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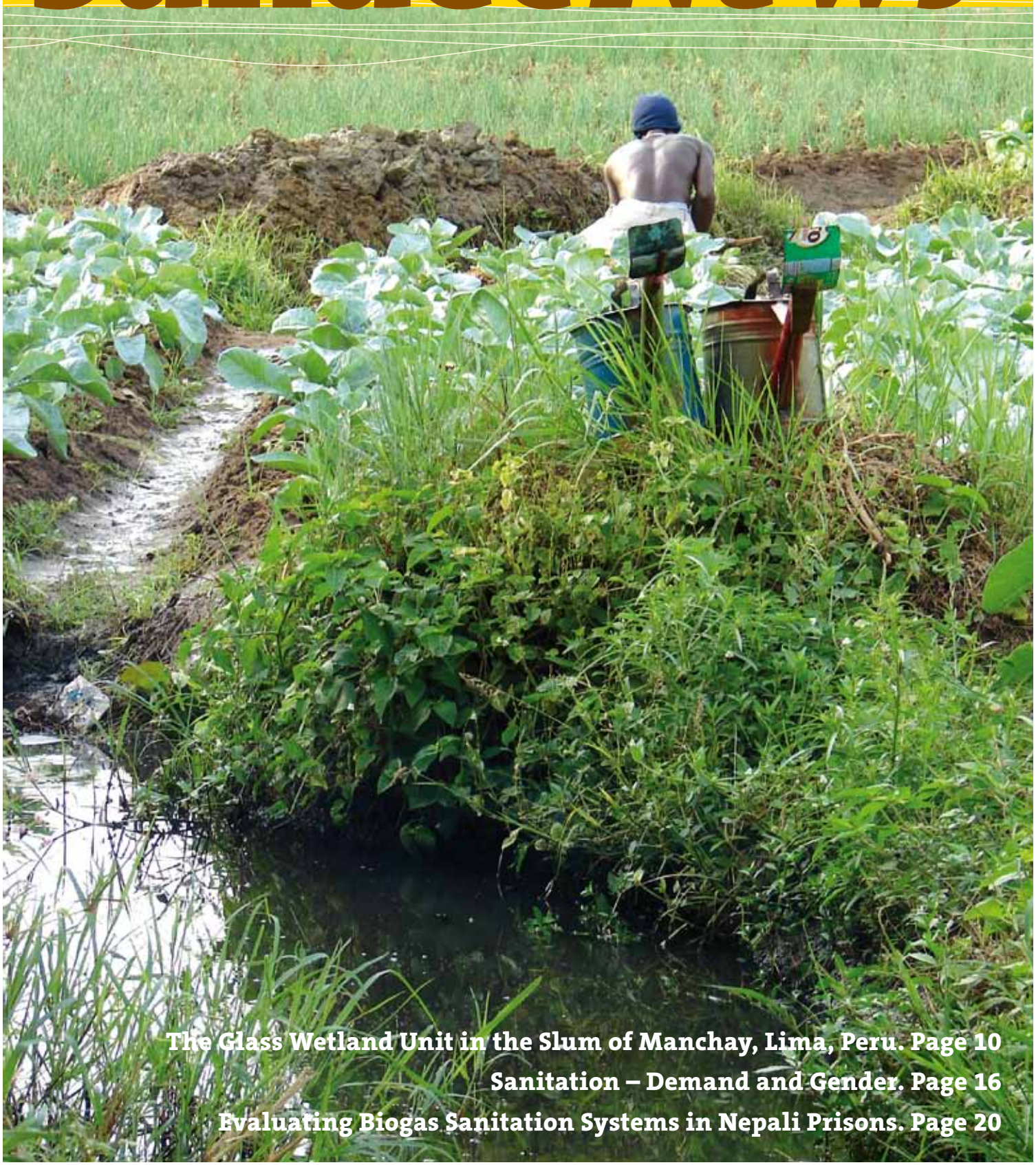

Clean Water for a Healthy World

“Understanding challenges related to water quality is about stimulating ideas, engaging research and involving stakeholders, as well as pushing forward commitment and action in the sanitation and waste management community”

This year’s World Water Day, “Clean Water for a Healthy World”, emphasises the issues around water quality. This topic is also being taken up by the World Water Week in Stockholm entitled “The Water Quality Challenge – Prevention, Wise Use and Abatement.” Eawag has a long tradition of expertise and excellence in research on microbial and chemical water quality issues. Sandec, through Rick Johnston, closely collaborates with the department of Water Resources and Drinking Water (W+T) and System Analysis, Integrated Assessment and Modelling (SIAM), in the Water Resource Quality (WRQ) project. This integrated project aims at developing a framework for mitigation of geogenic contamination in groundwater, particularly arsenic and fluoride.

Prevention of water pollution – at least from a microbiological perspective – really also means enhancing demand, use and provision of adequate sanitation facilities as well as good hygiene behaviour. Faeco-oral transmission pathways are not necessarily water-related, and it is essential to identify and understand the critical points of exposure to pathogenic substances along the water and sanitation cycle. An ongoing project within the framework of the NCCR North South (Research Partnerships for Mitigating Syndromes of Global Change) centres on such critical points of exposure linked to excreta and wastewater reuse in Vietnam. Furthermore, Sandec has obtained funding to explore the drivers of demand for sanitation users with a specific attention to the gender dynamics. Using former research projects on participatory planning in sanitation, current studies are now looking at impacts of such social mobilisation processes on the social capital of communities.

Demand for sanitation is not only required at household level, but also at other stakeholder levels along the sanitation chain to safeguarding public health and ensuring that the various forms of human waste are adequately collected and treated before reuse or discharge. In this regard we are convinced that the principle of “sanitation as a business” is very promising. Research into options creating value from waste is a consistent topic within all research groups at Sandec. This may comprise anaerobic digestion to obtain biogas as a valuable alternative to fossil fuel, to grow fodder in constructed wetlands or to process waste using the larvae of the Black Soldier Fly to obtain valuable feedstuff for aquaculture. Sandec continues to explore demand for other products and uses derived from excreta, urine, faecal sludge, greywater, and/or solid waste. Pursuing decentralised approaches and business opportunities for small and medium enterprises is considered an important element for replication and scaling-up.

Our research group on faecal sludge management went through a rough patch in the second half of 2009 as Doulaye Koné and Pierre-Henri Dodane both left Sandec for other exciting opportunities. Thanks to Mbaye Mbéguéré, based in Dakar, and his unfaltering dedication, research activities however did not pause. A new project in collaboration with ONEA (Office National de l’Eau et de l’Assainissement, Burkina Faso) on strategies for on-site sanitation and monitoring of off-site treatment was launched at the beginning of 2010. Magalie Bassan, new staff member of Sandec, is now conducting project activities in Burkina Faso. Meanwhile, the group is back to full strength with Linda Gaulke as group leader based in Switzerland. I warmly welcome her to the Sandec team. Finally, our latest project on decentralised wastewater management in the Nile Delta of Egypt was just launched while writing this editorial. So, I would also like to welcome our latest staff member, Philippe Reymond, in charge of this project and based in Cairo.

As usual, this newsletter just gives you a glimpse of Sandec’s projects, activities and research results. For more detailed information, please contact the authors of the individual articles. To ensure that this newsletter continues to meet your expectations, we hope you can spare a few minutes to give us your feedback by completing our online questionnaire at:

www.surveymonkey.com/s/sandecnews

Chris Zurbrügg
Director Sandec

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Department of Water and Sanitation in Developing Countries

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Joint Asian-African Project on Productive Sanitation

Within the third phase of the NCCR North-South Programme "Research Partnerships for Mitigating Syndromes of Global Change", a new project was launched to further develop a health and environmental risk-based assessment approach coupled with economic assessment methods to promote identification and application of sustainable sanitation options. Hung Nguyen Viet[1,2,3], Ives Kengne[4], Hoang Van Minh[5]

Introduction

Current global debates centre on increasing appropriate sanitation coverage to the poor and ensuring food security and safety. From a resource perspective (nutrients, organic matter and water), there is an obvious link between these two themes. In some regions of Africa and Asia, use of human excreta as fertiliser and wastewater for irrigation and aquaculture has a long tradition. The economic and environmental advantages of this practice are uncontested. Human waste products from sanitation are often reused since they offer significant business opportunities, help increase livelihood assets and provide food security to the poor and vulnerable. Reusing excreta contributes to recycling of nutrients and reduces the use of chemical fertilisers, thus decreasing the financial burden of the farmers and benefiting the environment. However, reuse of inappropriately treated excreta or wastewater may lead to negative health impacts. Inappropriate excreta handling (e.g. emptying, composting or field application) can endanger the health of farmers, and consuming of faecally contaminated food crops can affect consumers. An in-depth understanding of treatment processes in sanitation systems is required to best develop appropriate sanitation facilities. Furthermore, to best plan and implement appropriate recycling strategies, knowledge on the cost-benefit of reusing sanitation products is required as well as on health risks and environmental impacts. This research project aims at developing a health and environmental risk-based assessment approach coupled with an economic appraisal to foster identification and application of improved sanitation options in a developing country context. The project focuses on three research themes: 1) health and environmental risk, 2) treatment options for livelihood opportunities and agricultural production and 3) cost-benefit analysis of sanitation options.

North-South research partnerships

The project, which forms part of the NCCR North-South research programme, with field studies in South-East Asia and Africa, is headed by three postdoctoral researchers. In Switzerland, Eawag/Sandec and the Swiss Tropical and Public Health Institute (Swiss TPH, Basel) are the main research institutions, which will be working in close collaboration with partners in Asia (Hanoi School of Public Health (Vietnam), National Institute of Hygiene and Epidemiology (Vietnam), Hanoi Medical University (Vietnam), Asian Institute of Technology (Thailand) and Africa (University of Yaoundé (Cameroon), Centre Suisse de Recherche Scientifique (Côte d'Ivoire) and University of Cocody (Côte d'Ivoire). All these institutions have either already worked together previously in the NCCR North-South programme or have just joined recently.

1) Health and environmental risk

This project topic continues previous research on health and environmental risk assessment [1]. Since past research has revealed significant health risks from excreta handling, the new project will continue to identify further points of critical exposure to sanitation products. One aspect, requiring more elaborate consideration, focuses on assessing exposure to human excreta during agricultural reuse. The study will particularly i) define the main environmental factors influencing die-off of pathogens in excreta during composting (the commonly practiced treatment method) and during subsequent application in agriculture, ii) assess pathways, frequency and intensity of human exposure to excreta during composting and agricultural use iii) determine appropriate intervention scenarios based on existing practices or newly proposed alternatives to improve handling of excreta to reduce health risks and maximise agricultural nutrient value. "Human exposure to excreta reuse and health risks related to options of handling excreta in agriculture" will be the main topic of Tu Vu Van's doctoral thesis (cf. page 24) hosted at the Hanoi School of Public Health (Photo 1).

To improve sanitation planning, the research project will also further explore the

Photos 1: Farmers working without protective clothing on fields in northern Vietnam.

Photo 2: Market of the forage plant *Echinochloa pyramidalis* in Cameroon.

relation between environmental impact assessment and health risk assessment approaches when evaluating a deficient sanitation system. Using a case study in Côte d'Ivoire, nitrogen flows will be determined for a sanitation system and include health risks related to use of polluted water in urban fishing lakes and for irrigation. With the use of a developed systemic model we hope to subsequently help identify suitable planning strategies for sustainable sanitation based on the integration of economic, ecological and health aspects. "Planification intégrée de la gestion durable de l'assainissement environmental par une modélisation couplée en milieu urbain tropical: Application à la ville de Yamoussoukro, Centre Côte d'Ivoire" *(Integrated planning of sustainable environmental sanitation management by coupled modelling in tropical urban areas: Application to the city of Yamoussoukro in Côte d'Ivoire)* will be the topic of a PhD thesis of Parfait Kouame Koffi (cf. page 12) hosted at the University of Cocody, Abidjan. An Excel-based practical tool shall help integrate the assessment of environmental impact and health risk regarding sanitation and waste reuse options. A simple model will help estimate health risks of a specific population segment exposed to sanitation products at specific critical exposure points and should also comprise an assessment of environmental risk. The methodologies used will rely on quantitative microbial risk assessment (QMRA) and Material Flow Analysis (MFA).

2) Treatment options for livelihood opportunities and agricultural production

This project topic will further develop innovative human waste treatment technologies to enhance and create added value from sanitation products and also to minimise potential health risks from their use. In the socio-economic context of developing countries, combining excreta and wastewater treatment with production of forage and marketable compost can provide a local economic basis to sustain part of the costs of sanitation [2]. Ebenezer Soh K. (PhD student) will focus his research on physicochemical and hygienic aspects of wastewater reuse after post-treatment of the percolate from faecal sludge dewatering beds, while Marie Madeleine Ngoutane (PhD student) will investigate "Operational conditions that affect safety and nutritive value of the forage plant *Echinochloa pyramidalis* used for sludge treatment" (Photo 2). Furthermore, co-composting of plants and biosolids from the treatment facility will be tested to help formulate better guidelines for the production of safe by-products from faecal sludge treatment. The methods used here will comprise parasitological, microbiological, physicochemical, and bromatological analyses of sanitation products, soil and plants, as well as typical analytical engineering approaches used in research on wastewater treatment. Furthermore, socio-economic studies will help assess market potential and willingness to buy or use forage plants grown on faecal sludge and wastewater.

3) Cost-benefit analysis of sanitation options

This project topic aims at generating more scientific evidence on cost-benefit aspects of sanitation options in the context of Vietnam. One further objective will be to develop capacity of researchers to conduct economic evaluation of sanitation interventions – a still lacking skill. Cost-benefit analysis assesses and calculates the equivalent monetary value of the benefits and costs of community projects to determine their feasibility [3]. Costs and benefits of different sanitation options (expressed in monetary terms) will be measured and compared. These costs (societal perspective) include both capital (construction, equipment etc) and recurrent costs (operation, maintenance). Both health and non-health benefits of sanitation interventions will be measured. Health benefits include inpatient and outpatient care and averted self-treatment costs (direct benefits), productivity loses due to morbidity, averted mortality (indirect benefit). Non-health benefits comprise time-saving aspects, a reduction in water and environmental pollution, business gains, foreign direct investments, tourism, livestock, fish production etc. This research will use literature review and secondary data analysis as methods. Moreover, a small-scale empirical research will be conducted as a case study. This theme will be finalised by a review report on economic aspects of sanitation interventions worldwide and in Vietnam, as well as on methods for cost-benefit analysis of sanitation interventions in Vietnam. The theme is headed by Dr Hoang Van Minh from Hanoi Medical University.

Expected research outputs

The project shall allow four PhD students to pursue their degrees and shall also give three postdoctoral researchers the opportunity to advance with their research. Newly acquired knowledge on pathogen flow and behaviour in a sanitation system and human exposure to waste in the local context will contribute to a better understanding of the health risks. This knowledge shall be disseminated through peer-reviewed publications and development of tools for practitioners. The project expects to develop a practical tool for environmental sanitation planning to improve stakeholders' knowledge on the health and environmental consequences of their planning decisions. Research findings will assist in understanding the waste treatment opportunities and contribute to livelihood assets for the poor whilst ensuring low health risk and minimal environmental impact. Research outputs will include guidelines for treatment technologies, allowing optimal recovery of waste products. Respective dissemination of these findings shall facilitate implementation of such technologies. Finally, further developed methods of economic analysis, linked with practical tools for multi-stakeholder planning, will help decision-makers in improving their choices of sanitation options as well as safeguarding health and the environment.

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Parasitic Infection from Agricultural Wastewater and Excreta Use in Vietnam

Two cross-sectional surveys, conducted during the rainy and dry season in Hanam, Vietnam, identified prevalence of and risk factors for helminth and protozoal infection. The high prevalence rates indicate that wastewater and excreta are the main risk factors for parasitic infection.

Phuc Pham Duc[1,2,3], Hung Nguyen Viet[1,3,4], Jakob Zinsstag[1], Phung Dac Cam[2], Peter Odermatt[1]

Epidemiological study in Hanam

The study was conducted in the Nhat Tan and Hoang Tay communes, Hanam province, located some 60 km south of Hanoi. Sanitation facilities at household and community level are generally poor in this area. Nhue river water, with untreated wastewater from households, industry and hospitals from the city of Hanoi, is intensively used for irrigation in these two communes.

The household survey, conducted during the rainy (June – August) and dry (March – May) season, comprised 794 people from 215 households and 861 people from 270 households, respectively. Questionnaires were used to obtain information on the demographic and socioeconomic status of the households and their exposure to excreta and wastewater. Multiple-stool samples were collected from all participants, and standard laboratory techniques were applied to diagnose helminth and protozoal infection [1], [2].

Sanitation and common practices

During the rainy season, 95.8 % of surveyed households use a latrine and 92.3 % in the dry season, whereof 60 % spread human excreta on their agricultural fields in the rainy season and 51.5 % in the dry season. Most households use domestic wastewater and Nhue river water for rice and vegetable cultivation and fish breeding (86.4 % and 85.9 %, respectively).

Parasitic infection of households

According to parasitological studies, 302 people (47.6 %) were infected with at least one of the three helminth species in the rainy season and 336 people (46.3 %) in the dry season. During the rainy season, 18.9 % were infected by *Ascaris lumbricoides*, 37.6 % by *Trichuris trichiura* and 2.1 % by hookworm. In the dry season, the same parasites were diagnosed in 28.0 %, 42.4 % and 2.1 % of the study participants, however, infection intensity was generally low [3]. Furthermore, protozoal intestinal infections were also diagnosed. *Entamoeba histolytica* (6 %) and *Giardia lamblia* (2.4 %) were recorded in the rainy season; *Entamoeba histolytica* (6.7 %), *Cryptosporidium parvum* (9.6 %) and *Cyclospora cayetenensis* (2 %) in the dry season.

Risk analyses revealed that use of human excreta is closely related to a general risk of helminth infection in both the rainy and dry season (Odds Ratio [OR] 1.88; P< 0.0001, and OR 1.84; P< 0.0001, respectively) with prevalence rates of 57 % and 58 %, respectively, in the group exposed to excreta. A significant difference in helminth infection rates was also observed among people exposed to wastewater in the rainy (57 %) and dry season (52 %), and among those who were not exposed (OR 1.96; P< 0.001, and OR 1.53; P = 0.003, respectively) (Fig. 1). However, access to latrines had no effect on helminth infection rates. Agricultural and aquacultural activities are significant risk factors for all helminth infections in the rainy and dry season (OR 1.55; P = 0.005, and OR 1.4; P = 0.021, respectively) with a prevalence of 53 % and 50 %, respectively. More women (53 %) were infected by helminths than men (42 %, P = 0.002). Children under five revealed the lowest infection rates during the rainy season (35 %) and dry season (39 %), whereas the highest prevalence rates were detected among the 46–60-year age group during the rainy season (54.5 %) and (58.5 %) in the dry season (Fig. 2). In both seasons, the over 15-year olds with a lower level of education revealed significantly higher risks of infection by any type of helminth compared to those with a higher education level.

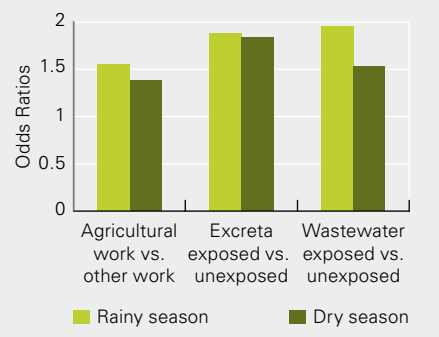

Figure 1: Odds ratios (OR) of agricultural activities and excreta and wastewater exposure as a function of general helminth infection in both seasons.

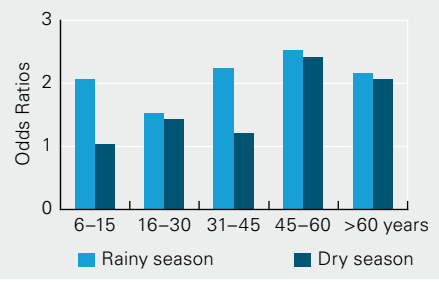

Figure 2: Odds ratios (OR) as a function of different age groups vs the 1–5-year group diagnosed with general helminth infection in both seasons.

Conclusions

Our study, conducted in the rainy and dry season, revealed that human excreta used as fertiliser and wastewater as irrigation water in agriculture, are important risk factors for parasitic infection. Our research currently focuses on diarrhoeal disease episodes from human excreta and wastewater exposure in the same community.

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Health Risks from Excreta and Wastewater to Vietnamese Farmers

Diarrhoeal infection risks caused by exposure to human excreta and wastewater were studied in Hanam province, North Vietnam. Untreated wastewater, discharged into watercourses by households and urban settlements further upstream, is highly contaminated with pathogens. Overall excreta handling and use of untreated wastewater for rice cultivation lead to high risks of infection of the exposed population. Nguyen Cong Khuong[1,2,5], Pham Duc Phuc[3,4], Tran Huu Bich[1], Hung Nguyen-Viet[1,2,4]

Wastewater and excreta use in Hoang Tay and Nhat Tan

The Kim Bang district in the province of Hanam, situated 60 km downstream of Hanoi, lies at the bank of the Nhue river receiving untreated wastewater from different sources upstream (households, industry, hospitals etc.) from the city of Hanoi. In the communities of Hoang Tay and Nhat Tan in the Kim Bang district, residents use this polluted river water and wastewater to irrigate crops and for aquaculture. The study presented here assessed microbial infection risks related to excreta and wastewater use.

Microbiological analyses and exposure assessment

The quantitative microbial risk assessment (QMRA) method was used to determine the risk of infection from wastewater and excreta use in agriculture and aquaculture [1]. 137 wastewater samples were collected in eight sampling rounds once every fortnight from the Nhue river (54 samples), from wastewater at household level (24), fishponds (32), fields (22), excreta composts and raw-eaten vegetables (5). Three pathogens were analysed quantitatively: *Escherichia coli* by MPN (most probable number) method and the protozoan parasites *Giardia lamblia* and *Cryptosporium parvum* by staining with fluorescent monoclonal antibodies and microscopic observation. A survey was conducted with 235 households to assess people's exposure to wastewater and excreta use in agriculture, i. e. working in the fields, swimming and fishing in the river, contact with wastewater in the household, handling of excreta etc. Finally, the risk of diarrhoea from all these different exposure categories was calculated using estimated probability density functions randomly sampled by Monte Carlo simulation.

Microbiological contamination

E. coli concentration was highest in household wastewater (2.107 MPN per 100 mL^{-1}) and lowest in Nhue river water (14.105 MPN per 100 mL^{-1}). Also *G. lamblia* and *C. parvum* had the highest load in household wastewater with 178 and 238 cysts per 100 mL^{-1}, respectively. All *E. coli*, *G. lamblia* and *C. parvum* concentrations in household wastewater were significantly higher than in any other sample ($P < 0.05$). *G. lamblia* in composted excreta numbered 120 cysts per g^{-1}, whereas *C. parvum* was not observed in any sample. The exposure survey revealed that people were exposed when handling excreta (emptying latrines, composting excreta and field application of excreta) (34 %). Furthermore, exposure was high during rice cultivation when using excreta and wastewater (90 %) for irrigation and during individual contact with pond and lake water (19 %) (Fig. 1). It should be noted that fieldwork, such as ploughing, rice seeding and transplanting, are the most common critical activities associated with high exposure to wastewater and excreta.

Infection risks

We calculated infection risks for both single and multiple exposures (annual risk). *G. lamblia* caused higher infection risks than *E. coli* and *C. parvum*, particularly when exposed during transplanting of rice seedlings (4.10^{-2}). Infection risk is far greater when handling excreta. People exposed to Nhue river water during vegetable cultivation, show annual infection risk by *E. coli, G. lamblia* and *C. parvum* in the range of 2.9×10^{-4}, 3.9×10^{-2} and 2.7×10^{-2}. The study revealed that wastewater and composted excreta in the Hoang Tay and Nhat Tan communities of Hanam province contain high pathogen loads compared to specifications in the WHO guidelines on wastewater and excreta reuse (33–690 times in the case of *E. coli* for instance) [2]. Protective measures during wastewater and excreta handling, adhering to the national composting guidelines and raising awareness of the population with regard to risks, are considered the most effective intervention measures to reduce infection risks.

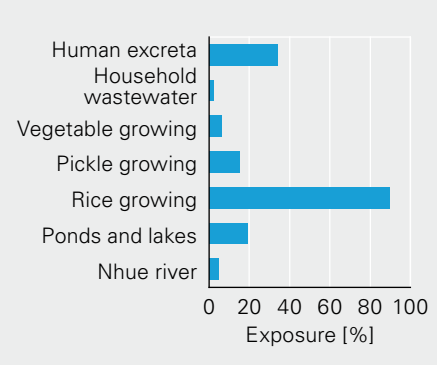

Figure 1: Exposure to excreta and wastewater (%) through agricultural activities.

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A New Perspective for Sludge Management

Treatment of faecal sludge in low and middle-income countries is still considered a loss-making business. However, use of a beneficial insect may finally trigger a paradigm shift.

Stefan Diener[1], Dang Hong Nguyen[2], Thammarat Koottatep[2], Antoine Morel[1]

Organic waste material, which often makes up more than 50 % of total waste, is scarcely reused in low and middle-income countries. Municipal organic waste generated by households and markets often remains uncollected. Restricted accessibility and low profitability lead to a limited collection pattern within the municipalities. In unserved areas, organic solid waste is generally dumped on streets and in drains, thereby increasing the risk of flooding, creating breeding places for disease transmitting insects and rodents, and causing olfactory nuisance.

Another central issue is the **management of faecal sludge** (FS). FS accumulating in septic tanks, latrines and other on-site sanitation facilities, contains high levels of nutrients and also pathogens. Despite its nutritional value, sludge generated in urban and peri-urban areas is frequently not reused in agriculture. The reasons are attributed to long distances between sludge producers and potential users of the treated sludge and to its complex treatment that reduces the economic viability of proper faecal sludge management. In Thailand, only 20 % of the municipalities operate sludge treatment plants. In most cases, sludge is discharged into surface waters or reused without adequate treatment as soil conditioner and nutrient source in (peri-urban) agriculture. Such practices expose farmers and consumers alike to considerable health risks from the extremely high pathogenic contamination of the sludge.

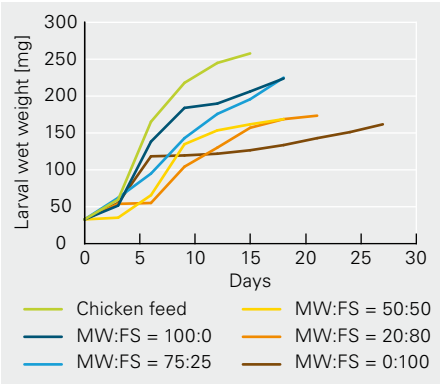

Figure 1: Weight gain of black soldier fly larvae fed with chicken feed or different mixing ratios of market waste (MW) and faecal sludge (FS).

Photo 1: Black soldier fly, *Hermetia illucens* L. (left: adult, right: larvae).

Fly larvae for sludge management

Viewing FS and organic waste as a free and valuable resource rather than an expensive waste creates new economic niches and turns waste collection and treatment into a profitable business. One promising approach is to use the larvae of the black soldier fly *(Hermetia illucens* L. (Photo 1) to transform organic waste into valuable products. These larvae, which feed voraciously on decaying organic material, reduce up to 80 % of the dry matter and produce a nutrient-rich byproduct in the form of the last larval stage, the so-called prepupae. Their protein content (amounting to about 40 %) makes them a valuable alternative to fishmeal in animal feed. This offers new opportunities for small entrepreneurs in developing countries to combine waste management and feedstuff production.

A recent study, conducted at the Asian Institute of Technology (AIT) in Bangkok, Thailand, in collaboration with Sandec, investigated use of these critters in treating dewatered faecal sludge. The objective of the study was to examine decomposition of organic waste streams, particularly as regards treatability of faecal sludge.

Promising experiments at AIT

The experiments were conducted in the laboratory using larvae derived from a soldier fly colony raised in a small greenhouse on the AIT campus. The sludge, originating from nearby septic tanks of the municipal service providers, was dewatered (63 % H_2O) in a small-scale drying bed. To determine digestibility and optimal mixing ratio of faecal sludge and market waste, larvae were fed different ratios of these waste products (0 %, 25 %, 50 %, 80 %, and 100 % FS) every three days until all larvae had transformed into prepupae. To allow for source-dependent development times, the effective waste material reduction was divided by the number of days the larvae fed on the material, thus obtaining the waste reduction index (WRI).

Larval performance in the faecal sludge experiment was compared to data obtained from a similar experiment using oil and grease waste as well as chicken feed (control) as feed source.

Larvae of the black soldier fly were not only able to survive and even develop in pure faecal sludge, but were also capable to significantly reduce the sludge biomass. Nonetheless, the larvae developed much faster when market waste was added to the faecal sludge to enhance the nutritive value of the larvae's feed source (Fig. 1). The resulting prepupae were also much fatter than when feeding on faecal sludge only. The combination of faecal sludge with market waste in a 50:50 ratio promises to be a good combination of prepupal biomass production and efficient waste reduction. Furthermore, experiments with oil and grease waste from the cantine's grease trap let us assume that soldier fly larvae can also process these waste products. These promising results prompted Sandec to plan an extended research project in Thailand in close collaboration with AIT and other partner institutions in Switzerland and Germany.

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Material Flow Analysis – A Tool for Nutrient Resource Management

Nutrient recycling from human waste for production of animal feed provides an alternative to the use of chemical fertilisers and commercial animal feed. It also contributes to minimising water and soil pollution.

Nga Do-Thu[1], Antoine Morel[2,3], Phuc Pham-Duc[4], Hung Nguyen-Viet[3,5,6], Thammarat Kootattep[2]

Hoang Tay and Nhat Tan

The study site comprises the two neighbouring communes of Hoang Tay and Nhat Tan, Kim Bang district, Hanam province, Vietnam. The 16 293 inhabitants (in 2008) are spread over a total area of 8.61 km^2. Livestock, paddy fields and sanitation systems are the main sources of nutrient generation. The study site has no wastewater treatment plant, and wastewater from households and livestock etc. is discharged via the sewage systems directly into the water channels or fishponds. Some of the solid waste is collected and disposed of in an uncontrolled landfill.

Method

The adapted MFA [1] was first applied to this rural area of Vietnam. The simplified model, visualising all the current human activities focuses on some key activities, with their main input and output flows, including their interactions [2]. Necessary data was obtained from available sources, such as statistics, local and international research reports and scientific literature, and complemented by experts' views. Model parameters were determined by an acquired understanding of the system and based on a nutrient balance concept. Moreover, conducting plausibility and parameter assessments could solve data uncertainty and scarcity. Alternatively, model simulations were used to quantify nutrient flows and identify their corresponding key parameters illustrated in a flow diagram. Moreover, the effects of potential mitigation measures could then be calculated and discussed for different scenarios by adjusting their respective parameters.

Photo 1: Livestock manure is fed into a biogas reactor and effluent is then used in agri./aquaculture.

Results

The main annual N input to the study site originated from chemical fertilisers applied to rice paddy fields (177 ± 7 tonnes), and from commercial fish and animal feed (245 ± 11 tonnes). The main output into water bodies and soil/groundwater originated from drainage systems (42 ± 3 tonnes) and paddy field runoffs (116 ± 6 tonnes). Yet, it is important to note that large amounts of nutrients could be recycled as animal feed or fertiliser. For example, 214 ± 56 tonnes of N from wastewater, faecal sludge or manure (53 % of total N), as well as from organic solid waste are generated annually by households, markets and crop residues. Only 30 % of total N from markets and household organic solid waste were recycled to feed animals, pigs and poultry. Yet, only 49 % of the manure was reused as fertiliser. Therefore, 51 % of total N from manure and wastewater was discharged into water bodies and soil/groundwater, equalling 216 ± 6 tonnes – an amount exceeding the chemical fertilisers used (177 ± 7 tonnes). Consequently, reuse of wastewater and manure to fertilise rice paddy fields was an economical way to reduce the use of chemical fertilisers (Photo 1).

Two scenarios for the study site were created based on the developed MFA model. Firstly, by 2020, if sanitation systems and farming habits of local communities remain the same, the amount of N from wastewater is expected to increase by 50 %. The amount of N from faecal sludge and organic solid waste could triple compared to the 2008 status (Scenario 1). Secondly, by 2020, if on-site sanitation systems were improved by increasing the annual emptying frequency factor of septic tanks or pour-flush latrines, N could be reduced five times, once from biogas and 0.3 times from pit latrines to almost reach the 2008 status (Scenario 2). If wastewater, pig manure and organic solid waste were recycled, and on-site sanitation systems improved as aforementioned, the amount of N could be reduced significantly.

Conclusions

The adapted MFA method is an ideal technical basis for planning and decision-making, especially in developing and emerging countries with limited technical and financial resources. The visualisation results obtained also raised the awareness of local populations regarding the critical local pollution situation. Moreover, based on the scenarios described, local authorities could also develop nutrient recycling strategies instead of continuing to damage soil, groundwater or Nhue river water.

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The Glass Wetland Unit in the Slum of Manchay, Lima, Peru

The project describes the implementation of a demonstration pilot plant for wastewater treatment from a school in the slum of Manchay, Lima, Peru. A subsurface horizontal-flow constructed wetland (SSHF-CW) plant was built with glass walls for purposes of dissemination and education. The project reveals the potential of decentralised wastewater treatment plants in low-income peri-urban areas.

Camilla Archetti[1,2], Marco Ragazzi[2], Guido Zolezzi[2]

Introduction

Decentralised sanitation systems, increasingly used in peri-urban and rural areas of low and middle-income countries, provide appropriate and sustainable solutions to water scarcity problems [2], [5]. Decentralised sanitation services contribute to wastewater source separation, collection and treatment of blackwater, greywater, urine, and sludge in terms of conveyance, on-site recovery, nutrient and water reuse, energy saving and production. Effective decentralised services require integration of sustainable technological approaches (selecting, testing, implementing) in close collaboration with the community and based on the local/national context [6], i. e. management potential and existing regulations. These key components are required to develop successful decentralised wastewater treatment strategies at local and national level. A comprehensive case study of a peri-urban area in Peru is examined here in more detail. Since creation of the Ministry of the Environment in May 2008, Peru is undergoing an important change in its national environmental planning strategy. The country is currently experiencing a shift in institutional arrangements and leadership regarding environmental issues. All water-related management activities are gradually being placed under the authority of this new government entity [4].

Study location and context

Manchay is one of the three poorest peri-urban arid squatter settlements of the city of Lima, Peru, with an ever increasing population of currently 70 000 (Photo 2). Manchay established itself as an illegal settlement following the exodus from the urban centre heavily hit by terrorism and guerrilla warfare in the seventies. Sicknesses and epidemics significantly affect children and the quality of life of the entire population. Land tenure and property rights are also of major concern along with the extreme vulnerability to natural hazards. Daily life of the population is also affected by the dry climate of the region, i. e. common spaces and recreational areas suffer from the absence of trees and vegetation. Water and wastewater management can play a key role in this context, particularly in reducing the spread of epidemics [8]. Despite recent government investments in basic water supply and sanitation infrastructure, the level of service is still inadequate due to poor management and uneven distribution of benefits, thereby continuing to expose the entire area to water-related health risks. Several development projects are currently implemented in Manchay, primarily by the "Missioni Francescane ONLUS" of the Autonomous Province of Trento, Italy. To alleviate the precarious unemployment situation in the area, the Technological Institute "Juan Pablo II" developed a major programme for training young professional. One of the aims of the Institute and its Board of Directors is to positively impact the local area also from a health, social and environmental perspective. "Manchay Verde" (Green Manchay) was launched as a pilot project in 2008 to specifically bring about a visible and permanent change in people's water use and sanitation habits through community participation and novel technical solutions [7].

Wetland pilot plant

A wetland pilot plant was therefore set up for school wastewater treatment and reuse in irrigation of local plants (Photo 1). The general objective of this project component is to develop best practices in decentralised wastewater treatment and reuse that would help improve the wastewater and sanitation planning strategy of the local municipality. Its specific objectives include: (a) technical analyses of feasibility and suitability of this treatment technology within the context of Manchay [3], (b) use of the pilot plant as didactical interactive field class for the primary, middle and high school of Manchay, (c) scaling up the plant and replicating it on a larger scale, (d) involving more actors and reusing the resources for greening the area. The pilot SSHF-CW (subsur-

Photo 1: The Manchay glass wall wetland pilot plant, Lima, Peru, April 2009.

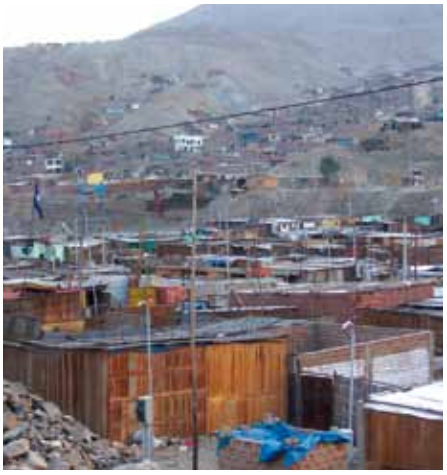

Photo 2: The slum of Manchay, Lima, Peru.

Parameters	Sample description (15 April 2009)	
	Inflow	Outflow
pH	7.2	8.0
Temperature [°C]	21.4	18.4
COD [mg O_2/L]	570	180
Kjeldahl nitrogen [mg N/L]	137	84.8
Total coliforms [NMP/100 mL]	1.6 x 10^8	1.6 x 10^6

Table 1: First sample results.

face horizontal-flow constructed wetland) was designed and implemented within the framework of a PhD research conducted under the supervision of the Faculty of Engineering of the University of Trento, Italy. A first survey in January 2009 revealed that the existing septic tank was the only treatment step in place. The settled sludge volume was first measured to assess the residual capacity of the septic tank. The results showed that it could still operate a few more years without having to be emptied, provided the wastewater characteristics remained the same. Construction of the pilot plant started in February 2009 and was completed in April 2009. Its current operation monitors and analyses its removal efficiency. Two units were constructed downstream of the septic tank. The first unit comprises an accumulation and equalising tank, while the second unit is composed of the horizontal-flow constructed wetland. The water flows by gravity from the first to the second unit. The pilot plant is equipped with glass walls for educational purposes and to reveal its component parts. The bed comprises four different gravel/sand layers decreasing in grain size from bottom (gravel, 2 cm) to top (coarse sand, 2 mm). The planted macrophytes are native species, namely *Totoras (Schoenoplectus californicus* ssp. *tatora)*. Finding and collecting the necessary filter material and tools were the main difficulties encountered during pilot plant construction. Screens for selecting different filter material sizes had to be built and the filter material filled manually into the plant. In terms of time schedule and man-hours, these activities had a significant repercussion on the outputs of the entire project. SSHF-CW became operational in the summer of 2009. A one-year field measurement survey will be conducted to evaluate plant efficiency. This survey will involve participation of the "Universidad Agraria La Molina", with a Master student supervised by two professors. A first sample was taken two months after plant operation. Table 1 illustrates pH, temperature, COD, and TKN (Total Kjeldahl Nitrogen) in the first sample. Analysis also revealed a 2-log removal of total coliforms. Due to the aridity of the area, part of the investigation of the present research also takes the nutrient potential of the wastewater into account for reuse in irrigation and in compliance with the Peruvian wastewater reuse standards. Pollution/eutrophication risk for surface and groundwater resources is significantly reduced on account of the low water table in this area. Many different stakeholders were contacted and also involved during the planning phase. To meet the educational objectives of the pilot plant and to develop environmentally oriented activities, the schools of the area (elementary and secondary) organised a coordination committee formed by teachers. These are planning to use the pilot plant as a field laboratory for students enrolled in science and environmentally related programmes.

Conclusions

Since many years, decentralised wastewater management is seen as the most feasible approach to cope with sanitation challenges in peri-urban areas of developing countries facing severe infrastructural deficiencies [1]. The presented pilot project reveals that this kind of technology has a high operational potential and can be scaled up to replicate small-scale models. Reuse of wastewater or non-potable water for irrigation contributes to solving the problems of water-deprived areas worldwide. Adequate treatment of wastewater prior to reuse is important to reduce potential health and environmental risks. Not all treatment technologies show the same removal efficiency. Pertinent literature is still scarce on data comparison or information about basic parameters affecting these efficiencies, which are strongly dependent on the local context. As shown in the present study, implementation of pilot treatment plants is important to further investigate and collect the necessary data to formulate sound solutions based on the local technological and cultural context. Participation of local communities, local actors and stakeholders is a key aspect in development cooperation projects such as the one described above.

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Optimising Environmental Sanitation in Yopougon, Côte d'Ivoire

Côte d'Ivoire, especially Abidjan, is still facing environmental sanitation problems despite continuous efforts from national and international agencies. This study analyses material flows in various sanitation options in Yopougon, Abidjan, in order to develop sustainable mitigation alternatives to current environmental risks. Parfait Kouame Koffi[1,2], Kouassi Dongo[1,2], Hung Nguyen-Viet[3,4], Guéladio Cissé[1,4]

Environmental sanitation in Yopougon

Aspects of environmental sanitation should be included in each and every planning process. Yet, environmental sanitation issues still create problems in developing countries, particularly in Côte d'Ivoire. In Abidjan, uncontrolled urban waste causes huge damage to aquatic systems (Photo 2). The UNIWAX basin of Yopougon, Abidjan, forms part of the urban area, and the authorities have difficulties in selecting an appropriate sanitation system for this area. Large wastewater and solid waste quantities are discharged untreated into the Ebrié lagoon (Photos 1 and 4). Wastewaters from industry, hospitals, markets, as well as from the formal and informal business sector are also transported to the same lagoon via the sewage and stormwater system [2], [4]. Solid waste and wastewaters contain nutrients, such as nitrogen and phosphorus, considered as indicators of pollution. In Yopougon, the poor urban populations, which have settled around the UNIWAX canal, use polluted water for various activities like urban agriculture with significant detrimental health impacts. This study applies the Material Flow Analysis (MFA) method to analyse N and P flows in Yopougon in order to develop sustainable sanitation options for wastewater management.

Applications of MFA to UNIWAX basin

The UNIWAX basin of Yopougon, located in Abidjan, southern region of Côte d'Ivoire, covers an area of 2520 ha with more than 450 000 inhabitants [2], [4] grouped into formal settlements with sanitation facilities and services and informal settlements without sanitation systems (Photo 3).

The Material Flow Analysis (MFA) method allows to describe the fluxes of resources used and transformed as they flow through a region, through a single process or via a combination of various processes. In developing countries, MFA has proved to be a suitable tool for early detection of environmental problems and development of appropriate solutions [1]. This method has been recently adapted and used for sanitation planning systems in developing countries. However, its application has encountered difficulties with regard to data collection (data necessary for MFA is often scarce in developing countries), and therefore an iterative approach has been applied [3] to overcome data deficiencies.

Photo 2: Wastewater and solid waste are discharged together into the drainage channel along the informal settlements of Yopougon.

Photo 1: UNIWAX canal of Yopougon, Abidjan, Côte d'Ivoire.

The UNIWAX basin was used as system boundary in this study [2]. The following nine processes and goods were studied within the system: hospitals, industry, markets, formal and informal settlements, septic tanks, wastewaters, solid waste, and drinking water. Finally, the substances N and P and their dynamics in the system were analysed from "cradle to grave".

An Excel spreadsheet was used to formulate the transfer equations, and STAN 1.1.3 to visualise substance flows [5]. The study used available data from scientific articles, reports and national statistical databases to feed the model.

Photo 3: Deficiency in wastewater management in the informal settlements of Youpougon, Abidjan.

Results

The results obtained reveal that a large amount of nitrogen (31 817 tonnes/year) and phosphorus (412 225 tonnes/year) is discharged into the environment. This is caused by leaking of the dysfunctional sewer network and, thus, infiltration of wastewater into the subsurface. Nutrients are also discharged into the lagoon through the wastewater of Yopougon's CHU hospital centre (1300 tonnes/year of nitrogen and 280 tonnes/year of phosphorus).

The following three sanitation options were proposed to improve environmental sanitation management: (i) natural lagoons for wastewater storage, (ii) co-composting for sludge and organic waste and (iii) a wastewater treatment facility. These technological options were selected based on the objective to achieve a healthy living environment, collection of drainage water and solid waste and appropriate wastewater treatment in compliance with environmental standards. The technological options modelled could reduce water pollution in the basin by about 75 %. Each sanitation option was also assessed in relation to criteria of sustainability, adaptability and manageability. The 1st option, relying only on lagoons, could not contribute significantly to a sustainable environmental management of the basin. The 2nd option, combining lagoons and co-composting, is already more promising as it considers management of both solid waste and wastewaters and may generate income for the population. The 3rd option, with a wastewater treatment plant located downstream of the basin, would reduce the nutrient inputs into the lagoon by 90 %. Yet, it would only improve wastewater treatment and not benefit the UNIWAX basin and its population in terms of economic opportunities.

Conclusions

This study reveals that the Material Flow Analysis method allows to understand environmental pollution and select sustainable sanitation options for wastewater management in the context of developing countries, especially in Yopougon. The co-composting option is considered most interesting, as it could generate income for poor populations around the UNIWAX canal.

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Photo 4: Another view of the UNIWAX canal of Yopougon, Abidjan, Côte d'Ivoire.

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Financial Assessment of Dakar's Sewer vs Faecal Sludge Management

In Senegal's capital Dakar with its approx. three million inhabitants, investment and O&M costs of the conventional, centralised sewer system are considerably higher than those of the on-site faecal sludge management (FSM) system. The income generated by user fees is insufficient to cover the expenses of the centralised sewer system, yet recovery of FSM charges appears easier. Mbaye Mbéguéré[1,2], Pierre-Henri Dodane[4], Ousmane Sow[3], Doulaye Koné[2]

Introduction

Access to adequate sanitation systems is of vital importance in reducing poverty [1]. The significant efforts made over the last years (between 1990 and 2004) in this sector have provided 1.2 billion people worldwide with access to improved sanitation [2]. Many experts agree that a fully sewered system covering a whole urban area is prohibitively expensive and cannot meet the needs of the poor.

On-site sanitation systems with appropriate FSM may, however, offer a technically and economically feasible alternative. An economic and financial flow analysis of the sanitation systems is necessary to improve management in this sector [3].

Based on real field data from Dakar, this study assesses the investment and operating costs of conventional sewers and on-site sanitation systems with FSM. This comparison is limited to the economic aspects of the two systems, as both are efficient from a sanitary and environmental perspective. The comparative study was mainly conducted in the district of Cambérène, where about 250 000 people are connected to the sewer and an activated sludge treatment plant, and around 160 000 inhabitants are serviced by on-site facilities, whose contents are collected by emptying trucks and treated on drying beds.

Methodology

The following tasks were performed to establish economic and financial flow diagrams of a given sanitation system:

Identifying the stakeholders

The role of stakeholders and cash relationship between each stakeholder was identified along with the main items of expenditure. Financial contributions by various stakeholders were analysed in terms of staff/salary cost so as to assign them to:

- The sewer system or the FSM system.
- Investment or operation activities.
- Major items of expenditure of the two systems.

The sewer system includes the sewer itself, pipe connections to the sewer, pumping station, and treatment plant. The FSM system comprises the pits (as the predominant on-site sanitation facilities), the emptying trucks and the FS disposal/treatment facility.

Establishing the assessment base

The assessment base is the number by which a given amount is divided to obtain the same unit of comparison. Each stakeholder involved in sanitation incurs capital expenditures (relating mainly to building of the infrastructure) and operation expenditures (relating to operation of the infrastructure). Cost items relate to the number of inhabitants affected by this expenditure rather than to m^3 of water transported/treated. The unit cost, used as financial assessment base, is the cost per inhabitant.

Efficiency of the sanitation system is best highlighted if costs are given per beneficiary of the sanitation system, thereby also assisting decision-makers in determining sanitation tariffs.

Cost adjustment hypothesis

Older infrastructure costs were updated on the basis of the French Construction and Civil Engineering (CCE) index rather than on the use of the simple overall inflation rate, since the Senegalese currency (FCFA) is indexed to the French monetary unit, the Euro [4].

Depreciation costs of the investment were subsequently integrated into the operating expenses.

Costs were expressed in USD (2007).

Results

Breakdown of sewer system costs

Cambérène's sewer network spreads over roughly 340 km with 26 pumping stations. Its cost is determined on the basis of the recently built Sahm Notaire municipality, a neighbouring area forming part of Cambérène and exhibiting similar independent variables (Fig. 1).

The capital costs of the sewer depend on network size, wastewater volume to be collected and topography. Indeed, Dakar's topography is relatively flat, its soil sandy and thus easy to excavate.

Construction of pipe or house connections involves increased household investments. A connection costs USD 760 and includes construction material and labour costs.

The operating costs of the sewer system are financially supported by ONAS and divided between sewer network and treatment plant.

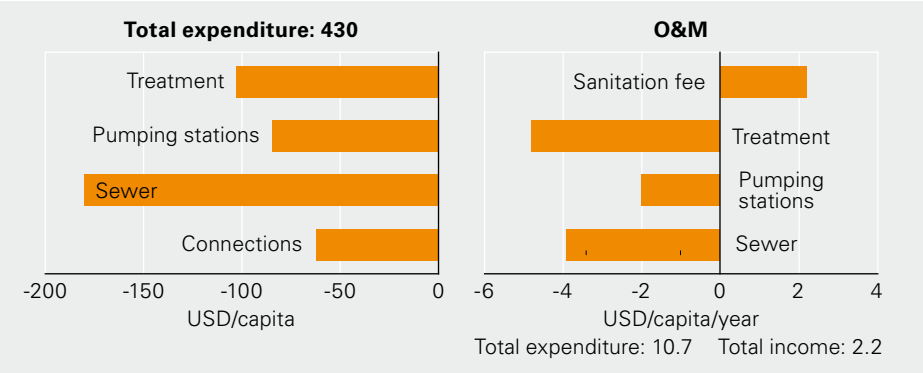

Figure 1: Cost allocation of the centralised sewer system.

– The operating costs of the sewer include unclogging, scrubbing and repair of damaged pipes. The costs per inhabitant total about USD 3.90/year.
– The operating costs of pumping stations, amounting to about USD 2/inhabitant/year, comprise energy costs for pump operation, security measures, cleaning, and repairs.
– The overall operating costs of the wastewater treatment plant amount to USD 1 223 400/year for treating a wastewater volume of 14 000 to 15 000 m^3 per day, or 250 000 person equivalent. A biogas recovery facility has reduced the operating costs by 20 % (30 % of the energy is supplied by recovered biogas).

The households connected to the sewer system pay a sanitation fee proportionate to their drinking water consumption. Indeed, for every m^3 of water consumed, the beneficiary pays on average USD 0.10 for sanitation. As the average water consumption per inhabitant and day in Dakar amounts to 60 litres, the cost per beneficiary and year totals USD 2.20.

Breakdown of the FSM system costs

The system's costs are broken down according to the stakeholders involved (Fig. 2).

Depending on their degree of involvement, all the stakeholders of the FSM system chain, including donors, households and emptying companies, participate in the investment:

– Donors have invested USD 654 000 in Cambérène's FS treatment facility. With its 161 000 beneficiaries and current situation, this corresponds to USD 4.10 investment cost per inhabitant.
– The companies providing sludge emptying services are regarded as the mobile network of the FSM system. Their operation is preceded by an investment (approx. USD 30 000) in an emptying truck currently servicing on average 10 440 beneficiaries per year.
– The inhabitants are the main beneficiaries of the FSM system. They pay mainly for pit construction. Based on the required maintenance work and PAQPUD's processed data (ONAS sanitation programme), the cost for a single pit has been determined at USD 460. The cost per inhabitant amounts to USD 46, based on a 10-member household [3].

FSM operating costs:

– Households served by FSM pay USD 5/y/capita for emptying their on-site facility.

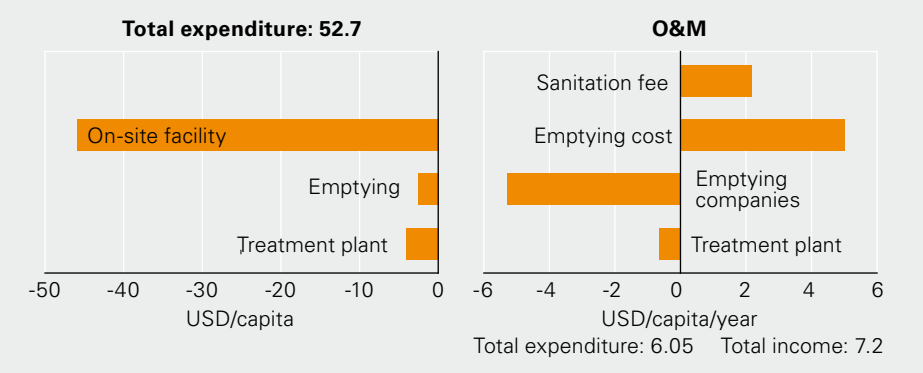

Figure 2: Breakdown of FSM costs.

– Emptying companies pay USD 5.30/year/capita for the emptying service and discarge at the FS treatment plant.
– Operating and maintaining the FS treatment facility costs USD 0.65/year/capita.

ONAS also receives USD 2.20/year/capita from the sanitation fee indexed to the water consumption tariff.

Conclusions

A comparison of the two sanitation systems allows the following conclusions:

– Investment in Cambérène's sewer system is far more expensive than in the FSM system.
– Even allowing for depreciation, operation of a FSM system is two times less expensive than a sewer system, mainly incurred by the sewer pumping station and intensive treatment requiring energy, chemicals and O&M.
– To meet the operating budget of the sewer system, ONAS is currently levying a fee from all of Dakar's population, even from the FSM-serviced population who is not connected to the sewer system. If only those connected to the sewer would pay for its operation, a mere 20 % of its operating costs would be covered; the remaining costs would have to be borne by the government or external donors.
– The FSM system reveals a slight deficit mainly incurred by transport expenses and not by treatment costs. Improvements are necessary mainly at transport level as recommended by experts [5].
– Yet, if the sanitation charge levied by ONAS from those serviced by on-site systems were in fact reinvested in servicing the same people, it would allow to compensate for all the losses and even generate profit or reduce the emptying costs.

According to the study, FSM is affordable by the population and also offers several positive externalities. FSM is experiencing a strong economic expansion (increase in emptying companies) and has a promising future, since most of the peri-urban population has no access to an adequate sanitation infrastructure. Official FSM acceptance and support could save large investment costs for the donors and create an income-generating sector. A dialogue should occur between the various stakeholders in the sanitation sector to mitigate the operating costs of the FSM beneficiaries, organise cost recovery and determine the conditions rendering domestic sludge emptying profitable and FSM sustainable.

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Sanitation – Demand and Gender

Our new NCCR North-South applied research project entitled "User Driven Sanitation – Gender and the Challenge for Sanitation Demand" deals with the main factors influencing choice and demand for sanitation. The four-year research project, combining social sciences (environmental psychology, gender studies, development economics, and political science) with environmental engineering, studies the main constraints affecting the lack of sanitation in urban and peri-urban areas. Christoph Lüthi[1], Elizabeth Tilley[1]

The most recent update of the Joint Monitoring Programme (WHO/UNICEF, 2010) clearly reveals that the number of people without access to basic sanitation will **not** be halved by 2015. If current trends continue, an additional billion people who should have benefited from MDG progress will miss out. By 2015, the number of people without access to basic sanitation will total 2.7 billion [1]. Though sanitation coverage in North African, Asian and Latin American countries continues to rise, albeit at a very slow pace, a significant number of people, especially the most vulnerable, including indigenous communities and urban slum dwellers remain unserved. This research project attempts to elucidate the reasons for not reaching the set target. "User Driven Sanitation" will conduct research on three interrelated topics: (i) enabling environments, (ii) (household) behaviour and demand and (iii) genderised sanitation.

Creating enabling environments

This theme addresses the underlying governance arrangements for sanitation at national and local government levels. Why have countries like Bangladesh been able to strengthen governance arrangements and ratchet-up service delivery in the past decade, while others, such as Uganda or Nepal remain woefully behind? What are the ingredients of successful enabling environments both at national and municipal levels? Researchers will be carrying out comparative analyses in selected countries in Africa, Asia and Latin America to investigate the key determinants and elements of an "enabling" environment – and likewise identify the main "disabling" factors.

Drawing on Sandec's long expertise in participatory projects and community-based environmental sanitation planning, one research theme will try to improve our understanding of participatory processes in low-income urban settlements. Can multi-stakeholder, community-based planning such as Eawag/Sandec's Household-Centred Environmental Sanitation (HCES) planning strengthen social capital and generate empowerment? An ex-post study of past participatory planning processes aims at determining whether communities are satisfied with such bottom-up processes and if they provide a more effective manner of implementing urban infrastructural projects.

Triggering household behaviour and demand

A decade after the adoption of the MDGs, the international community is still struggling to scale up sanitation coverage, especially in poor rural and urban environments. The starting point of this research theme deals with the question that household demand for improved sanitation in developing countries is a behavioural process that is not very well understood, especially in poor informal settlement areas around the world. Our study will include drivers that influence technology selection of improved sanitation facilities and hygiene behaviour. Past research suggests that economic drivers and situational factors, such as prestige, well-being and privacy are decisive issues [2]. This research seeks to identify the main factors influencing selection of sanitation technology and explore the most effective social interventions influencing household demand and behaviour for improved sanitation in an urban context.

Field research will be conducted in Kampala's informal settlement areas, currently housing 60 % of the urban population (Photo 1). Following a baseline survey in ten selected slum settlements, social interventions will be defined to promote behavioural change and trigger demand. For more than 1½ years, different interventions will be tested in field experiments to determine the most effective ones. So far, various models on behavioural change have been evaluated for their suitability in sanitation. According to the theory of 'Planned Behaviour' and 'Health-Action-Process Approach', individuals' demand for sanitation and behaviour are governed by their attitudes towards the desired behaviour, social norms, expected outcomes, and perceived behavioural control or self-efficacy. Our PhD student Innocent T. Kamara (cf. page 27) from Makerere University will be responsible for conducting this innovative research.

Photo 1: A variety of targeted social interventions must be applied to trigger demand for improved sanitation in urban areas. Pictured: New sanitation facilities in a Kampala informal settlement.

Photo 2: Sensitisation of school children is also crucial for improved sanitation and hygiene behaviour at home.

Genderising sanitation

Despite the fact that several Millennium Development Goals (MDGs) directly address women, the linkages and interdependencies between those goals and the ways in which the pursuit of one goal can strengthen the others have not been fully investigated. Moreover, very few studies have approached sanitation through a gender lens (Photo 2).

Education is one of the key determinants for development, yet education of girls still lags behind, and drops off sharply in secondary school [3]. The importance of educating girls in fighting poverty has been widely recognised (Photo 3). Still more appalling are studies (like a recent one from Nepal), which reveal that more than half of the girls interviewed mentioned that they had missed school because they were menstruating [4].

Furthermore, public toilets are often the only sanitation option in urban environments – especially for women (who seek more privacy than men). The fact that women must travel to, wait and pay for inadequate services negatively impacts their health, safety and economic opportunities.

Yet, beyond anecdotal and simplistic reports [5], there is a discouraging lack of information about what girls and women want and need from a sanitation facility.

By offering women the opportunity to express their requirements for improved sanitation facilities and implementing those suggestions, we will investigate the effects on their education and economic opportunities. Specifically, this interdisciplinary research seeks to:

a) understand the coping strategies currently employed by women and girls as they struggle to meet their sanitation needs in shared sanitation settings (both schools and public toilets);
b) investigate and test the methods required to approach the sensitive topic of hygiene and elicit genuine needs, opinions and suggestions;
c) assess the impact of empowering women to have a say in their sanitation; and,
d) understand the effects that improved sanitation have on the lives of women and girls using the facilities.

By partnering with the Interdisciplinary Centre for Gender Studies (ICFG) in Berne, our team will develop innovative methods to understand the problems, develop and test interventions as well as set up guidelines and best-practices based on the outcomes of the work. We are still looking for partners interested in cooperating and facilitating parts of the fieldwork.

NCCR research partnerships

User Driven Sanitation research is conducted by renowned universities and research institutions on four continents. The research project is conducted by Eawag/Sandec in collaboration with the Asian Institute of Technology in Bangkok. In Eastern Africa, our main partner institution is the Department of Civil Engineering at Makerere University in Kampala. In Latin America, we collaborate with FLACSO – the Latin American Faculty for Social Sciences and the National University of Honduras (Postgraduate Unit on Social Studies). In Switzerland, Sandec's main research partner is the ETH Nadel Institute of Development Economics. Clearly, these multi-country and interdisciplinary research partnerships are a challenge to coordinate but ultimately rewarding in their interdisciplinary research scope and outreach.

Expected research outputs

The four-year NCCR North-South research project will see two completed PhDs and several peer-reviewed articles on the aforementioned themes. Based on the outcome of the work, it will also develop and test interventions as well as set up guidelines and best-practices. This applied interdisciplinary research project also plans to develop guidelines on gender sensitive sanitation technology and revise the household-centred environmental sanitation guidelines.

Photo 3: Proper school sanitation facilities are one of the key determinants for keeping girls in school.

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[5] Reed, R.A. and Shaw, R.J. (2008): Sanitation for primary schools in Africa. WEDC, Loughborough University, UK.

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Mitigating Greenhouse Gas Emissions by Institutional Biogas Plants – A Case Study in Dar es Salaam

Though the waste sector is responsible for only limited global greenhouse gas (GHG) emissions, mitigating these gases also constitutes a waste management issue. Especially decomposition of organic material on uncontrolled landfills leads to undesired methane gas production. Anaerobic digestion of organic solid waste in decentralised biogas plants is one option to minimise these GHG emissions.

Yvonne Vögeli[1], Annette Nantongo[2], Christian Zurbrügg[1]

The African waste sector produces 6.8 % of the continent's total GHG emissions, primarily from methane formation in open dumps [1]. A comparison reveals that composting and anaerobic digestion of the organic waste fraction are the most viable treatment options appropriate for developing countries to minimise carbon emissions. Composting is neutral in terms of carbon emissions, and anaerobic digestion combined with energy recovery is carbon negative [2]. Since municipalities are frequently not capable of financing the implementation of such improved waste management systems, the Clean Development Mechanisms (CDM) and the voluntary carbon offsetting programmes (cf. box) are likely sources of investment. Waste management methodologies approved by the CDM comprise landfill gas capture, composting and anaerobic digestion of organic solid waste.

Clean Development Mechanism
The CDM is one of three market-based mechanisms endorsed by the Kyoto Protocol to reduce GHG emissions. CDM allows emission reduction projects in developing countries to earn Certified Emission Reduction (CER) credits; each equivalent to one tonne of CO_2. These CERs can be traded, sold and used by industrialised countries to meet part of their emission reduction targets established in the Kyoto Protocol.

Voluntary carbon offsetting projects
In the much smaller voluntary market, individuals, companies or governments purchase carbon offsets to mitigate their own greenhouse gas emissions from transport, electricity or other sources. For example, an individual purchases carbon offsets to compensate for the greenhouse gas emissions caused by personal flights. Many companies offer carbon offsets as an up-sell during the sales process to allow customers to reduce the emissions caused by the products used or services purchased (such as offsetting emissions resulting from a vacation flight, car rental, hotel stay, consumer good etc).

Though the CDM projects are on the increase worldwide, their number is still negligible in Africa. The continent accounts for less than two percent of the 2 000-plus registered CDM projects worldwide. Of the current 41 registered projects on the African continent, ten are associated with the "waste handling and disposal" sector, whereof nine projects focus on landfill gas capture and one on centralised anaerobic digestion of municipal solid waste. (http://cdm.unfccc.int; March 2010)

GHG emissions from waste decomposition and transport

Based on the example of Dar es Salaam, a recent study, headed by Sandec and UNESCO-IHE [3], is appraising GHG emission reduction from decentralised biomethanation of kitchen waste compared to landfilling or dumping. The IPCC (Intergovernmental Panel on Climate Change) guidelines have been used for these calculations. Currently, 42 % of the generated waste in the city is transported to a landfill 35 km from the centre, where the organic fraction is decomposed under anaerobic and aerobic conditions. This low collection coverage is attributed to a recent change in disposal system that led to longer transport routes. Fig. 1 illustrates the calculated methane emissions over a 20-year period based on the current waste management system. It also reveals that, compared to the entire organic fraction, kitchen waste decomposes quickly and is mainly responsible for methane production over the period considered.

GHG emissions from waste transport to the landfill are comparatively insignificant. Over a 20-year period, the emissions from waste transport account for only 4 % (260 000 t CO_2e) compared to 96 % (5 700 000 t CO_2e) from waste decomposition. These total annual emissions of 300 000 t CO_2e caused by the current waste disposal system in Dar es Salaam result in annual per capita emissions of 0.06 t CO_2e. Based on the total per capita emissions in Tanzania, reported as 1.0 t CO_2e by the UN statistics division, the current solid waste management system is responsible for 6 % of the annual per capita emissions.

Kitchen waste treatment in institutional biogas plants

Azania secondary school is the first institution in Dar es Salaam equipped with biogas plants for on-site food waste treatment (Photo 1). The gas produced is used for cooking and replaces part of the charcoal. The available food scraps from the school (~32 kg/day) hosting on average 110 students, are now turned into biogas instead of being dumped at the landfill where they would have otherwise produced 8.3 tonnes of CO_2 equivalents per year.

When calculating the avoided GHG emissions from kitchen waste treatment in a biogas plant, due regard should be given to methane losses caused by physical leakage amounting to 10 % of the total methane production according to IPCC estimates. However, in the case of the ARTI systems used at Azania, gas loss caused by the space between digester and gasholder amounted to 17.5 % of the total gas production [4]. As the global warming potential of methane is 21 times stronger than of carbon dioxide, the escape of biogas impairs considerably the positive balance. In the case of Azania, gas loss accounts for annual emissions of 3.62 t CO_2e, thus only achieving a 56 % reduction in total GHG emissions that would have otherwise resulted in waste degradation on landfills. If the ARTI design is improved and gas loss minimised, this figure

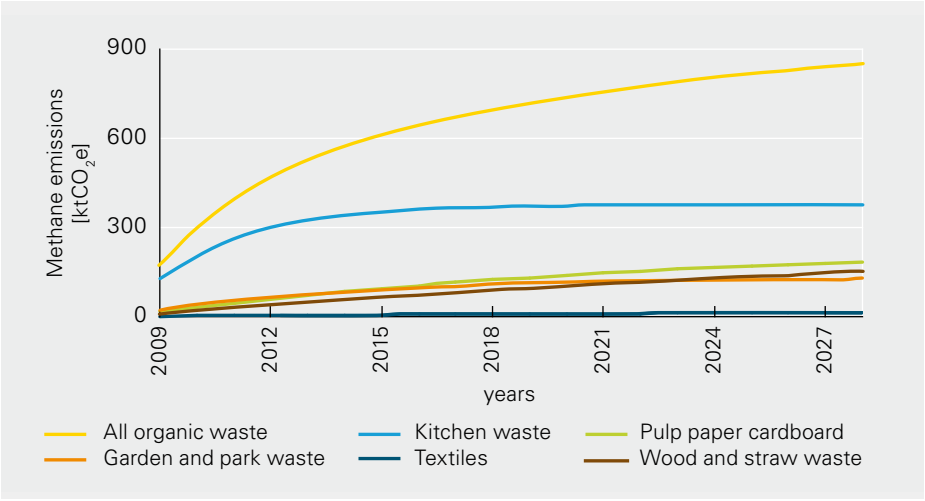

Figure 1: Methane emissions as a function of the current waste dumping system over a 20-year period.

would certainly reflect a far greater emission reduction.

Since firewood or charcoal is regarded as carbon neutral, our calculations did not consider reductions in gas emissions when using biogas in place of the traditional cooking fuel. In cultures where LPG (liquefied petroleum gas) is the main source of cooking fuel, replacement of this fossil gas would result in an even better carbon balance. Furthermore, potential replacement of chemical fertilisers by the digester effluent is not accounted for, as the effluent at Azania is currently not used for land application.

Small-scale biogas plants as CDM or voluntary carbon offsetting projects

With regard to potential financing options of such initiatives through CDM or voluntary carbon offsetting projects, the study reveals that institutional biogas plants would be eligible to claiming CERs and taking part in the global carbon trading. However, to make a project economically attractive and cover the transaction costs, it should reach about 10 000 CERs annually (the EU price in March 2010 was around 13 Euros/CER). In other words, about 1600 schools of similar size as Azania (i. e. 32 kg/d food waste) would have to be equipped with biogas plants. Yet, to comply with the regulations for small-scale projects under the UNFCCC (United Nations Framework Convention on Climate Change), the upper limit of 60 000 CERs per year should not be exceeded. Furthermore, project emissions from physical leakage should remain below 15 000 t CO_2e. Consequently, by taking a 10 % gas loss into account, a maximum number of 7 500 institutions could be grouped into one project. Above this limit, the more complex methodologies for large-scale projects, leading to higher transaction costs, would have to be applied. Investigations in Tanzania have shown the current lack of initiatives to develop a CDM or voluntary carbon offsetting project for decentralised anaerobic digestion of kitchen waste.

According to the Designated National Authority (DNA) responsible for validation of CDM and voluntary carbon offsetting projects in Tanzania, the limited number of projects is attributed to low political awareness, the non-conducive investment climate in Africa and limited institutional capacities. Efforts to overcome these barriers were made at the second Africa Carbon Forum in Kenya in March 2010, where the focus was placed on national and regional capacity building, mobilisation of resources and on Africa-friendly methodologies. Already, Africa has seen a strong growth trend in the past few years and many projects are in the pipeline for validation or registration.

Even if biogas plants for treating kitchen waste at institutional level do not form part of a carbon-financing project, they should be considered more often as an alternative to waste dumping as they offer a promising option to improve waste management systems and reduce GHG emissions.

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Photo 1: ARTI biogas systems at Azania secondary school, Dar es Salaam.

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Evaluating Biogas Sanitation Systems in Nepali Prisons

The armed conflict between Maoist rebels and government forces between 1996 and 2006 increased the number of detainees in Nepali prisons. Heavily overcrowded jails and obsolete infrastructures led to extremely poor water, sanitation and environmental conditions, thereby severely affecting the detainees. Yvonne Vögeli[1], Christian Lohri[1], Christian Zurbrügg[1]

To mitigate this situation, the International Committee of the Red Cross (ICRC) decided to assist the prison authorities by providing technical expertise to ensure access to improved infrastructure, such as water supply and sanitation for all detainees. The Water and Habitat unit of ICRC has initiated a biogas programme whose aims are to:

- Improve the prisons' wastewater treatment (lower the health risk for the detainees).
- Provide a renewable source of energy for the jails to reduce use of traditional fuels (wood and kerosene) and improve the kitchen environment (lower indoor air pollution).
- Use the biogas slurry as fertiliser.
- Promote construction of biogas plants at institutional level in other prisons.

To implement five biogas sanitation systems in three district jails in Nepal, an agreement was signed between ICRC and the local expert partner "Biogas Sector Partnership Nepal (BSP-N)" in January 2007. Construction of all the systems was completed in May 2008 (Photo 1). To assess the efficiency and sustainability of the said projects after one year of operation, ICRC entered into partnership with Eawag/Sandec to conduct an independent evaluation of the structural, operational and maintenance aspects as well as of the environmental impact of the biogas systems and their acceptance by the users and beneficiaries. The study [1] was conducted between April and June 2009.

The Nepali biogas plant design, promoted by BSP-N, is based on the modified GGC2047 model, whose shape is similar to that of a Chinese fixed dome digester. The five digesters installed are 3 x 10 m^3, 1 x 20 m^3 and 1 x 35 m^3 in size. The smallest prison numbers 100 detainees and the largest 270, with a small separate female section in all three jails.

Gas production

Average gas production generated only by human waste amounts to 28 NL/person/day. With additional feedstock, such as the entire kitchen waste produced (in one prison), gas production increases to 62 NL/person/day. When comparing the measured gas production with the estimated design-based gas production, the actual gas production in four of the five digesters is higher than initially estimated. The difference in expected and measured gas output can be explained by the indicators listed in Table 1, i. e. differences in actual number of detainees and amount of kitchen waste input compared to the originally expected values.

Treatment efficiency

Total solids (TS), volatile solids (VS) and chemical oxygen demand (COD) of the effluent are good indicators for treatment efficiency. In other words, the lower the concentration, the higher the performance efficiency of the biogas facility. The effluent consists of very liquid slurry with a low TS content of about 4 g/L. The organic matter content is rather low with VS ranging between 24 and 44 % and COD content amounting to about 500 mg/L, thus indicating a satisfactory system efficiency

Effluent analyses in the storage pits revealed acceptable *E. coli* concentrations for restricted irrigation as stipulated in the WHO guidelines for the safe use of wastewater. In some cases, helminth eggs, as a further indicator organism, were, however, not entirely eliminated by anaerobic digestion and the sedimentation process.

Economic aspects

Since biogas replaces other cooking fuels and saves money formerly spent on septic tank emptying, the economic benefits are directly dependent on the amount of biogas produced. These figures differ in each jail. In jail 1, where kitchen waste is fed to the digesters, 41 % of the money formerly spent on conventional cooking fuel is saved by biogas generation. In jails 2 and 3, 17 % and 22 % savings have been reported since installation of the biogas

Photo 1: Biogas plant in a Nepali prison.

Operational setup

While the toilets of the detainees and the prison's kitchen with its biogas stoves are located within the prison walls, the digester and effluent pits are situated outside the prisons' grounds and thus not accessible to the inmates. Feeding chambers for kitchen waste were either built inside or outside the internal precincts of the prisons. Contrary to most western jails, the security staff and wardens do not perform any tasks inside the prison walls but are stationed outside the external security boundaries.
The prisoners prepare their own meals in groups or individually and are allowed to leave the internal security precinct to perform assigned tasks only after obtaining special permission from the "chaukidar" (leader of the detainees). An appointed detainee is usually in charge of kitchen waste management and receives a monthly wage from the other inmates. To enhance gas production, kitchen waste is added to three of the five digesters. The organic waste from the other two digesters is sold to pig farmers.

		Jail 1 10 m^3	Jail 1 20 m^3	Jail 2 10 m^3	Jail 2 35 m^3	Jail 3 10 m^3
Expected number of detainees [pers.]	2007	68	119	115	206	74
Observed number of detainees [pers.]	April – June 2009	65	135	115	155	106
Expected kitchen waste input [kg/d]	2007	4	43	0	73	0
Observed kitchen waste input [kg/d]	April – June 2009	3	45	0	3	0
Expected gas production [L/d]	2007	2000	4000	3000	7000	2000
Measured gas production [L/d]	June 2009	**2120**	**9210**	**3310**	**4800**	**3450**
Difference between expected and measured gas production [%]		+6%	+130%	+10%	-31%	+73%
Daily gas production per person [NL/pers./d]	June 2009	29.5	61.9	25.9	27.9	29.2
Gas burning period [h/d]	June 2009	6.5	19.5	9	10.5	9.5

Table 1: Gas production (estimated and measured).

system. Accounting for the investment costs, the approximate amortisation period for jail 1 is 1.5 years, 5.4 years for jail 2 and 3.7 years for jail 3.

Recommendations

With regard to digester design, no major adjustments had to be made to the modified GGC2047 model. The system with underground fixed-dome digesters, compensation chambers and overflow point is well established and appropriate for the Nepalese context.

Concerning the operational aspects, kitchen waste management needs to be examined carefully before dimensioning a biogas system. Furthermore, detainees should be convinced of the benefits of additional organic waste feeding into the digester. Kitchen waste feeding has to be organised with the competent persons and a salary system put in place. Collection buckets for organic waste should be provided and appropriate feeding cycles planned.

As regards the use of slurry, analyses have revealed its potential in restricted irrigation. Instead of promoting the spreading of slurry on vegetables, irrigation of banana trees seems a more promising alternative, especially since direct contact between effluent and fruit can be ruled out. Banana trees are widespread in Nepal, its fruit is popular among Nepalese and its trees have high water demands and high nutritional requirements.

Though the technical evaluation of all the digesters provided very positive results, key importance should be placed on system maintenance. Since none of the three prisons has a clear maintenance scheme, smooth operation of the facilities cannot be ensured. In the event of problems, the "chaukidar" (leader of detainees) acts as a trouble shooter (given his privilege to leave the internal prison grounds). Therefore, wardens, security staff and "chaukidar" have to be made more aware of the necessity of regular maintenance.

In addition to this "in-house" maintenance, the biogas plants should be maintained by an external party (the biogas construction company or an independent expert) at least once a year.

Conclusions

This evaluation reveals that biogas plants are an appropriate option for combined treatment of blackwater and kitchen waste in prisons or in similar public establishments in developing countries. However, the saying "a technology is only as good as its operation and maintenance" also applies to the biogas/prison context. The best promotion of a technology is its proper functioning and acceptance by its users. As regards biogas digesters at public institutions, strong feelings of ownership and responsibility for maintenance are crucial points requiring special attention. If not properly operated and maintained, adverse effects, such as methane emissions (greenhouse gas) or health risks caused by leaking gas pipes in the kitchen, can clearly exceed the benefits.

The positive experience gained in Nepal encouraged ICRC to apply this approach to other prisons in different countries and promote biogas plants at institutional level (prisons, schools and hospitals) to improve the sanitary conditions and provide renewable and clean cooking energy.

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Reducing Diarrhoea with SODIS and Promoting Hygiene in Ng'ombe Slum, Zambia

The positive health effects in the Ng'ombe slum in Lusaka can be attributed to the consumption of safe water. A health impact survey reveals that irregular and regular SODIS use reduces diarrhoea incidence among children below five by 59.4 and 54.0 %, respectively compared to the control group. Users with a high consumption of treated water also exhibit improved hygiene behaviour. Trained households, which did not apply SODIS, more often used other household water treatment methods and had 12.7 % less diarrhoea than untrained households. Aleksandra Gara[1], Monika Tobler[2], Regula Meierhofer[2]

Introduction

SODIS – a simple disinfection method of microbiologically contaminated drinking water (www.sodis.ch) – has been promoted by Sandec for more than 10 years in areas where people have no access to safe drinking water. Currently, about 4.5 million people in over 30 countries use SODIS for treating their drinking water.

SODIS promotion in Zambia started in August 2008 in collaboration with the local NGO Keepers Zambia Foundation (KZF). The local Health Coordinating Committee (HCC) was entrusted with the fieldwork in Lusaka's slum Ng'ombe – an unplanned settlement of more than 90 000 inhabitants and very poor water and sanitation infrastructure.

Prior to introducing SODIS, the HCC conducted water, sanitation and hygiene promotion activities in Ng'ombe using boiling and chlorination as water treatment methods. Since November 2008, the Ministry of Health has been distributing free chlorine to all members of the community via the local health centre. However, users often abandoned chlorination when free distribution of the product was discontinued. The local HCC thus perceived the need to introduce SODIS as a further household water treatment option.

Promotion approach

SODIS was first implemented and promoted in Ng'ombe from August 2008 to July 2009. Three technical staff from KZF, two executive members of HCC and 60 promoters selected from the community were initially trained in SODIS and hygiene promotion. This group then went on to train, through group trainings and monthly household visits by promoters, 1600 households in water treatment with a special focus on SODIS and hygiene. Drama and role-play were additional tools used together with distribution of stickers and posters. Fieldwork was supplemented by a national awareness raising campaign on TV and radio.

A survey, conducted in Ng'ombe between October and December 2009, assessed the level of behavioural change among the community trained during the first phase of the project. It also evaluated the health impact on people consuming treated water and on non-users. Aleksandra Gara, a student of the London School of Hygiene and Tropical Medicine, supervised data collection in Ng'ombe. The five interviewers of the study were students of the University of Zambia who had not been previously involved in the project.

Materials and methods

Sample selection

Households with children below five years of age were randomly selected to obtain a representative sample of 1600 trained households. 300 of the 543 households with children below five and reported as SODIS users by June 2009 were selected from a lottery box. 150 control households were chosen by random route sampling (every 5th household on the transect route) from old Ng'ombe, an area that had not been subjected to any promotional activities.

Questionnaire

The survey questionnaire addressed general demographic issues, illnesses of all children under five, uncooked food and all liquids consumed by the children under five, as well as water treatment, hygiene and sanitation practices of the households, SODIS use in the households along with general observations of the households and surroundings. Questions related to SODIS were asked at the end of the questionnaire to discourage respondents

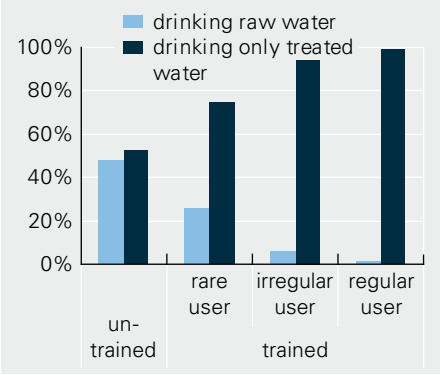

Figure 1: Percentage of children from trained and untrained households drinking raw water or only safe water (N=690).

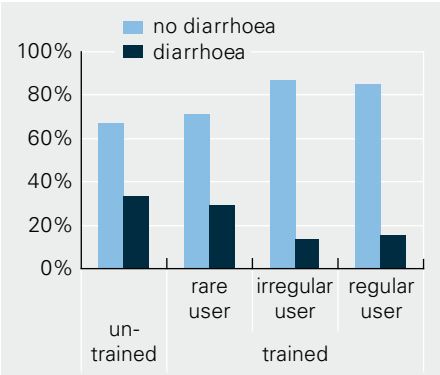

Figure 2: Percentage of children from trained and untrained households with diarrhoea (N=690).

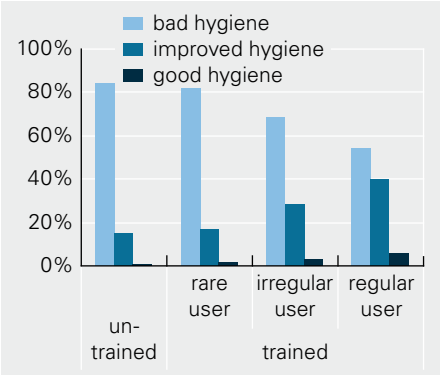

Figure 3: Percentage of trained and untrained households with bad, improved or good hygiene practices (N=458).

from giving biased answers to the initial questions on health and risk factors.

Data analysis

Epi-Data 3.1 was used for data entry, and the entered data was subsequently analysed by Excel and SPSS 17.0. Based on the variables collected, the following three indexes were established: a SODIS user index, a hygiene index and an economic index.

The SODIS user index grouped all households into rare, irregular or good users. The index is based on frequency of SODIS practice reported and assessed by the interviewers, ability of the respondents to explain SODIS, last SODIS application by the household, and number of bottles per person in the household.

The hygiene index classified all households according to their excellent, good or poor hygiene practices. This index is based on the intervals adults and children washed their hands, if the household consumed only treated water, on observed cleanliness of the household and surrounding area, and on frequency and manner of hand washing.

The economic index classified all households into wealthy, middle class or low class. The index was based on the number of electronic equipment, stove or fridge owned by the household, type of materials used to build the house and floor, fuel used to cook food, if the household numbered more or less than 2.5 persons per room, number of daily meals consumed by the household, source of water used, frequency of fruit or vegetables consumed, type of household toilet used, and the interviewers' welfare rating of the household.

Results

A total of 460 households were interviewed between 6 and 16 October 2009. Of the 460 households, 299 had been trained in SODIS use since August 2008; the remaining 161 households had no SODIS training (controls). The survey collected data on 716 children.

A greater number of trained households seemed to belong to the higher and middle class, and more untrained households to the lower class (P-value = 0.031). However, the economic index did not reveal a statistically significant difference between trained and untrained households (P-value = 0.114).

SODIS practice and safe water consumption in Ng'ombe

SODIS application at community level was assessed by the SODIS application index dividing households into untrained and trained, which were further subdivided into three groups, including rare, irregular and good users. Among the trained households, 39.4 % use SODIS regularly (16.7 %) or irregularly (22.4 %), while 60.8 % are rare users. SODIS users and non-user complement their HWT practice with other treatment methods (boiling and chlorination. 94 % of the children from households classified as irregular SODIS users consumed only safe water compared to 99 % of the children from households classified as good SODIS users (Fig. 1).

Illness and risk factors

Illness level among the surveyed children was divided into heavy, light, no diarrhoea but ill, and not ill. A child was classified as having diarrhoea if it meets the WHO criteria for diarrhoea with three or more loose stools within the last 24hrs during the last two weeks prior to being interviewed. Diarrhoea was classified as heavy if the child was reported ill for three days or more, and light if diarrhoea lasted two days or less. If the child did not meet the criteria for diarrhoea but presented one or more of the following symptoms: stomach pain, vomiting, no appetite and fever, it was classified as non-diarrhoeal.

Prevalence of diarrhoea (heavy and light) amongst children below five of the untrained households totalled 33 %, while 29 % diarrhoea prevalence was detected among children below five in the group of rare users (12.7 % less diarrhoea cases than in untrained households), 13 % in the group of irregular users (59.4 % less diarrhoea cases than in untrained households) and 15 % in the group of good users (54.0 % less diarrhoea cases than in untrained households) (Fig. 2).

Prevalence of illnesses other than diarrhoea (stomach pain, vomiting, no appetite, and fever) amongst children under five from untrained households totalled 8.0 %, while 13.0 % of the children in the rare users group were found to be ill, i. e. 9.6 % in the irregular users group and 5.6 % in the regular users group. The fact that there is no difference (p = 0.138) between non-diarrhoeal illness amongst users and non-users corroborates the assumption that the reported difference in diarrhoea cases between users and non-users is not likely to be attributed to systematic error or reporting bias.

A direct comparison between children consuming only safe water and those still consuming raw water throughout the groups reveals that the children drinking only safe water have 33.2 % less diarrhoea than those consuming raw water (p = 0.002).

Hygiene practice

Hygiene levels differed strongly between the groups with high levels of safe water consumption (regular and irregular users), the rare users and the untrained households (Fig. 3). Users with a high consumption of treated water also revealed a better hygiene behaviour: 28 % of irregular users showed improved hygiene practices and 3 % good hygiene practices, while 40 % of regular users revealed improved hygiene practices and 6 % good hygiene practices.

The hygiene behaviour of untrained households and the group of rare users did not greatly differ, i. e. 15 % of untrained households showed improved hygiene behaviour and 0.6 % good hygiene behaviour, while 17 % of the rare users revealed an improved hygiene behaviour and 1.7 % good hygiene practices.

When comparing diarrhoea with the hygiene index, an important difference can be noted between households with good hygiene behaviour and those with poor hygiene practices. Those with poor hygiene practices revealed a greater incidence of heavy diarrhoea.

Conclusions

This study concludes that consistent consumption of only treated water and improved hygiene practice are closely related to a decrease in diarrhoeal illness.

Regular SODIS users are characterised by an increased intake of safe drinks and better hygiene behaviour. Yet, the question whether the training approach used led to an increase in drinking water treatment and better hygiene or if individuals already exhibiting improved hygiene are more likely to implement the method or a combination of both remains to be determined.

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Improving Farmers' Wastewater Handling Practice in Vietnam

This study focuses on perceptions and awareness of farmers and practical aspects of wastewater reuse in two communities of northern Vietnam. The results reveal that raising farmers' awareness of the health risks associated with wastewater reuse and improving their ability to cope with these risks enhances safe handling of waste and contributes to improved hygiene and health practices.

Tu Vu Van[1,2], Pham Duc Phuc[3,4], Nguyen Thanh Huong[1], Andrea Tamas[2], Christian Zurbrügg[2]

Agricultural wastewater reuse in Vietnam

Use of wastewater for irrigation and in aquaculture has a long tradition in Vietnam. While this practice has advantages in terms of economics and environmental impacts, it poses nonetheless potential health risks if wastewater is not properly managed.

In Nhat Tan and Hoang Tay, two communities situated in the Hanam province in northern Vietnam, farmers practice reuse of untreated wastewater. However, these farmers rarely use protective measures when handling wastewater. Diarrhoeal rate is 1.5–2 times higher in these two communities than in other villages of Hanam province. Furthermore, Hanam is also one province where incidence of gastrointestinal illness is highest with 1.5–2.2 % compared to other provinces also directly or indirectly affected by the polluted Nhue and Day rivers [1]. We believe that the negative health impacts on farmers can be attributed to their lacking awareness of the health risks associated with wastewater reuse and their poor hygiene behaviour.

Protection Motivation Theory (PMT)

Health behaviour theories explain behavioural changes, in particular the mechanisms that either shape an intention to change behaviour or help to maintain a specific health behaviour. The PMT is one of the health behaviour theories, which includes the element of self-efficacy as one separate component. Self-efficacy affects the intention to change risk behaviour, as the effort required to attain the goal and the necessary persistence to continue in spite of barriers and setbacks may undermine motivation [2]. Therefore, PMT was applied to explore awareness and hygiene practices of people using wastewater in agriculture. Our study aimed at developing a questionnaire to assess perceptions of fear of disease, self-efficacy, response-efficacy, severity, vulnerability, as well as aspects of motivation, hygiene practice and hygiene practice in relation to wastewater use in order to provide the basis for suggesting improvement interventions of safe reuse practice (Fig. 1).

Method

First we conducted qualitative research in the form of 30 in-depth interviews, group discussions and observations in the Nhat Tan and Hoang Tay communities to formulate the questionnaire centred on PMT. The questionnaire-based survey was then conducted with 335 persons, whereof 66 people were interviewed a second time to verify reliability of the questions. Cronbach's Alpha, used to determine reliability of the questionnaire, is a measure for internal consistency or reliability and should total 0.65 or higher to express reliability.

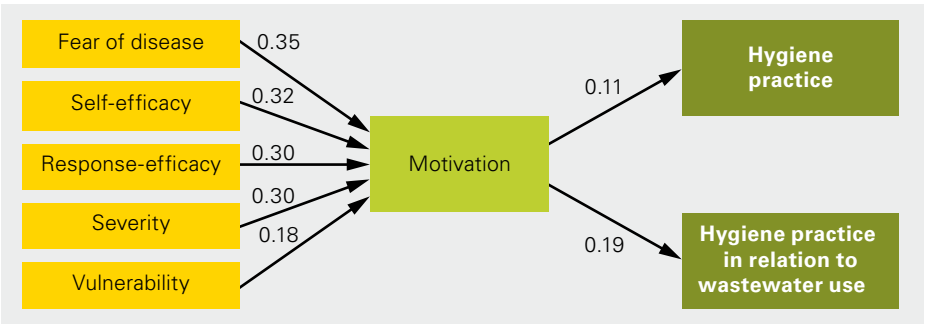

Figure 1: Correlation between awareness, motivation and hygiene practice.

Results and conclusions

People in the study area perceive wastewater as smelly and black in colour, whose contact can cause skin problems (e.g. itching). Farmers feel that fish from the Nhue river and vegetables irrigated with wastewater are potential causes for diarrhoea. When working with wastewater, women use protective wear more often than men. This can be explained not by increased awareness but rather due to the fact that women spend more time in the fields than men and pay more attention to their skin and beauty.

The questionnaire, containing 34 questions focusing on eight different aspects, revealed a reliability index exceeding 0.65 Cronbach's Alpha. Correlations of PMT coefficients varied between 0.11 and 0.35 ($P<0.05$). These correlations show that motivational aspects can be improved by increasing fear of disease and perceived self-efficacy, response-efficacy and threat severity. However, the data reveals that the relation between motivation and practice of improved hygiene was rather weak.

[1] Environment Report of Vietnam, 2006.

[2] Rogers, R.W. (1983): Cognitive and physiological processes in fear appeals and attitude change: A revised theory of protection motivation. In J. Cacioppo & R. Petty (Eds.), Social Psychophysiology. New York: Guilford Press.

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The authors acknowledge the support received from the **Swiss National Centre of Competence in Research (NCCR) North–South**: Research Partnerships for Mitigating Syndromes of Global Change, co-funded by the Swiss National Science Foundation (SNF), the **Swiss Agency for Development and Cooperation (SDC) and Eawag's Partnership Programme (EPP)**.

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New Publications

The Compendium of Sanitation Systems and Technologies is now available in four languages.

During the 2008 International Year of Sanitation, Sandec launched a new kind of interactive, sanitation planning handbook – The **Compendium of Sanitation Systems and Technologies**. This one-stop overview of all sanitation technologies available, written in simple, accessible language with graphic illustrations, addresses planners and homeowners alike. The two-part handbook presents systems design and technology information sheets used for modular planning and sanitation system development from unserviced small towns in Burkina Faso to large capital cities in South-East Asia. The first **English** edition has become so popular that it has been translated into **Vietnamese, French** and **Spanish**, the latter will be released shortly. All language versions are available as open source downloadable documents or they can be ordered as hard-copies from Sandec's website. Sandec is now preparing further translations in Urdu, Nepali and Chinese – expect the list to grow! The composting publication can be downloaded from www.sandec.ch

The Manual on Decentralised Composting in Low and Middle-Income Countries is now available also in French and Hindi

This book provides systematic assistance in setting up decentralised composting schemes. It focuses on prevailing challenges posed by decentralised composting projects and recommends measures to avoid problems through improved strategic planning, organisational, institutional, and operational procedures. It mainly centres on neighbourhood-based systems, thus covering not only composting plants with daily capacities of up to five tonnes, but also offering information on primary waste collection systems. Several case studies and exercises assist in transferring the concept to the prevailing individual situation. The Annexe provides various useful sheets with technical drawings, monitoring forms, draft contracts or quality standards. The handbook addresses individuals, community-based organisations, NGOs, municipal authorities, as well as staff of donor organisations, and facilitates the dissemination of decentralised composting schemes worldwide.

Available online from www.sandec.ch or order free copy from info@eawag.ch

Sustainable Sanitation in Cities – A Framework for Action

This forthcoming SuSanA (sustainable sanitation alliance) publication seeks to define what sustainable sanitation means in the urban context and how this can be achieved within the constraints and complexities of the urban environment. The authors redefine the relationship between sanitary engineering and urban planning and thus contribute to the ongoing debate on urban sustainability. The book is dedicated to innovative approaches to sanitation and illustrates what putting sustainable sanitation into action means in practice. It features over 20 case studies from both North and South.

By Lüthi C., McConville J., Norström A., Panesar A., Parkinson J., Saywell D., Schütze T., and Ingle R., June 2010, 112 pages, Papyroz Publishing.

Available as an open-source publication from www.susana.org

People's Choice First

A 4-Country Comparative Validation of the HCES Planning Approach for Environmental Sanitation

From 2006 until the end of 2008, the participatory Household-Centred Environmental Sanitation approach (HCES) was tested in seven different urban and peri-urban sites across Africa, Asia and Latin America. Case studies from four of the seven sites are presented and analysed in this publication. More than just offering a summary of what happened during the planning process, the goal of presenting these case studies is to analyse why it happened the way it did.

Unique aspects of this publication include:

- Case studies covering three continents, from small sections of dense urban areas to large, peri-urban communities.

- Summaries of fully completed, as well as partially completed, case studies, along with the reasons for respective successes and failures.
- Analysis of the true duration and costs associated with so-called "participatory planning" in challenging urban environments.

It is our hope that planners, engineers and policy-makers using the HCES or a similar approach will find this collection of experiences useful and informative about people-centred planning approaches.

By Lüthi C., Morel A., Kohler P., Tilley E., NCCR North-South Dialogue, No. 22, 2009, 132 pages. The PDF version of this paper can be downloaded from www.north-south.unibe.ch under "Publications" or from www.sandec.ch

Forthcoming Event and Course

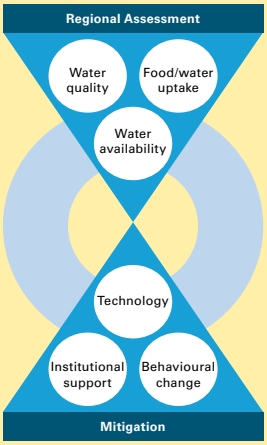
WORLD WATER WEEK in Stockholm, September 5–11, 2010

Eawag's Water Resource Quality project will host a side event on **"Poison in the Well: Mitigation of Geogenic Contamination"** at the World Water Week Conference organised by SIWI (Stockholm International Water Institute) in Stockholm on **6 September 2010 at 17:45–18:45.**

Contamination of drinking water with naturally occurring chemicals, especially arsenic and fluoride, poses a public health threat for hundreds of millions of people. Eawag's Water Resource Quality project (**www.wrq.eawag.ch**) is developing a framework to mitigate the effects of geogenic contamination.

Framework components include:

- Global and regional GIS maps for predicting areas where geogenic contamination may occur.
- Material Flux Analysis tools to quantify exposure through food and drinking water.
- Tools for modelling availability of alternative water resources, including under different climate change scenarios.
- Assessment and improvement of arsenic or fluoride removal technologies appropriate for low-income countries.
- Analysis of how these technologies can be situated within the social and institutional setting of the affected area.
- Methods for using psychological theories of behavioural change to identify and evaluate effective strategies for the adoption of water treatment technologies.



The mitigation framework developed will include both an interactive online manual and a toolbox of resources and methodologies for use by practitioners, illustrated by examples from China, Bangladesh and Ethiopia.

PEAK Advanced Course

PEAK Advanced Course V31/10
Improvement of Drinking Water Quality in Developing Countries:
Microbial and Geogenic Contamination

Waterborne pathogens and geogenic contaminants, particularly arsenic and fluoride, pose serious public health challenges, especially in less developed countries. During the **three-day PEAK Course, held at Eawag from 5–7 October 2010**, participants will learn about the occurrence and severity of such problems, as well as management strategies and decentralised technologies for water quality improvement.

The course, conducted in English, targets water and sanitation professionals working in strategic planning, design and implementation in developing and emerging countries, who wish to learn more about household drinking water quality.

The brochure with registration form can be downloaded from **www.eawag.ch/lehre/peak/kurse/index**

New Faces

Innocent Tumwebaze Kamara from Uganda completed his MSc in Clinical Epidemiology and Biostatistics at Makerere University in Uganda in 2009. He acquired field experience from working with WaterAid Uganda before joining Sustainable Sanitation and Water Renewal Systems (both NGOs in the Water and Sanitation sector in Uganda). In late 2009, Innocent started his NCCR North-South-funded PhD thesis with SIAM and Sandec on User-Driven Sanitation with focus on demand and behaviour for improved sanitation facilities in urban slum communities. Innocent is enrolled at the School of Public Health, Makerere University College of Health Sciences, Uganda.

Tu Vu Van from Vietnam completed his Master's thesis in Public Health at Hanoi School of Public Health in 2009. From August to December 2009 he worked at Eawag/Sandec in the fellowship Partnership Programme (EPP) to finalise his Master's degree on "Developing a tool to assess human behaviour in agricultural reuse of wastewater and excreta based on the Protection Motivation Theory framework". His current PhD, which he is completing within the Programme of the Swiss National Centre of Competence in Research (NCCR) North-South, focuses on analysing human exposure to excreta reuse, as well as health and environmental risks related to options of excreta handling in agriculture in Vietnam.

Philippe Reymond, Environmental Engineer EPFL, is now in charge of the new "Egyptian-Swiss Research on Innovations in Sustainable Sanitation" (ESRISS) based in Cairo, Egypt. The project aims at developing and pilot testing innovative and reuse-oriented sanitation concepts for peri-urban and rural areas of the Nile Delta. In the past, Philippe worked for Eawag/Sandec in Togo on participative faecal sludge management at city level and in Ghana on on-site wastewater treatment for urban agriculture.

Parfait Kouame Koffi holds a Master in Hydrogeology from the University of Cocody, Côte d'Ivoire. His current PhD thesis, conducted within the NCCR Phase 3 programme and in collaboration with CSRS (Swiss Centre for Scientific Research in Côte d'Ivoire), aims at developing a practical model for sustainable environmental sanitation management planning in urban tropical regions based on Material Flow Analysis (MFA) and QMRA (Quantitative Microbiological Risk Assessment) methods and applying it in Yamoussoukro, Côte d'Ivoire.

Linda S. Gaulke completed her PhD in Environmental Engineering at the University of Washington in Seattle Washington, USA. She holds degrees in Mathematics, Soils Science and Environmental Engineering. Linda will be working as a Research Scientist in Excreta and Wastewater Management at Sandec. Her research has encompassed many aspects of sanitation and treatment processes, including appropriate technologies and management systems for decentralised wastewater treatment and reuse, biosolid nutrients use and their impact on soil health, as well as the treatment of emerging contaminants.

Ebenezer Soh Kengne is a PhD student in Plant Biology at University of Yaoundé I in Cameroon. He is completing, within the NCCR Phase 3 programme, a doctoral study on wastewater and faecal sludge treatment in collaboration with Sandec. He will be studying low cost technologies for faecal sludge and wastewater treatment with emphasis on health risk mitigation and livelihood opportunities.

The Sandec Team

From left to right:
Standing: Rick Johnston, Camilla Archetti, Stefan Diener, Sämi Luzi, Magalie Bassan, Urs Schweizer, Elizabeth Tilley, Caterina Dalla Torre, Petra Kohler, Philippe Reymond, Regula Meierhofer, Christoph Luethi, Andrea Tamas, Christian Zurbrügg, Roland Schertenleib, Nicolas Estoppey, Yvonne Voegeli, Monika Tobler, Mbaye Mbéguéré
Kneeling: Valérie Cavin
Missing on photo: Hung Nguyen Viet, Lars Osterwalder, Linda Gaulke, Martin Wegelin, Matthias Saladin, Löic Decrey, Christian Lohri, Sylvie Peter; Associated doctoral students: Noah Adamtey, Mingma Gyalzen Sherpa, El Hadji Mamadou Sonko, Marie-Madeleine Ngoutane Pare, Jean Birane Gnin, Tu Vu Van, Ebenezer Soh Kengne, Parfait Kouame Koffi

On the Bookshelf

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

Water and Sanitation

Increasing Functional Sustainability of Water and Sanitation Supplies in Rural Sub-Saharan Africa
The objectives of this perspective paper are to distil the foundational components of sustainability in water and sanitation, analyse the main barriers toward establishing these components and suggest feasible solutions for overcoming barriers within the context of rural sub-Saharan Africa. To identify these key components, the necessary and universal sustainability factors for rural water and sanitation supplies were extracted from existing literature.
Dynamic operation and maintenance is especially critical, and has largely been overlooked by providers, operators and managers of water and sanitation supplies. The research community of engineers and scientists, as well as field practitioners are encouraged to use the described three components as a basis for rigorous inquiry into sustainability of water and sanitation supplies. Ultimately, improving sustainability of water and sanitation supplies will result in salient and lasting gains in health and economic development throughout sub-Saharan Africa.
By Montgomery M. A., Bartram J. et al., 2009, Env. Eng. Sci. 26(5):1017–1023.

Water, Sanitation and Hygiene Interventions to Combat Childhood Diarrhoea in Developing Countries
The International Initiative for Impact Evaluation (3ie) works to improve the lives of people in the developing world by supporting the production and use of evidence on what works, when, why, and for how much. The first 3ie synthetic review, made in collaboration with the Campbell Collaboration, updates estimates of health impacts of various WASH interventions and examines reasons underlying the success (or lack thereof) in reducing diarrhoeal morbidity. The review attempts to quantify the degree to which impact studies are affected by respondent bias, as well as how sustainable the impacts are likely to be. The authors find a dearth of studies of long-term sustainability of WASH interventions, but are able to show that short-term studies tend to find larger impacts than longer-term assessments.
By Waddington H., Snilstveit B., White H., and Fewtrell L., August 2009, 119 pages. Available from www.3ieimpact.org

Excreta and Wastewater Management

A Rapid Assessment of Septage Management in Asia Policies and Practices in India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand, and Vietnam
This report comprehensively documents the state of septage management for onsite sanitation systems, the main form of urban sanitation in many Asian cities. It provides a regional analysis of key challenges and existing good practices related to septage management, and highlights strategies through which governments, water and wastewater operators, and development assistance agencies can promote sustainable management practices.
The Department of Water and Sanitation in Developing Countries (Sandec) at the Swiss Federal Institute of Aquatic Science and Technology (Eawag) also collaborated with ECO-Asia in the assessment.
By USAID and the Swiss Federal Institute of Aquatic Science and Technology, Duebendorf, Switzerland, January 2010, 142 pages. Available from www.waterlinks.org/septage-report

Wastewater Irrigation and Health – Assessing and Mitigating Risk in Low-Income Countries
The overall sequence of sections addresses key issues concomitant with wastewater irrigation in developing countries (risk assessment, risk mitigation, wastewater use governance), while the individual chapters aim at concise information primarily on microbiological but also chemical risks. Targeting developing countries, the book also tries to address situations where legislation and institutional capacities are constraints and where the availability of data for risk assessments is limited. The book should be useful for all those working to assess and mitigate health risks from the use of wastewater and faecal sludge in agriculture, under conditions where wastewater treatment is absent or inadequate to safeguard public health. In this respect, the book builds on and complements the international Guidelines for the Safe Use of Wastewater, Excreta and Greywater published in 2006 by the WHO in collaboration with FAO and UNEP.
Edited by Drechsel P. et al., 2010, 433 pages, Earthscan/IWMI/IDRC, ISBN 978-1-84407-795-3. Available as pdf from www.iwmi.cgiar.org/Publications/books/pdf/Wastewater_Irrigation_and_Health_book.pdf

Technology Review on Urine Diversion Components – Overview of urine diversion components such as waterless urinals, urine diversion toilets, urine storage, and reuse systems
This new publication is an important contribution of the GTZ programme "Sustainable Sanitation – ecosan" as it brings together scattered knowledge around the topic of urine diversion in a concise manner. The publication explains the purposes of urine diversion, its benefits and challenges, urine precipitation, urine treatment and reuse in agriculture. Further, it provides an overview on design and operational aspects related to the necessary equipment, such as waterless urinals and urine diversion toilets including supplier information and indicative costs.
The Appendix contains a worldwide listing of suppliers for waterless urinals and urine diversion toilet pedestals and squatting pans. This technology review is designed to help people working on sustainable solutions for excreta management.
By von Münch, E., Winker, M., December 2009, 32 pages, German Development Company (GTZ), Sustainable sanitation - ecosan programme, Appendix, February 2010, 18 pages. Available for download from www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9397.htm or with direct link www.gtz.de/en/dokumente/gtz2009-en-technology-review-urine-diversion.pdf
Hard copies are available on request from ecosan@gtz.de

Solid Waste Management

Solid Waste Management in the World's Cities
Using the framework of Integrated Sustainable Waste Management (ISWM), the report compiles unprecedented research from 22 cities across six continents. It uncovers the rich diversity of waste management systems in place throughout the world, and draws out the practical lessons for policymakers. The volume is essential reading for all professionals and policymakers in the field, as well as a valuable resource for researchers and students in all aspects of urban development.
By UN-Habitat, March 2010, 224 pages, ISBN 9781849711692. Available from www.earthscan.co.uk/?TabId=102382&v=512376

Converting Waste Plastics into a Resource – Compendium of Technologies and Assessment Guidelines
Economic growth and change in consumption and production patterns lead to a worldwide rapid increase in waste plastics from around five million tonnes in the 1950s to currently almost 100 million tonnes. An effective conversion requires appropriate technologies to be selected in compliance with local economic, environmental, social, and technical characteristics. This Compendium is compiled to assist in the selection process of technologies for the conversion of waste plastics into solid, liquid and gaseous fuels. Assessment guidelines assist in data collection and analysis for establishing a database on waste plastics to further develop viable business propositions for converting waste plastics into fuels.
By the UNEP Programme, Div. of Technology, Industry and Economics. International Environmental Technology Centre Osaka/Shiga, Japan, December 2009, 69 pages. Available from www.unep.or.jp/ietc/SPC/publications.asp

Converting Waste Agricultural Biomass into a Resource – Compendium of Technologies
Globally, 140 billion metric tonnes of biomass waste, equivalent to about 50 billion tonnes of oil, are generated every year from agriculture. As raw material, biomass from organic waste has an attractive potential for large-scale industries and community-level enterprises. The appropriate choice of technologies is a vital precondition for efficient and effective conversion. This Compendium is compiled to assist in selecting the most suitable technologies. Technologies converting different types and amounts of agricultural waste biomass are also considered, however, the Compendium covers only those using cellulosic agricultural waste biomass.
By the UNEP Programme, Div. of Technology, Industry and Economics. International Environmental Technology Centre Osaka/Shiga, Japan, October 2009, 441 pages. Available from www.unep.or.jp/ietc/SPC/publications.asp