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Looking beyond Technology: An Integrated Approach to Water, Sanitation and Hygiene in Low Income Countries

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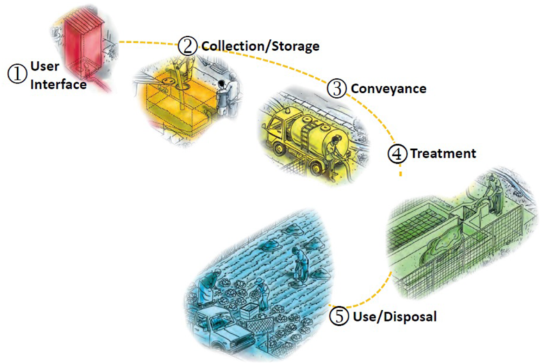

Despite investment stimulated by the Millennium Development Goals (MDGs), sanitation-related diseases, such as diarrhea, cholera and typhus, remain a leading cause of death of children under five in low-income countries. Prevention of diarrhea requires a combination of access to safe drinking water, good hygiene and adequate sanitation. The sanitation problem has proven to be particularly intractable, demonstrating the shortcomings of past efforts that have focused on increasing access to toilets. An alternative view positions the toilet within a service chain that extends to the final point of disposal or end-use of excreta-derived products. An integrated perspective that addresses improved planning, takes advantage of economic opportunities, incorporates specialized technology, and follows-up with behavior change could help to ensure not only access but also sustainable use, operation and maintenance of water, sanitation and hygiene interventions.

INTRODUCTION

The challenge of reducing mortality and morbidity associated with endemic diseases, such as malaria, tuberculosis and HIV/AIDS, in low-income (i.e., developing) countries is widely recognized. Significant effort and indeed progress have been made in combating these diseases.[1] In 2010, however, diarrhea and related diseases such as cholera and typhus still accounted for 10% of all childhood deaths on a global basis, which was nearly the same as malaria, measles and AIDS combined.[2] Diarrhea-induced loss of vitamins and nutrients can lead to malnutrition, leaving children in a weakened state and at risk of further infection and stunted development.[3−6] Progress has been made in combatting diarrheal disease, but it persists as a significant contributor to childhood mortality despite simple and widely available treatments and preventative technologies.[5,7,8]

Diarrhea is the result of exposure to pathogens that are transmitted via environmental exposure and poor hygiene.[8] A lack of household-level toilet facilities, inadequate treatment of human excreta, poor hygienic practices and lack of access to safe water contribute directly to the incidence of diarrhea. As shown in Figure 1, many pathways can contribute to the transmission of diarrheal disease. Measures such as the provision of safe drinking water that address only a single pathway may result in limited improvement in health outcomes. Perverse outcomes, such as an increased amount of untreated wastewater in the immediate environment, may also result when water supply to the household is increased without a concurrent improvement in sanitation. Thus, while it is commendable that the target for access to safe drinking water in the Millennium Development Goals (MDG) has been met, the benefits associated with this may be compromised by the anticipated failure to meet the sanitation goal to "halve, by 2015, the proportion of the population without sustainable access to. . .basic sanitation". Over one billion people still lack access to adequate sanitation and alternatives to open defecation.[9] This situation highlights the need for a more comprehensive and contextualized approach that moves beyond providing toilets.

International discussion is now ongoing to elaborate the post-2015 Sustainable Development Goals, which will be submitted to the General Assembly of the United Nations (UN) in September 2014. The working document for the UN Open Working Group (OWG) defines a focus area on "Water and Sanitation", which includes an explicit reference to hygiene.[10] The inclusion of hygiene addresses a key gap in the MDGs and targets important hand-to-food and hand-to-mouth pathways for disease transmission (Figure 1). In addition, the issue of sustainable provision of water and sanitation services is emphasized in a set of recommendations based on international consultations.[11] This emphasis on sustainability and the explicit recognition of the role of the private sector reflect the lesson learned that installing water supply, water treatment and sanitation technologies does not ensure their maintenance and use.[12] Failures have been attributed to inadequate planning and financing as well as a lack of skilled operators and repair capacity.[13−15]

Clearly, there has been significant development since building and counting toilets and water pumps was the norm.

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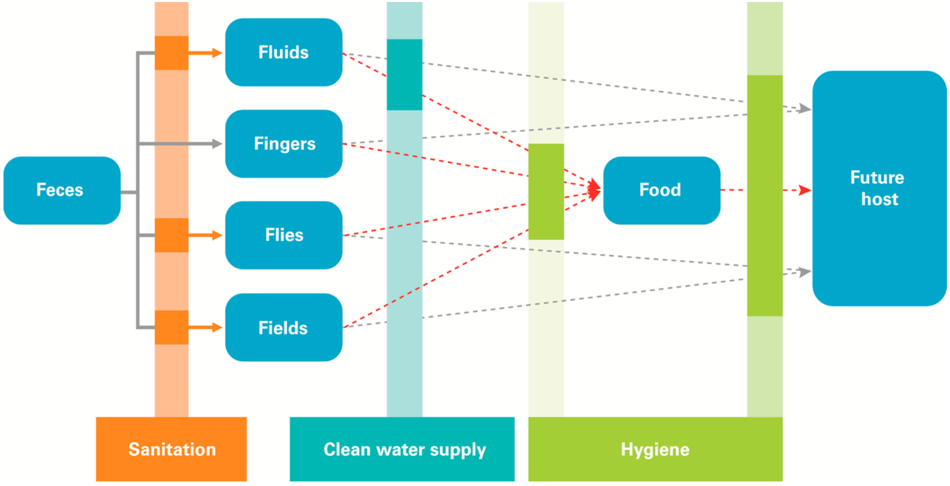

Figure 1. Pathways of disease transmission and possible interventions (often referred to as the "F diagram"). Note that "fluids" refers mainly to drinking water but can include other contact with surface water (e.g., through washing or bathing). "Fields" can include surfaces inside as well as outside the home. Modified from the Web site http://water.worldbank.org/shw-resource-guide/sanitation-and-hygiene-why-they-matter.

There is now increased recognition of the interconnectedness of water, sanitation, and hygiene (WaSH) as well as of the overlapping goals of human and environmental health. To increase access to sustainable sanitation, however, a more integrated approach is still needed. In this article, we highlight four key aspects that have been developed and used successfully (albeit mostly separately) to address WaSH challenges. We argue here for their joint recognition and implementation. Specifically, we examine the roles of planning, economic opportunities, specialized technology, and behavior change both to highlight the far-reaching efforts that are currently underway and to encourage a broader dialogue in the WaSH sector in order to achieve greater success in post-MDG efforts.

AN INTEGRATED PERSPECTIVE FOR WATER, SANITATION AND HYGIENE

Adequate technologies are indisputably a core element of meeting needs in the WaSH sector. The emphasis on access in the MDGs had the tendency to focus efforts on improving the design and dissemination of technology and, specifically for sanitation, on lowering the costs of toilet construction and providing access to toilets for more people (e.g., through subsidies).[16] The integrated perspective that we promote here extends beyond a focus on technology and is intended to meet the goals of achieving sustainable service provision and of exploiting synergies between WaSH efforts, the improvement of livelihoods and environmental protection.

This integrated perspective incorporates four aspects, the first of which is an *enabling environment* that provides the societal framework conditions needed to support uptake and sustainable use of technologies; without this, the investment of resources is likely to be ineffective. An enabling environment includes political, legal, institutional, financial, educational, technical, and social conditions relevant to the type, scale and requirements of the technologies and/or practices to be implemented.[15,17] The second aspect of *economic opportunities and incentives*, which explicitly includes consideration of the service sector, creates conditions that can help to offset sanitation costs and reduce the uncontrolled discharge of excreta to the environment.[18] This and the third aspect, *technology beyond the toilet*, are based on an integrated chain of technologies that starts at the user interface (i.e., the toilet) and continues to the final point of disposal and/or end-use of excreta-derived products. In this context, technical gaps in that hinder safe disposal or resource recovery can be identified. Finally, the fourth aspect of *motivation and drivers of behavior change* is critical to sustainable use and maintenance.

In presenting this integrated perspective, we draw on examples that span the range of WaSH practices and technologies. A particular emphasis on sanitation reflects the intractability of this problem in low-income countries where the challenges include not only the lack of sewers and dependence on on-site technologies but also financial constraints and often fragile institutions.

The Enabling Environment. The concept of an enabling environment (developed in the context of planning processes) has six key elements: (1) government support (including political will), (2) the legal and regulatory framework, with appropriate standards and codes at national and municipal levels, (3) institutional arrangements that can support planned technological interventions, (4) effective local skills and capacity for sustainable use, operation and maintenance of the planned technologies, (5) financial arrangements that facilitate the mobilization of funds for implementation, and (6) socio-cultural acceptance such that prevailing attitudes are aligned (or at least not be fundamentally incompatible) with the technologies or practices to be implemented, which should be matched to the user's perceptions, preferences and level of commitment.[17]

Ideally, all elements of the enabling environment would be supportive of, consistent with or, at the least, amenable to the technologies to be implemented. One challenge in this regard is the need to legitimize and regularize informal, entrepreneurial businesses that play a key role in providing sanitation services, specifically in fecal sludge (FS) management. Entrepreneurs who empty and transport sludge are often harassed, denied permits, or banned from discharging sludge at treatment facilities, despite the essential nature of their role in the sanitation service chain.[19] Investment in the construction of FS treatment plants would be of little or no benefit if a legal framework is not in place that allows for FS collection and transport. Critical deficits in the enabling environment may lead to failures in implementation, use and operation as has been reported in many cases in the WaSH sector.[12−15]

Assessing the enabling environment requires multistakeholder participation; such participation in the decision-making and planning process has been recognized as a key factor in the ultimate success of sanitation systems.[20] Appropriate stakeholder engagement (beginning with an analysis to identify key stakeholders) is considered to be an indispensable component of the planning process.[21,22] Information is needed on who will be affected by a project and who could influence it, which individuals, groups or agencies will need to be involved and what capacity development required to support such involvement. Often, however, the individuals and/or groups that set priorities and make choices regarding sanitation technologies and systems are not those whose participation, either as users or service providers, will eventually determine the success of the system. This highlights the need to match participation to the level of the planned intervention. Participatory processes can also result in unintended domination of the discussion by community leaders or elites.[23] In the case of women, there has been a systematic failure to account for their differential access and influence in the decision-making process.[24,25] For informed choice to be the basis for decision-making, information on various approaches and technical alternatives must be made accessible.[26]

Legal and cultural contexts can have profound implications for the feasibility and acceptability of planned WaSH interventions. Increased attention to mapping and addressing barriers to interventions should help reduce costs and wasted time, promote sustainable use and operation and allow business opportunities to be exploited.

Economic Opportunities and Incentives. The consideration of the complete sanitation service chain (i.e., from the toilet as the user interface to the final point of discharge and/or end-use of excreta-derived end-products) allows the opportunities for economic gain to be identified and can also highlight where subsidies and financial incentives may still be needed. In the context of on-site sanitation facilities, emptying and transport are critical services, which are often provided by small-scale entrepreneurs.[27,28] Expanding entry into the service sector and better integrating current members will create conditions that can help to offset sanitation costs, generate employment and reduce the uncontrolled discharge of excreta to the environment.

It must be recognized that sustainable business models are challenging to put into practice and, given the lack of controls and appropriate incentives, there is always a possibility that sludge will be dumped indiscriminately rather than being discharged at a treatment or disposal facility (even where they exist).[29] A franchising model has been proposed as a way to provide institutional support for individual operators and improve efficiency and service reliability; this model has been successfully pilot tested for cleaning and maintenance of sanitation facilities in schools in the Eastern Cape province of South Africa.[30] Monitoring performance and ensuring timely payment are critical aspects of service provision that could benefit from increasingly accessible communication and information technologies, such as mobile phones.[31]

Recovering value from excreta has been identified as a possible means to improve livelihoods and/or to offset costs associated with sanitation systems.[27,32,33] For example, the use of urine-diverting dehydration toilets (UDDTs) could provide a concentrated source (i.e., urine) of the nutrients nitrogen (N) and phosphorus (P). One method to recover nutrients from urine (mainly P but also some fraction of N) is the precipitation of struvite ($NH_4MgPO_4{\cdot}6H_2O$). A study conducted in Nepal, however, indicated that partial nutrient recovery was unlikely to be able to cover the costs associated with urine collection and the purchase of magnesium salts required by the process.[34] Direct use of urine in agriculture is limited by the lack of awareness of the nutrient content of urine; in a study conducted in a rural area in South Africa, more participants in a survey believed that urine would kill plants than help them grow.[35] Concerns about odor and health risks were also expressed and would need to be addressed for this resource to be exploited, which would be particularly beneficial where fertilizers are not used. Even where fertilizers are used, some of the demand could be met by use of excreta-derived end-products; an analysis for rural households in China suggested that this could be about 15% of the fertilizer demand.[18]

Fecal sludge offers a wider range of potential end-products or end-uses including: combustion of dry sludge as fuel, generation of biogas from sludge by anaerobic digestion, use of protein from larvae growing on sludge in animal feed, use of dried sludge in building materials and use of treated sludge as a soil conditioner or organic fertilizer.[27,32] The technologies required to support these end-uses have different investment and operational costs; the end-products bring different returns in a variety of markets.[27] Each end-product and its associated technologies must be evaluated in local contexts (e.g., local sludge characteristics and markets)[32] to estimate its economic potential. Until now, none of the end-product revenues has proven to be sufficient even to recover investment and operational costs fully. A comparative study of sewer-based sanitation and FS management in Dakar indicated that, at present, almost no monetary benefits are derived from excreta-derived end-products there.[36]

Another economic aspect in sanitation provision is the use of financial incentives. Subsidies have been used to motivate toilet purchase and construction, but incentives directed toward increasing the use and maintenance of existing toilets are not commonly applied in sanitation programs. Conditional cash transfers have been shown to be an effective tool in promoting children's vaccination and school attendance,[37] which, like sanitation, are socially desirable but may be too costly or a low priority for poor households. Conditional cash transfers were pilot-tested in a study of UDDT use; cash incentives for delivering urine tanks to collection points were found to increase the use of toilets in households where they had already been installed.[38] Although the various costs (i.e., payment for collection) and benefits (i.e., increased toilet use and reduced urine discharge to the environment) are not yet fully quantified, the pilot study suggests that sanitation incentives could promote positive outcomes for the environment, health and productivity.

Ultimately, multiple benefits (including the improvement of both service levels and employment opportunities) could be realized by uniting relevant stakeholders in the sanitation service chain. This will require a combination of efforts. For example, barriers to entering the sanitation service market could be reduced by providing loans or franchising opportunities and streamlining administrative processes. Financial incentives could promote sustainable operation and maintenance at both the household and centralized treatment level. Establishing viable service chains and especially realizing the potential of resource recovery will require that technology gaps are identified and filled.

Technology beyond the Toilet. Technology gaps in the sanitation chain from the toilet to the final point of disposal and/or end-use of excreta-derived end-products can be found at all stages: sludge collection and transport, sludge treatment and resource recovery. By filling these gaps, nutrients and other beneficial resources can be recovered, economic opportunities can be leveraged and environmental discharges can be minimized. Most importantly, effective barriers between humans and excreta can be ensured.

Effective resource recovery from excreta requires that toilet design, collection and transport, and treatment steps are appropriate for the intended end-use. For example, in the initial design of UDDTs installed in Durban (South Africa) by the eThekwini Water and Sanitation unit, urine was simply infiltrated into the ground adjacent to the toilets, since the main goal of urine diversion was to simplify the dehydration of feces.[39] Nutrient recovery from urine was only later identified as a way produce a valuable local fertilizer and reduce pollution of water resources.[40] Nutrient recovery, however, would require not only a cost-effective urine collection system but also a technical process that is more efficient than the demonstrated method of struvite precipitation. One approach (currently being tested in a field trial in South Africa)[40] for complete nutrient recovery is a combination of nitrification and distillation.[41] Biological nitrification can stabilize urine against N loss and control odors but requires careful monitoring of the process pH. Distillation is effective in reducing the volume of the stabilized urine and inactivating pathogens.

In the case of resource recovery from FS there are a number of technical challenges that need to be addressed. The variability of FS itself poses challenges for its treatment even when the treatment processes, such as drying beds, are well established. To address this, standardized methods of FS characterization are needed that can support process design and optimization. Sludge collection also poses a major challenge, particularly in dense settlements with narrow streets that are not accessible for vacuum trucks. Improved treatment technologies that are compatible with the desired end-uses are also needed. For example, methods of increasing FS drying rates so that it can be coincinerated as a dry fuel in industrial applications are being developed in Dakar and Kampala (Uganda).[42] With the growing recognition of the importance of FS management, substantial effort is being directed toward developing and implementing technologies that will address all stages of FS collection, transport and treatment.[43] Significant work remains, however, to optimize resource recovery and the protection of public health.

By moving beyond the toilet and directing increased funding and operational support to developing and scaling up WaSH technologies throughout the entire service chain, public and environmental health outcomes can be improved. The potential to recover water, nutrients, organic matter and energy can create perceived (and real) value for excreta and provide added incentives for sustainable operation.

Motivation and Drivers of Behavior Change. In the context of leveraging positive outcomes for human health, the environment and livelihoods, the motivations and drivers for using, purchasing and maintaining technologies are critical. It is important to understand how positive behavior change happens and can be sustained.

Motivation and behavior change must be considered at various points in WaSH interventions, from participation in planning to the use of a novel toilet and ultimately to the use of excreta-derived products, which involve various actors. For example, information about WaSH interventions provided by health professionals (who believe that health concerns motivate behavior) can fail to stimulate the intended response.[3] Beneficial health outcomes may, however, also be achieved even if they are not a conscious goal but essentially a byproduct of other motivations. Employment in the provision of WaSH services or products can improve livelihoods, incentivizing use of such services and products. Financial returns on excreta-derived end-products (e.g., the use of biogas from anaerobic digestion for cooking) may reduce the disincentives associated with a given technology and may actually generate dedicated use and commitment especially, in the biogas example, where fuel is expensive. In sub-Saharan Africa where poor soil fertility and the lack of access to fertilizers have been identified as major contributors to malnutrition,[44] the demonstrated efficacy of using locally produced fertilizer or urine directly as a fertilizer could not only increase crop yields and help to improve food security but also encourage more dedicated use and/or maintenance of sanitation facilities.[35]

Structured information on drivers of behavior change and habit formation can be useful in providing an evidentiary basis for psycho-social interventions. Factors contributing to behavior change have been identified in field applications of the RANAS (risk, attitudinal, normative, ability, and self-regulation) model.[45] In the case of a community fluoride filter in rural Ethiopia, a survey of socio-psychological factors influencing filter use and subsequent analysis of differences among users and nonusers supported an increase in consumption of the filtered water through persuasive arguments that changed price perception.[46] Increased use of fluoride-removing household filters was achieved when filter distribution was accompanied by a psycho-social intervention.[47] The RANAS model has also been used to identify psychological factors (i.e., the importance of using a clean toilet, the effort involved in cleaning the toilet, the disgust felt from using a dirty toilet and cleaning habits) that determined participation in the cleaning of shared toilets in Kampalan slums in Uganda[48] and has provided a basis for interpreting the effectiveness of a variety of interventions intended to promote hand-washing after the 2010 earthquake in Haiti.[49]

Changing individual attitudes toward sanitation through intervention at the community level is the cornerstone of community led total sanitation (CLTS), which has focused on eliminating open defecation with considerable success in rural settings.[50] Criticisms have been levied, however, that practices endorsed by CLTS infringe human rights by using social stigma to promote behavior change and may result in serious breaches of ethics.[51] Issues with the sustainability of CLTS programs have also been raised.[52] Nonetheless, CLTS provided the ground-breaking understanding that community norms and motivations such as prestige can be more effective in driving behavior change than health messages.

Acceptance of any technology or practice is inherently contextual and not necessarily guaranteed. For example, waterless technologies based on separation and dehydration have ecological benefits, including reducing demand on often-scarce water resources, but they may not meet cultural expectations in communities that use water for anal cleansing. Care must be taken during the planning phase to ensure that any requisite behavior change would be possible at a later stage and that acceptance will not be limited by deeply held social or cultural beliefs. In addition, the motivation to use WaSH technologies or practices consistently will be critical to their success over the long-term.

NO "ONE-SIZE FITS ALL" SOLUTION

It is abundantly clear that there is no "one-size fits all" solution for ensuring universal adequate hygiene and sanitation. The appropriateness of any WaSH intervention, including technologies and service chains, must be evaluated with attention to the intended and actual beneficiaries, including direct users of the sanitation systems, service providers who benefit from business opportunities and producers or users of excreta-derived end-products. An overemphasis on technology and the even more narrow focus on the toilet at the expense of "downstream" technologies are likely to result in the neglect of other factors that can be critical to the success or failure of WaSH interventions. These pitfalls may be avoided by explicitly considering the enabling environment at early stages in sanitation planning, taking advantage of a range of financial opportunities and instruments, including a full sequence of technologies that address each step of the service chain and target resource recovery and considering behavior and acceptance at both the individual and community level.

With the MDG period drawing to a close, WaSH remains a challenge for the SDGs. As discussed here, there are many methods, technologies, and concepts that have been used to address WaSH deficits with partial success. An integrated approach that recognizes the legal, financial, social and technical opportunities as well as the challenges that persist could be instrumental in making further progress toward universal access to water and sanitation as proposed by the UN High Level Panel.[1]

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Notes

The authors declare no competing financial interest.

Biography

All of the authors are current members or, in the case of Elizabeth Tilley, a former member of the research staff at the Swiss Federal Institute of Aquatic Science and Technology (Eawag). Elizabeth Tilley is completing her Ph.D. at the Swiss Federal Institute of Technology (ETH) Zürich in the Department of Humanities, Social and Political Sciences. Christoph Lüethi, Ph.D., and Linda Strande, Ph.D., work in Eawag's Department of Water and Sanitation in Developing Countries (Sandec). Their research focuses on sanitation planning and sludge management. Hans-Joachim Mosler, Ph.D., and Heiko Gebauer, Ph.D., work in the Department of Environmental Social Sciences focusing on environmental and health psychology and business innovation. Kai Udert, Ph.D. works in the Department of Process Engineering specializing in decentralized treatment processes. Janet Hering, Ph.D., is the Director of Eawag and a professor at the Swiss Federal Institutes of Technology in both Zürich and Lausanne. Her research interests include the biogeochemical cycling of trace elements in natural waters, water treatment technologies for the removal of inorganic contaminants from drinking water, and the management of water resources and water infrastructure.

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