evaluated through a before-after control trial by the staff of a local

Max Friedrich

Photo 1: Interview with a primary caregiver.

Photo 2: School children practicing handwashing at classroom handwashing station.

Max Friedrich

health centre and primary school teachers under the supervision of the local NGO, ActionAid Zimbabwe. The school intervention (including the strategies for children), the community intervention (including the strategies for caregivers), and a combination of both were each implemented in areas that were spatially separated from areas receiving other treatments. The strategies were compared to control areas that received no intervention. A follow-up survey on handwashing practices and their behavioural determinants was conducted in 422 households and 20 schools six weeks after the campaign.

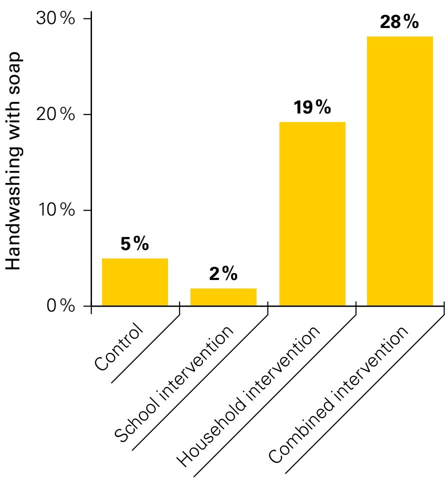

Figure 1: Observed handwashing frequency of primary caregivers at follow-up.

Findings

Among caregivers, observed handwashing frequency after the campaign was highest in the household and combined intervention groups (see Figure 1) [5].

Handwashing technique, measured as the number of correctly performed handwashing steps, improved from, on average, 5 correctly performed steps to 7 in the combined intervention group and to an average of 6.5 performed steps in the community intervention group. In intervention schools, 62 % of the classrooms had a handwashing facility with water and 55 % of the classrooms had a handwashing facility with soap six weeks after intervention. Handwashing frequency of children before the lunch break increased to 42 % in classrooms where soap and water were present. Interventions were only partly implemented as planned. The effects are expected to be larger after a completely implemented intervention.

Conclusion

The data-driven and population-tailored campaign substantially changed: (1) handwashing frequency and technique of primary caregivers at home, (2) availability and maintenance of handwashing stations at classrooms, and (3) handwashing frequency of school children before lunch breaks.

[1] Mosler, H.-J. (2012): A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. International Journal of Environmental Health Research *22 (5),* 431–449.

[2] Friedrich, M.N.D., Binkert, M.E., Mosler, H.-J. (2017): Contextual and psychosocial determinants of effective handwashing technique: recommendations for interventions from a case study in Harare, Zimbabwe. American Journal of Tropical Medicine and Hygiene, *96 (2),* 430–436, mdoi:10.4269/ajtmh.16-0553.

[3] Catalog of behavior change techniques. http://www.eawag.ch/fileadmin/Domain1/Abteilungen/ess/schwerpunkte/ehpsy/publ/Guideline/ESI_3.1_Catalog_of_behavior_change_techniques__BCTs_.pdf

[4] https://www.ranasmosler.com/single-post/2017/12/19/Pictures-of-behavior-change-techniques

[5] Friedrich, M.N.D., Kappler, A., Mosler, H.-J. (2018): Enhancing handwashing frequency and technique of primary caregivers in Harare, Zimbabwe: a cluster-randomized controlled trial using behavior and microbial outcomes. Social Science and Medicine, *196,* 66–76.

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Increasing Chlorination of Household Drinking Water in Chad

This study evaluated a behaviour change campaign promoting the uptake of household drinking water chlorination in communities along the Chari and Logone rivers in Chad. Results show that 64 % of the intervention participants reported chlorinating their drinking water at follow-up. Jonathan Lilje[1], Hans-Joachim Mosler[1]

Background

Cholera is still one of the most serious diarrhoeal diseases, with fluctuating case numbers around the globe possibly underrated and under-reported. In 2015, 42 countries reported 172 454 cases and 1 304 cholera-related deaths, with most cases and deaths occurring in African countries. The number of cholera cases rose to over 60 000 in 2010 and 2011 in Chad and Cameroon alone. The Lake Chad Basin is a hotspot that is frequently hit by cholera outbreaks that quickly spread across the region's porous borders. Consequently, the governments of Chad and Cameroon and the World Health Organization (WHO) are trying to establish a strategy of quick response and prevention for cholera and other diarrhoeal diseases in the region. As part of this strategy, a campaign was developed and implemented at the household level to promote drinking water disinfection using chlorine in several communities along the Chari and Logone riverbeds. The objectives of this evaluation study were to examine the effects of the interventions on participants' water treatment behaviour and changes in their psychological mindset concerning the target behaviour. The following research questions were addressed:

1. Did the campaign have a positive impact on water treatment among intervention participants?
2. Did the campaign affect psychological factors for drinking water treatment that were targeted by the campaign?
3. Which of these psychological factors were affected by the campaign and, therefore, influenced the behaviour?

Activities

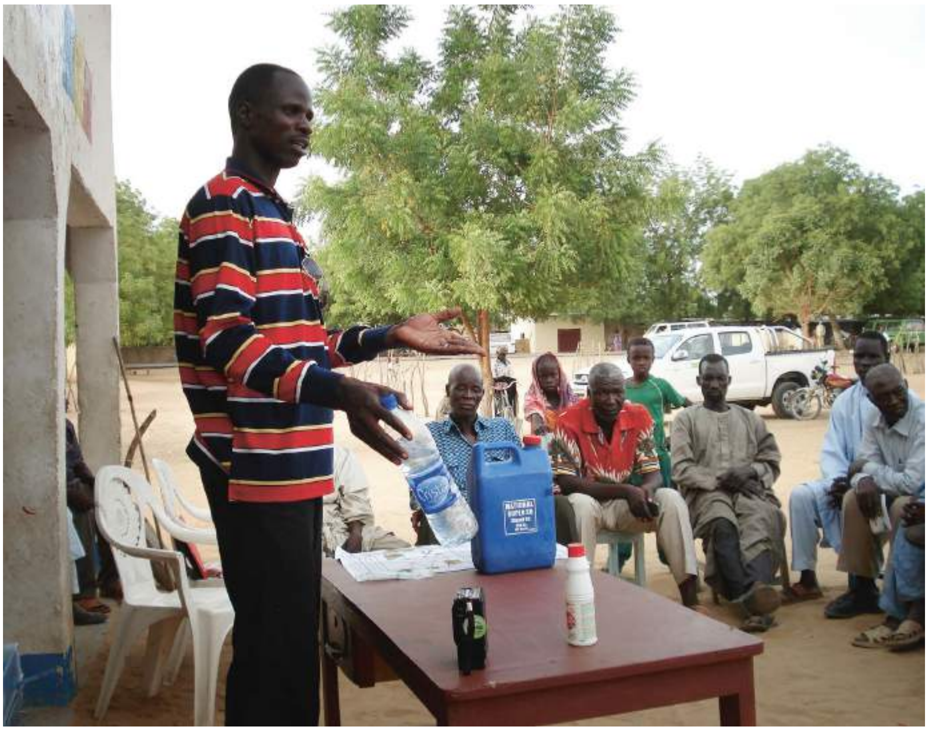
The intervention strategies were informed by a formative baseline study using the RANAS model [1] in December 2013 and May 2014 among 1 016 primary caregivers of children under the age of five. These surveys identified the psychological factors relevant to household water treatment, which were then recommended as the targets of promotional efforts to increase the uptake of water chlorination [2]. Interventions were developed specifically to target the following psychosocial factors: Perceived vulnerability and Health knowledge, Perceived behaviour of others, Social support and Social discourse, as well as Perceived self-efficacy and Action knowledge. According to these results, behaviour change techniques (BCTs) were selected from the RANAS catalogue of BCTs [3] and behaviour change strategies were designed to increase the chlorination of drinking water (See an illustrated catalogue of BCTs) [4].

The first element of the intervention was a pre-recorded audio advert that introduced several arguments and personal statements about water treatment. These statements were inspired by interview responses given during the baseline surveys (see Figure 1). Several BCTs were incorporated in this recording, such as "Inform about personal risk" (BCT 3), "Inform about and assess costs and benefits" (BCT 5), and "Provide instruction" (BCT 15) targeting risk, attitude, ability, and norm factors. The statements in the recording were mixed so that positive stances outweighed negative stances to support the impression that more people were engaged in the behaviour than those who were not and served as a means to target the perception of others' behaviour and others' approval ("Inform about others' behaviour", BCT 9; "Inform about others' approval/disapproval", BCT 11).

The second element was a poster communicating information on where and how diarrhoea is contracted and what can be done to prevent it (Photo 1). It was an adaptation of the F-diagram, which graphically depicts several pathways of diarrhoea propagation and how those pathways can be interrupted. The poster used BCT 1 ("Present facts"), targeting health knowledge and explaining to participants where and why they are at risk. Participants were encouraged to discuss the contents of the poster among themselves to spark social discourse on the topic (BCT 7: "Prompt to talk to others").

Jonathan Lilje

Photo 1: Participants looking at behaviour change poster on contamination pathways.



Jonathan Lilje

Photo 2: Practical demonstration of chlorination procedure during an intervention session.

The third element was a practical demonstration that mainly targeted how-to-do knowledge ("Provide instruction", BCT 15) and confidence in performance ("Demonstrate and model behaviour", BCT 17). Promoters demonstrated how to correctly apply chlorine products for drinking water disinfection, including how to calculate the dosage needed, to participants (Photo 2).

The fourth element, which concluded each session, was a public commitment appeal (BCT 10: "Prompt public commitment"). Participants were encouraged to make a public pledge in front of the assembled audience to treat their household's drinking water. Caregivers who were not heads of households were prompted to seek support from their heads of households (BCT 21: "Organize social support"). Participants who committed themselves to treating their household's drinking water received a commitment sign. This was a piece of blue cloth to be displayed on the participant's house.

The Ministry of Public Health (MSP) implemented the strategies in collaboration with the NGO CSSI (Centre de Support en Santé Internationale). Their effectiveness was assessed by a follow-up survey conducted in July 2016 to evaluate change in behaviour and behavioural factors. 162 (74 %) of the 220 interviewed caregivers confirmed having visited at least one session and remembered information received on household water treatment. Recall of intervention elements and materials was good, with 95 % of intervention participants remembering the poster, the demonstration session, and the public commitment element, while the audio recording was recalled by 83 % of participants.

> "I went to buy "eau de javel" (liquid chlorine solution) at the local market, the price is about the same as for a pack of salt or sugar and it serves to treat the drinking water for our family for a whole month. Some people say it is too expensive or that they don't have the money for that. But if you think about the costs to buy medication each time when your kids fall sick, it is actually not that much money."

Figure 1: An example statement played during the audio recording targeting perceived costs and benefits (BCT 5, translated from French).

Findings

64 % of intervention participants who had attended one or several of the intervention sessions reported chlorinating their drinking water compared to 42 % of non-participants and 30 % in the baseline sample before the intervention [5]. Interventions strengthened the perception of subjective vulnerability, perceived severity, health knowledge, perceived benefits, the descriptive norm, social support, action knowledge, and self-efficacy.

Conclusion

Water treatment rates were significantly higher in households that participated in an intervention campaign. Providing health knowledge and practical advice on how to implement it, such as demonstrating how to treat water, proved to be a strong lever for behaviour change. In addition, the organisation of social support strategies within households helped. The strongest influence between the intervention and behaviour was participants' increased trust in their own abilities to perform the behaviour and continue to do so.

[1] Mosler, H.-J. (2012): A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. International Journal of Environmental Health Research *22 (5),* 431–449.

[2] Lilje, J., Kessely, H. and Mosler, H.-J. (2015): Factors Determining Water Treatment Behavior for the Prevention of Cholera in Chad. The American Journal of Tropical Medicine and Hygiene *93 (1),* 57–65. https://doi.org/10.4269/ajtmh.14-0613

[3] Catalog of behavior change techniques. http://www.eawag.ch/fileadmin/Domain1/Abteilungen/ess/schwerpunkte/ehpsy/publ/Guideline/ESI_3.1_Catalog_of_behavior_change_techniques__BCTs_.pdf

[4] https://www.ranasmosler.com/single-post/2017/12/19/Pictures-of-behavior-change-techniques

[5] Lilje, J. and Mosler, H.-J. (2017): Effects of a behavior change campaign on household drinking water disinfection in the Lake Chad basin using the RANAS approach. Science of The Total Environment. *619,* 1599–1607. https://doi.org/10.1016/j.scitotenv.2017.10.142

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Toward a Sustainable Solution for Fluoride Mitigation in Drinking Water

The Fluoride Removal Technology Center provides access to safe drinking water to 36 000 people in the Ethiopian Rift Valley and has begun to implement a hybrid business model. Can a mix of commercial and community customers improve its financial sustainability and independence from donors? H. Gebauer[1], G. Virard[2], L. Osterwalder[3], C.J. Saul[1]

Photo 1: HEKS, OSHO & FRTC team at production site.

Fluoride Removal Technology Center

The Fluoride Removal Technology Center (FRTC) has been a pioneer in providing safe and affordable drinking water through community-based water systems in areas where groundwater fluoride levels exceed the WHO recommended threshold of 1.5 mg/L, consumption of which can pose serious health risk, such as dental and skeletal fluorosis [1]. FRTC has been working on fluoride mitigation in the Ethiopian Rift Valley and was set-up by the non-profit Oromo Self-Help Organization (OSHO). FRTC's vision is to carry out independent income generating activities, which are clearly distinct from OSHO's non-profit activities and projects, and it envisions providing safe drinking water as a self-sustaining business. Over the coming years, FRTC wants to prepare for further expansion and aims for gradual and careful growth.

Supported by Swiss Church Aid (HEKS/EPER) and Eawag, FRTC has made progress in the production and implementation of two types of filter media: bone char and Hydroxyapatite (HAP), which remove fluoride from water. FRTC has built the production facilities, continuously improved the production processes in terms of quality and costs, and developed the technical skills for installing and maintaining community filters. The main cost drivers have been the fixed costs for building the production infrastructure and variable costs in terms of labour and materials, i.e. raw bones for bone char and phosphoric acid for HAP production.

FRTC has acquired funding to build 22 community filters that can serve about 36 000 people with drinking water, which has had much of its geogenic fluoride removed, and a production facility with a production capacity of 50 kg HAP and 150 kg of bone char per day. 18 community filters use bone char and 4 use HAP as a filter material. Despite these technical successes, becoming financially sustainable remains a major challenge.

FRTC deploys the following approach to provide safe drinking water. It is responsible for installing and maintaining the community filters, producing filter material and selling it to water committees in the communities. These water committees are responsible for managing the existing water points, and are in charge of setting the selling price of the treated water and collecting the water revenues. Once the filter material has reached its absorption capacity, the water committees should use the revenues collected for purchasing new filter material. Two operational issues have arisen out of this approach: 1) the water committees often put off purchasing new filter material, which means that the filters no longer adequately mitigate fluoride levels, jeopardising the positive long-term health impact and 2) the water committees choose to charge prices that are too low for the safe drinking water and they cannot, therefore, pay market rate for the filter material. These prices rarely cover the actual production costs.

To tackle these problems, FRTC currently follows three innovation paths: i) optimising production processes, ii) embracing hybridity in FRTC's business model, and iii) regenerating filter material for further reuse.

Current innovation pathways

i) Optimising production processes

To reduce the production costs for bone char and HAP, FRTC systematically analyses the production process to improve key production indicators. For example, FRTC has now started to track the actual production yield in terms of the percentage of raw bones converted into bone char. By tracking the yield, FRTC is establishing improvements in the production parameters (e.g. raw bone quality and crusher performance) to increase the yield to the targeted value of 30 %. Furthermore, FRTC tries to minimise the time during which the two furnaces are idle, i.e. not producing bone char. Less idle time means that up to 2.5 more batches of bone char can be produced each month and HAP production could increase by an additional 10 batches. In the best case scenario, this would enable FRTC to increase annual production volume by 60 tons of bone char and 26 tons of HAP.

ii) Embracing hybridity in FRTC's business model

FRTC has started to extend its activities and has tapped into new segments, consisting of commercial customers. These segments include such customers as the Ethiopian government, National Railway Cooperation, and other non-profit organisations (e.g. World Vision). These customers pay considerably higher prices for the filter material, which has allowed FRTC to generate profit on this customer segment. In addition, tapping into this customer segment has increased the production volumes, which in turn has reduced the unit production costs for bone char and HAP. As a result, with the profits generated from these customers, FRTC was able to cross-subsidise the sale of community filters. FRTC would need to sell about 6.8 tons of bone char to this customer segment to cover the net losses of 50 500 ETB (~0.42 CHF / 10 ETB) for one bone char filter. Accordingly, FRTC has embraced hybridity in its business model by combining financial goals for targeting commercial customers and social goals for providing safe drinking water.

Achieving the financial goals aimed for with the commercial customers requires that FRTC formulate and implement an adequate sales plan. The sales plan has to clearly describe: 1) the target customers, 2) the predicted sales volumes for each of them, and 3) an estimated likelihood of the sales.

iii) Regenerating filter material for further reuse

FRTC has also begun to explore the opportunity to regenerate filter material. Regeneration means the removal of most of the adsorbed fluoride from the saturated filter material, so that it can be used again. It is expected that bone char could be regenerated up to three times and HAP even five times. While the regenerated bone char and HAP have a bit less fluoride uptake capacity than "fresh" filter material, the costs for regenerating bone char and HAP are significantly lower than the costs of producing new bone char and HAP. It was decided to regenerate the filter media at the production centre in Modjo and not onsite at the filter location. Accordingly, FRTC is establishing a logistical procedure on transporting the saturated material from the communities to Modjo and transporting the regenerated filter material back to the communities.

Thus, financial losses from the 22 community filters are being reduced. Concomitantly, there is less cross-subsidisation from the profits made with commercial customers. Ultimately, this leads to a more sustainable business and safe water provision. FRTC is now defining the processes and procedures for regenerating bone char and HAP.

Altogether, as these three innovations are currently unfolding, FRTC is getting closer to becoming financially sustainable, which in turn makes FRTC increasingly independent from donor funding. These innovations would first enable FRTC to maintain their 22 community filters with the 36 000 people benefiting from safe drinking water and could later permit FRTC to further increase the number of community filters. As a result, FRTC is decreasing its dependency on donor funding and increasing its impact on the communities it serves by ensuring safe water provision to the 22 community filters currently serviced. In the future, if successful, FRTC could expand further and serve additional communities.

Looking forward

Due to the unsustainable practices of many of the local water committees, FRTC is considering taking over the responsibility for the community filters. Instead of water committees selling the water and saving financial resources for the purchase of new filter material, FRTC would sell the water directly to community members, and renew the filter material frequently. Such frequent and regular exchange of filter material would no longer cause delays during which community filters reach their maximum adsorption capacity, jeopardising the positive health impact. Water committees would remain responsible for setting the actual water price, and would have a clearer sense of what their bill from FRTC would be.

While there are rational arguments for FRTC taking over the responsibility for the community filters, various uncertainties remain. FRTC needs to describe in detail what activities are included in managing the community filters, such as providing necessary services, i.e. repair and maintenance of the filters, as well as monitoring services to test water quality. It would be a comprehensive service, with no hidden costs for the communities. In addition, FRTC has to carefully communicate that the water committees still have the decision-making authority over water prices and that the community still owns the water sources. FRTC's objective is not to squeeze out any and all profit, but instead to guarantee access to safe water quality.

Lars Osterwalder

Photo 3: Water tank and bone char filter.

Lars Osterwalder

Photo 2: Children getting clean water at a kiosk.

[1] Fawell, J., Bailey, K., Chilton, J., Dahi, E., Fewtrell, L., Magara, Y. (2006): Fluoride in drinking-water. World Health Organization. Geneva.

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Videography to Understand Risks to Farmers Using Human Excreta

Disease transmission is influenced by how people move through their environment, how infected people spread pathogens, and how susceptible people are exposed to pathogens. First person perspective videography offers a glimpse into the lives of people most at risk. Timothy R. Julian[1,2], Hasitha S.K. Vithanage[3], Ana Karina Pitol[1,4], Mariska Ronteltap[3], Hidenori Harada[5]

Introduction

The use of human excreta for agriculture may spread pathogens to crops, such as rice or vegetables. Subsequent harvesting and consumption of the food may cause infection and illness. Similarly, handling human excreta followed by hand contact with one's face or mouth, may increase the risk of infection. Despite the importance of hand-to-mouth contacts, very little data are available on human-environment interactions [1]. To improve estimates of the risks of environmental interactions on the spread of disease, we are piloting the use of first person videography to capture human-environment interaction data. Study participants wear cameras (Go Pro Cameras) on their heads that record all of their activities for short periods of time (less than 1 hour). Trained data collectors then observe the video and use software to convert it into a detailed (second-by-second) time series of study participant activities. The result is high resolution time series data – known as Microlevel Activity Time Series, or MLATS – describing every object the study participant touched with their hands [2]. Example objects include mouth, hands, hand tools, plastic bags, soil and water.

Methodology

From November 2015 – February 2016, study co-author Hasitha Vithanage visited the Phu Xuyen district in Hanoi, Vietnam, and invited farmers who rely on human excreta as fertiliser for agriculture to participate in our research [3]. Twenty-five farmers agreed to wear cameras while they collected human excreta from their latrine or applied it to their agricultural plots (Photo 1). In total, 18.2 hours of video were collected, and the video was converted to MLATS data.

Photo 1: First person perspective video captures the range of motions of hands and hand-to-mouth contacts, which increase exposure to pathogens.

Results

The output included the frequency of farmers' contacts during collection and land application of human excreta. Surprisingly, the farmers contacted an average of 342 – 848 objects with their left or right hand every hour (Figure 1) [3]. The farmers often contacted handheld tools (i.e. shovels or rakes), plastic bags used to store excreta and seeds and human excreta. During excreta collection, the farmers also frequently contacted the toilet pit, while during land application the farmers frequently contacted mud and surface waters.

The contacts most influential to the spread of disease transmission (i.e. hand-to-mouth) were rare. Only four of the farmers contacted their mouths during the video and most did so only once. The infrequent hand-to-mouth contacts were surprising, as they were much lower than what had previously been observed in other studies.

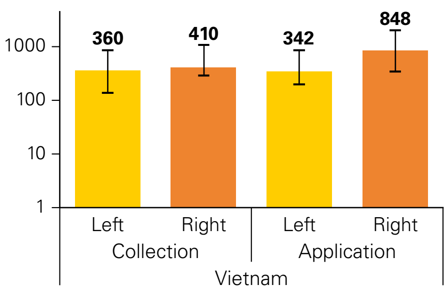

Figure 1: Frequency (#/hr) of hand contacts with objects of farmers during collection and land application of human excreta for agriculture.

Conclusion

The daily life of farmers in Vietnam, collecting and applying human excreta for land application, was captured on video, revealing substantially lower rates of high risk contacts (i.e. hand-to-mouth contacts) than expected from other studies, such as a study of U.S. office workers sitting at desks [4]. The findings imply that a farmer's risk of becoming infected due to hand-to-mouth contacts during human excreta collection and application is likely lower than previously believed. More data is needed on exposure pathways to better understand how infectious disease spreads [3].

[1] Julian, T.R., Bustos, C., Kwong, L.H., Badilla, A.D., Lee, J., Bischel, H.N., Canales, R.A. (2018): Quantifying human-environment interactions using videography in the context of infectious disease transmission. Geospatial Health *13 (631),* 195–197.

[2] Zartarian, V.G., Streicker, J., Rivera, A., Cornejo, C.S., Molina, S., Valadez, O.F., Leckie, J.O. (1995): A pilot study to collect micro-activity data of two- to four-year-old farm labor children in Salinas Valley, California. J. Expo. Anal. Environ. Epidemiol. *5 (1),* 21–34.

[3] Julian, T.R., Vithanage, H.S.K., Chua, M.L., Kuroda, M., Pitol, A.K., Nguyen, P.H.L., Fujii, S., Harada, H. (2018): High time-resolution simulation of *E. coli* on hands reveals large variation in microbial exposures amongst Vietnamese farmers using human excreta for agriculture. Science of the Total Environment *635,* 120–131.

[4] Nicas, M., Best, D. (2008): A study quantifying the hand-to-face contact rate and its potential application to predicting respiratory tract infection. J. Occup. Environ. Hyg. *5 (6),* 347–52.

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[5] Kyoto University, Japan

We would like to thank the farmers who volunteered to participate, Robert Canales for providing VTDPC, Chua Min Lee for help with video translation, and the financial support of Eawag, including the Eawag Partnership Program for Developing Countries, and the JSPS KAKENHI Grant (JP16H04436).

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Dr Halidou Koanda, Country Director for WaterAid in Burkina Faso


Basile Ouédraogo

Introduction

Dr Halidou Koanda is from Burkina Faso, a landlocked country in West Africa. He did his PhD at the École polytechnique fédérale de Lausanne (EPFL) in collaboration with Eawag/Sandec.

On choosing NCCR/NS programme

I was a PhD student of EPFL working at Sandec in a partnership between Eawag, EPFL, CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à faible coût) and 2iE (Institut International d'Ingénierie de l'Eau et de l'Environnment). I joined the NCCR/NS programme (National Center of Competence for Research North-South) to benefit from this large research network.

On how NCCR/NS was beneficial to his career

This programme gave me many opportunities to share my research, learn from others and network. At the end of my PhD, I was granted with funds to put in practice some results of my research, for which I am really grateful. The aim of the project was to strengthen faecal sludge management in the city of Ouahigouya, located in the north of Burkina Faso. This money was used to (i) develop some technologies for collecting faecal sludge and (ii) train the manual emptiers on how to manage faecal sludge well and to stay safe.

On the most eventful aspect of NCCR/NS

The programme regularly organised meetings for young researchers: regional meetings and International Training Courses.

On his time at Eawag

Most of the time, I was working very hard to meet the deadlines for my PhD dissertation. From time to time, I spent time with friends during weekends and visited places in Switzerland. I really enjoyed my stay in Switzerland.

On what he is presently doing

I am the Country Director for WaterAid in Burkina Faso since 1 June 2010. My responsibilities include: developing and delivering the Country Strategy in line with WaterAid's Global Strategy; leading, managing and motivating a team; representing WaterAid externally, ensuring that its vision, mission, values and aims are communicated in a positive and compelling way and facilitating relationship building with partners, staff and stakeholders; facilitating relationships between sector stakeholders to support development of the sector; collaborating with WaterAid colleagues to ensure effective working together; contributing as a Water-Aid Global and Regional leadership team member to support organisational effectiveness and development; ensure that the Country Programme has integrated equity and inclusion into its work; staying aware of the local funding context and identify appropriate funding opportunities; and ensuring that WaterAid's global policies are adapted to the country context.

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The Compendium of Sanitation Technologies in Emergencies is Now Available!

The Compendium of Sanitation Technologies in Emergencies is an adapted version of Sandec's Compendium of Sanitation Systems and Technologies for emergency contexts and the field of humanitarian aid. It was launched in April 2018, and is a comprehensive, structured and user-friendly manual and planning guide that supports and enables decision making for developing sanitation system design solutions in humanitarian contexts.

The Emergency Compendium covers 61 technologies, applicable to the different phases of an emergency and provides an overview of the key cross-cutting issues influencing technology selection and their implementation in humanitarian contexts. It compiles a wide range of information on tried and tested technologies in a single document and gives a systematic overview of existing and emerging sanitation technologies. In addition, it gives concise information on key decision criteria for each technology, facilitating the combination of technologies in the development of full sanitation system solutions, all linked to relevant cross-cutting issues.

More information on Sandec's work on emergency WASH, as well as a free download of the book is now available on the Sandec website at: sandec.ch/EmergencyWASH. An online version of the Emergency Compendium is under preparation.

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Dissemination Workshop on Groundwater Arsenic Contamination in Burkina Faso

In March 2018, Eawag-Sandec and 2iE-Ouagadougou organised a one-day workshop to disseminate the results of a 4-year joint study on geogenic arsenic contamination in Burkina Faso. Among the 55 participants from the water sector of Burkina Faso were representatives from the Ministry of Water and Sanitation, regional water agencies, NGOs, the private sector and the University of Ouagadougou. The topics explored the origin of the contamination, effects on human health and arsenic uptake pathways via food. An important part of the day was dedicated to the arsenic risk maps that were produced, enabling the location of contaminated areas and to viable water treatment solutions. Moreover, the participants had the chance to visit the 2iE laboratory and to become more familiar with arsenic testing methods and tools.

All workshop material is available for free at : https://bit.ly/2uz1NCs.

Anja Bretzler

The workshop took place in Ougadougou, a collaboration of Eawag and 2iE.

Forthcoming Event

Upcoming FSM5 Conference in Abidjan, Ivory Coast
18–22 February 2019

FSM5 will be the biggest dedicated sector event in 2019 for professionals, governments, policy-makers, utilities, development partners, investors, industries and service providers to coordinate, develop and share learning about providing affordable and workable solutions in faecal sludge management.

The focus of FSM5 will be to demonstrate FSM as a utility service that can be:

- Structured and regulated by governments
- Delivered in partnership with private service providers
- Organised to attract investment from governments, development partners, commercial banks, and private entities

Eawag-Sandec is a member of the Conference Organizing Committee and will be organising a themed workshop on capacity development for FSM during the conference.

→ For more information, please contact: https://fsm5.susana.org/en/facts

The Sandec Team

Maryna Peter

From left to right:
Front row: Elizabeth Tilley, Vasco Schelbert, Marta Fernández Cortés, Kondwani Chidziwisano, Imanol Zabaleta, Adeline Mertenat, Jasmine Segginger, Dorian Robinson, Samuel Renggli, Ariane Scherteinleib
2nd row: Michael Vogel, Abishek Narayan, Ulrike Feldmann, Fabian Suter, Dorothee Spuhler, Hussain Etemadi, Paul Donahue, Regula Meierhofer, Linda Strande, Leandra Roller, Nitesh Shrestha, Barbara J. Ward, Sara Marks
Back row: Bram Dortmans, Hans Mosler, Chris Zurbrügg, Moritz Gold, Christoph Lüthi, Nienke Andriessen, Nadège de Chambrier, Jan Freihardt, Clara Nicolai, Caterina Dalla Torre, Guillaume Clair
Missing in photo: Marius Klinger, Lukas Ulrich, Miriam Englund, Grégoire Virard, Philippe Reymond

New Faces

Marta Fernández Cortés, MSc in Architecture from the Polytechnic University of Catalonia, started her PhD research with the Strategic Environmental Sanitation Planning group in September 2017. Her research aims to understand sanitation provision for urban refugees in developing countries and the challenges of transitional contexts. She previously conducted research about WASH, social systems and urban morphology in two refugee settings in Jordan and Lebanon.

Clara Nicolai joined Sandec in October 2017 as a project officer to improve Eawag-Sandec's MOOC series "Sanitation, Water and Waste for Development" and its eLearning initiatives. She has an interdisciplinary academic background with core competencies in the environmental sciences, and previously worked in India on the reuse and recycling of human waste in agriculture. Her work requires her to stay updated on the research in all Sandec teams, which is a steady source of joy for her.

Vasco Schelbert, MSc in Sustainable Development (Uni Basel), joined the Strategic Environmental Sanitation Planning Group in November 2017 to strengthen its social science output. He is in charge of institutional WASH issues and collaborations with thematic groups and ESS, mainly working in schools and health centres. Vasco previously worked with Terre des Hommes in Nepal and Burkina Faso where he validated the FACET monitoring tool in health centres.

Abishek S. Narayan, MSc in Water Science, Policy and Management from Oxford University, started his PhD in Urban Wastewater Management for Developing Countries in March 2018 in the Strategic Environmental Sanitation Planning group. He will work on an interdisciplinary approach to Citywide Inclusive Sanitation in India, and has worked with various water and wastewater topics in Netherlands, Ethiopia, and India. He is the founder of the Clean Adyar Initiative, a river restoration action group in Chennai.

Stanley Bortse Sam, MSc in Environmental Biotechnology from Istanbul Technical University, joined Sandec in May 2018 as a PhD student. He is working with the Management of Excreta, Wastewater and Sludge (MEWS) group and his research focuses on understanding the governing mechanisms of solid liquid separation in faecal sludge for improved global sanitation. Before joining Sandec, he worked as a supervisor in a wastewater treatment plant treating gold mine effluents.

On the Bookshelf

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

Municipal Solid Waste Management

Organic Waste Recycling: Technology, Management and Sustainability

This book presents new concepts and strategies of organic waste management, which combine science, technology, and governance principles for sustainable waste treatment and recycling. And it emphasizes the benefits to be gained from the use of the recycled products.
By Polprasert, C., Koottatep, T., IWA, 4th Edition, 2017, 575 pages. ISBN: 9781780408200.

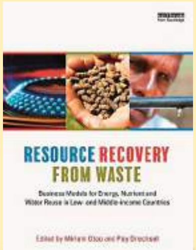
Making Waste Work: A Toolkit Community Waste Management in Low- and Middle-Income Countries
Making Waste Work is a practical toolkit, developed for the Chartered Institution of Wastes Management by WasteAid UK. It is an online and offline resource to motivate and inspire people to tackle the waste crisis locally, wherever they are. There is an Executive Summary, a Toolkit and 12 How-to-guides. The guides deal with such topics as "Measuring your waste" and "Making compost using worms".
By WasteAid UK (October 2017). The Executive Summary is available online and as a pdf download for print and mobile at:
https://wasteaid.org.uk/toolkit/summary/

Management of Excreta, Wastewater and Sludge

L'urine – de l'or liquide au jardin

The first book on urine fertilisation in French is now in its second "enriched" edition. Learn how to produce compost and fertiliser and how to best apply them on diverse crops.
By Renaud de Looze, Éditions de Terran, 2nd Edition, 2018, 142 pages.
ISBN: 9782359811001.

Resource Recovery From Waste: Business Models for Energy, Nutrient and Water Reuse in Low- and Middle-income Countries



Humans generate millions of tons of waste every day. This book shows how Resource Recovery and Reuse (RRR) could create livelihoods, enhance food security, support green economies, reduce waste and contribute to cost recovery in the sanitation chain.
By Otoo, M., Drechsel, P., Routledge, 2018, 816 pages. ISBN: 9781138016552.

Gestion des boues de vidange: Approche intégrée pour la mise en oeuvre et l'exploitation

Adaptation française de la première édition du livre Faecal Sludge Management Systems: Approach for Implementation and Operation. Ce livre est une ressource impressionnante qui fait le bilan des avancées scientifiques récentes et des solutions pratiques testées à l'échelle par les professionnels du secteur.
By Strande, L., Ronteltap, M., Brdjanovic, D. IWA, 2018, 466 pages. ISBN: 9781780409795.

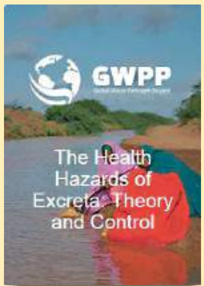
Strategic Environmental Sanitation Planning

Compendium of Global Good Practices: Urban Sanitation (2015)

The compendium brings together successful case studies on various themes of urban sanitation including policy reforms, reclamation and reuse of wastewater, value generation from waste and pro-poor sanitation strategies from across the world. The focus is primarily on good practices from developing countries, such as Thailand, South Africa, Philippines etc. that can be replicated in Indian cities.
By: NIUA, 2015, 64 pages. Downloads are free at:
https://pearl.niua.org/sites/default/files/books/GP-GL2_SANITATION.pdf

Water Supply and Treatment

Global Water Pathogen Project



The Global Water Pathogen Project aims at developing a knowledge resource to reduce mortality linked to water pathogens and the lack of safe drinking water and basic sanitation through creating the state-of-the-art knowledge hub on water-related disease risks and intervention measures, including new and emerging pathogens and updated scientific data. GWPP will focus on pathogens and pathogen risks from excreta.
http://www.waterpathogens.org/

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.

Faecal Sludge Dewatering

Faecal sludge dewatering is currently one of the biggest challenges for effective faecal sludge management. Combining stop motion animation, photos, graphics, video footage and interviews, this video explains what dewatering is and why it is so difficult for faecal sludge, highlights some areas of Sandec's research, and shows some potential solutions for the future.
Produced by: Sandec/Eawag.
Filmed and edited by: Paul Donahue. 2018, 4:20.
It can be seen at: https://bit.ly/2LAS0pN