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Sandec: Department of Water and Sanitation in Developing Countries
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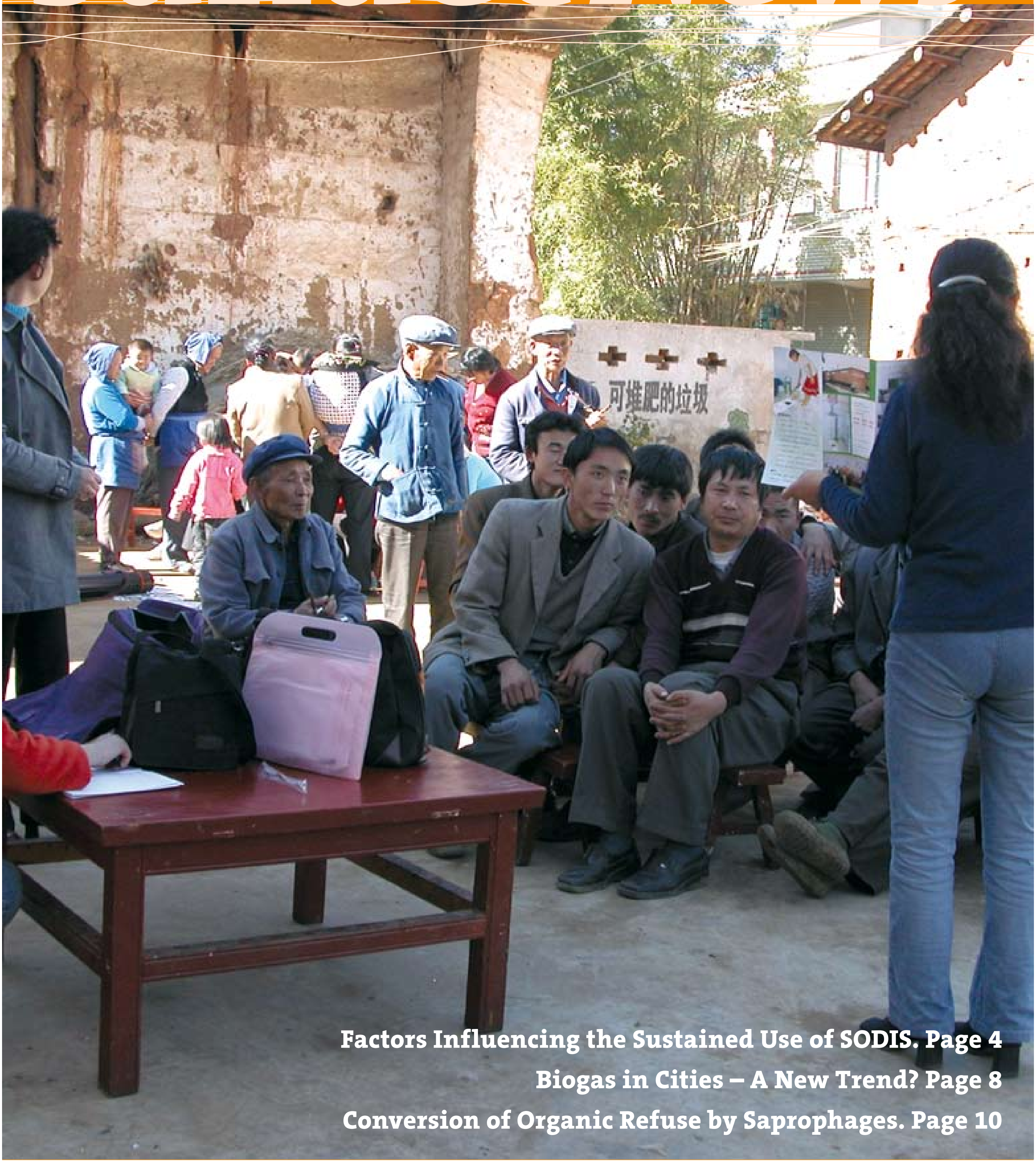
Sandec News



Ending the Sanitation Crisis

"Research and capacity development can help end the sanitation crisis! The focus on priority problems, suitable innovative approaches and technologies go hand in hand, with outreach going far beyond academia to integrate field practitioners and policy-makers"

According to a reader survey in the British Medical Journal, sanitation is the most important medical advance since 1840. Today, 2.6 billion people, including almost one billion children, still live without even the most basic sanitation. Every 20 seconds a child dies as a result of poor sanitation, i.e. 1.5 million preventable deaths each year.

The UN made an impressive commitment when sanitation was included in the targets of the Millennium Development Goal (MDG) No. 7, *"To halve by 2015 the number of people without access to safe drinking water and sanitation"*. This is an ambitious target! Today, halfway to this target, achievements in sanitation are slow in 74 countries. At the current rate of progress, the target is not likely to be met in sub-Saharan Africa until at least 2076! This lack of progress in sanitation and hygiene will have a significant impact on other MDG goals. Recognising this crucial role of sanitation, the UN General Assembly has decided to declare 2008 the International Year of Sanitation (IYS).

Sandec is paying special attention to this topic, fostering not only applied research and capacity development this year, but also strongly interacting and coordinating with local and international partners and institutions, including practitioners and policy-makers. A coordination action project of the EU called NETSSAF "Network for the development of Sustainable Approaches for large-scale implementation of Sanitation in Africa" has been able to bring together 19 members, each representing relevant fields of sustainable sanitation, to develop tools to enhance large-scale implementation. Further, Sandec is also active in SuSanA "Sustainable Sanitation Alliance", an open network of organisations active in the field of sanitation created to support the IYS. In a number of working groups, which form part of SuSanA, Sandec contributes to the development of fact sheets and supporting material to enhance sustainable sanitation on all stakeholder levels. Some of the activities are described in more detail in this Newsletter, and inquiries can be directed to our staff.

Though 2008 highlights the topic of "sanitation", Sandec nevertheless stills maintains continuity of research and capacity development in the other domains, such as water treatment (with SODIS projects and research on fluoride removal technologies) as well as solid waste management (projects in India, Tanzania and Lesotho). These issues, together with the topics of faecal sludge management (projects in Senegal, Cameroon, Thailand, Burkina Faso, and Togo), and strategic environmental sanitation planning (ongoing projects in Costa Rica, Tanzania, Kenya, Burkina Faso, Nepal, and Laos) pave the way to a holistic, integrated approach to water and environmental sanitation.

The past year has also shown some significant staff changes. Roland Schertenleib and Martin Wegelin retired. The younger members of Sandec can luckily still rely on their extensive knowledge and experience, as they remain active and involved in Sandec projects as Senior Consultants and are a daily source of inspiration. Sandec is obviously what it is today thanks to Roland Schertenleib. As founder of Sandec, he directed the department from a reference centre back in the late 1960s/1970s to an internationally renowned and respected research department of Eawag. We strive to maintain and further develop this position. Martin Wegelin, commonly known as Mr SODIS, is one of Sandec's pillars. With his SODIS development, research and demonstration projects, he achieved an impact that most researchers only dream of. We, the whole Sandec team, would like to express our sincere thanks to both Roland and Martin for their outstanding achievements. Together with our new staff, composed of motivated and committed young minds (cf. page 19), we shall pursue our objective of further ensuring capacity development and implementation of our research in academia, policy and practice. To reach this objective, you – our partners – are of course the main key to success. Close contact creates clear understanding and fosters trust and successful partnership. We shall continue in this direction and hereby invite you to do the same.

Chris Zurbrügg
Director Sandec

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Water and Sanitation in Developing Countries

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Factors Influencing the Sustained Use of Solar Water Disinfection (SODIS)

More than two million people currently use SODIS in 33 countries. Factors influencing sustained use of SODIS comprise the local availability of bottles, repeated promotion and training programmes, commitment of promoters, educational level of users, social pressure, and institutional aspects. Regula Meierhofer

Intervention strategies used for dissemination of SODIS

In 2000, Eawag/Sandec started SODIS promotion campaigns in selected developing countries. Pilot projects to educate users at the grassroot level in SODIS application were formulated in collaboration with local partner organisations, mainly NGOs experienced in health education. Implementation programmes, generally lasting for about 12 months, were developed after assessing the need to introduce SODIS and determining suitable local conditions for SODIS promotion. Follow-up projects in neighbouring areas were formulated based on the results obtained in the previous phase.

Information campaigns
- Promotion and information campaigns using the local mass media (TV, radio, newspapers)
- Public exhibitions and demonstrations at markets, in front of health posts
- Street plays
- SODIS entertainment night with songs, karaoke and plays
- Public display of posters and prompts in the project area
- Poster designing competitions

Advocacy
- Advocating by involving and convincing opinion leaders
- Submitting evidence of project impact to local authorities
- Creating involved stakeholder networks (NGOs and official institutions from the health, education and water supply sectors, universities, int. organisations)
- Setting up mechanisms to facilitate the exchange of information, such as regular meetings, workshops, electronic exchange of information
- Conducting water quality tests in front of the community

Training of users

Training and promotion of SODIS and hygiene aspects at grassroot level via promoters (staff of a local NGO, health workers, community volunteers):
- Raising awareness and behavioural change via participatory methods such as PHAST (Participatory Hygiene and Sanitation) Transformation)
- Using locally adapted training materials (posters, flyers, pamphlets, calendars)
- Training during group and community gatherings (mothers' & youth groups etc.)
- Regular household visits
- Promoting through schools

Table 1: Diffusion and promotion interventions.

The implementation strategy was developed in a joint exercise with Eawag/Sandec. Local partners developed their own approach in their field of expertise, but were supported by Eawag/Sandec in strategic planning and capacity development on technical aspects [1].

From working with NGOs towards partnership with governments

Working through NGOs during start-up of activities in a country proved to be quite effective as their management structures are lean and flexible and sound results can be obtained within a relatively short time. Though the collaboration with NGOs can produce quick results in a confined area, the sustained activity of the organisation is dependent on available external funds. The potential for upscaling SODIS dissemination at national level therefore relies on the funds available.

Evidence of health improvements among SODIS users trained by the NGO partners is an excellent tool to support advocacy activities with national governments and official institutions. Successful collaboration with government institutions is achieved by involving the extension services of the health, education and water supply sectors, as these have a great potential to reach a large number of people. Moreover, the normative functions of institutional bodies facilitate the promotion of SODIS at grassroot level, as they can officially sanction a method or an approach. Official statements and policies provide credibility, and programme sustainability is strengthened if it forms part of the national extension and education plan.

Between 2000 and 2005, the SODIS promotion and dissemination programme focussed on a collaboration with NGOs as partners for SODIS implementation. Since then, a gradual shift has taken place to increased collaboration with government institutions. Official institutions are directly involved in implementing SODIS projects in Pakistan, Nepal, Uzbekistan, Indonesia, Vietnam, Philippines, Bhutan, Ecuador, Bolivia, Nicaragua, Honduras, Guatemala, and El Salvador.

Project evaluations of SODIS implementation in 18 countries and two socio-scientific assessments [6], [7] reveal that a sustainable spread of the method is dependent on the promotion approach. One year after project implementation, 20–80 % of the trained people used SODIS on a regular basis. This variation in actual acceptance and use of the method has prompted us to look into factors influencing the sustained use of SODIS at grassroot level.

In the following chapter, the insights gained on the factors influencing the sustained use of SODIS, are based on half-yearly project evaluations in Nepal, India,

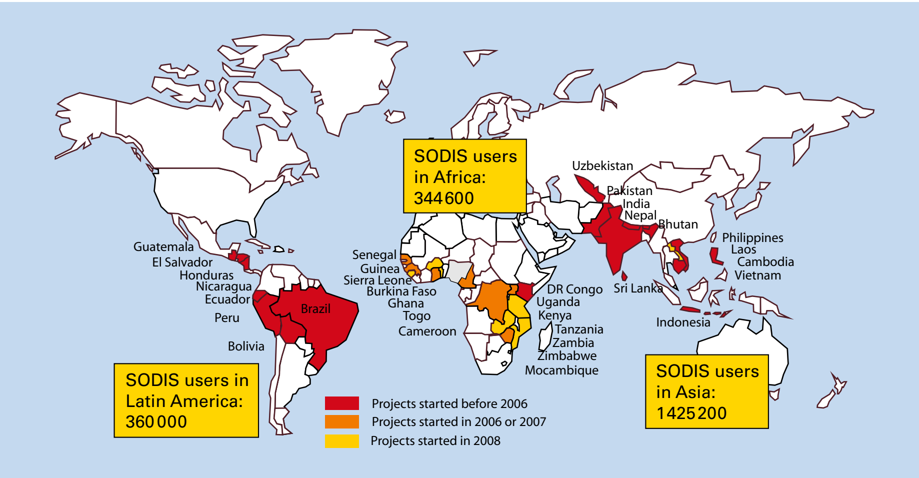

Figure 1: More than two million users currently implement SODIS in 33 countries.

Pakistan, Uzbekistan, Indonesia, Kenya, Uganda, Bolivia, Nicaragua, Peru, Ecuador, Guatemala, Honduras, and El Salvador and on two socio-scientific assessments.

Factors influencing the sustained use of SODIS at grassroot level

Availability of bottles. Local availability of the required bottles (PET or glass) is crucial for sustainability of SODIS application. In many areas, accessibility of PET bottles is the limiting factor for regular SODIS application. Creation of a micro-enterprise to secure the supply of bottles appears to be the solution to address the lack of PET bottles in some areas. East Lombok is a successful example of a bottle supply scheme. During project implementation, the health system set up a supply scheme, which buys empty bottles from the PET bottle producer and sells them to the users at the health posts. The secured bottle supply ensured the high spread of SODIS practice in the project area: originally, the inhabitants of 100 sub-villages in East Lombok were planned to be trained. At the end of the project, 80 % of the population in 144 sub-villages or 130000 people used SODIS to treat their drinking water.

Single information events are not sufficient to achieve a behavioural change. Habits are hard to change. Interventions with just one information event are not sufficient to establish a sustainable SODIS practice [5]. Long-term interventions with promoters visiting trained users regularly over several months after conducting initial training are required to raise awareness and establish sustainable practices [1].

Motivated promoters play a key role Local SODIS promoters play a key role regarding acceptance and use of SODIS at grassroot level. SODIS practice was the highest in villages where locally respected persons worked as highly motivated and convinced promoters.

A socio-scientific study on the effectiveness of different SODIS dissemination strategies in Bolivia revealed that promotion of SODIS by skilled staff of local authorities or local NGOs was the most effective strategy [6].

Another field study in Nicaragua concluded that intention to use SODIS and the actual use of SODIS are related mainly to an overall positive attitude. Well-designed promotion activities, particularly in the choice of highly motivated promoters capable of inspiring confidence in the new technology, positively influence adoption and use of the method [7].

SODIS acceptance and use by the local population in Uzbekistan were also highly dependent on the motivation and initiative of key officials in the field. Users in the rural community also accepted SODIS more readily if the method was introduced by the official health workers rather than by the NGO staff who originally initiated SODIS pilot activities in Uzbekistan [4]. The influence of the promoters is reflected in the health impact assessment conducted in the project areas in November 2006: highest SODIS adoption rate was found in the Burkhara (50 %) and Sirdaryo Provinces (75%), where a 57 % reduction in diarrhoea incidence in just one year was achieved. The control group in the same region reported a comparatively lower reduction in diarrhoea of only 7 %. SODIS use and also diarrhoea reduction were much lower in the two other project regions of Karakalpakstan and Ferghana. The project team attributes this difference in adoption of the method and related health impact to the highly committed official field staff in the Sirdaryo and Burkhara Provinces [4].

Similarly, direct observations of the author during a project mission to Nepal in 2007 revealed that a highly motivated and committed Health Volunteer in Thimi was able to motivate 80 % of the population in her working area to use SODIS, whereas other, less dedicated volunteers in the same city reached about 50 % SODIS use in their respective working zones.

Education level influences willingness to behavioural change. People with a higher education, such as teachers, health workers or village leaders, were more difficult to convince that SODIS can efficiently treat drinking water. Bacteriological water quality tests with raw and treated water were effectively used to reduce scepticism about the microbiological efficiency of the method. Field observations in Bolivia and Nepal as well as a project evaluation in Kenya revealed that once doubts on SODIS efficiency were dispelled, people with a higher education and higher economic status are more likely to adopt SODIS, improve their hygiene behaviour and also sustain it over a longer period [2].

Social pressure influences behaviour. SODIS acceptance is more prominent in areas where SODIS is clearly visible in the community (many bottles on the roofs or in front of the houses) and used by a great number of people, including community leaders. Observations made in several project areas and confirmed by the field study in Nicaragua reveal that the intention to use SODIS is related to the use of SODIS by neighbours [7]. Different tools can be used to enhance the visibility of SODIS in a project area: dissemination of messages through mass media (TV, radio etc.), display of posters in prominent areas of the community, public exhibitions, and the display of signs at the entrance of the house, indicating that this household is using SODIS for drinking water treatment.

Conclusions

SODIS is currently used in 33 countries. A large variation of 20–80 % adoption and sustained use of the method was observed at grassroot level and can be attributed to the different circumstances encountered during project implementation. A widespread dissemination and sustained use of the method can be reached if: the carriers of the message (the promoters) are convincing, committed and respected persons; enough bottles are available for sustained application; several training events are conducted; the method is practised by many other users and thus clearly visible; implementation strategies are tailored to the education level of the recipients; a health improvement is felt by users; and both the institutional setup and official backup of the method are supportive.

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Improving Fluoride Removal Efficiency

Bone char is a highly efficient fluoride removal material, however, its lifespan is rather limited. Laboratory experiments reveal that the addition of pellets containing phosphate and calcium can extend the lifespan of bone char filters. Kim Müller, Francis Kage, Esther Wanja, Michael Mattle, Lars Osterwalder, Annette Johnson

According to UNESCO estimates, more than 200 million people worldwide rely on drinking water with fluoride concentrations exceeding the international WHO guideline of 1.5 mg/L [1]. While industrialised countries commonly use activated alumina or membrane technology to remove fluoride from drinking water, defluoridation is still uncommon in low and middle-income countries. A survey of defluoridation treatment in Eastern Africa reveals that bone char filtration is an efficient and viable fluoride removal method. Increasing the uptake capacity of bone char and thus prolonging the lifespan of the filters can, however, reduce maintenance requirements and improve treatment sustainability, especially for remote areas.

Improving bone char filters

In the 1990s, research experiments were conducted to extend the lifespan of bone char filters by adding calcium and phosphate to the water [2]. This new method was then referred to as co- or contact precipitation. Fluoride concentrations are reduced by both precipitation and sorption reactions in contact with hydroxyapatites ($Ca_5(PO_4)_3OH$), the main component of bone char. In 1995, this method was field tested in a community pilot plant in Tanzania [3]. Though filter lifespan was increased, high maintenance requirements due to continuous calcium and phosphate supplies hindered large-scale implementation. To overcome this drawback, the Catholic Diocese of Nakuru (CDN), a Kenyan faith-based organisation, took on the challenge of developing pellets that contain calcium and phosphate mixed with the bone char filter material. These pellets slowly release the required chemicals for fluoride precipitation into the water without creating additional maintenance efforts to the user. According to preliminary, unpublished lab investigations at CDN, this method prolongs the lifespan of the filters compared to filtration by bone char alone.

In-depth lab investigations

Eawag and CDN are currently conducting comprehensive lab analyses to acquire an improved understanding and to optimise contact precipitation for enhanced filter performance. The potential of contact precipitation can best be assessed in fixed-bed experiments carried out both at Eawag and CDN, using PVC columns filled with 260 mL of filter material (hereafter referred to as one empty bedvolume, eBV). For column experiments at Eawag, distilled water spiked with 6 mg F/L was used. CDN's columns were fed with natural Kenyan groundwater containing 6.0–6.3 mg F/L. The columns were run at a constant flow rate of 10 eBV/d (gravity flow with clamps for flow rate regulation at CDN, peristaltic pumps for flow rate regulation at Eawag).

Fig. 1 shows fluoride breakthrough curves for bone char and contact precipitation columns conducted at Eawag and CDN. Addition of pellets significantly prolongs the filter's lifespan, i.e. by a factor 6 in the case of synthetic water and 3 with natural Kenyan groundwater. The results obtained from the contact precipitation experiments at Eawag correlate well with those of CDN, as breakthrough of bone char was increased by a factor 2 under natural groundwater conditions compared to distilled water spiked with fluoride. Higher pH-buffering capacity in natural groundwater and possible precipitation processes with naturally occurring calcium (3 mg/L) and phosphate (0.3 mg/L) may enhance fluoride removal with bone char.

Uptake capacity in the case of distilled water spiked with fluoride increases from 0.6 mg F/g to 3.7 mg F/g filter material for bone char and contact precipitation, respectively. Removal efficiency is generally higher than 98 % for the first few eBV. The contact precipitation experiment at CDN revealed slightly lower removal efficiencies, averaging 90 % for the first 300 eBV. The steeper breakthrough curves for bone char columns indicate faster removal processes compared to contact precipitation, where the outlet fluoride concentration only rises slowly.

Only the beginning...

These lab findings reveal that contact precipitation can improve filter performance, however, far more experiments will have to be conducted to scientifically describe and optimise this method. A PhD study is currently determining and quantifying the different fluoride removal mechanisms of the contact precipitation method. In parallel, ongoing testing and monitoring of pilot implementation in Kenya and Ethiopia will complement the lab findings with field data.

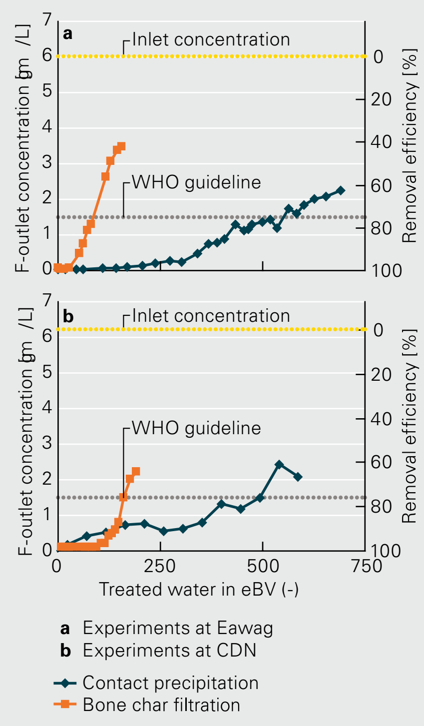

Figure 1: Fluoride breakthrough curves as a function of treated water in empty bedvolumes (eBV).

In 2006, Eawag and CDN initiated a collaboration to: i) further develop and optimise low-cost defluoridation methods applicable in low and middle-income countries and ii) facilitate its implementation.
Contact: annette.johnson@eawag.ch and cdnwaterquality@yahoo.com

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Household-Centred Solutions

Last year, Sandec chose six sites to validate the household-centred approach in Burkina Faso, Kenya, Tanzania, two in Costa Rica, and Laos. First results from the selected sites reveal that the multi-stakeholder approach can enhance the taking of decisions in urban service delivery. Christoph Lüthi

The sites selected vary in size and context, with target populations ranging from 1000 to 35000 inhabitants. New approaches in environmental sanitation planning for unserved urban and peri-urban areas are currently being tested together with our partner institutions. Most of the six sites have already undergone the following steps:

– launching of the planning process;
– submitting of a 'status report' analysing the current enabling environment and current environmental sanitation coverage;
– assessing user priorities, i.e. identifying community priorities and their willingness to contribute.

After completing the planning process at the different sites, the potentially most important HCES steps 5 and 6 were initiated, i.e. identification of technical, institutional and financial options for improved services, and discussion of service combinations regarding solid and liquid waste as well as greywater reuse etc. To carry out these two steps, different participatory approaches will be tested by bringing together sector knowledge from sanitary engineers/planners and context-specific community experience.

Step 5 of the HCES approach focuses on 'identification of options'. However, instead of just simply identifying technology options, Sandec has recently developed a planning tool, the "Compendium of Sanitation Systems" (cf. page 18) to assist users in identifying compatible and appropriate technologies to build a sustainable sanitation system. This Compendium is targeted at engineers, planners and other professionals primarily responsible for selecting and proposing the "possible" options. Use of the Compendium presupposes some basic knowledge in sanitation. Though some concepts and processes may be new, the underlying principles should be easily understood. The objective is to effectively increase the range of previously neglected options and potential variations. 'Possible' systems identified by engineers/planners will be negotiated by the community in a workshop before selecting the most suitable in terms of socio-economic, cultural and technical conditions. We call this approach the informed 'systems' approach.

This does not exclude the choice of multiple systems or technologies for different users or urban areas, which may overlap to varying degrees (e.g. lower income households could opt for the low-cost 'Arborloo' latrine, while the more expensive 'Urine Diverting Dry Toilet' is a technically more advanced option). Step 6 will subsequently integrate the sanitation system(s) and other environmental services based on institutional arrangements and level of stakeholder involvement. What should be done if stakeholders fail to reach consensus or if shortlisted sanitation options differ significantly? A multi-step negotiation process, involving the community, sector experts and a good process moderator, will probably have to be conducted.

We are confident that once the negotiation process of the informed 'systems' approach is completed, the environmental sanitation service plans can be readily developed and adopted. Improved urban services will be subsequently implemented by the end of this year. Sandec has initiated accompanying research in selected HCES sites:

– In Waruku, Kenya, the long-term effects of greywater reuse in urban agriculture are being analysed (UNESCO-IHE Master Thesis).
– Usefulness of the Material Flux Analysis (MFA) approach as an analytical tool for HCES has been assessed (EPFL Master Thesis) in collaboration with CREPA in Fada, Burkina Faso.
– We are piloting a number of cost-effective sanitation technologies and evaluating user acceptance in the low-income settlement of Chang'ombe in collaboration with IHRDC (Ifakara Health Research and Development Centre) in Dodoma, Tanzania.

In the past year, the approach received increased acknowledgement and acceptance by the international WatSan sector. HCES was presented at the WSSCC Planning Meeting in Geneva in 2007 and at the 33rd WEDC Conference in Accra, Ghana in 2008. It will also be featured at the World Water Week in Stockholm this coming August.

The HCES guidelines can be downloaded from www.eawag.ch/hces

Sandec

Photos of three planning exercises: Laos, Tanzania (Dodoma), Costa Rica

Key aspects of the household-centred approach:
- sustainable environmental sanitation solutions are central to improving both human dignity, health and environmental concerns;
- people's skills, abilities and knowledge are valued;
- multi-stakeholder approach engaging authorities, utilities to local beneficiaries;
- formation of a locally based taskforce to champion the HCES process;
- mobilisation of local and national resources to enable implementation; and
- cradle-to-grave systems approach for sanitation planning

Biogas in Cities – A New Trend?

Anaerobic Digestion of Kitchen and Market Waste in Developing Countries

So far, several million conventional biogas plants, using predominantly animal manure as feedstock, have been successfully installed in rural areas of developing countries. However, can anaerobic digestion also be a suitable technology to treat organic household waste in urban and peri-urban areas to alleviate the solid waste crisis in cities of the developing world? Yvonne Vögeli, Chris Zurbrügg

In many cities of developing countries, the most serious environmental and health problems are related to inadequate solid waste management (SWM). Progressing urbanisation and rapid population growth lead to increasing amounts of waste, thereby also increasing pressure on local authorities responsible for the provision of safe and reliable public services. Municipal Solid Waste (MSW) in developing countries is rich in organic material (up to 70 %). However, if this organic fraction is not managed adequately, it causes nuisance for urban dwellers and pollutes the environment due to its easily biodegradable nature. Unreliable collection leads to smelly dumps in neighbourhoods and attracts animals, such as rodents, the typical transmitters of diseases. Lack of treatment or non-engineered and unsafe disposal causes soil, surface water and groundwater pollution through leachate, and uncontrolled methane emissions contribute to global warming. Consequently, particular attention should be given to the organic fraction of municipal solid waste. Some treatment options for biodegradable waste, such as aerobic composting or direct animal feeding have been identified in practice and are more or less well-recognised as proven solutions in certain contexts. Nevertheless, there is still scope for improvement by increasing the value and further potential benefits of the treatment steps and generated products. Aside from using worms or larvae to digest the waste (as described in another article of this Sandec News issue), anaerobic digestion (AD) or biomethanation of organic solid waste is likely to be a promising treatment option. Under anaerobic conditions, bacteria break down the organic matter and produce biogas. This mixture of CO_2 and methane (CH_4) can be used as an energy source for cooking, lighting or even to generate electricity, thereby replacing other fuels. The digestate, similar to compost, can be used as soil conditioner in agriculture or landscaping since it contains nutrients and is rich in organic matter. AD of organic solid waste is already widespread in industrialised countries and is gaining importance given the growing demand for renewable energy and high market prices for fuel. To date, AD of livestock manure, as major feedstock, is common mainly in rural areas of low and middle-income countries. In urban or peri-urban settings, where organic solid waste is predominantly available as feedstock, the accessible knowledge and information on technical and operational feasibilities, challenges and opportunities is limited. This lack of research and development and/or limited spread of knowledge and information is astonishing in the light of the enormous waste problems faced by most urban areas in low and middle-income countries.

Situation analysis in South India

A literature review and Internet search [1] conducted by Sandec on anaerobic digestion of organic solid waste in developing countries identified South India as a location characterised by numerous research, development and implementation activities. Research institutions, NGOs and commercial organisations active in the sector have jointly generated much knowledge and experience in anaerobic digestion of kitchen/market waste as well as organic household waste. In August 2007, an on-site assessment and evaluation study examined 16 biogas plants in different South Indian cities. All the visited plants developed by Indian research institutes, private enterprises or local NGOs were specifically designed to treat organic solid waste rather than manure. Plant size and scale of operation vary from smallest household plants (1–5 kg/d), medium-size facilities at institutional and municipal level (< 3 t/d) to large-scale facilities of up to 100 t/d capacity.

The feedstock used for digestion comprises kitchen waste from households, canteens and restaurants, market waste

Photo 1: BIOTECH biogas plant fed with canteen waste (30 kg/d) in Trivandrum, India.

(vegetables, fish), waste from slaughterhouses and – in a few plants – also toilet waste. The biogas generated by the anaerobic digestion process is generally used directly for cooking in close proximity to the plant. This is the easiest and most efficient way of using the gas, as complicated storage and transport are not required nor any further treatment steps (e. g. hydrogen sulphide removal). In other cases, the generated gas is used for street lighting or converted into electricity. The type of gas use depends not only on the daily amount generated, but also on the spatial and site-specific location of the plant.

The main motivation of plant developers and operators is driven by the need to find *waste treatment solutions.* The perceived comparative advantage of anaerobic digestion is its controlled and contained (closed) waste treatment process perceived as a technically advanced but "clean" solution not requiring much surface area. In this sense, generation of biogas is seen as a welcome added value of the technology and not necessarily as the decisive factor for choosing anaerobic digestion over another organic waste treatment option. Furthermore, little attention is often paid to the digested residues (solid and liquid fractions) and their agricultural, gardening or landscaping value. Scarcity of well-documented information on gas generation rates in relation to loading rates, types of waste, reactor volume, retention time, or also characteristics and composition of residues is therefore not surprising.

To date, all the evaluated experience points to the fact that the initiative and motivation to support, develop, invest, and operate biogas plants is driven by the interest of researchers, private enterprises or NGOs. Though national government agencies, such as the Ministry of New and Renewable Energy (MNRE) or the Indian Renewable Energy Development Agency Limited (IREDA) promote, develop and provide financial assistance to renewable energy and energy efficiency/conservation projects, the support from local governments, specifically from municipal authorities responsible for waste management is largely lacking. These waste treatment options are rarely embedded in the urban strategic waste management plan and therefore often remain isolated individual initiatives. This is all the more surprising as India has an innovative legal framework and city authorities are liable to promote waste segregation at source to avoid biodegradable waste disposal in landfills. According to current legislation, biodegradable waste must be processed by composting, vermicomposting, anaerobic digestion or by any other appropriate biological process. Unfortunately, legislation is not yet fully implemented. However, the existence of such a legal framework, in combination with the interest of municipal authorities in finding solutions to comply with these rules, can significantly contribute to promoting biogas plants in India. Furthermore, promotion of anaerobic digestion can achieve substantial momentum, since the technology qualifies as a CDM project (avoiding uncontrolled methane emissions from dumped waste on landfills). CDM is an arrangement under the Kyoto Protocol, allowing industrialised countries with a greenhouse gas reduction commitment to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries. CDM investments may thus further boost development and implementation of AD facilities in developing countries.

Experience from India shows that AD of organic solid waste is a promising technology in developing countries with a tropical climate. Biogas plants treating organic solid waste in urban areas have a great potential. Sandec's solid waste research activities will look at the performance of small and medium-size biogas units to collect scientific evidence on gas production, gas composition and effluent quality, as well as study the economic aspects of this waste treatment method. Preliminary monitoring results of a household biogas plant in Tanzania will be available at the end of 2008 (cf. box).

Anaerobic digestion of kitchen waste at household level in Dar es Salaam, Tanzania

Photo 2: ARTI biogas plant in Dar es Salaam, Tanzania.

The ARTI Compact Biogas Plant is a small household system developed in India for the daily treatment of 1–2 kg of food waste. This widespread system in South India is now being promoted in Tanzania and Uganda. Though a seemingly successful approach, data on its performance in Africa is still scarce. Further information will be required to obtain a detailed assessment of this treatment option. Monitoring of an ARTI biogas plant at household level and experiments at the Ardhi University of Dar es Salaam shall provide reliable data on daily gas production, gas composition, effluent quality, and suitability of this technology with different feedstock, including convenience of operation. This project will be launched in July 2008 in collaboration with the Ardhi University of Dar es Salaam and the University of Applied Sciences in Zurich.
For further information on this technology, kindly consult www.arti-india.org

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Conversion of Organic Refuse by Saprophages (CORS)

Composting is a proven technology for organic waste treatment under certain site and context-specific conditions. Nevertheless, there is still scope for improvement by increasing the value and potential benefits of organic waste treatment and its products. Sandec is currently evaluating and developing a CORS system using larvae of the Black Soldier Fly for organic waste treatment in low and middle-income countries. Stefan Diener, Chris Zurbrügg

The method used to handle, collect, store, and dispose of the waste generated by human activity determines the environmental and public health risks. Poor, inaccessible and marginal urban areas suffer most from deficiencies in public service and infrastructure; thus aggravating poverty, health and social marginalisation. Municipalities and other key urban stakeholders have recognised these risks and have set high priorities in finding sustainable solutions to improve waste management [1]. Improvements of sustainable waste management approaches using resource recovery and a closed-loop economy are, in fact, clearly linked to issues of employment opportunities and income generation, both in the formal and informal sector. Recycling of inorganic materials (glass, metal, plastics) from municipal solid waste already constitutes an important source of income and employment, especially in low and middle-income countries. However, recycling and reuse of organic waste material is still fairly limited despite its very high recovery potential. For reasons of deficient waste collection services (typically one to two thirds of the solid waste generated is not collected), organic waste, often mixed with human and animal excreta, is dumped arbitrarily in streets and drains, where it causes pipe and drain blockages, flooding and breeding places for disease transmitting insects and rodents, including odour nuisance. Finding appropriate and sustainable solutions for organic waste treatment thus constitutes a major thrust in the endeavour to improve solid waste management.

CORS

Use of CORS (Conversion of Organic Refuse by Saprophages) provides a potential and proven solution to treating organic waste by feeding it to organisms (saprophages) specialised in decaying matter. Probably the most well-known application of CORS is vermicomposting, where worms and microorganisms turn organic waste into a dark, earth-smelling, nutrient-rich soil conditioner (Photos 1–4) for use in agriculture and landscaping. Much research has been conducted on the treatment process of organic residential or market waste and livestock manure. At the agronomic research station of the Instituto Tecnológico de Costa Rica in San Carlos, for instance, the manure of 45 pigs is transformed by earthworms into compost in just eight weeks. The pig manure produced in one week is stored for five weeks in a dry area. The mature material is then filled into plastic crates and inoculated with earthworms from the former compost generation before the containers are left to rest for another three weeks prior to use.

However, CORS approaches are also used in natural, non-engineered environments. The introduction of cattle in Australia led, for instance, to the generation of large amounts of cow dung, which the native beetle fauna was unable to handle. The accumulated dung contributed to the widespread proliferation of the bush fly Musca vetustissima, to nuisance and to increasing disease transmission. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) subsequently introduced several non-native coprophagous beetles, which buried the dung to breed their offsprings and thus withdrew the flies' means of reproduction [2].

CORS is not only applied to solid waste. At Wageningen University, experiments with the aquatic worm Lumbriculus variegatus led to a noteworthy reduction of faecal sludge volume. The treatment reactor, containing one sludge and one water compartment, is divided by a carrier material on which the worms position themselves with the tail protruding into the water and

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Photos 1–4: Different CORS protagonists, clockwise from top left: vermicomposting using Eisenia fetida (Photo: Robin DeGrassi), dung beetles Onthophagus gazella (Photo: T. Murray), larvae of the Black Soldier Fly, Hermetia illucens (Photo: Sandec), experimental set-up of sludge treatment with Lumbriculus variegatus (Photo: T. Hendrickx).

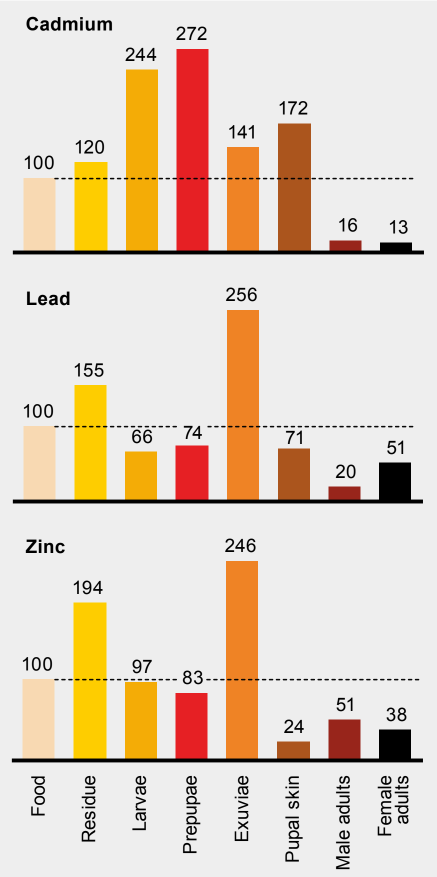

Figure 1: Fate of heavy metals fed to Black Soldier Fly larvae in per cent of food concentration.

the head in the sludge. L. variegatus feeds with its head but breathes and defecates via its tail. Aerating the water thus allows the worms to breathe while the sludge is being fed and digested [3].

Income generating waste treatment

Sandec is now evaluating another simple CORS technology that promises to combine waste treatment and generation of a valuable (by-)product, which in fact, is the organism feeding on waste itself. The life cycle of the non-pest Black Soldier Fly, Hermetia illucens fits this purpose very well (Fig. 2). The larvae, which voraciously feed on organic material, reduce its dry mass by 40–50 %. This figure corresponds to a similar reduction likely to be achieved by composting or biogas digestion units. Yet, it is not only the ability to reduce waste that makes the Black Soldier Fly a promising waste manager. After feeding extensively on waste, the larvae or the so-called prepupae (the last larval stage) crawl out of the waste in search of a dry pupation site. The prepupae can thus be easily harvested by simply channelling their migration paths into a collection vessel.

The prepupae bodies are rich in protein and fat and thus an excellent component of animal feedstuff for aquaculture or poultry production. Feeding experiments replacing fishmeal by larvae meal revealed highly promising results [4, 5]. Such feed of animal origin is also becoming a very attractive and urgently needed alternative, given the growing global role of aquaculture and the increasing but ecologically questionable demand for fishmeal. The growing demand for fishmeal is currently reflected by steadily mounting market prices. In this case, waste management using the larvae of the Black Soldier Fly may not only become a self-sustained waste treatment option, but a profitable and flourishing business.

Current research results

Sandec's solid waste research on CORS technologies centres on experiments conducted in a climatised room in Dübendorf, Switzerland. These small-scale experiments provide the scientific basis for the next scaled-up phase, where research will be conducted in a pilot treatment plant in Costa Rica. The research will focus on the following three areas: waste degradation potential, quality and quantity of the prepupae and microbiological safety of the residue.

First laboratory results allow to assume an ideal daily loading rate of 3–5 kg/m^2 for kitchen and market waste, and 6–8 kg/m^2 for manure and human faeces. With such feeding rates, the dry mass can be reduced by 40–50 %. However, these preliminary results need to be verified on a larger scale under outdoor conditions, for instance, in the planned facility in Costa Rica.

The fate of pollutants, such as heavy metals, is another aspect of concern during the waste treatment process. Organic waste from street sweepings may, for instance, show elevated concentrations of heavy metals. Do such pollutants affect the treatment process or the final prepupae quality? In small-scale laboratory experiments, larvae were given organic material spiked with selected heavy metals (cadmium, lead and zinc). The fate of these heavy metals was then traced throughout the waste treatment process. The results obtained show that prepupae accumulated cadmium within their body, whereas lead and zinc were found concentrated in the discarded skin after moulting (Fig. 1). Therefore, if prepupae are used as feedstuff, larval food with high cadmium concentrations should be avoided.

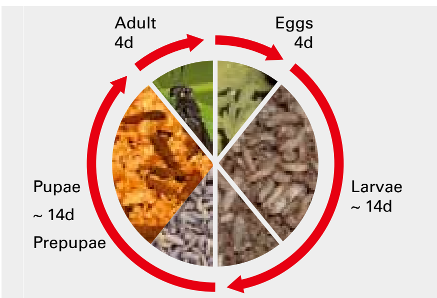

Figure 2: Life cycle of the Black Soldier Fly, Hermetia illucens at 25 °C.

The next experimental phase will examine the fate of human intestinal parasites originating from and transmitted by human faeces, as adequate sanitation services are not available for a large part of the population in low and middle-income countries Such human and animal parasital infections are unfortunately common, particularly soil-transmitted helminth infections, mankind's most prevalent infections [6]. Since helminths are robust parasites, they are good indicators of the hygienisation performance of a human waste treatment system. A study by Erickson et al. [7] with larvae of Hermetia illucens revealed a reduction in E. coli and Salmonella enterica. However, the ability of H. illucens to eliminate helminth eggs shall be tested this year during a research collaboration between Sandec and the Instituto Tecnológico de Costa Rica in Cartago.

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Technology Transfer – Forage Plants Used in Faecal Sludge Dewatering Beds in Sub-Saharan Africa

In collaboration with the Asian Institute of Technology (AIT), Bangkok, Eawag has previously demonstrated that constructed wetlands, especially in Thailand, offer a viable solution for the treatment of faecal sludge. However, since the characteristics of sludge vary widely from one region to another, appropriate indigenous plants had to be identified so as to ensure successful operation of these facilities. Doulaye Koné[1] and Ives Kengne[2]

In urban areas of developing countries, especially in those of sub-Saharan Africa, on-site sanitation systems predominate over sewered alternatives. Since area-wide sewerage is not affordable, they will play an important role in excreta disposal for decades to come. Unfortunately, the gap in knowledge on low-cost and efficient treatment options is one of the main factors leading to the uncontrolled discharge of untreated faecal sludges (FS) into drains, water bodies and open land spaces. This improper practice is at odds with ecological principles, as the faecal sludge contains high concentrations of pathogens and pollutants impairing public health and the aquatic environment. In Cameroon as in other sub-Saharan countries, eutrophication of lakes and streams is significant, and diseases linked to poor water and sanitation management remain burning issues. Faecal sludges contain extremely high pathogen concentrations responsible for the elevated endemic rate of excreta-related diseases, especially among children [1].

Development of efficient and low-cost methods for separation of the solid and liquid fraction is a key requirement for sustainable management of faecal sludge. This step is essential to avoid hygienic problems and allow the recovery of resources or energy [2, 3]. If well managed, vertical-flow constructed wetlands (VFCW) could be efficiently used to tackle the lack of treatment options in Africa.

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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) and the Swiss Agency for Development and Cooperation (SDC). Additional support was also provided by the **International Foundation for Science (IFS, Sweden, grant W4115/1).**
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Vegetation and operation

Experiments, conducted on a yard-scale at the University of Yaoundé I, Cameroon, over the last three years, aim at assessing the effects of FS application on the performance of the system in order to determine the factors likely to affect its sustainability (Photo 1). Faecal sludges were applied weekly on beds vegetated either with antelope grass *(Echinochloa pyramidalis)* or papyrus *(Cyperus papyrus)*. This allows the solid phase to be retained on the surface of the filtering matrix, where it undergoes mineralisation, while the liquid phase is drained out of the system for further treatment. Prior to sludge application, young shoots or fragments of *E. pyramidalis* stems with at least one internode and old fragments of rhizomes of *C. papyrus*, weighing 300 to 350 g (fresh weight), were allowed to grow for six weeks in a media saturated with raw domestic wastewater.

System performance

For six months, the sludge loads were gradually increased by a mixture of FS from traditional pit latrines, septic tanks and public toilets delivered by emptying trucks to reach nominal solid loading rates of 100, 200 and 300 kg TS (total solids)/m^2/yr. Faecal sludges, stored in two tanks (1 cm^2 each), were stirred prior to each loading. This gradual SLR (sludge loading rate) increase was performed to avoid withering of the macrophytes due to the application of rapid and large amounts of pollutants, and to master all the adverse conditions that could hamper the experiments. The beds were subsequently fed at nominal loading rates for another six months at one application per week, except in E. pyramidalis beds whose FS application was interrupted for one month during plant harvesting and regrowth. SLRs were derived from TS content of the raw sludge prior to each application. Since the TS contents were constant, the hydraulic sludge load applied to the beds was determined each time according to the following equation:

$$\text{Hydraulic load (l)} = \frac{C1}{} \times \frac{1}{C2 \times 52}$$

with: C1 = annual loading rate (kg TS/m^2/yr)
C2 = TS content of each newly delivered raw FS by the mechanical emptiers (kg/L)

Based on the results obtained, both indigenous plants were found suitable for dewatering of highly concentrated FS in tropical regions at 100 kg TS/m^2/yr. Indeed,

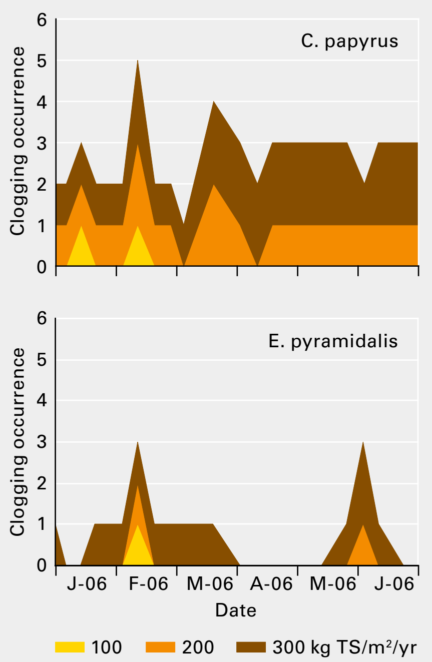

Figure 1: Occurrence of clogging events in the different beds as a function of the solid loading rates applied.

Sandec

Photo 1: Pilot beds of the VFCW developed for the FS dewatering study in sub-Saharan countries.

bed clogging, the main operational problem encountered in such a system, rarely occurred at this loading rate (Fig. 1). The average dry matter content for this SLR amounts to ≥ 30 % prior to each weekly application. However, at ≥ 200 kg TS/m^2/yr loading rate, clogging occurrence was higher in the *C. papyrus* beds than in those of *E. pyramidalis* (Fig. 1). These results contrast with the operational loading rates of less than 80 kg TS/m^2/yr generally applied in Europe and North America [4, 5], but lie within the range of previous work conducted in Thailand [6]. Pollutant removal efficiencies, based on average differences in input and output fluxes, revealed that beds vegetated either with *C. papyrus* or *E. pyramidalis* performed relatively well for solids, nutrients and organics, irrespective of the solid loading rates applied, with removal rates often higher than 78 % (Table 1). Despite these good removal efficiencies, the percolate concentration in pollutants remained relatively high. These percolates will need to undergo further treatment in constructed wetlands or waste stabilisation ponds to comply with reuse standards for unrestrictive agriculture.

A comparison of the growth characteristics of the plants in constructed and natural wetlands indicate that both macrophytes adapted and developed relatively well when loaded with faecal sludge. As a result of FS applications, shoot numbers at harvesting were two to four times higher in dewatering beds despite their short period of growth. Indeed, their density at harvesting varied from 260 to 400 and from 56 to 150 shoots/m^2 for *E. pyramidalis* and *C. papyrus*, respectively. Cross-surveys of their density in natural wetlands revealed an average of 89 and 24 shoots/m^2 for *E. pyramidalis* and *C. papyrus*, respectively. This significant growth rate can be attributed to the availability of sufficient nutrients, especially nitrogen and phosphorus contained in faecal sludge. An important development of the aerial parts of antelope grass was noted in the beds, thus requiring frequent harvests to allow a regrowth of new shoots from the rhizomes. Shoots growing from the rhizomes are expected to create enough tubular spaces during wing movement, and enhance FS dewatering rather than the growth of shoots from the aerial internodes. A potential annual harvest of at least 150 dry tons/ha of this highly prized local forage plant can be obtained if harvested thrice a year. Severe signs of plant wilting were nevertheless observed when loaded with FS exhibiting high salinity (15 mS/cm), such as those from public toilets, especially when the infiltration rate was slow. Monitoring of the effects of salinity on the growth and nutritive value of the antelope grass is currently being conducted.

Extensive rhizome growth, as well as weak and slow culm regrowth were identified as potential factors limiting the use of *C. papyrus* for FS dewatering when loaded at more than 100 kg TS/m^2. Easy regrowth of *Echinochloa* shoots was observed from the fragments of stems remaining in the beds after the harvest of shoots by cuttings. As regards the operational conditions of the sludge treatment plant, this could be an interesting aspect pleading in favour of the use of this macrophyte. Indeed, easy regrowth could result in a time and money saving factor.

At least 2000 tons of fresh weight/ha/year biosolids can be accumulated on top of the beds. These biosolids can be considered as mature compost even without being subjected to the classic mesophilic, thermophilic and maturation phase for their stabilisation. Indeed, their C/N ratio was equal to 11, a value close to that generally found in mature composts. Furthermore, the humification indices obtained, especially the degree of polymerisation of 3.7, was higher than that found in other mature co-composts [7]. The biosolids also exhibited high nutrient contents with total N and P_2O_5 accounting for up to 2 and 2.3 % DM, respectively. Nevertheless, helminth eggs remained relatively higher (79 eggs/g TS on average) than the WHO guidelines of less than 1 helminth egg/g TS for unrestricted agricultural use, thus requiring longer storage periods or co-composting to obtain a safer product.

The findings of this research were considered an added value pleading for the development of this ecotechnology in Africa. Indeed, besides the primary goal of using the VFCW to tackle the lack of affordable FS treatment options, the harvested macrophytes (antelope grass) could be used as fodder for sheep and goats. The high mineral content of the produced biosolids could also serve as organic soil amendment, reduce the need for fertilisers by local farmers and generate funds to sustain the system if properly managed.

Parameters	Average Removal Efficiencies
TVS	95.4 – 98.9
TS	90.2 – 95.8
NTK	89.5 – 95.7
NH4	77.6 – 90.9
COD	97.8 – 99.2

Table 1: Pollutant removal efficiencies of the VFCW for FS dewatering.

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Development of Nitrogen Transformation Model for VFCWs Treating Faecal Sludge

The thousands of tons of faecal sludge currently collected every day from on-site sanitation installations are not properly disposed of, especially in developing countries. In Bangkok, only 8.5 % of the 4600 m^3 of FS collected daily are treated in faecal sludge treatment plants [3]. Among the potential low-cost treatment systems, which enhance nutrient and biosolids recovery for reuse purposes [1], the vertical-flow constructed wetland (VFCW) system has proven robust for efficient FS dewatering and quality biosolids production [2]. Atitaya Panuvatvanich[1,2], Thammarat Koottatep[1], Doulaye Koné[2]

Early 1997, three pilot-scale, vertical-flow constructed wetlands were developed at the Asian Institute of Technology (AIT) in Bangkok. Based on the available experimental data, the optimum solids loading rate was established at 250 kg TS/m^2.yr with a 6-day percolate impoundment. The CW units treating faecal sludge achieve 80–96 % removal efficiencies for COD, TS and TKN. The current knowledge on nitrogen transformation within the system could be useful to further develop system design. This study aims at identifying nitrogen transformation pathways and kinetics of processes corresponding to nitrogen compounds, such as organic nitrogen, ammonia nitrogen and nitrate nitrogen in vertical-flow constructed wetland (VFCW) for treating faecal sludge.

Methodology

Experimental setup

Five laboratory-scale VFCWs, located at the Environmental Research Station of the Environmental Engineering and Management Programme of AIT, Thailand, were used for this research.

Lab-scale VFCW units

Each unit, consisting of a square plastic tank, was planted with cattail (Typha augustifolia). The effluent outlet was divided into two groups as shown in Figs. 1a and 1b, without and with water holding in the drainage layer. A PVC pipe was connected to the effluent outlet of three laboratory-scale VFCW units to maintain a constant water level in the drainage layer, as illustrated in Fig. 1b.

Preliminary findings

Figure 3, which indicates influent and effluent nitrogen concentrations in form of org-N, NH_4-N, NO_2-N, and NO_3-N, reveals that 94 % of the influent N concentration is in the form of NH_4-N. After ponding for six days, the TN removal efficiency in Unit 1 was higher than in Unit 2 by about 10 %. Similarly, the TN removal efficiency in Unit 3 is higher than in Units 4 and 5 by about 8 % and 26 %, respectively. This indicates that accumulated sludge may affect total nitrogen removal efficiency of the systems. Moreover, VFCW operated with percolate impounded in large gravel layers does not reveal a significant difference in terms of TN removal efficiency, as compared to a VFCW operated without percolate impoundment.

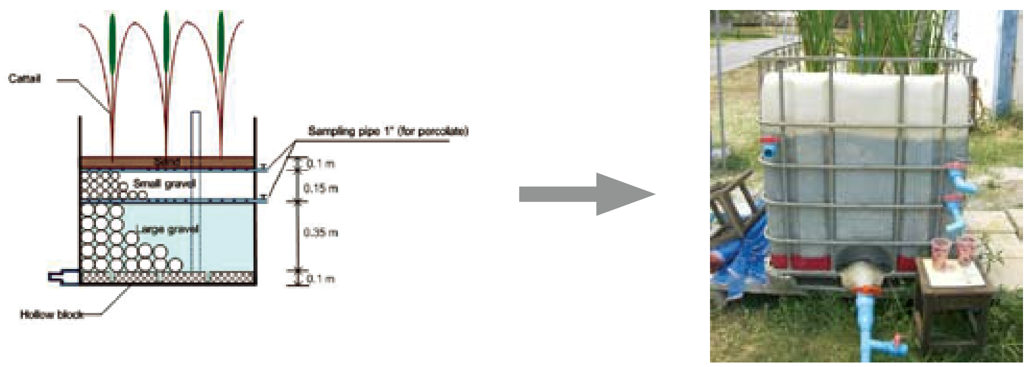

Figure 1a:
Without retained percolate in large gravel layer

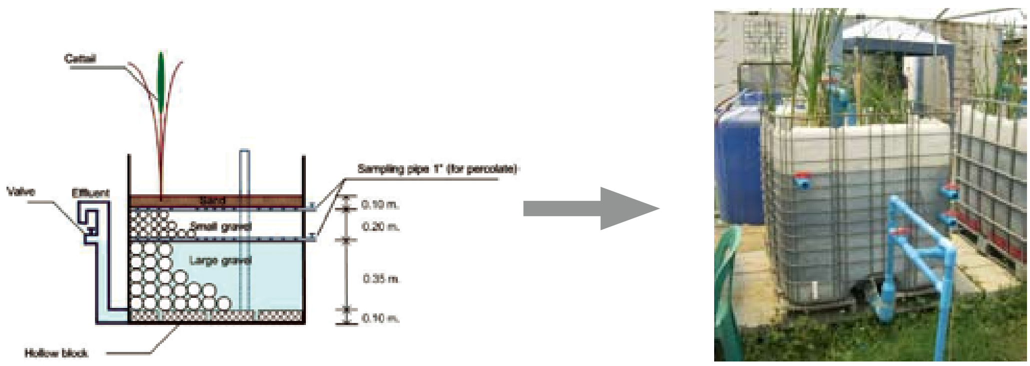

Figure 1b:
With percolate retained in large gravel layer

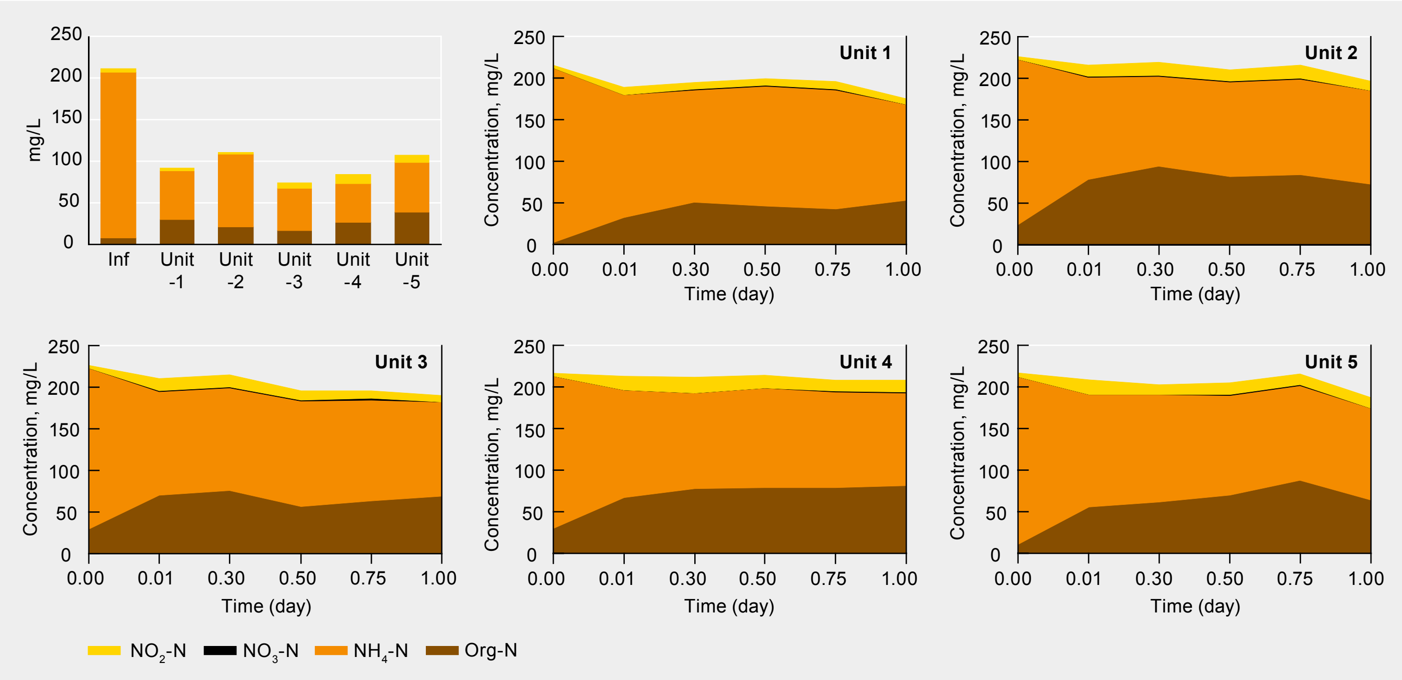

Figure 2 (top left): Profiles of nitrogen compounds after passing the sand layer in lab-scale VFCW units.
Figure 3: N compounds in influent and effluent of each unit (1–5).

With regard to nitrification in the sand layer, preliminary results indicate that approximately 50% of NH_4-N concentrations disappear and NO_2-N concentrations increase by about 80 %. NO_3-N concentrations increase by about 40 % in relation to the influent concentrations (Fig. 2). This indicates that NH_4-N was probably converted through nitrification to NO_2-N and NO_3-N after passing the sand layer. Moreover, plant uptake or another mechanism could be responsible for unrecovered NH_4-N in this layer.

After sludge accumulation at various depths on the top of the VFCW, org-N concentrations increased by about 90 % in relation to the influent concentrations. The results reveal that the different levels of accumulated sludge had no significant effect on nitrogen transformation in the sand layer.

Moreover, the different drainage types, either with or without retained percolate in the system, also had not effect on nitrogen transformation in the sand layers (Table 1).

Further investigations

Based on the preliminary results, the following three investigations will also have to be carried out to identify nitrogen transformation in the vertical-flow constructed wetland:

1) Ammonia volatilisation, nitrification, denitrification, and plant uptake – the main mechanisms for nitrogen transformation.
2) Relationship between sand layer depth and nitrogen conversion.
3) Releakage of nitrogen from accumulated sludge.

Accordingly, ammonia volatilisation, nitrification and denitrification will be examined in new column units and controlled conditions. Two new lab-scale VFCW units at different depths of the sand layer will be set up to investigate the relationship between sand layer depth and nitrogen conversion. Finally, small units will be installed at different depths in the accumulated sludge to study nitrogen releakage.

Type of influent	Drainage type	Units	Depth of accumulated sludge (cm)
AIT wastewater (NH_4^+ concentration adjusted with soluble NH_4Cl solution)	Without impounded percolate in large gravel layer	1	0
		2	10
	With impounded percolate in large gravel layer	3	0
		4	10
		5	20

Table 1: Configuration of experimental unit.

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Turning Waste into a Fertiliser

The authors of this article have recently developed COMLIZER, a fertiliser made of municipal solid waste, faecal sludge and mineral fertiliser. Since this new product meets the crop nutrient requirements and has an excellent soil conditioning quality, it has become an attractive source of nutrients for farmers. Noah Adamtey[1], Olufunke Cofie[1], Godfred K. Ofosu-Budu[2], Dionys Forster[3]

Ghana's municipal waste consists mainly of household (domestic) and market waste (69 %). On average, about 1800 t of municipal solid waste (household/market waste) and over 600 m³ of human excreta are produced daily in Accra. However, the waste is poorly managed due to logistics reasons (waste collection vehicles/containers), financial constraints and lack of skilled personnel [1]. Nevertheless, as this waste contains considerable amounts of plant nutrients, it can be used, if managed properly, to produce food crops safe for human consumption. Furthermore, food production has been decreasing in the tropics as a result of reduced soil fertility, i. e. declining soil organic matter content, low availability of plant nutrients, poor water infiltration and water holding capacity [3]. Crop cultivation in and around urban areas has recently been intensified to meet the growing urban food demand.

In 2002, a pilot co-composting plant was set up in Buobai, Ghana, 15 km from Kumasi's city centre (6°41' N, 1°37' W) to study municipal solid waste (SW) and faecal sludge (FS) treatment and reuse in urban and peri-urban agriculture. The co-compost produced at this plant from SW and FS revealed fairly high phosphorus (≤ 3 %) and potassium (≤ 3 %) contents, but a low nitrogen concentration averaging 1 %. Moreover, since co-compost releases nutrients only slowly, its N mineralisation rate amounted to less than 10 %. The farmers' reticence to buy and use the product as an alternative nutrient source in crop production can be attributed to its low nitrogen content and costs required to transport the large co-compost volumes [2].

As nitrogen is the most limiting element of all main nutrients in tropical soils, any soil amendment should be able to supply enough N to meet the crop requirement. Enriching co-compost with minimum amounts of inorganic fertiliser is therefore an option to overcome the low N content, to reduce the total volume to be transported to farm sites and, thus, make the product attractive for farmers.

Production and enrichment of co-compost

The organic fractions of market and household waste were separated from the total waste generated and composted with dewatered faecal sludge at 2:1 ratio (v/v). Co-compost quality was monitored using pH, temperature, nitrate and ammonia nitrogen, as well as cress (Lepidium sativum) germination. The mature co-compost was subsequently air-dried to less than 10 % moisture content and sieved through a 2-mm mesh. The sieved co-compost (1.5 % N content) was then enriched with ammonium sulphate (21 % N) until the co-compost and inorganic N fertiliser each contributed 50 % of the total N content in the resulting product, the so-called COMLIZER.

Characteristics of COMLIZER

The agronomic importance of COMLIZER was tested on maize grown on sandy loam soil subjected to additional irrigation. Maize yield from COMLIZER-treated plots with 91 kg N ha^{-1} was 3 % higher than NPK (15-15-15) + ammonium sulphate with 150 kg N ha^{-1}, and 11 times higher than soil alone (Photo). Nitrogen and phosphorus uptake in maize plants from COMLIZER-treated plots were 11 and 29 % higher than NPK (15-15-15) + ammonium sulphate, resp., and three times higher than soil alone. The organic matter content of soil treated with COMLIZER was 22 % and 64 % higher than NPK (15-15-15) + ammonium sulphate and soil alone. Crop water use efficiency was 12 % higher in COMLIZER-treated crops over NPK (15-15-15) + ammonium sulphate and 9 times over soil alone, whereas the heavy metal content in maize (grain and plant) was far below WHO's threshold value.

Compared to NPK (15-15-15) + ammonium sulphate, COMLIZER made from municipal waste co-compost and inorganic fertiliser improves crop yield, nutrient uptake, soil organic matter content, and crop water use efficiency. Hence, municipal waste is not a waste after all, as COMLIZER has the potential to meet farmers' needs to enhance crop production.

Photo: Maize cobs and mature plants grown (a) on soil; (b) on COMLIZER-treated plots with 91 kg N ha^{-1} and (c) with 150 kg N ha^{-1} NPK (15-15-15) + ammonium sulphate.

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Contact: n.adamtey@cgiar.org
The research was supported by the NCCR North-South and IDRC Agropolis.

[1] AMA (2006): Municipal solid waste and biosolids generation & management in Accra, Ghana, Accra Metropolitan Assembly (AMA). Personal Interview conducted on 20.01.2006.

[2] Danso, G., Drechsel, P., Fialor, S., Giordano, M. (2006): Estimating the demand for municipal waste compost via farmers' willingness-to-pay in Ghana. Waste Management 26 (12), 1400–1409.

[3] FAO-RAF (2000): Integrated soil management for sustainable agriculture and food security. Case studies from four countries in West Africa, FAO Regional Office, Accra, Ghana.

New Publications

Capacity Development with Sandec's Training Tool

Lack of knowledge is a major barrier preventing large-scale and effective water and sanitation improvements. To ensure state-of-the-art training and education of sanitary and environmental engineers, both lecturers and students must be able to easily gain access to training materials covering not only topics relevant to high income countries (sewers, activated sludge, wastewater treatment or membrane bioreactors). Instead, teaching should specifically cover technologies and approaches adapted to situations in developing countries. It should also raise the attention to the fact that technologies alone cannot solve the problems but must be based on the socio-cultural, economic and institutional context. Following the numerous requests for such possibly free materials, Sandec has initiated a project aiming at creating a pool containing Sandec's numerous literature notes and presentations collected over several years. In a first step, all existing lecture materials will be structured, collated and enhanced by PowerPoint presentations, lecture notes and further reading material. The product – the "Sandec Training Tool" – addressing interested lecturers, students or practitioners, will subsequently be available free of charge as CD and download.

The "Sandec Training Tool" is divided into two overview modules entitled "Overview" and "Environmental Health", four thematically focussed modules on "Household Water Treatment and Safe Storage", "Sanitation Systems and Technologies", "Faecal Sludge Management" and "Solid Waste Management", and finally a Module on "Planning for Environmental Sanitation" (Fig. 1).

All modules, interlinked through an html-user-interface can be accessed by any Internet browser. The user can thus navigate through the materials and find documents related to his/her specific interest. A stand-alone application on a CD will not require Internet access. Since the PowerPoint presentations will be available as open source, they can be adapted if necessary by local lecturers in their teaching and training activities.

Figure 1: User-Interface provides access to the seven modules and all specific documents.

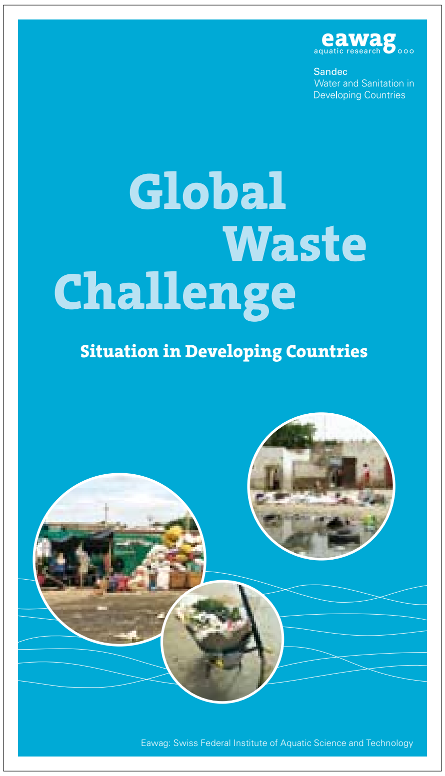
A preliminary version of Sandec's Training Tool shall be finalised in September 2008 and distributed to selected partners for testing and reviewing. The feedback from end users will then contribute to complement and update the seven modules with specific exercises, case studies and other missing topics. Sandec hopes that this tool will create improved preconditions for enhanced capacity development in the sector.

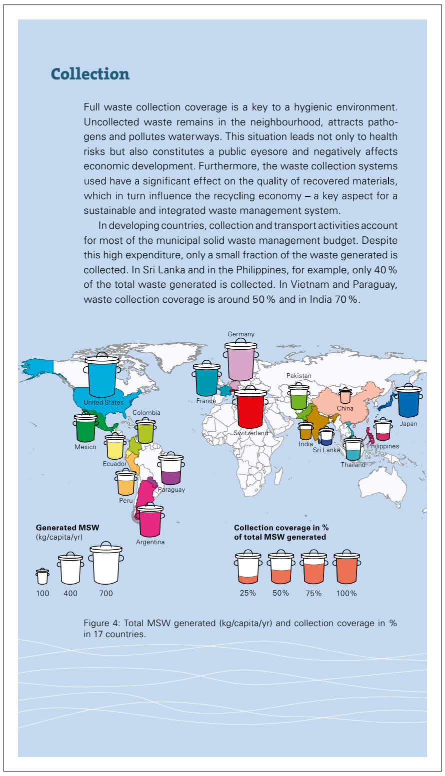
New Booklet on Global Waste Challenge

Management of Municipal Solid Waste is one of the major challenges worldwide. Inadequate collection, recycling or treatment and uncontrolled disposal of waste in dumps lead to severe hazards, such as health risks and environmental pollution. This situation is especially serious in low and middle-income countries.

This booklet aims at raising the awareness of the appalling situation related to Municipal Solid Waste Management in developing countries. Data on MSW reveals the differences between high-income countries and the developing world. We believe that bilateral and multilateral development cooperation has an important role to play, as it can catalyse solid waste management efforts if treated on a higher priority level.

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





Collection

Full waste collection coverage is a key to a hygienic environment. Uncollected waste remains in the neighbourhood, attracts pathogens and pollutes waterways. This situation leads not only to health risks but also constitutes a public eyesore and negatively affects economic development. Furthermore, the waste collection systems used have a significant effect on the quality of recovered materials, which in turn influence the recycling economy – a key aspect for a sustainable and integrated waste management system.

In developing countries, collection and transport activities account for most of the municipal solid waste management budget. Despite this high expenditure, only a small fraction of the waste generated is collected. In Sri Lanka and in the Philippines, for example, only 40 % of the total waste generated is collected. In Vietnam and Paraguay, waste collection coverage is around 50 % and in India 70 %.

Figure 4: Total MSW generated (kg/capita/yr) and collection coverage in % in 17 countries.

Compendium of Sanitation Systems and Technologies – Not Just Another Sanitation Book

For more than a year, the members of the Strategic Environmental Sanitation Group have been compiling, researching, writing, and designing a comprehensive handbook for sanitation professionals. In August 2008, the 'Compendium' will finally make its long awaited debut. Elizabeth Tilley

Every year, hundreds of publications on sanitation appear on the market. This time around, the International Year of Sanitation will see the Internet and the bookshelves crammed with even more literature on the latest membrane technologies in Switzerland, aquaculture projects in India and Ecosan projects in China. Not content to be left behind, Sandec is planning to launch a book of its own: the Compendium of Sanitation Systems and Technologies – but why will it be different?

Every day, Sandec has the opportunity to work with NGOs, regional engineers, city planners, and municipal officers who are tackling the massive problem of providing sanitation to the billions of people that are currently without. These professionals are, by and large, highly trained and have advanced degrees in engineering, planning or community development; they have sound technical backgrounds and working experience in industry or research. What they lack is not skill or dedication, but access to information and exposure to alternative or cutting-edge ideas. While most universities still only teach traditional sewer-based sanitation systems (regardless of their location), a growing movement recognises and understands the importance of technologies previously deemed 'non-technical', which are now regarded as appropriate, sustainable and urgently needed.

Unfortunately, with limited access to information, to the newest journal articles, to international conferences, where these technologies are presented, or even to highspeed Internet (where many reports are now published), the professional charged with the mammoth task of providing sanitation to their cities and countries, are severely limited in the variety and number of resources that they can access. Practitioners in the field have no need for another publication on sewers, but rather a publication that shows them all the options available, including sewers. This is what makes the "Compendium" different.

The goal of the Compendium is threefold: firstly, to expose the user to a broad range of sanitation systems and technologies that he/she may not have known about or may not have considered; secondly, to help the user understand how to link and choose different sanitation technologies, and finally, to describe and provide an unbiased view of the advantages and disadvantages of different technologies. Essentially, by bringing together the information contained in hundreds of publications, we can provide a brief, yet concise resource that can be used as an informed starting point for a more comprehensive approach to sanitation planning – something a sanitation textbook just cannot do.

As in all disciplines, there are schools of thought that differ both in their approach and their recommendations. The goal of this publication is to overcome ideological biases and present the advantages and disadvantages for each technology in the continuum from 'low-tech' to 'high-tech'. In this way, not only can users assess their options more fairly, but also select and combine different options from different 'schools' not usually thought to be compatible. For example, in one of our study sites in Costa Rica there is a dense informal settlement with small, poorly functioning septic tanks (a fairly standard, textbook derived technology). A standard approach to improve this situation would be to empty all the septic tanks in a massive but unsustainable government programme and hope they continue functioning for another year or two, or seal up the tanks and install expensive sewers that connect to the main sewer line: a service few can afford. It is this type of limited assessment of the classically available options and their often unattainable costs that causes hopelessness and prevents sanitation from being prioritised and realised in the communities that need it most.

Instead of conventional solutions, we hope to offer tools and resources to achieve environmental, operational and financial sustainability that meet local sanitation needs. One possible approach gleaned from Compendium System 7 (Simplified sewerage with semi-centralised treatment), would be to leave in place the overworked septic tanks, allow them to act as settling tanks to remove solids and then connect the tanks to low-cost, simplified sewers, which can be installed on the property (rather than under the streets). The sewers transfer the effluent to an engineered wetland for final treatment. Solids would be removed from the settling tanks with a locally operated pump and transport tank and co-treated with organic waste in a small co-composting facility. Combining standard with innovative technologies is beyond the scope of most design manuals. However, it is exactly this kind of modular planning and system development that the Compendium is meant to encourage.

The Compendium is 150 pages long and available for download from:
www.sandec.ch

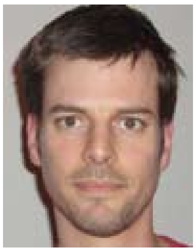
Requests for hard copies can be made by writing to caterina.dallatorre@eawag.ch

Sandec

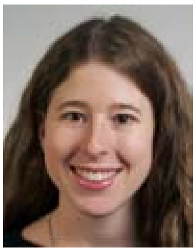
Finding the information they need when they need it: Project planners in Chamg'ombe, Tanzania.

New Faces

Marie-Madeleine Ngoutane Pare, Plant Biologist, started her PhD thesis with Sandec in 2007 on "Factors influencing the nutritive value of antelope grass (Echinochloa pyramidalis) grown on faecal sludge and wastewater in constructed wetlands". Mrs Ngoutane is currently enrolled at the Department of Plant Biology, University of Yaounde I, Cameroon under the co-supervision of Dr Doulaye Koné, Sandec and Prof. Amougou Akoa, University of Yaounde I.



Samuel Luzi, environmental scientist, joined the SODIS team in March 2008 after completing his PhD thesis at the Center for Security Studies, ETHZ, in the field of conflict and cooperation in transboundary river basins. He will be in charge of coordinating the SODIS projects funded by the SOLAQUA Foundation in Asia and Africa.



Monika Tobler, biologist, was appointed SODIS Project Officer in March 2008. After two years of employment with FAO in Burkina Faso, she is now responsible for several SODIS projects in Africa with special focus on East Africa.

Mingma Gyalzen, Sherpa, environmental scientist from Nepal, started his PhD thesis at the Asian Institute of Technology (AIT) in 2007 in collaboration with Sandec. His first contact with Eawag dates back to 2002 with the SODIS programme implemented in Nepal. For his Master's degree in Environmental Science at the UNESCO-IHE Institute for Water Education in Delft, The Netherlands, he once again collaborated with Sandec on the topic of faecal sludge management in the Kathmandu Valley. His PhD now focuses on the Household-Centred Environmental Sanitation Planning (HCES) process and its specific challenges and opportunities in the Nepalese context.

Atitaya Panuvatvanich, Thai PhD student from the Asian Institute of Technology (AIT) in Bangkok, Thailand, collaborated with Sandec on Faecal Sludge Management in January 2006. After working as Research Associate on a Decentralised Wastewater Treatment project (DEWAT) for two more years at AIT, she has now started a dissertation on the "Development of Nitrogen Transformation Model for Vertical-Flow Constructed Wetland Treating Faecal Sludge". Her PhD focuses on nitrogen transformation pathways and kinetics of nitrogen compounds, such as organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen in Vertical-Flow Constructed Wetland (VFCW) treating faecal sludge.

The Sandec Team

Sandec

Back from left to right: Mbaye Mbéguéré, Martin Wegelin, Doulaye Koné, Antoine Morel, Christoph Lüthi, Roland Schertenleib, Caterina Dalla Torre, Stefan Diener, Regula Meierhofer, Pierre-Henri Dodane, Monika Tobler, Kim Müller, Samuel Luzi, Dionys Forster
Front: Chris Zurbrügg, Yvonne Vögeli, Elizabeth Tilley, Valérie Cavin, Karin Güdel

Missing on photo: Benjamin Hemkendreis, Susanne Koller, Lars Osterwalder, Sylvie Peter, Melanie Savi

Associated doctoral students: Noah Adamtey, Horacio Chamizo, Marie-Madelaine Ngoutane, Atitaya Panuvatvanich, Yuttachai Sarathai, Mingma Sherpa, Narong Surinkul

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, solid waste management, urban agriculture, as well as excreta and wastewater management sectors.

Water and Sanitation

Liquid Gold: The Lore and Logic of Using Urine to Grow Plants
This book tells you how urine – which contains most of the nutrients in domestic wastewater and usually carries no disease risk – can be utilised as a resource.Liquid Gold features three ways to use urine hygienically and productively for plant growth, with studies that show the science behind this practice. Several advocates of urine diversion and their gardens are profiled, demonstrating that using urine as a fertiliser is a feasible, safe and cost-saving way to prevent pollution and save on fertiliser costs.
By Steinfeld D., 2005, 96 pages, ISBN 978-0-9666783-1-4. Available from http://www.ecowaters.org/products.html

Reusing the Resource: Adventures in Ecological Wastewater Recycling
Imagine a future in which gardens, greenhouses and groves of trees replace sewage outfall pipes and leaching fields. Sewage will grow ecological tree plantations that provide fuel, fibre, construction materials, wildlife habitat, and beautiful landscapes. A pig farm's wastewater will fertilise a tree farm instead of pollute a river. A house's wastewater will irrigate and fertilise its surrounding landscape. A planted roof will collect and filter rainwater for use in the house.
By Steinfeld C. and Del Porto D., 2007, 124 pages, published with UNICEF, ISBN 0-9666783-2-X. Available from http://www.ecowaters.org/products.html

The Last Taboo – Opening the Door on the Global Sanitation Crisis
This book is highly readable, exhaustively informative, and will be of considerable help to those trying to adapt and redesign toilet technologies for local conditions. Its multifaceted approach has important implications for attaining the Millennium Development Goal for sanitation.
By Black M. and Fawcett B., 2008, 272 pages, ISBN 9781844075447 (paperback), ISBN 9781844075430 (hardback). Available from http://www.earthcan.co.uk/?tabid=1494

Solid Waste Management

Improving Municipal Solid Waste Management in India – A Sourcebook for Policy Makers and Practitioners
Though this book is about SWM in India, we expect that its content will also help local governments throughout the developing world to plan and implement sustainable solutions to the waste management challenge. The publication was prepared by the World Bank Institute, Infrastructure Professionals Enterprise, Centre for Environment Education and by Eawag/Sandec.
By Zhu D., Asnani P.U., Zurbrügg C., Anapolsky S., Mani S., 2008, 176 pages, ISBN 978-0-8213-7361-3. Available from http://findarticles.com

Management of Solid Wastes in Developing Countries
This book is a collection of selected articles on key issues of proper management of solid waste. It shows "state-of-the-art and perspectives" as well as best practices of waste management topics of technical, economic, social, and institutional nature. The publication has been prepared by the International Waste Working Group (IWWG).
By Diaz L.F., Eggerth L.L., Savage G.M., 2007, 430 pages, ISBN 978-88-6265-000-7. Available from http://www.cisapublisher.com

Solid Waste Management and the Millennium Development Goals
This booklet is the third in a series published by the CWG (Collaborative Working Group on Solid Waste Management in Low and Middle-Income Countries). The CWG is concerned to spread information that will help to improve standards of solid waste management using publications, workshops and other means.
By Gonzenbach B. and Coad A., 2007, 34 pages, ISBN 3-908156-11-4. Available from http://www.cwgnet.net/

Urban Agriculture

Profitability and Sustainability of Urban and Peri-urban Agriculture
The challenge is for urban agriculture (UA) to become part of sustainable urban development and to be valued as a social, economic and environmental benefit rather than a liability. This paper aims at providing pertinent information on profitability and sustainability of UA to a wide audience of managers and policy-makers from municipalities, ministries of agriculture, local government, non-governmental organisations (NGOs), donor organisations, and university research institutions. It aims at highlighting the benefits of linkages between agriculture and the urban environment, leading to a more balanced understanding of the conflicts and synergies. It examines how UA can contribute substantially to the Millennium Development Goals (MDGs), particularly in reducing urban poverty and hunger (MDG 1) and ensuring environmental sustainability (MDG 7).
By van Veenhuizen R. and Danso G., 2007, 95 pages, FAO. Available as pdf from http://www.ruaf.org/files/2838.pdf

Irrigated Urban Vegetable Production in Ghana: Characteristics Benefits and Risks
More than 200 000 urban dwellers eat exotic vegetables daily on Accra's streets and in canteens and restaurants. Most of the perishable vegetables are produced on open spaces in the cities or their fringes due to insufficient cold transport and storage. This activity is highly profitable and can lift vulnerable groups out of poverty. It can also contribute to flood control, land reclamation and city greening. However, poor farmers have increasing problems finding in and around the cities unpolluted water sources for irrigation. This book gives a comprehensive overview of urban and peri-urban vegetable farming in Ghana's major cities, with a special focus on "wastewater" use. It ends with recommendations on how in a low-income country like Ghana health risks for consumers could be effectively reduced, while simultaneously supporting the important contribution of open-space urban and peri-urban agriculture. The book highlights further research needs and will serve students, the academia and decision-makers as an important resource.
By Obuobie E. et al., 2006, IWMI-RUAF-CPWF, 150 pages, ISBN 92-9090-628-6. Available from http://www.ruaf.org/node/1046

Excreta and Wastewater Management

Towards an Improved Faecal Sludge Management (FSM)
Proceedings of the 1st International Symposium and Workshop on Faecal Sludge Management Policy held in Dakar, Senegal from 9–12 May 2006. The goals of the Symposium comprised the identification of key issues and challenges in FSM, discussion of effective policies and approaches as well as the development of concrete steps for sustainable FSM improvement. A French version entitled **"Vers une Gestion Améliorée des Boues de Vidange (GBV)"** with all the relevant documents and presentations is also available both as download or CD.
Contacts: Koné, D. and Saywell D., May 2006, 32 pages. Both versions available from http://www.sandec.ch/