The Bill & Melinda Gates foundation

Landscaping of Technologies

An output of the project *"Landscaping and Review of Approaches and Technologies for Water, Sanitation and Hygiene: Opportunities for Action"*

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This document should be read alongside the three outputs of the Project entitled:

"Landscaping & Review of Approaches and Technologies for Water, Sanitation and Hygiene: Opportunities for Action"

Commissioned by the Bill & Melinda Gates foundation and prepared by a Consortium of Cranfield University, IRC (Delft) and Aguaconsult.

The other outputs are as follows:

The main Landscaping and Review Report

Landscaping of Approaches

Landscaping of Technologies (this document)

Disclaimer

The views expressed in this document are those of Cranfield University, Aguaconsult Ltd., and the International Water and Sanitation Centre (IRC), and may not reflect the views of the Bill & Melinda Gates Foundation.

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Executive Summary

This landscaping document was prepared as part of a broader review of the water, sanitation and hygiene (WS&H) sector commissioned by the Bill & Melinda Gates foundation (the foundation). This is a supporting document to the main report, which provides an overview of *technologies* that have been employed in the delivery of water, sanitation and hygiene services. The document provides a framework for assessing and appraising technologies and explores the reasons for the past take up, or failure, taking into account requirements for management, operation and maintenance. It provides a number of recommendations as to the most promising technologies and areas where further research and development may be required.

Key Findings

The landscaping of technologies, or landscaping, shows that technological solutions are available to satisfy virtually any requirement within the WS&H sector, but, very importantly, such technologies cannot and must not be considered in isolation. Full consideration must be given to the local social, political, economic, institutional and environmental contexts in which they are intended to function. Technology interventions are very unlikely to succeed on a scalable and sustainable basis without full local social, political, and economic 'ownership'.

Furthermore, it is becoming increasingly well-understood that in order to have any chance of success, technology interventions must consist of carefully considered combinations of 'software' (approaches) and 'hardware' (the technologies themselves). Implicit within this trend is the realisation that technologies should ideally be demand-driven, and that such demand for specific technologies can only be stimulated by using the most current thinking in terms of approaches, for example through social marketing or the development of entrepreneurial capacities (see the approaches landscape document).

The above statement might appear to imply that a technology is almost less important than the approaches with which it is combined, and this is to a great extent true. We certainly do not believe that technology development should be an exclusive priority for investment, but that does not necessarily mean that new or existing technologies should not be developed or improved at all.

Experience has frequently proven that, in general, any technology developed for use within the sector should be appropriate: it should have technical simplicity, ease of use, be of low - or very low - cost, low energy usage, low maintenance, minimum or zero consumables, good reliability, and be very robust. This in turn implies that sophisticated technologies would be best avoided.

However, there is still clearly a case for improving and developing more sophisticated technologies which may be able to lead to a radical step-change in impacts and scale. The most important learning point is that we must avoid any temptation to believe that (sophisticated) technologies can be developed into 'silver bullets' that will resolve the complex nature of challenges facing the sector.

A case in point is the current preoccupation with nano-technology in the industrialised world. For example, consider membrane technology. To be useful for water treatment, filtration membranes need to have sub-micron pore-sizes. These are commonly known as 'nano-membranes', and would certainly rank at present as 'sophisticated' technology. They are exciting, and many developers are working on blue-skies variations at lower cost and higher performance, but the reality is that it will take order of magnitude resources to bring such technologies to a point where they can comfortably be considered 'appropriate' for developing country contexts. The same could be said for many other sophisticated technologies.

….continued overleaf

Executive Summary
continued

Having said all of the above, we do believe that our work on assessing the technology landscape has flagged a small number of blue-skies technologies which, if developed, could make significant contributions in the longer-term. These received a short appraisal during the course of this project work, but would need much more in-depth appraisal for the purpose of determining the possible costs, risks, and rewards for the sector if attempts to bring them to the level of 'appropriate technology' were to be successful at scale.

The tables below and on the following page provide a summary of the most important conclusions and recommendations regarding the landscaping exercise for specific categories of technologies; a page number is provided for ease of reference to the location in the body of the report for further detail on the topic in question.

Executive Summary: Sector-wide Possible Key Initiatives and Leverages

Data Quality: There are huge shortcomings within the Sector concerning data collection, quality, updating, storage, and retrieval. The foundation could have a strong role in raising awareness of the importance of good quality data and information in the Sector, and its unique influence could leverage further international support.	*p18* *p25*
Technology Definitions: The whole area of Technology Definition could well benefit from an initiative aimed at producing an expanded and more precise range of definitions that would be helpful in the context of technology and intervention evaluation in the Sector in general.	*p21*
Global Tracking and appraisal of technology developments: In the medium to long term it could clearly be of advantage to the Sector if an entity or mechanism could be set up to identify and monitor technology improvements and new technology developments occurring around the world. This would be a big initiative to undertake, but significant leveraging should be possible through other international entities.	*p22*
Global tracking of research and funding co-ordination: In the medium to long term it could also clearly be of advantage to the Sector if an entity or mechanism could be set up to monitor relevant research projects occurring around the world, and co-ordinate and arrange funding, ideally linked into the entity proposed above for global tracking of technology development. Implicit in this initiative is the idea that research and development activities could be better matched to the needs of the Sector, as stated in the Approaches Landscape document.	*p22*

Executive Summary
continued

Executive Summary: Technology-related Possible Key Initiatives and Leverages

Water Resources: See 'data quality', as listed in the table of sector-wide Initiatives above.	*p18* *p25*
Water Sources: Roofwater harvesting technologies and very low-cost water-well drilling technologies should be further investigated/developed, with potential leverage focused around entrepreneurial and commercial activity.	*p26*
Water Lifting & Carrying: There should be a renewed focus on handpumps, and on reducing the high cost of community solar pumping, and a focus on new water-carrying technologies, leveraging the adaptation of developed-world backpacking/camping/military technologies to the needs of women in the developing world.	*p27*
Water Storage: Focus should centre on improving cost, durability, and health protection for in-house storage (at present in earthenware jars, buckets, plastic jerry cans) up to approximately 100 litres capacity, and household (external) water storage (for rainwater or piped water constructed from high density polyethylene, brick or stone masonry, or ferrocement) up to approximately 10,000 litres capacity.	*p28*
Water Delivery: Big impact in towns and cities could be achieved by improving low-cost and accurate water metering thereby making revenue collection fairer for both poor and wealthy users. Technology development in piped water supply systems (towns and cities) should focus on leakage detection and control.	*p29*
Water Treatment: Interventions by the foundation to strengthen user awareness and demand, to create incentives for entrepreneurial activity, and to promote training and institutional and policy reform, will all help to create investment in technologies to improve water quality.	*p32*
Excreta Disposal: Low-cost pit latrines with 'non-stick' pans coated with, for example, Teflon to improve cleanability would be worth developing as an alternative to concrete slabs. Refocusing on achieving cheaper Ecosan construction, together with Interventions to change social attitudes to handling and use of faeces, will promote local entrepreneurial composting and emptying activity. Further promotion and cost-reduction is needed in the various methods of emptying or moving pit latrines. A change of attitude is needed amongst policy makers and engineers to allow use of on-site facilities in urban areas. Affordability must be linked to ability to pay: women and girls want better facilities but lack ability to pay. Support for the development of promising blue-skies enzyme combinations technology could significantly reduce the frequency of latrine emptying. There is no "one-size-fits-all" solution. Cross-subsidy will probably be needed.	*p36*
Wastewater & Stormwater Disposal: Attempts at leveraging should focus around combinations of re-use of wastewater, open-drains, latrine emptying, and composting, aimed at creating entrepreneurial activity supported by local authority, and at overcoming social despondency, taboos, and strong lack of financial resources.	*p38*
Solid Waste Disposal: Interventions should focus on creating a financial and social environment for self-sustaining recycle and compost entrepreneurs, and engendering social acceptability of such enterprises.	*p40*
Personal & Household Hygiene: Demand creation for personal and household hygiene products could leverage small-scale private commercial supply of products. Encouragement of wholesalers/retailers to package products in small quantities could enable increased uptake, even where unit costs cannot be significantly reduced.	*p42*
Hygiene Behaviour Change: Foundation investment in technologies for hygiene promotion could leverage funds from electronic and media equipment producers, if there were sufficient publicity incentives for them.	*p43*

1. Overview

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1. Overview

1.1 Overview Summary

Section 1 - Overview *page 7*

This Section gives the reader a brief explanation of process and logic used in the preparation of this document. It leads into a quick reference summary of the resulting structure (see last box on this page).

Section 2 - Contextual Technology Issues *page 19*

This Section discusses several very important contextual technology issues which exert a considerable influence over the technology landscape:

- the risks of considering technologies in isolation of context;
- the importance of allying technologies with approaches;
- affordability;
- availability, innovation, and local manufacture;
- how interventions can cause a one-time change from self-reliance to interdependence;
- how user unfamiliarity is a challenge to technology designers;
- the importance of specifying appropriate technology.

Section 3 - Sector-wide Technology Issues and Potential Initiatives *page 13*

This Section details issues which affect the whole Sector, and suggests Sector-wide initiatives which could greatly improve selection and deployment of interventions.

- the shortcomings in data collection, quality, and dissemination within the Sector;
- the need for a set of more precise Technology Definitions;
- risks;
- the potential advantages of setting up an entity to monitor relevant technology development;
- the potential advantages of setting up an entity to co-ordinate relevant academic research.

Section 4 - Landscape Assessment Summary *page 24*

Section 4 forms the main part of this document. There are 5 Broad Functional Categories, sub-divided into 11 Technology Categories, which are reported in terms of:

- proven technologies;
- emerging technologies;
- blue-skies technologies;
- constraints to uptake;
- possible key initiatives and leverages.

Section 5 - Annexes *page 44*

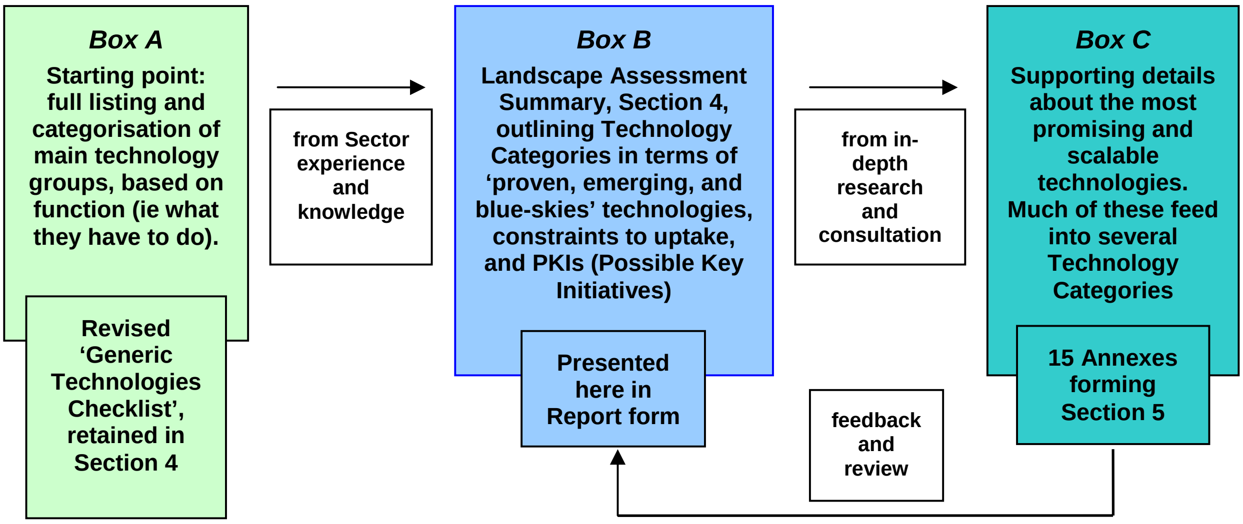
Section 5 consists of the 15 Annexes written in greater detail in support of the 11 Technology Categories summarised in Section 4.

NOTE:

1. The process used in arriving at the contents of Sections 3 and 4 is explained in detail on the next page (Section 1.2).
2. For quick reference, the contents of Sections 3 and 4 are shown in tabular form on page 10 (Section 1.3).

1.2 Process, Logic, Structure

Technology Landscaping has broadly followed the process as shown schematically below:



As shown in Box A above, the process of drafting this document started with a full and raw listing of all relevant technologies in terms of generic function, rather than in terms of specific commercial makes and models. This was to avoid creating a huge list running to many hundreds or even thousands of individual technologies, which would not have been susceptible to meaningful analysis in a project of such short duration.

The list was then refined and allocated into the five ‘broad functional categories’, with these then sub-divided into the eleven ‘technology categories’, as detailed visually for quick reference in the table on the next page (Section 1.3). As shown in Box B above, the landscape assessment summary was then drafted, based on professional experience in the sector.

The list has been retained as the ‘generic technologies checklist’ with all of the technologies grouped in the relevant technology category in text boxes on the right hand side of the pages of the landscape assessment summary, in order to ensure that no significant area of technical intervention has been missed.

Detailed analysis (Box C) then followed which, together with intra-team discussion and workshops, that included sector practitioners from around the world, produced insights that have been fed back into the Landscape Assessment Summary (Box B), in a continuous refinement and validation process. The relationship between Boxes B & C above has therefore been iterative.

1.3 Structure of Sections 4 & 5

As mentioned in the previous two sections, the landscape assessment has been based on:

- **5 broad functional technology categories**, sub-divided into
- **11 technology categories**, supported by
- **15 annexes**

Section 4 ***Landscape Assessment Summary***			***Section 5*** ***Annexes***	
5 Broad Functional Categories	***11 Technology Categories***		***15 Annex Topics***	
Water Resources	**4.1** *p24*	Water Resources Assessment	**5.1** *p45*	Data collection, handling, storage, access
Water Supply	**4.2** *p26*	Water Source Works	**5.2** *p50*	Groundwater source construction
	4.3 *p27*	Water Carrying & Lifting	**5.3** *p55*	Handpump technology
			5.4 *p59*	Solar water pumping
			5.5 *p64*	Household water carrying
	4.4 *p28*	Water Storage	**5.6** *p69*	Rainwater storage
	4.5 *p29*	Water Delivery	**5.7** *p74*	Urban water supply technologies
Water Treatment	**4.6** *p30*	Water Treatment	**5.8** *p80*	Household water treatment
			5.9 *p90*	Community-level water treatment
Sanitation	**4.7** *p33*	Excreta Disposal	**5.10** *p98*	Improved on-site sanitation technologies
			5.11 *p102*	School-friendly sanitation
			5.12 *p106*	Latrine Emptying
			5.13 *p109*	Bio-additives
	4.8 *p37*	Wastewater, Stormwater Disposal		See Section 3.8 Assessment
	4.9 *p39*	Solid Waste Disposal		See Section 3.9 Assessment
Hygiene	**4.10** *p41*	Personal & Household Hygiene	**5.14** *p115*	Hygiene hardware
	4.11 *p43*	Hygiene Behaviour Change	**5.15** *p120*	Hygiene promotion tools

NOTE:

Certain Annexes may relate to several technology categories: for example, Annex 5.11 'School-friendly sanitation' contains material relating to 4.7 'Excreta Disposal', 4.10 'Personal & Household Hygiene', and 4.11 'Hygiene Behaviour Change.

1.4 Annex Summaries

The Table gives summaries of the 15 annexes that have been written for the 11 technology categories.

It could in theory be useful to be able to quote the scale of applicability and/or numbers of served for each of the technology categories, but we believe that this to could lead to very risky assumptions. This issue is discussed in more detail in Section 3.1 (page 18).

Technology Category	***Annex Topics***	**Ref**	***Summary of Annexes Contents***
Water Resource Assessment	**Data collection, handling, storage, and access**	**5.1** *p45*	Data on water resources, water point locations, water supply and sanitation system functionality, hygiene practices, and many other aspects of WS&H is sorely lacking and badly needed. Monitoring is generally under-valued and under-funded. Technologies for monitoring rainfall, river and lake levels, groundwater levels, and water quality are generally very old-fashioned and dependent on unmotivated human operators. Modern computer software (GPS, GIS), communications and information technologies are rarely used. Community level monitoring tools are hardly developed.
Water Source	**Groundwater source construction**	**5.2** *p50*	As much as 50% of potable water supply globally is from groundwater. Groundwater supplies at least one third of the world's population, and is particularly important in rural environments and to serve small towns. Access to groundwater, especially in Africa, is very expensive, but solutions to this problem exist.
Water Lifting and Carrying	**Handpump technology**	**5.3** *p55*	In India alone there are estimated to be 3m handpumps. 1.3 billion people use handpumps worldwide. 500-750m people use open wells, which could be made safe by the use of a handpump. Even after decades of work, handpump selection, local manufacture, management and maintenance still pose major challenges.
Water Lifting and Carrying	**Solar water pumping**	**5.4** *p59*	Solar energy has obvious attractions, but the major drawback is the still very high capital cost. The major cause of high costs is the relatively low efficiency of photovoltaic cells in converting solar to electrical energy. Nevertheless, solar systems are being used in some developing country situations with success.
Water Lifting and Carrying	**Household water carrying**	**5.5** *64*	Approximately 2.3bn people get their water from an unimproved source (the 1.1bn unserved) or from a communal improved source at some distance from their home (1.2bn). All these people have to carry water home on head or back, and many will have to do so for the forseeable future. The task of water carrying falls in particular to women and children, who literally shoulder the burden on behalf of the total numbers just mentioned. Technologies exist and could be further developed to alleviate this burden, even while the main emphasis of water supply improvement should rightly lie in improved access to sufficient quantities of safe water.
Water Storage	**Rainwater storage**	**5.6** *p69*	Where rainwater harvesting is not already used, meaning long journeys to unimproved/improved water sources, water storage could make a vast difference at a time of year when rural people are especially busy and especially hungry. It is estimated that 450-630m could benefit significantly from these technologies, especially if water storage costs were to be substantially reduced.
Water Delivery	**Urban water supply technologies**	**5.7** *p74*	Construction of water supply systems in urban slums is impracticably expensive if conventional industrialised country engineering "standards" are followed. Alternatives exist, including over ground pipe systems and inexpensive technologies for accurate metering of piped water supply, permitting wider access to piped supplies and more effective and fairer revenue collection.

Water Treatment	**Household water treatment**	**5.8** *p80*	In communal water supply systems water is often re-contaminated between source and point of use. In small communities lack of economy of scale may stop the use of community-level water treatment facilities. In other situations water quality may still be poor even after treatment by a utility. In such cases household level (point-of-use) water treatment may be attractive to users.
Water Treatment	**Community-level water treatment**	**5.9** *p90*	Water treatment cannot and should not always be carried out at household level. In larger rural communities, small towns, and cities, economies of scale and management dictate the use of technologies and processes which are designed to deliver potable water to whole communities or populations.
Water Treatment	**Water treatment for arsenic, fluoride and iron**	**5.8** *p80* **5.9** *p90*	In Bangladesh alone 46-57m people may be at risk from arsenic levels above the WHO guideline limit of 0.01mg/l (BGS, 2000). UNICEF estimate that "tens of millions" in 25 countries are at risk from high fluoride levels. Perhaps one third of all groundwater sources have iron contents which cause taste or staining problems, which may cause users to reject otherwise good quality sources.
Excreta Disposal	**Improved on-site sanitation technologies**	**5.10** *p98*	Existing technologies for the disposal of human excreta on-site (ie not involving conveyance of excreta off-site) suffer from a number of drawbacks. They can be smelly, difficult to keep clean, attractive to flies, and require periodic emptying. Moreover the nutrient-rich material is rarely used for productive purposes, so missing income generating opportunities. Latrine slabs, pour-flush bowls, latrine superstructures, and designs of composting (Ecosan) latrines could all be improved, to the benefit of many of the 2.6bn unserved as well as many of the "served" currently using inferior technologies.
Excreta Disposal	**School-friendly sanitation**	**5.11** *p102*	Improvements to sanitation designs have been limited. Child-friendly sanitation designs have been even more limited (ie appropriately scaled, avoiding darkness, removing sense of danger and unpleasantness). A particular sanitation/hygiene issue is that of the provision of facilities for private and dignified menstrual management for girls of school age. Without such facilities, girls miss out on much schooling, to the detriment of their own lives, and of development in general.
Excreta Disposal	**Latrine emptying**	**5.12** *p106*	The 1bn people living in urban slums who would benefit from on-site sanitation solutions also need access to pit emptying services. In rural areas there may be possibilities to abandon pits once filled, and construct new latrines. This is not possible in urban areas, so pit latrine emptying is needed. Technologies exist, and with modification to local circumstances, and the right business models, pit emptying services could take off.
Excreta Disposal	**Bio-additives**	**5.13** *p109*	A range of micro-organisms (bacteria, fungi) exist which claim to accelerate the bio-degradation of pit latrine contents. Some (highly expensive) are used in the military context to degrade excreta. There are also promising blue-skies enzyme technologies which could solve the major problem of disposal of pit latrine contents, if they could be developed to the point at which they were highly effective. Pit emptying would no longer be needed, and pit latrines could remain in place semi-permanently.
Personal and Household Hygiene	**Hygiene hardware**	**5.14** *p115*	In order to put hygiene messages into practice simple low-cost devices are needed for dispensing handwashing water. Soap or alternatives must be available. Technologies such as dish drying racks, designs for bathing shelters and urinals are also needed.
Hygiene Behaviour Change	**Hygiene promotion tools**	**5.15** *p120*	Hygiene promotion is primarily a matter of approach, but a number of audio-visual tools, and devices for demonstrating key messages are necessary. Devices such as wind-up radios, robust TV, video, DVD technology, and germ visualisation technologies are of value.

2. Contextual Technology Issues

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2. Contextual Technology Issues

2.1 Importance of context

It cannot be repeated often enough that for an intervention to have a chance of sustainable impact at scale, technologies must be allied with approaches that are appropriate to the local culture and context. It is extremely difficult to quantify culture and context in a failsafe way, although many generalised models have been proposed. Each intervention must be considered on its own merit, with attention to the detail of local culture and social attitude, community 'ownership', local entrepreneurial activity, and local authority. Technologies must not be viewed as stand-alone, or blue-print, solutions to problems.

2.2 Combining Technologies with Approaches

In considering the wide range of technologies available to the WS&H sector, a number of broad groupings were identified as of special interest, either because of a particular R&D requirement (*e.g.* better fit to purpose, lower cost) or because of their potential to have significant and sustainable impact at scale.

One very important general caveat however is that we do not believe that the highest priority for investment should be on new technology development. In general adequate technologies do exist somewhere in the world for most of the important WS&H functions. If modified to local context, combined with appropriate approaches, and supported through attention to the key enabling factors (see Landscaping of Approaches document), much progress can be made in the sector with what we know already.

2.3 Affordability

Few technologies are universally applicable. Even technologies such as the bicycle, which are to be found in all countries, and ubiquitous goods and consumables such as jerry-cans and soap, are accessible to those above certain cash income levels, but not below. The 400 million chronically poor, and many of the additional 800 million on "less than $1 a day" (approximately 1.2 billion in total) enjoy very few "modern" technologies – *i.e.* artefacts made of plastics and metals. However, even though purchasing power may be very low, if items are packaged in small enough quantities, or if credit is made available, some of the poor can access such technologies. As well as being small, 'incomes' of the poorest are (a) often seasonal or very intermittent, and (b) not always readily convertible to cash.

2.4 *Availability, innovation, and local manufacture*

The promotion of public domain designs has to some extent constrained the development and deployment of commercial handpump models. From the point of view of the (mainly European) private sector, this has been disadvantageous. However, there is little doubt that the development of public domain designs has benefited developing countries, which have largely adopted such models as their national standards.

All technologies need maintenance, repair, spare parts, and eventually total replacement. In the case of public domain technologies such as slow-sand filtration (in which all components can be sourced locally) the possibility exists to manage the technology effectively (given the skills, incentives and conducive operating environment). However, if a low-income country is dependent on commercially manufactured and imported technology (anything from sachets of household water purification powder to sophisticated package plant for water treatment), and if supply chains fail (*e.g.* through adverse pricing or through the manufacturer going out of business), then the sustainability of the technology is threatened.

Developing countries vary in the level of their national manufacturing capabilities, and in their access to international markets for technology and investment financing. Many African countries have only rudimentary manufacturing capacity, and so they rely heavily on imports – of everything from pipes and pumps to chemicals and cement. Importation can itself be problematic because of duties and taxes, bureaucracy and corruption. Different sources of technology lead to multiple standards and specifications. Quality control of imported technology is often very poor. In contrast, some Asian countries, notably India and China, have burgeoning national manufacturing capability and far lower dependence on imported technology. Asia exports many water and sanitation technologies to Africa.

So far, there has been little in the way of promising local WS&H technology innovation in Africa, and the WS&H sector cannot effectively support the long-term development of generic science, technology and manufacturing capacity on its own. In Uganda, attempts were made some years ago to encourage local manufacture of the country's standard handpump. This was done through importation of below-ground components (from India), combined with local manufacture of the pump head. This arrangement continued for some time, until it was realised that importation of the complete units from India was significantly cheaper. Now there is no handpump manufacture in Uganda

2.5 *From Self-Reliance to Interdependence*

Once modern technologies are adopted by the poorest users or user groups who previously had little or no contact with such technologies, a significant, once-only change occurs. People are moved from a state of self-reliance to a situation of (inter)dependence. They require support in terms of repair or maintenance skills, spare parts and advice; assistance when group organisation breaks down; and in some cases on-going subsidy or financial support. Structures of support (usually consisting of some combination of user groups, local businesses, local Government, and/or NGOs) need to be set up and maintained. In low-income countries the resources available from users or external (including Government) agencies to run such support infrastructure are very limited. There may also be significant local/national constraints in relation to importation and rapid acquisition of replacement and spare parts from abroad. Creation of this inter-dependence is inevitable, but the rate of change from self-reliance to inter-dependence has to be phased carefully to match the pace of the various players involved, and capacity-building is essential if the process of sustainable change is to accelerate. The introduction of new technology without such support is a recipe for non-sustainability.

2.6 User Unfamiliarity is a Challenge for Technology Designers

It is the widespread experience of those attempting to introduce external technologies into developing countries that the combination of user and operator unfamiliarity with modern technology often leads to very premature damage or breakdown (compared to contexts in which technology-familiarity is much higher). Examples of this experience include:

- children swinging on the handles of handpumps, or banging the handles against the stops, and so damaging them;
- misuse of tools, or using the wrong tools, causing damage to technology;
- over-tightening of bolts and nuts;
- failure to change engine oil or replace air and oil filters at the right intervals;
- cross-threading of threaded joints;
- generally failing to handle technology with care.

2.7 Appropriate Technology

Technologies for low-income households and communities in the developing countries must fit at least the following six criteria. They must be:

- Desirable to the users;
- affordable in capital terms (by end-users directly, ideally; alternatively to Government or NGO programmes which are subsidising technologies for the very poor);
- affordable in recurrent terms (here the full operation and maintenance costs need to be borne by the users);
- physically robust;
- manageable by the network of user-group and support organisations which must maintain the technology – not exceeding the level of complexity which the support infrastructure can handle;
- replacement and spare parts must be reliably available in-country.

The first three points highlight the importance of value, accessibility and sustainability from the user point of view. If users either do not want or cannot afford a particular technology, then it is a non-starter. If on the other hand the technology is desirable (for reasons of social status, attractiveness to the individual, or utility) and affordable, as well as being available in the market, it has potential for take-off.

The last two bullet points in the list above illustrate the importance of the linkage between technologies and approaches. The enabling factors and service delivery approaches described in detail in the Landscaping of Approaches document exist to support end-users' enjoyment of the benefits of WS&H technology. In particular, the importance of capacity-building of user groups and supporting entities (private and public sector) is highlighted once again.

3. Sector-wide Technology Issues

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3.3 Risks.. p21
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3.5 Global tracking and appraisal of technology developments........ p22
3.6 Global tracking of research and funding co-ordination............. p22

3. Sector-wide Technology Issues

3.1 Data quality: collection, storage, retrieval

Section 4.1 (Water Resources Assessment) begins with the words "*There is a widespread scarcity of reliable, long-term data on rainfall, evaporation, river and lake levels, and groundwater resources, as well as the quality of both surface water and groundwater.*"

And this is how we found that it continued for virtually all the Technology Categories when we attempted to find scale, numbers, and percentages. No meaningful data are available concerning technologies for:

- 4.1 Water Resource Assessment;
- 4.4 Water Storage;
- 4.6 Water Treatment;
- 4.8 Wastewater & Stormwater Disposal;
- 4.9 Solid Waste Disposal;
- 4.10 Personal and Household Hygiene;
- 4.11 Hygiene Behaviour Change.

This does not necessarily mean that data does not exist anywhere, in some form: the problem is that it can be impossible to discover it even if it does exist. It is not at all uncommon for senior experts to be unaware of the existence of data relevant to their speciality, particularly if such data is held in places where they would not normally expect to find it. Sector organisations holding such data do not necessarily file all potentially useful data such that it can be easily found and accessed by electronic or even verbal/written searches.

The block-charts on the next page illustrate the numbers and percentages by region that we have been able to find from the JMP (Joint Monitoring Programme, http://www.wssinfo.org/en/welcome.html) for:

- 4.2 Water Sources, total served 284 million;
- 4.3 Water Lifting & Carrying, total served 1128 million;
- 4.5 Water Delivery, total served 2342 million;
- 4.7 Excreta Disposal, total served 2263 million.

But it is imperative to view these charts and numbers of total served with the following in mind:

- The data is at best estimated, and many discrepancies exist in the JMPdata.
- The data for selected representative countries for each region (up to 6 per region) have been extrapolated to represent the whole region.
- And a very important caveat: the data for existing served do not indicate or imply suitable water or sanitation technologies for the unserved.

It would certainly be helpful to be able to quote more such rough figures, scale of applicability, and number of people served by technologies within the categories, but there are massive voids in data availability, and the data that does exist is of very dubious quality. It is therefore very risky even to guesstimate such figures: they can frequently evolve into 'credible' numbers on which future decisions are based.

Annex 5.1 p45

Possible Key Initiative with leverage possibilities

All of the above illustrate the huge shortcomings within the sector concerning data collection, quality, updating, storage, and retrieval. This is a potential key initiative in which the foundation could have a strong role in raising awareness of the importance of water sector data and information, and its unique influence could leverage further international support in this area.

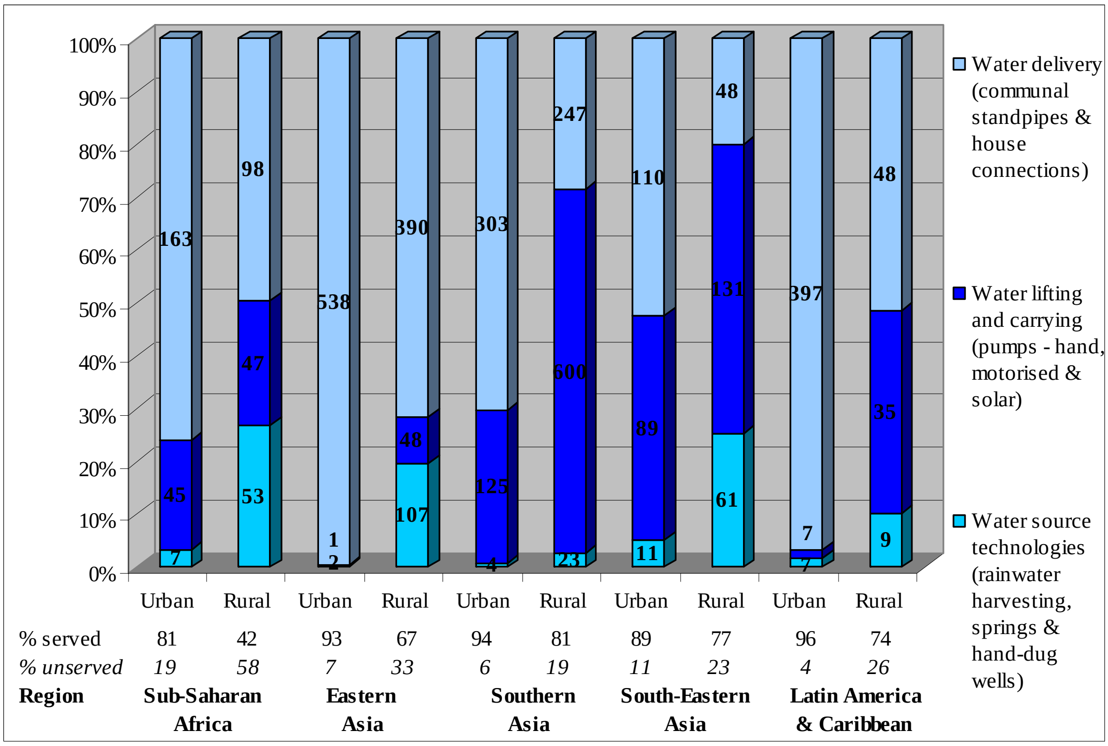

Figure 1: Estimated percentages of those served with improved drinking water sources using particular technologies by developing world regions (all numbers in millions). *Note: the only water treatment technology data available was the use of bottled water by 6m urban and 1m rural Indonesians (South-East Asia)*

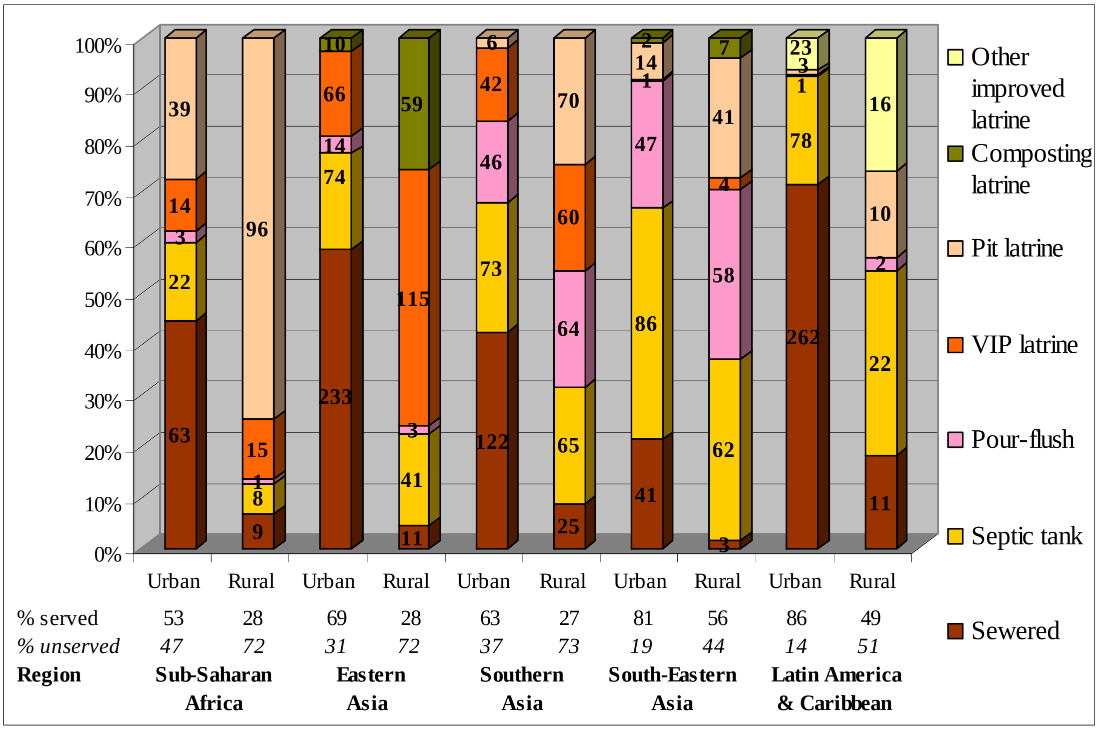

Figure 2: Estimated percentages of those served with improved sanitation facilities using particular technologies by developing world regions (all numbers in millions). Note data include use of some shared facilities (considered 'unimproved' by JMP).

3.2 Technology Definitions

In reference to technologies in general, it is common to distinguish between those which are "proven", those which are "emerging" and those described as "blue-skies" technologies, *i.e.* those which have not yet developed beyond the conceptual stage.

There are two main issues with the above technology definitions in this WS&H sector:

1. They require different interpretation when applied to developing country contexts rather than industrialised country contexts, as discussed below; and
2. For several reasons, there is scope for further refinement and detailing of this classification, especially at regional and country levels, as discussed on the next page.

Concerning the first issue, these categories are useful in the relatively uniform and predictable operating environment of industrialised countries, where commercially manufactured technologies are built to published standards and specifications, user familiarity with technology is high, operator specialist skill levels are good, energy supplies are uniformly reliable, spare part supply chains are in place, and the institutional environment is conducive to doing business efficiently.

In most developing countries, the situation is very different. Not only are the factors just mentioned far less favourable in general, but there are also enormous differences between countries and within countries (especially across the rural - small town – urban contexts which are distinguished elsewhere in this work). Consequently the three-fold distinction between technology groups, as outlined above, is a less useful representation of reality. The situation on the ground is far more complex.

The table below proposes a clarification of the three-fold technology classification just referred to, in a form more applicable to the present work. In the Landscape Assessment Summary, the definitions below are used.

	Standard Industrialised Country Categories	***Development Context Definitions for this Report***
Proven (Dominant)	Clearly functional. In widespread use. Industry standard technology. Nothing novel. Little scope for improvement. Examples include both standard public domain process technologies (*e.g.* coagulation and sedimentation), as well as commercially supplied technologies such as electric pumps.	Well established and widely used globally in a wide range of country contexts, and in rural, small town and urban environments. Examples mostly consist of the standard public domain technologies. Commercially supplied technologies (with the exception of public domain handpumps for example) can be problematic because of non-standard fittings or specifications, making inter-changeability difficult if one manufacturer drops out of the market.
Emerging	Proven to work (*i.e.* does what it claims to do, in technical terms) at laboratory or pilot scale. Not yet tested at scale, or if so only to limited extent. Yet to be adopted as industry standard. Examples include Ecosan, already used in some developed countries but not yet fully adopted as industry standard in appropriate locations.	Proven to work at laboratory or pilot scale. Possibly tested successfully at scale in a few countries or contexts (this being the main difference with industrialised country definition). Not yet globally applied, but looks promising. For example solar water pumping – used in some developing countries with success, but not yet very widespread. In the developing countries, emerging technologies will only move up to "proven" status if local manufacture or supply to high quality standards is assured.
Blue-Skies	Conceptualised but not yet designed or tested. Still at back-of-envelope status. Needing investment to get to pilot testing. For example, 'Aquaporins' (the use of water molecule selective cell-wall channel as water filtration), or 'Nanomembrane Technology'.	"If only" status. Function conceptualised (*e.g.* rigid one-piece pump-rod which could be cut to length and connected on site, up to 100 m length). Not yet tested. Similar definition to that of industrialised country.

3.2 Technology Definitions
(continued)

The second issue concerning technology definitions is that the 'proven, emerging, blue-skies' nomenclature is used within the sector with varying interpretation and understanding. The nomenclature can certainly be confusing, as shown by the following two examples.

The DEKA Research and Development Organization's Enhanced Distillation technology for water purification is clearly based on 'proven' technology in industrialized countries, but it has not even begun to 'emerge', because it is not yet known if it will meet DEKA's performance expectations in developing country contexts. If it does succeed technically in the field, will it then be deemed to be 'emerging'? And does this therefore make it currently a 'blue-skies' technology?

Consider also the appropriate technology improvements [phase-change incubator and SODIS (see also http://www.sodis.ch/)] proposed by the Massachusetts Institute of Technology (MIT). They are not 'proven', they have not 'emerged', but they are not really 'blue-skies' either: they actually represent small improvements to existing technologies, but which have never been tried.

Possible Initiative

Some of the above observations might seem pedantic and/or irrelevant. But it is often too easy for over-simplified or inappropriate labelling to cause misinterpretation and unwarranted subjective bias towards or away from a technology, causing collective objectivity to be compromised. The whole area of technology definition could well benefit from an initiative aimed at producing an expanded and more precise range of definitions that would be helpful in the context of technology and intervention evaluation at both regional and country level in the sector in general.

3.3 Risks

Many risks exist of a general type such as the commonly quoted example of the risk of creating wastewater disposal problems by upgrading or providing new water supplies. Such risks are variable in severity according to context, and they are rarely 'clear-cut' and 'quantifiable'.

The discussion of risk becomes much more meaningful during the detailed contextual risk assessment and evaluation which is essential during feasibility planning for any proposed interventions:

- the risk of specified equipment being technically unfit for purpose should be minimal,
- maintenance/spares costs and risks should usually be fairly well-quantifiable,
- the lack of adequately funded local expertise can vary and be a less accurately quantifiable risk,
- local authority risk will exist in many contexts, but its cost at feasibility stage will be the least easily quantifiable, and will have the near certainly of being difficult to control.

This last category touches on the most serious potential risk of all: the quality, extent, and spirit of financial governance (corruption).

Only risks that are regularly present have been listed in Section 4 (Landscape Assessment Summary), and these are mostly in the sanitation sections. Many other less clear-cut risk areas are inherent within the Section 4 Landscape Assessment Summary text and the Section 5 Annexes.

3.4 Comparing technology costs

There is obviously a natural inclination to try to tabulate a comparison of the costs of all technologies offering a solution to a common need. The capital and operational costs in the industrialised country context may well be easy to find and compare, but in developing country contexts the true operational costs will vary, because the appropriate combinations of technologies and approaches will vary according to each particular context.

For example, treatment costs per litre for potable water are often listed for each available water treatment technology. Given a known quality of feed-water (this parameter is often overlooked) and a specified potable water quality to be achieved, suppliers can quote treatment unit costs in an industrialised country context. But at that point of the enquiry the equipment is either not yet manufactured, or it is in a factory not in the country where its use is being considered, so there will be many further costs to be incurred, varying very much according to the local context, before potable water becomes available to the intended users.

It can be risky to 'guesstimate' costs based purely on supplier quotes without regard to context: a detailed (business) plan will be needed for any proposed intervention in its intended (developing country) context to get at anything near the true operational costs, let alone the costs of scalability and those of the all-important sustainability.

3.5 Global tracking and appraisal of technology developments

One of the questions which became evident during the drafting of this Technology Landscape was quite simply "How does the sector keep up with landscape developments?" The amount of research going on around the world is clearly immense, and is being carried out from many differing points of view, both commercial and non-commercial. The challenge is to identify the potentially interesting technologies as they are proposed or concept-proven, before they die for lack of interest, investment, or uptake.

Possible Key Initiative with leverage possibilities

It would be clearly useful to the sector as a whole if an entity or mechanism could be set up to identify and monitor technology developments occurring around the world. But would this be possible? Even with today's electronic data storage and access, how could a data-capture facility be structured that recorded everything potentially worthwhile or interesting in a particular sector? To implement such a 'global' entity would be a big initiative to undertake, but significant leveraging should be possible, and in the medium to long term, such an initiative could make a very serious contribution to the WS&H sector.

3.6 Global tracking of research and funding co-ordination

It is often the case that inadequate funding leads to erosion of significant potential gains from the work of good scientific practitioners in first-class research establishments around the world. Two typical examples are the bio-additives (enzyme combinations) work at Rhodes University, South Africa, and the work on urban drinking-water, wastewater and stormwater at Carnegie Mellon University, USA. There will be a large number of other similar examples.

This is probably because within the WS&H sector many companies will struggle to generate sufficient profits and reserves to fund large research budgets. Research in this environment will often take years to bring technologies to a point at which commercial development can start, and the risk of failure is always present.

Possible Key Initiative with leverage possibilities

As with technology developments above, it could clearly be very useful if an entity or mechanism could also be set up to identify and monitor relevant academic research projects around the world, and to co-ordinate and arrange funding for such research. To implement such a 'global' entity would again be a big initiative to undertake, but significant leveraging should be possible, but In the medium to long term, such an initiative could again make a very serious contribution to the Sector.

4. Landscape Assessment Summary

Water Resources

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Water Supply

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Hygiene

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Water Resources

4.1 Water Resources Assessment

Landscape Assessment Summary

Background

There is a widespread scarcity of reliable, long-term data on rainfall, evaporation, river and lake levels, and groundwater resources, as well as the quality of both surface water and groundwater. Data on leakage and water use in piped (urban and small town) water supplies is also limited, and this has resource implications. Low-income countries naturally put greater priority on the delivery of water and sanitation services than on data acquisition, but this creates resource management problems over the long-term. The problem of limited understanding and monitoring of water resources will become more acute as the impacts of climate change and instability bite deeper. The requirements for water resource assessment technologies vary between the international, national, sub-national, and end-user levels, although overlaps do exist.

International and National Levels:

These higher levels lack high quality information of the 'bigger picture' of water resources. At national and international levels the issues of water allocation between competing uses and users, and agreements between nations sharing international river basins can only be addressed if there is sound understanding of the water resources, and reliable real-time monitoring of amounts, flows and water levels. There is a need for improvement in:

- measurement, modelling, and remote sensing of groundwater, surface water and rainfall;
- Geographic Information Systems (GIS) and other electronic forms of data storage and presentation; and
- geological and geophysical databases.

Sub-National Level:

At sub-national level, there is a need for similar information as above, but in addition there is a need for reliable spatial mapping and databases of water supply sources and schemes, in particular:

- maps and user-data relating to existing systems;
- their functionality and condition; and
- the quality of the water they are providing.

Generic Technologies Checklist

1. **Rainfall monitoring**
2. **River level and flow measurement**
3. **Lake / reservoir level measurement**
4. **Geophysical and topographic surveying**
5. **Groundwater level monitoring**
6. **Artificial groundwater recharge**
7. **Water quality monitoring**
8. **GIS (including use of remote sensing and GPS)**

End-User Level:

At the user level, there is little prospect of encouraging democratic choices and user demand for change unless appropriate data and information exist. There is rarely detailed consumer information on critical water quality characteristics (*e.g.* faecal contamination, arsenic, chlorine, fluoride) of domestic water. Portable water quality testing kits cost $4,000 capital and $1 per test. Water quantity can be measured by dippers down a borehole linked to a pressure transducer: self-contained testing with loggers costs $1,000. Technologies for monitoring water quality are generally too expensive or complex for widespread distribution to consumer groups. Furthermore, a major constraint is the inability of government (and to a lesser extent end-users and the private sector) to afford and/or operate existing proven and relatively high-end technologies, and to usefully disseminate the resulting information. There is therefore a real need for:

- monitoring technologies which can be used by communities to record their own water data (rainfall, river, lake and groundwater levels, and water quality); and
- information and communication technologies for rapid reporting of faults with existing water supply services.

……continued on next page

Water Resources

4.1 Water Resources Assessment

continued

Landscape Assessment Summary

Proven Technologies:

Technologies suitable for assessing and monitoring water resources, and handling information at the international, national and sub-national level already exist, and are widely used in the industrialised countries where the costs of human operators have driven the development of remote automatic monitoring, telemetry and electronic databases. In developing countries, these technologies are needed (but not generally used, for reasons of cost) for different reasons, namely the unreliability of (underpaid) operators, and the lack of incentives for high quality data collection.

Emerging Technologies:

These include lower-cost adaptations of "industrialised-nation" technologies which may begin to make water remote resource monitoring more affordable as costs of electronic components and Information and Communication Technologies (ICTs) continue to fall. This applies to some geophysical equipment (for groundwater exploration) currently costing approximately $20,000 for a geophysical survey kit, but requiring skilled geo-physicists to operate (rather than underpaid operators) automatic weather stations and data loggers, satellite imagery and GIS software.

Blue-skies Technologies:

At end-user/community level, traditionally there has been little acquisition or provision of information on water resources and quality, largely due to the complex nature of technologies that measure parameters of value to the end-user/community. A focus on community (user-group) level monitoring through development of 'if only' technologies for water level and water quality measurement and reporting would lead to the development, distribution and use of:

- cheap, user-friendly, robust sensors for end-users, and other near-user monitors.

Constraints to increased uptake

A number of constraints are common to all data collection and information technologies:

- the costs involved in modifying technologies to context, followed by large scale investment to effectively instrument and network nations;
- the issue of incentives, and the related institutional issues involved in making water resources data publicly available; and
- the technical skills and capacity to implement programmes

Generic Technologies Checklist

1. ***Rainfall monitoring***
2. ***River level and flow measurement***
3. ***Lake / reservoir level measurement***
4. ***Geophysical and topographic surveying***
5. ***Groundwater level monitoring***
6. ***Artificial groundwater recharge***
7. ***Water quality monitoring***
8. **GIS (including use of remote sensing and GPS)**

Annex 5.1 p45

Possible Leverages for increased uptake

All external support agencies and donors value high quality information, and are often frustrated by its absence. However, few have the long-term commitment or the vision to invest in this important aspect of the sector (the exceptions to this being the World Meteorological Organisation 'WHYMAP' Programme and the World Bank / Global World Partnership 'GWMATE' Programme). The foundation could have a key role in raising awareness of the importance of water sector data and information, and its unique influence could leverage further international support in this area. It is not realistic to expect national governments to invest heavily in this aspect, but once systems are in place, national institutions could maintain and operate them, given suitable incentives.

Water Supply

4.2 Water Sources

Landscape Assessment Summary

Proven Technologies:

There are many proven technologies which capture, protect, or access rainwater, surface water or groundwater:

- roofwater harvesting (widely used, but often in a rudimentary way);
- rainwater harvesting from ground surfaces (limited application, but an example is the rock catchments of Gibraltar);
- protected springs (widely used in hilly, medium to high rainfall areas), $500 per spring for 250 people (i.e $2/capita);
- infiltration galleries (sometimes used to access naturally filtered surface waters, and with potential for wider utilisation);
- abstraction from rivers and lakes, with or without reservoir storage (major source for many cities, as well as for poor rural populations with no alternatives);
- hand-dug wells (used by about 0.5bn people), $1,500 for 30m depth, 250 people with handpump i.e. $6/capita, risk of medium-high maintenance costs; and
- tubewells and boreholes (used by more than 1bn people), $5,000 for 60m depth, 250 people borehole plus handpump i.e. $20/capita – up to $50/capita if motorised / solar pump used) risk of high maintenance costs.

Constraints on increased uptake

In the context of the 'unserved', priority should normally focus on facilitating wider access to rainwater (because it is on-the-spot) and groundwater (because of its relatively ubiquitous nature and relative ease of protection). The main constraint on uptake is cost.

Annex 5.2 p50

Possible Key Initiatives and Leverages for increased uptake:

There are therefore two key water source groups of technologies that should be further investigated and/or developed, and there is potential leverage focused around entrepreneurial and commercial activity:

- **Roofwater harvesting technologies** for those users with very limited funds to invest. The benefit of such technologies is that they provide water at the home (and not at a considerable distance from it), at the time that it is most needed (during the busy farming season, which often coincides with a hungry season before harvest). The key requirement here is water storage technology in the **volume range 100-10,000 litres**, at a price of no more than **US0.5-1.0 cents per litre** capacity;
- **Water-well drilling technologies** (at **very-low-cost**)**,** to increase access to shallow groundwater for domestic, agricultural or multiple-uses. Known technologies exist (hand augering, hand percussion, sludging and jetting), and have been used in specific locations (Nigeria, Niger, Madagascar, India, Bangladesh, Bolivia) with some success. However, further technology development is needed, and much wider application in suitable areas. Target cost estimates should be in the order of **US$500-1000** for a simple drilling rig, capable of drilling shallow boreholes for less than **US$100**.

But neither of these local sources is very practicable in urban slums: in such situations distant, treated, groundwater or surface water sources would need to be used.

Generic Technologies Checklist

9. Household rainwater catchment
10. Atmospheric water collection (fog catchment, dew, condensers)
11. Dam/reservoir storage
12 River and lake intakes
13 Infiltration galleries
14 Spring protection
15 Hand dug wells and drilled boreholes

Water Supply
4.3 Water Lifting and Carrying

Landscape Assessment Summary

Proven Technologies:

- bucket lift from open water sources (wells and rivers);
- handpumps for wells and boreholes: see 4.1 above for costs and maintenance risks;
- motorised (diesel-powered) pumps: see 4.1 above for costs and maintenance risks, pumps powered by renewable energy sources (wind, and see solar below): see 4.1 above for costs and maintenance risks;
- water carrying on head or back;
- water carrying by wheeled vehicle or pack animal;

Emerging Technologies:

- **New handpump technologies** now exist, particularly in the low- to medium-lift (up to say 25m) category, following development focused on public domain shallow and deep well pumps in the years since the end of the UN water decade in the 1980s;
- **Solar water pumping** is widely used, but not widely enough in the developing world context. Efficiencies of PV Cells (Photovoltaic Cells) and modules are still improving, and costs decreasing, but neither fast enough. A big push to develop and promote solar technologies could lead to significant improvements in PV Cell efficiency and big capital cost reductions, a situation analogous to the uptake of calculators, computers, and mobile 'phones. Costs $20-50 per capita depending on depth: high maintenance costs for breakdowns.

Generic Technologies Checklist

16. Handpumps
17. Solar and wind (renewable) pumps
18. Powered (non-renewable) pumps
19. Load carrying

Constraints on increased uptake:

The most poorly served suffer from one or more of three main technology-related problems as follows:

- **poor quality supply** through having to draw water from an open (and therefore probably contaminated) source;
- **unreliable supply**, because of pump breakdown; and
- **excessive expenditure of time and energy** through having to carry water over long distances in containers not designed for the purpose.

Annex 5.3 p55
Annex 5.4 p59
Annex 5.5 p64

Possible Key Initiatives for increased uptake:

The above constraints could be addressed by:

- A renewed focus especially on **handpumps** which are truly maintainable at village/community level;
- A renewed focus on **community solar pumping** (see above) which is at present has high capital cost; and
- A focus on **new water-carrying technologies**, perhaps adapting developed-world technologies from the leisure (backpacking/camping) and military sectors to the needs of women in the developing world.

Water Supply

4.4 Water Storage

Landscape Assessment Summary

Proven Technologies:

- **service reservoirs** in piped water supply systems (enabling short-term storage for release according to demand; constructed from high density polyethylene (HDPE), brick or stone masonry, ferrocement, reinforced concrete, or steel), up to several hundred thousand litres capacity; and
- **larger reservoirs**, on- or off-stream, created by damming or diverting streams and rivers (constructed from compacted earth, rockfill, masonry or concrete).

Used, but unsatisfactory due to cost, durability, or inadequate protection:

- **in-house storage** (at present in earthenware jars, buckets, plastic jerry cans), up to say 100 litres capacity; and
- household (**external**) water storage (for rainwater or piped water – the latter at ground level or elevated, constructed from high density polyethylene, brick or stone masonry, or ferro-cement), up to say 10,000 litres capacity. 500 litre jars $100-$300 /m3, 20m3 ferro-cement tanks $20 (China) up to $75 (Uganda) per m3.

Generic Technologies Checklist

20. Household storage
21. Closed communal storage

Annex 5.6 p69

Actionable Key Initiatives

Focus should centre on the last two technologies above, which are regularly used as the only options possible, but which can have very unsatisfactory health issues:

- **In-house water storage** often leads to re-contamination of water supplies which are of good quality at source. The Oxfam Bucket (1977) overcomes this problem, and has been widely used in refugee situations, but has not taken off in the development context. At about US$4.50, it provides water storage at about five times the price of a standard plastic jerry can. Market testing at a competitive price would reveal whether there is demand for the benefits the container can offer.
- **Household (external) water storage.** Existing technology for (100 litres to say 10,000 litres or 10m^3), is expensive HDPE(high density polyethylene) and ferro-cement in Uganda about US8-10 cents per litre, ferro-cement US2.5 cents in India), and so most poor households own only one or two 20-litre jerry cans or equivalent. In India, International Development Enterprises (IDE) has developed a prototype low-cost 10,000 litre water storage unit that they claim will sell at an unsubsidized price of about 0.4 cents (US) per litre. If this technology were to be fully proven, scaled up and adapted (in various capacities and forms) to a variety of rural, small town and urban environments, it could revolutionise safe water storage for the poor, enabling wider use of rainwater harvesting, intermittent piped water supplies, and multiple uses of water.

Water Supply

4.5 Water Delivery

Landscape Assessment Summary

Proven Technologies:

Delivery of water to domestic water users can take a number of forms:

- in containers (plastic bags, bottles);
- at public kiosks and communal standpipes (public taps, with or without on-the-spot payment);
- pressurised and gravity pipelines; and
- at yard and house connections (private, metered, taps).

Generic Technologies Checklist

22. Piped networks with communal taps and house connections

23. Metering technology

24. Leakage detection technology

Annex 5.7 p74

Actionable Key Initiatives:

- **Metering.** Improved low-cost and accurate metering at the level of private (franchised or other) providers, and at household level (in towns and cities), could make a significant contribution to the level and fairness of revenue collection from both poor and wealthy users. This would have particularly large impacts in cities where cross-subsidies are sought in order to serve the poorest members of the population better.
- **Leakage detection and control.** Technology development in piped water supply systems (for towns and cities) needs to focus on leakage detection and control (for which technologies exist, but usage needs to increase).

4.6 Water Treatment

Landscape Assessment Summary

Background:

Protection of water sources can minimise the need for complex, costly or time and energy consuming treatments, which require significant levels of training, incentivisation and supply chains to operate and maintain. When necessary however, treatment technologies aim to improve water quality:

- to make it safe to drink; and
- to fit end-user preferences for taste, colour, and odour.

Water can be treated at various stages between the source and the end users:

- a limited number of technologies can be applied at source, but most are used after water has been abstracted;
- conventional treatment technologies are managed at the level of the water supply scheme (rural, small town, or urban), usually by skilled, paid, operators, between the point of abstraction and the distribution system; and
- household or point-of-use water treatment technologies operate in the home after end-users have collected their water.

Various technologies can be used in rural, small town, urban contexts, depending on:

- the quality of the raw water; and
- local institutional, financial and technical capacity/ability to manage them.

Proven Technologies:

In urban or small town utilities, conventional non-commercial (*i.e.* unpatented, with no intellectual property implications) treatments (chemical coagulation, sedimentation, sand or media filters, disinfection with chlorine, ultra-violet or ozone) are the most effective technologies to provide safe drinking water (point-of-use PUR tablets cost $US 0.25/m3) but such treatments:

- have high capital and running costs (buildings, equipment, chemicals, energy);
- external finance is often required (especially when tariffs fail to cover the full costs of water supply) and they are complex to manage and maintain; and
- sustainability is more related to management (incentives, supply chains, financial aspects) than the technology itself.

For the last 100 years, these communal treatment techniques have seen little innovation apart from the development of membrane and desalination technologies, which are very costly, fragile, dependent on foreign commercial suppliers for replacement parts, and difficult to operate in developing country contexts without significant foreign assistance.

Simpler and less expensive membrane treatments may have a significant impact on urban/small town water supply in the future. Existing, relatively cheap, treatment methods could be further promoted at the communal scale:

- sand filtration and multi-stage filtration can offer good water quality and be managed at community level (small town/urban) much more easily than treatments involving imported high cost chemical coagulants;

……continued on next page

Generic Technologies Checklist

25. ***Coated treatments***
26. ***Coagulants (including conventional, natural, household)***
27. ***Sedimentation***
28. ***Filters (including slow / rapid sand filters, specific filter media)***
29. ***Treatments for removal of chemicals (especially arsenic, iron and fluoride)***
30. ***Aeration***
31. ***Membrane technologies***
32. ***Desalination (distillation techs, membranes, reverse osmosis, electrodialysis)***
33. ***Disinfection (including boiling, chlorination, solar disinfection, ultraviolet lamps, ozone)***

4.6 Water Treatment

continued

Landscape Assessment Summary

Emerging Technologies:

- Most recent developments in low-cost water treatment have been made for use at the source (well chlorinators, coated treatments) or at the household level (ceramic and biosand filter, $20 per filter, $4 per user), for rural, small towns and/or urban users;
- Use of *moringa* seed extracts to replace chemical coagulants, as is currently being trialled at pilot and full scale in Tanzania and Malawi; and
- For household-level use a wide range of technologies has been developed and proven effective in different, developed world contexts, to deal with turbidity, pathogens and specific chemical compounds.

Blue-Skies Technologies:

As described above, there is no lack of effective technologies to treat water, but technical solutions are not always adapted to the constraints of the contexts in which they are introduced. In particular, new technologies usually need to be proven in the developed world context in order to find a route to 'conventional' financial survival, before attempting adaptations for developing country contexts.

For example, there are several technologies proven or concept-proven in the developed world, which have yet to emerge in developing countries contexts, generally due to price constraint and/or the availability of a reliable electricity supply. Examples, in no specific order, are:

- Vapour Compression (VP) Enhanced Distillation. Small units (DEKA) capable of purifying about 45 litres per hour requiring a modest electrical supply. Claimed to be robust and maintenance-free, and to purify any quality of feedwater. Possible issues caused by producing very pure water with uncharacteristic lack of 'flavour' or 'odour';
- CDT (Capacitive Deionisation Technology) Carbon Aerogel electrodes. Currently produced as large container-based or mobile units (CDT Systems, Inc.) developed for emergency disaster-relief (brackish water) use, but the company is attempting to develop carbon nanotubes, implying smaller discrete unit size. This technology can be solar-powered, and at small scale may prove interesting. Electrodes need replacing at intervals; and
- Magnetic Activated-Water Treatment (Liquid Separation Inc.), which strips electrons from flowing water causing the water to lose the ability to bond to itself or to contaminants, thereby facilitating filtration or settlement treatment. A further advantage is that many waterborne micro-organisms do not survive the process, although the reasons are not yet proven (possibly due to DNA destruction).

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Generic Technologies Checklist

25. Coated treatments
26. Coagulants (including conventional, natural, household)
27. Sedimentation
28. Filters (including slow / rapid sand filters, specific filter media)
29. Treatments for removal of chemicals (especially arsenic, iron and fluoride)
30. Aeration
31. Membrane technologies
32. Desalination (distillation techs, membranes, reverse osmosis, electrodialysis)
33. Disinfection (including boiling, chlorination, solar disinfection, ultraviolet lamps, ozone)

Landscape Assessment Summary

Blue Skies Technologies (continued):

A technology currently under attempted development with a certain amount of promise:

- The use of Quaternary Ammonium Silanes (QAS), (Aquaya Institute) as microbe-killing coatings applied to the inside of water bottles/containers, and larger storage containers. This technology requires considerably more development to have a chance of proving technical, contextually deployable, and commercial viability as a point-of-use (POU) treatment. Ensuring that all contaminants come within sufficiently close proximity of the coatings to guarantee killing may well prove more difficult than developing a satisfactory permanent bonding-process for the coatings.

On the far blue-skies horizon, there are interesting and potentially game-changing water filtration technologies under investigation/development, but it is early days, with a considerable amount of human and financial resource necessary for success to become a possibility:

- On such is the use of plant Aquaporins (mammalian Aquaporins will encounter Regulation difficulties), which are highly selective channels in cell-walls which only permit the passage of water molecules: these can be considered as one of nature's own filtration systems. The interest is whether such cells/molecules could be deployed in commercially viable water filtration membranes.
- Potentially novel, inexpensive ways of producing and supporting/deploying nano-membranes for water filtration. Nano-membrane filtration technologies do already exist, but are as yet neither robust, nor inexpensive, nor simple enough to operate and maintain in most developing country contexts.

Constraints on increased uptake:

- Technologies, either for communal or household levels, are not always adapted to end-user needs and preferences (reduced burden, easy operation and maintenance (O&M), affordability, taste, smell, colour of water);
- Supply chains for spares (ceramic candles, chemicals) are often problematic because of low demand, institutional or logistical problems; and
- If economies of scale are not achieved, technologies remain expensive for many households.

Annex 5.8 p80
Annex 5.9 p90

Possible leverages for increased uptake:

Possible leverage which could be achieved through interventions by the foundation should take into account the following:

- improved water quality in all types of water supply system (whether managed at small community level, by a private operator, or by a public utility) depends heavily on public perception of water quality issues, and on user demand. Investments in technology will therefore be more likely to achieve impact if they are complemented by interventions to strengthen user awareness and demand.
- Technology interventions (e.g. in point-of-use methods, or alternatives to chemical coagulants) still require attention to supply-chain issues. If there are sufficient incentives, and a sufficiently large market, for the private sector to take care of this aspect, then impact can be more sustainable than otherwise. At household level, micro-credit may need to be used to enable poorer households to purchase consumables.
- Interventions in technology require attention to capacity-building in its widest sense, *i.e.* including not only training but also institutional and policy reform, and assured resourcing.

Generic Technologies Checklist

25. *Coated treatments*
26. *Coagulants (including conventional, natural, household)*
27. *Sedimentation*
28. *Filters (including slow / rapid sand filters, specific filter media)*
29. *Treatments for removal of chemicals (especially arsenic, iron and fluoride)*
30. *Aeration*
31. *Membrane technologies*
32. *Desalination (distillation techs, membranes, reverse osmosis, electrodialysis)*
33. *Disinfection (including boiling, chlorination, solar disinfection, ultraviolet lamps, ozone)*

Sanitation
4.7 Excreta Disposal

Landscape Assessment Summary

Background:

The vast majority of those living in poverty in developing countries either defecate and urinate on the ground with little or no privacy, or use a simple, generally unsanitary, dry latrine. This is grossly demeaning, unpleasant, inconvenient, and a serious health hazard, especially in poor urban areas where open land is at a premium, population density is very high and a contaminated environment endangers residents.

It is estimated that at least 2.6 billion live without safe excreta disposal in rural, small town, and urban areas. Excreta disposal is socially sensitive in most cultures, and is therefore often not prioritised either by local people or their representatives, or by the engineers who dominate the environmental health sector. Nevertheless, demand is high, especially in urban areas where inconvenience is greatest, particularly amongst women and girls.

There is no "one-size-fits-all" solution, as can be seen from the following:

Technologies for excreta disposal exist for most situations, and are generally categorised as:

- **'on-site' or 'off-site'**, depending on whether excreta are removed from the household or not; and
- **'dry' or 'wet'**, depending on whether water is involved in the system.

Current improvement technologies are based either on:

- containment on the household plot, or
- water transport of waste in sewer pipes to a disposal site, preferably after treatment to render it safe.

Selection of a specific technology is based on:

- local culture, including consideration of anal-cleansing methods and materials;
- social segregation, gender specificity, menstrual hygiene, children's needs;
- availability of water, soil conditions, level of the water-table; and
- available skills and materials, costs and affordability, size of plots.

……continued on next page

Generic Technologies Checklist

34. *On-site sanitation (including pit latrines, low-cost VIP, Ecosan, non stick pan, water saving technologies)*
35. *Septic tanks*
36. *Bio-additives*
37. *Emptying (pits and septic tanks) and sludge management*
38. *Conventional sewerage*
39. *Condominial and low-cost sewerage*
40. *Sewage treatment (including settled sewerage, natural and conventional treatments)*

Sanitation

4.7 Excreta Disposal

continued

Landscape Assessment Summary

On-Site Technologies

Proven and actionable:

- **Simple pit latrines (dry)** range from a hole in the ground with squat-planks, with open-roofed privacy structure of branches, leaves and cloth (unsafe, bad smells, fly-ridden, not often used), to a brick- or concrete-lined pit, supporting a concrete slab with 'keyhole' and 'plug' to reduce smells and flies, enclosed by a roofed masonry privacy structure with door (total cost about US$30-60).
- **Ventilated Improved Pit (VIP) latrines (dry)** include a ventilation pipe, a fly-screen, and a dark super-structure for effective smell and fly reduction (total cost about US$50-150). But even lower-cost designs, which can be built for as little as US$20 using local materials, have not been popular enough
- **Pour-flush latrines (wet)** include a water-seal to avoid smells and flies, but require a modest reliable source of water, and are therefore only suitable where water is available and accessible. Use of water encourages good hygiene, therefore these latrines are particularly appropriate where water is generally used for anal-cleansing (most of South Asia). Costs are normally similar to those for VIP latrines but the Total Sanitation approach in Bangladesh has built designs costing as little as US$3-15 for materials alone.

On-Site Technologies

Proven but not easily actionable in these Contexts:

- **Septic tanks (wet)** are expensive to build and contain faecal and other waste in water, and require land for safe drainage of dangerous effluent and periodic emptying and safe disposal of solids.

On-Site Technologies

Emerging, (proven), actionable:

- **Ecological Sanitation ('Ecosan') (dry)** aims to produce a re-useable and valuable compost from faecal waste by maintaining a relatively dry pit environment (sometimes needing separation of urine from faeces) and suitable composting conditions (addition of ash). Often based on twin-pit: one in use, the other decomposing. Much promoted by some sanitation specialists and used in Scandinavia, South Africa (EnviroLoo) but very little used as yet in the developing world. Use is constrained by capital cost (US$50-175 in India), social attitudes to the handling and use of faeces (widespread taboo), and thus the need for a market.

On-Site Technologies

Risks

- Poorly designed facilities may fail, dis-motivating further development;
- Unsafe disposal of pit latrine contents is a serious risk after emptying;
- New bio-additives require careful risk assessment to avoid environmental risks;
- Inadequate decomposition of excreta in ecosan latrines can endanger the health of both those handling it and consumers of produce grown using it.

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Generic Technologies Checklist

34. On-site sanitation (including pit latrines, low-cost VIP, Ecosan, non stick pan, water saving technologies)

35. Septic tanks

36. Bio-additives

37. Emptying (pits and septic tanks) and sludge management

38. Conventional sewerage

39. Condominial and low-cost sewerage

40. Sewage treatment (including settled sewerage, natural and conventional treatments)

Sanitation

4.7 Excreta Disposal *continued*

Landscape Assessment Summary

Off-Site Technologies

Proven and possibly actionable in some Contexts:

Two alternative sewer technologies (higher capital costs) have been developed which compete on a lifetime-cost basis with on-site latrine technologies (regular emptying and sludge disposal costs) in very high density areas as follows:

- **Simplified sewers (condominial/shallow)** use lower-cost specifications but still require adequate water and need good user-community involvement in planning, design, and operation, without which they will block and fail. They must be linked to municipal systems for treatment and/or disposal.
- **Settled sewers** use small diameter shallow pipes taking only liquid effluent from settling or septic tanks, which can therefore be used when land is unavailable for infiltration of effluent. To avoid blockages, good community understanding of this system and regular effective tank emptying and safe disposal of sludge is needed. The pipes must be linked to municipal systems for treatment and/or disposal. Cost approx US$400-800 per household, less in very dense settlements.

Off-Site Technologies

Proven but non-actionable in this Context:

- **Conventional sewers and 'western' treatment plants** are often still seen as 'the answer' for urban areas by many authorities and engineers, but they require substantial and unavailable amounts of water. They are expensive and complex to build, operate, and maintain, requiring very high capital expenditure, good skills and management, and costly energy supplies for aeration and pumping.
- **Simple, natural processes** for treatment of sewage discharging from either conventional or alternative sewers can be particularly efficient in warm climates, such as waste-stabilisation ponds (lagoons), or reed-beds, although relatively large land areas are required. However, operation and maintenance of even these simple technologies is frequently inadequate.

……continued on next page

Generic Technologies Checklist

34. *On-site sanitation (including pit latrines, low-cost VIP, Ecosan, non stick pan, water saving technologies)*
35. *Septic tanks*
36. *Bio-additives*
37. *Emptying (pits and septic tanks) and sludge management*
38. *Conventional sewerage*
39. *Condominial and low-cost sewerage*
40. *Sewage treatment (including settled sewerage, natural and conventional treatments)*

Blue-Skies Technologies:

Micro-organisms and enzymes are being promoted as additives for significantly accelerated decomposition of faecal sludge in latrine pits. But at present, increasing effluent digestion using available bio-additives normally requires good oxygenation and maintenance of optimal conditions: this will be very difficult in latrine pits.

However, if further research and development (R&D) could yield robust safe organisms which could work well in such a strongly anaerobic environment whilst at the same time yielding safe fertiliser products, the possibilities for reduced pit-size, less frequent emptying, and safer, less unpleasant, usable end-product could impact very favourably. The underlying constraint will always be the avoidance of forced aeration, which is costly.

Ongoing Research at Rhodes University in South Africa is making promising progress in the use of enzyme mixtures for significant reduction of sludge solids. This is interesting, and should be kept in view. Adequate finance is probably lacking.

Generic Technologies Checklist

See any of the previous three pages.

Annex 5.10 p98
Annex 5.11 p102
Annex 5.12 p106
Annex 5.13 p109

Possible Key Initiatives and Constraints on increased uptake:

Factors influencing uptake and use of on-site technologies are as follows:

- **There is no "one-size-fits-all" solution.** Technologies/Approaches must be based on 'incremental improvement' in affordable and achievable steps, depending on the local context and household circumstances. Improvements (dry or wet) to the Simple Pit Latrine are unaffordable to many, especially in rural areas where it is simply not a high priority. Cross-subsidy will almost certainly be needed to achieve 100% coverage.
- **Cost.** A range of designs should be offered and promoted, appropriate for local and individual affordability (as in 'Total Sanitation'). Lower-cost easily cleaned alternatives to concrete slabs might be developed in plastics. Alternative VIP designs already exist but are not widely used.
- **Cleanliness.** In order to get used, latrines must be clean (and therefore easily cleanable) and pleasant. This requires responsibility, good organisation, and appropriate technology. A 'non-stick' pan coated with Teflon, for example, to improve cleanability, would be worth developing.
- **Ecosan.** Constrained currently by capital cost, and social attitudes to handling and use of faeces. Interventions to promote local entrepreneurial micro-management, composting, and emptying (see below), and refocusing on achieving cheaper construction.
- **Bio-additives, blue-skies research.** Frequency of latrine emptying could be significantly reduced, and the economics of entrepreneurial composting could be well-improved by supporting the development of promising bio-additives such as enzyme combinations. There could be significant spin-offs for improving treatment of other effluents from such research.
- **Facilities for emptying or moving latrines**. In poor urban areas space limits the number of latrines, and many individuals may utilise one latrine. Emptying is usually by hand, and extremely unpleasant, and facilities for safe disposal are essential. Existing manual or mechanical means of emptying (MAPET or Vacutug) in dense slums appear to work well, but further promotion and cost-reduction is required.
- **Attitude Change amongst Authorities and Engineers.** In many countries, current legislation and regulations prohibit the use of on-site facilities in urban areas. Attitude change is needed, since low-cost sewers will not in the foreseeable future be economically feasible in most slums.
- **Linking affordability to ability to pay.** Women and girls often want better facilities but lack the means to pay. Approaches need to tackle the gender issues involved.
- **Sanitation improvements must be linked to hygiene promotion.** An accessible water supply must be provided for sanitary use, and social marketing techniques must promote hygiene awareness, especially post-defecation handwashing.

Sanitation

4.8 Wastewater & Stormwater Disposal

Landscape Assessment Summary

Background:

Alongside excreta, wastewater ('grey' water or sullage, deriving from all hygiene-based uses of water, and usually considered as water that is not grossly contaminated with human faeces), stormwater and solid waste (refuse or garbage) can all produce significant environmental health problems, because:

- They encourage breeding of disease vectors (mosquitoes, flies, rats etc);
- They cause environmental pollution to surface water and groundwater;
- They may include hazardous materials (from medical facilities and industrial facilities);
- They need safe and reliable disposal; but
- Conventional, 'western' disposal technologies and services are expensive to build, operate, and maintain.

These are all significant, recognised problems in densely populated urban areas, but safe disposal of wastewater is also very important in rural areas. It must also be remembered that increased water supply will lead to more wastewater and even greater need for safe disposal.

Generic Technologies Checklist

41. Latrines for wastewater drainage

42. Open drains of various designs.

43. Sewers of all types

On-site Technologies

Proven, actionable:

- **Re-use** of wastewater for small-scale agriculture and/or other purposes has valuable economic potential.
- **Soakaways** for wastewater are simple but can block and need renewal.
- **Latrines** are sometimes used for wastewater disposal, but this often overloads the surrounding soil and leads to smelly conditions in the pit.

Off-site Technologies

Proven & possibly actionable:

- **Open drains**, either un-lined or lined, are relatively expensive to construct, but can be built and maintained with good local community involvement, providing paid employment, but regularly become blocked with refuse, soil etc and need thorough, regular maintenance.
- **Drains** combining a small channel for daily wastewater and a large one for stormwater can be effective, but are also expensive to build and need careful maintenance; can be combined with use of flat land specifically designed for dispersal of stormwater floods.
- **Conventional, simplified and settled sewers** can all be used for wastewater removal as well as excreta, but are expensive to build, operate and maintain.

……continued on next page

Sanitation

4.8 Wastewater & Stormwater Disposal

continued

Landscape Assessment Summary

Constraints to uptake:

- **Cost** is the principal constraint to improved drainage.
- **Safe discharge.** All off-site drainage technologies require a safe discharge either to a wastewater treatment plant, or a wetland, or a surface water body with adequate dilution.
- **Low-lying or unstable slopes.** Drainage of wastewater and stormwater is a particular problem in poorer urban areas, which tend, often, to be low-lying or on unstable slopes.
- **Housing Density.** Potential for on-site disposal is limited because of housing density.
- **Mechanical lifting** of such water is not generally feasible except in extreme emergencies.

Risks:

- Drains are often used for disposal of excreta: links between better drainage and safe excreta disposal are therefore needed.
- Increased water supply will inevitably lead to more wastewater, requiring safe disposal.

Generic Technologies Checklist

41. *Latrines for wastewater drainage*
42. *Open drains of various designs.*
43. *Sewers of all types*

Key Initiatives with possible leverages for increased uptake:

Attempts at leveraging here should focus around combinations of re-use of wastewater and open-drains, aimed at creating entrepreneurial activity supported by local authority. Such economic activity may be only viable when considered in conjunction with latrine emptying and composting (see Possible Leverages under Excreta and Solid Waste Disposal – sections 4.7 and 4.8). But social despondency, taboos, and strong lack of financial resources will be difficult to overcome.

4.9 Solid Waste Disposal

Landscape Assessment Summary

Background:

Successful disposal of solid waste depends on good collaboration between residents, businesses and collective facilities, and local authority or private contractors. It is an increasing problem as wealth increases (even in slums), as increasing amounts of non-biodegradable materials are used. Such waste often contains hazardous materials requiring special attention.

Generic Technologies Checklist

44. Plastic recycling

45. Composting (including conventional and vermi-composting)

46. Medical waste management

Proven and actionable technologies:

Re-use and recycling:

- Has considerable economic and entrepreneurial potential and is much more widely practised in developing country cities than in the industrialised world (until recently);
- Much waste can be re-used or recycled;
- Particular hazards to scavengers / waste-pickers / recyclers; and
- There may be potential for innovative recycling of plastics.

Transport:

- Collection and transport of solid waste are expensive and tend to be labour-intensive, despite the availability of a range of vehicles, from handcarts, through animal-drawn carts to compactor trucks; and
- Costs may be partly offset by resale of products such as composting.

Composting:

- Has economic and entrepreneurial potential;
- The organic fraction of solid waste in developing countries is much higher than elsewhere, therefore potential for composting is greater;
- Experience shows that the quality of composting needs to be high and the market is usually small, unless actively promoted; and
- Vermi-composting, using worms to promote decomposition, has potential.

Proven Technologies, but non-actionable in this Context:

Incineration:

- Is prohibitively expensive for most solid waste in developing countries because of moisture content and low calorific value. Air pollution is a significant hazard.

Landfill:

- Is often uncontrolled and therefore polluting, especially of groundwater and surface water bodies;
- Uses potentially valuable land on the outskirts of cities, but needs to be close enough to the source of waste to make transport economically viable; and
- Measures to make landfill safe, by ‘sanitary’ measures, are well known but little practised in the developing world – not seen as a high priority.

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Sanitation

4.9 Solid Waste Disposal *continued*

Landscape Assessment Summary

Constraints to uptake:

Most wastewater, stormwater and solid waste in poor areas of developing country cities and towns is completely uncontrolled and presents a significant public health risk:

- Residents generally recognise the unpleasantness of their environment but are powerless to affect the situation;
- Local governments lack skills and financial resources;
- Collective action is needed, combining efforts of residents, businesses, local government and private enterprises;
- Major investment is needed, which generally only comes about through economic development and taxation; and
- Poor people cannot invest in these relatively expensive facilities and services,

Risks:

- Scavengers' health is at risk from their involvement in re-use and re-cycling activities; and
- Unsafe disposal of solid waste gives rise to numerous environmental risks.

Key Initiatives with possible leverages for increased uptake:

Safe recycling and transport of solid waste and wastewater, including composting of organic materials, has considerable potential for local entrepreneurial activity. All potential up-take of these technologies is constrained by significant social and economic factors, and therefore financial interventions should focus on creating a financial and social environment for self-sustaining recycle and compost entrepreneurs, and engendering social acceptability of such enterprises.

Generic Technologies Checklist

44. Plastic recycling

45. Composting (including conventional and vermi-composting)

46. Medical waste management

Hygiene

4.10 Personal & Household Hygiene

Landscape Assessment Summary

Background:

Technologies for personal and household hygiene aim to provide people with convenient and effective ways of protecting themselves, their water and their food from contamination through contact with dirty hands, insects, and contaminated soil. Although linked with hygiene, safe household water storage is considered separately (see water supply). See also wastewater, storm water and solid waste disposal which relates to environmental sanitation and also to household waste disposal.

None of these technologies alone can significantly improve health, since better health is brought about primarily through behavioural change, which is as much a matter of education and promotion, as having the physical means to act on educational or promotional messages. However, these technologies can enable people to put their hygiene education into practice, or simplify and improve the way they do it.

Proven Technologies:

Most hygiene related technologies have been designed and proven for a long time:

- Many different low cost water dispensers have been designed to make hand washing easier, some with recycled material, others with possibilities for manufacture by local commercial businesses;
- Conventional soap, either industrial or traditional, enable body and hand washing, and laundry. People value the convenience, dignity and prestige it provides;
- Alternatives such as ash and mud for hand washing are effective, but their use depends highly on culture and education, and their use is not very widespread;
- Various technologies exist for menstrual hygiene, but most women use old clothes or pieces of cloth that need to be washed. Disposable pads and other materials are not yet widely used, but were they to be, they would present a significant problem of safe disposal;
- Infant excreta management technologies such as washable nappies and potties exist but are not widely used;
- Anal cleansing products are largely cultural (paper, water, leaves) and are usually available; and
- Household cleaning products (detergents, bleach); devices to protect cooked food or drying dishes from soil or insect contamination; traps, chemicals and nets against disease vectors are also usually available, although expensive for poor households.

Although proven and readily available, many of these technologies are not widely used. Possible improvements include:

- Cost reduction, as many people cannot afford a bar of soap, a food cover, a dish stand, insecticides, detergents, bleach, nappies, potties;
- Improvements to products to make them more user-friendly, e.g. "soap-on-a-rope"; and
- Demand creation, commercial and social marketing, improved availability on local markets.

Generic Technologies Checklist

47. Hand washing products (soap and alternatives)
48. Water dispensers
49. Water heating
50. Showers / bathrooms
51. Laundry facilities
52. Menstruation management
53. Infant excreta management: potties and nappies
54. Anal cleansing products
55. Kitchen and utensils hygiene
56. Household vector control

……continued on next page

Hygiene

4.10 Personal & Household Hygiene

continued

Landscape Assessment Summary

Emerging Technologies:

A few technologies have been developed more recently, but remain expensive and not widely used:

- Non water-requiring soaps in liquid forms can be used to disinfect hands although they are not effective for cleaning visibly soiled hands; and
- Solar and electric water heaters make body, dish and clothes washing more convenient in cold regions.

Blue-Skies Technologies, Gaps in Technologies:

- More adequate (low-cost, culturally acceptable, recyclable or biodegradable) hygiene products and facilities to manage menstruation could greatly benefit older (school-age) girls and women. Not least among the benefits of such technologies and interventions would be the increased prospect of keeping girls in school.
- Products for mothers to wipe or handle their children's faeces hygienically (low-cost biodegradable wipes or gloves) could have significant impacts.

Constraints to increased uptake:

- The main constraint is that of price, in relation to (women's) income. Women's (Mothers') Demand often exists but prices are usually too high and consequently supply chains are then inadequate for products to reach end-users on a reliable basis.
- The second constraint is lack of awareness of the existence of certain products.

Annex 5.14 p115

Key Initiative and possible leverages for increased up take:

- The main means of leverage is that of demand creation (for hand-washing water dispensers, soaps, menstrual management materials, and infant anal cleansing materials) leading to small-scale private commercial supply of products.
- Encouragement of wholesalers and retailers to package products in small quantities could enable increased uptake, even where unit costs cannot be significantly reduced.

Generic Technologies Checklist

47. Hand washing products (soap and alternatives)
48. Water dispensers
49. Water heating
50. Showers / bathrooms
51. Laundry facilities
52. Menstruation management
53. Infant excreta management: potties and nappies
54. Anal cleansing products
55. Kitchen and utensils hygiene
56. Household vector control

Hygiene

4.11 Hygiene Behaviour Change

Landscape Assessment Summary

Background:

The promotion of hygiene behaviour is largely a matter of social marketing and individual and public education in health and hygiene, and consequently falls primarily under "Approaches". However, various technologies and materials are necessary for the process of communication and demonstration, and there is some scope for the development of new technologies which can enhance these processes.

Proven Technologies:

- Conventional technologies in this area consist of posters and other paper-based materials, which are widely available and require no further consideration here.
- Standard audio-visual equipment such as computers, overhead, slide and multi-media projectors, TV, video and DVD, whilst proven, could benefit from enhanced robustness for field use.

Emerging Technologies:

Technologies which can bring hygiene messages closer to more people, more frequently, and in a more visual and forceful manner, are of special interest:

- Low cost or low-maintenance radios (including wind-up and solar powered models) for mass communication of promotional programmes such as soap operas to mass-promote hygiene (in conjunction with development of radio and TV networks and sets);
- CD-ROMs with visual aids and supporting material for hygiene promoters; and
- Technologies for demonstration of dirty hands, like UV sensitive powder and glitter.

Blue-Skies technologies, Gaps in Technologies:

- Simple, rapid bacteriological water testing technologies to observe and compare the quality of various sources (protected, unprotected, treated, untreated) could convince many people to improve their facilities and their behaviours.

Constraints to increased uptake:

- Most of the technologies described here are for purchase by Government and NGO programmes involved in hygiene promotion activities.
- International NGOs are often aware of what is available, while local NGOs and Government agencies are often less informed as to what tools exist for health and hygiene promotion.
- It is appropriate for hygiene promotion messages to be tailored very specifically to the target audience, so there are limits to the production of "off-the-peg" materials.

Generic Technologies Checklist

57. Paper based educational material

58. Tools for participatory processes (games, drama props, puppets, pocket voting)

59. Electronic communication technologies (TV, video, DVD, CD-ROMS, audiotapes, wind-up radios)

60. Hand washing promotion technologies (UV sensitive powder, glitter)

61. Tools for bacteriological demonstrations (microscope, hand lenses)

Annex 5.15 p120

Possible leverages for increased up take:

Foundation investment in technologies for hygiene promotion could leverage funds from electronic and media equipment producers, if there were sufficient incentives for them in the form of publicity.

5. Annexes

Annex 5.1	*Data collection, handling, storage, and access…*	*p45*
Annex 5.2	*Groundwater source construction…………………*	*p50*
Annex 5.3	*Handpump technology……………………………...*	*p55*
Annex 5.4	*Solar water pumping………………………………*	*p59*
Annex 5.5	*Household water carrying………………………….*	*p64*
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Annex 5.1 Data collection, handling, storage and access

In low-income countries there is a lack of reliable and comprehensive, long-term data for both surface waters and groundwater resources. Data on water quality, leakage, and use of piped and point water supplies is also limited. The paucity of information has implications for integrated water resource management (IWRM).

Challenges

1. Low priority is given to data acquisition by many low-income countries which results in limited understanding and monitoring of water resources at the international, national, sub-national, and end-user levels.
2. The lack of high quality information for understanding the 'bigger picture' of water resources is linked to a failure of reliable and real-time monitoring of water quantities, flows, levels and quality essential for effective planning and management.
3. Without external assistance it is cost prohibitive to adopt technologies for data collection, manipulation and storage suitable for local contexts and to establish effective national monitoring networks.
4. There is frequently a lack of transparency and sharing of data between government departments, organisations, officials and end-users which leads to inefficiency.
5. Institutional and technical manpower capacity are limiting factors in the collection, manipulation, storage and dissemination of water-related data. For example, the Uganda Joint Sector Review, 2004 mentions the lack of capacity of human resources no less than 83 times.

http://www.lboro.ac.uk/well/resources/Publications/Country%20Notes/CN13.1%20Uganda.htm

Reed B.J. and Coates S. (2003). Sector-wide capacity building: a discussion paper on making investments in training address the real needs of the sector. WEDC, Loughborough University.

6. Even if available, information on critical water quality characteristics (e.g. faecal contamination and arsenic, chlorine and fluoride levels) of domestic water is rarely made available to consumers.
7. Technologies for monitoring water quality are generally too expensive or complex for widespread distribution to consumer groups.

Possible solutions

1. Various international collaborations are seeking to address the lack of global hydro-geological and water quality information. Such initiatives are at present reliant on inadequate data provided by many low-income countries. As a result of this international co-operation it is to be hoped that data collection and its reliability will improve over time.

BOX 1: International initiatives for water resource information

World Bank/Global Water Partnership Groundwater Management Advisory Team (GW-MATE)

Seeks to facilitate management systems to address groundwater resource management and protection needs.

http://wbln0018.worldbank.org/essd/rdv/GWMATE/AR/cover.nsf/HomePage/1?OpenDocument

Worldwide Hydrogeological Mapping and Assessment Programme (WHYMAP)

A consortium set up in 2001 to collect, collate and visualise hydrogeological information at the global scale to convey groundwater-related information:

http://www.bgr.bund.de/nn_670840/EN/Themen/Wasser/Projekte/Berat__Info/whymap/whymap__projektbeschr.html#doc519828bodyText2

Aquastat

FAO's information system on water and agriculture collects statistics on water resources. Data obtained from national sources are systematically reviewed to ensure consistency in definitions and between countries sharing the same river basin. A methodology has been developed and rules established to compute the different elements of national water balances. It is hoped that through the comparative analysis of available country statistics on water resources the most reliable and complete dataset of water resources by countries is obtained and that the results could help harmonise currently available water resources databases.

http://www.fao.org/ag/agl/aglw/aquastat/water_res/index.stm

Watermark

This site is dedicated to the development of water supply surveillance and monitoring in low-income and transitional countries. The information available from this site contributes to the World Health Organization's *Guidelines for Drinking Water Quality*.

http://www.lboro.ac.uk/wedc/watermark/index.htm

2. To address the need to improve data collection, its management and dissemination, there is a need for capacity building in terms of the enabling environment, organisation development and human resource development.

BOX 2: Capacity Building for Integrated Water Resources Management (CAPNET)

A global network established by UNDP in 2002 committed to capacity building in the water sector. The regional and country networks are now well established for scaling up delivery of capacity building on IWRM and bring together experienced educators, trainers and researchers in water related fields. A summary of the successes and challenges can be found in the short version of the Completion Report.

http://www.cap-net.org/showhtml.php?filename=aboutcapnet_progress

UNESCO-IHE support for capacity building in China
http://www.unesco-ihe.org/vmp/articles/Projects/PRO-20050510-15-39-23.html

3. The collection of high quality data, its storage, manipulation and dissemination is key to management and understanding of water resources. Country examples of projects specifically aimed at data collection include the Hydrology Project in India and Water Point Mapping in Malawi and Tanzania.

BOX 3: Hydrology Project – India

Phase 1: 1995-2001 (Total cost US$ 162.4 million)

The Hydrology Project aims to assist the Government of India (GOI) and the seven participating states to develop comprehensive, easily accessed and user friendly data bases covering all aspects of the hydrological cycle, including surface water and groundwater in terms of quantity and quality and climatic measurements, particularly of rainfall.

Special attention has been given to standardization of criteria, processes and procedures for measurement of hydrological parameters and for storage and retrieval of information so that data series are compatible and the data bases interactive. The project also includes: upgrading and expanding the physical infrastructure for all aspects of the collection, collation, processing and dissemination of hydrological and hydrometeorological data; provision of equipment and materials; institutional strengthening including technical assistance and training.

http://web.worldbank.org/external/projects/main?pagePK=64312881&piPK=64302848&theSitePK=40941&Projectid=P010485

Phase 2 2006- (Total cost US$ 105 million)

Phase 2 will extend and promote the sustained and effective use of the Hydrological Information System, established under the India Hydrology-I Project, by all potential users concerned with water resources planning and management, both public and private

http://web.worldbank.org/external/projects/main?pagePK=104231&piPK=73230&theSitePK=40941&menuPK=228424&Projectid=P084632

BOX 4: Water Point Mapping (WPM) - Malawi and Tanzania

WaterAid has collected data on water point distribution in Malawi and Tanzania to facilitate more equitable access to services using a Geographical Information System (GIS) for data analysis.

Access to data has the potential to significantly shift power from practitioners to beneficiaries. It is however, often the case that poor men and women cannot access the information provided. The use of water point mapping and its impact on government planning, policy processes and monitoring processes is limited because there is a lack of capacity among district staff to handle data and the complexities of the GIS.

In Malawi obtaining governmental backing and ownership of WPM has proved a difficult task, while first governmental feed-back in Tanzania has been very positive so far. http://www.wateraid.org.uk/documents/waterpointmapping_tanmal_dec__05.pdf

4. Although project funding usually includes expenditure on expensive technologies, costs need somehow to be reduced so that they are affordable by governments in low income countries. A solution to the cost of technology also needs to take account of the often unreliable electricity supplies and the lack of skilled technical staff available to use the technologies such as GIS effectively.

Example costs for WaterAid WPM in Malawi: US$525,000 including:
Setup (including Global Positioning Systems (GPS) and GIS) US$25,000
Cost of mapping 50,000 water points US$ 500,000
Development of a cheap, user-friendly, robust, single point sensor that is linked to a functional telemetry 'warning' system would be invaluable for data collection. The sensor would measure required water parameters (water level and critical water qualities) and, as in developed countries, provide remote automatic monitoring of groundwater, being linked via a mobile phone network to provide assessment and monitoring of the water system.

Water quality can be accurately measured with technologies ranging from consumables (e.g. litmus paper, or nitrate testing equipment), through Ph probes ($1,000) to field kits such as DelAgua and portable spectrophotometers ($3,000).

Groundwater levels can similarly be measured with a range of existing equipment, from simple dippers, through self contained pressure transducers with loggers ($900), to geophysical survey 'kits' ($20,000) although there is a need to improve current levels of accuracy of the latter.5.Monitoring technologies which enable communities to record their own water data - groundwater levels (in addition to rainfall, river, and lake levels) and water quality and information and communication technologies (ICTs) for rapid reporting of faults with existing water supply services will serve to empower local communities while also providing monitoring data to water authorities.

Appropriateness of solutions

The problems surrounding groundwater and surface water data are mainly ‘software’ problems linked to lack of capacity but also ‘hardware’ issues relating to the cost and appropriateness of technological solutions. Both need to be addressed together to achieve a satisfactory outcome.

Annex 5.2 Groundwater source construction

Well construction is conveniently categorised under four headings:

- hand-dug wells (not considered further after this section),
- human powered (very low cost) drilling methods,
- small conventional drilling rigs,
- large conventional drilling rigs.

Table 1 (from Carter, 2005) summarises some key features of these four categories. In the following sections the focus is on the latter three categories.

Challenges

1. The costs of borehole and well[1] construction can be extremely high, especially in sub-Saharan Africa (SSA). It is not uncommon to find costs of US$10-15,000 in many countries of SSA, compared to about one tenth of that cost in, say, India.

   The reasons for this huge difference in cost are numerous, including:

   - the far smaller and less assured market for wells in SSA compared to India,
   - the more limited development of local private drilling contractors in SSA, with correspondingly limited price competition,
   - more limited capacity of local manufacturers and suppliers,
   - the great distances involved, combined with poor road infrastructure, and correspondingly high mobilisation costs in SSA,
   - the difficulties of "doing business" in SSA (including company registration, importation, and fair competitive tendering),
   - weaknesses in public sector procurement procedures and contract management.

[1] The term "borehole" usually means a groundwater source constructed by a drilling rig. The word "well" can mean a hand-dug or drilled source. The term "tubewell" is used in Asia to refer to a small diameter (drilled) groundwater source. In this Annex all three terms are used, sometimes synonymously, to refer to groundwater sources regardless of diameter or depth.

Table 1: Features of hand-digging, human-powered drilling, and 'conventional' drilling.

Feature	Hand-digging	Human-powered drilling	Conventional – small rigs	Conventional – large rigs
Construction technology	Headframe (tripod), windlass, rope, buckets, picks, shovels, hoes, chisels, hammers, dewatering pump, human labour. Sometimes: air supply, temporary support for excavation, explosives.	Frame, scaffold, or tripod (usually), drill pipes/rods, simple drill bits, rope, human labour, (for jetting or wasboring: small pump)	Light trailer-mounted or portable, site-assembled machines; pickup or alternative form of transport; drill pipes, mud pump, drill bits, compressor, hammer.	Truck- or trailer- mounted machine, trucks, pickups, drill pipes, mud-pump, compressor, hammer, temporary casing, drill bits.
Well lining options	Brick or stone masonry, in-situ or pre-cast concrete.	Traditional (eg bamboo) casing and screen, or plastic casing and screen.	Usually plastic casing and screen.	Steel, plastics – manufactured wellscreen and plain casing.
Well diameter	Minimum 1m, usual maximum 10m (parts of Asia).	Minimum 50mm, usual maximum 150mm (exceptionally up to 250mm)	50mm to 200mm, most commonly 100-150mm.	50mm to 1.2m Handpump wells commonly 150mm with 100mm linings.
Well depth	Commonly up to 30m, in extreme 120m.	Typically up to 30m	Typical maximum 50-100m	To 1000m+ Most water supply wells less than 100m.
Water abstraction options	Bucket-lift, handpump, suction lift by motor-pump.	Handpump, suction lift pump, occasionally submersible pump.	Handpumps, small electric submersibles, suction pumps (in favourable cases).	Handpumps, submersible pumps, suction pumps (in favourable cases).
Notional capital cost of construction technology[4]	"Improved" well construction equipment say US$5000	Traditional systems US$100. Simple "kits" and rigs up to US$5000.	US$20-30,000 for rig and drilling accessories (drill pipe, drill bits, mud pump). Extra for vehicles, compressors.	US$100-250,000.
Notional capital cost of well	20m "improved" well say US$1000	Traditional systems as little as US$10, with engineered rigs US$1000	Around US$1000.	20-30m borehole say US$5000. Not unusual to find cases 2-3 times this figure, especially in Africa.
Construction safety	Down-hole hazards: asphyxiation, gas, falling objects, hole collapse, falling on ascent/descent.	Hazards to hands, heads, backs, from human labour	Hazards associated with rotating machinery, compressor hose failure, falling objects.	Hazards associated with rotating machinery, reciprocating machinery, handling heavy loads, compressor hose failure, falling objects.
Construction speed	A few weeks to many months.	A few days to two weeks.	One to a few days.	Commonly one day.

Possible solutions

1. Reducing the cost of conventional drilling for scale-up .

   The technical and contractual means of reducing drilling costs are well known and include:

   - drilling at the smallest diameter required to accommodate the pump;
   - avoiding excessive drilling depths;
   - constructing open-hole (i.e. no casing) or using PVC well linings rather than steel;
   - using smaller, lighter rigs with smaller fleets of support vehicles,
   - issuing packaged (i.e. multi-borehole) drilling contracts, clustered spatially and by geology, to reduce mobilisation costs.

   Figure 1 below summarises the ways in which cost reduction can be achieved.

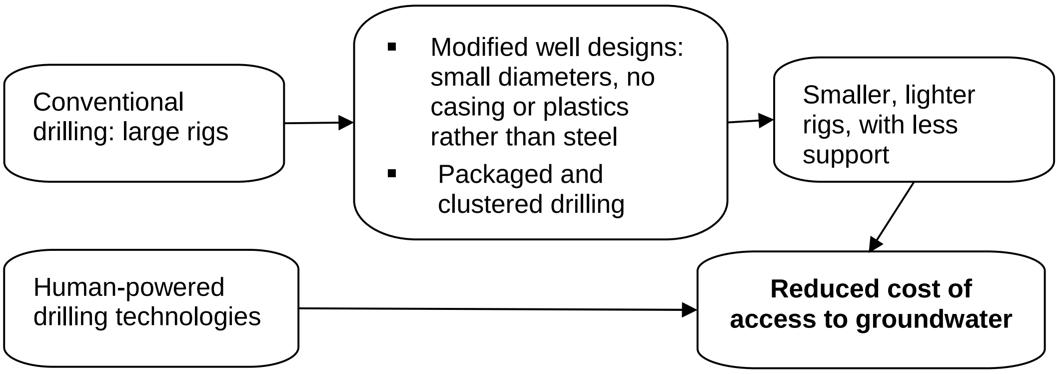


Figure 1: Reducing the cost of groundwater source construction

In principle, these measures can reduce drilling costs very significantly (sometimes by as much as half), especially where sources are to be used for handpump supplies

The achievement of reduced drilling costs requires supporting measures outside of the realm of technology or simple contractual details. Such measures include:

- ensuring a steady and significant flow of work for private sector well drilling contractors;
- ensuring that competitive bidding for drilling contracts is transparent and fair;
- developing greater and more detailed understanding of national hydrogeology;
- negotiation with Governments concerning standard designs. This can often require long periods of evidence-gathering in order to bring about agreed changes in practice;
- improved supervision capacity, in order to ensure that rapid and technically sound decisions concerning depth of drilling can be taken on site;

- encouragement of local supply ,or preferably manufacture, of PVC well screens and casings
- easing of importation difficulties (taxes, bureaucratic delays) for equipment, spare parts and consumables.

2. Drilling does not always require heavy equipment and large investments. Traditional, human-powered drilling technology used in north India, for example, can produce a water well for around US$10 – an extreme perhaps, but indicative of what is possible when simple technologies are used in the right environments.
   Four main very low cost (human-powered) drilling technologies exist. Each has numerous local modifications and adaptations. The four technologies are:

   - ***Hand augering*** is operated by rotating a steel drill pipe which has a cutting tool at its tip. As drilling progresses, the cutting tool or bit collects the spoil, and the column of drill pipe has to be lifted periodically to be emptied. As drilling progresses, new lengths of drill pipe are added successively at the top of the column.
   - ***Hand percussion*** operates by lifting and dropping a heavy chisel suspended on a rope or cable to break the rock formation, followed by the use of a different type of tool (a bailer) to clear the hole of debris.
   - ***Sludging*** is a traditional technique practised especially in India, Bangladesh and Nepal. It consists of a slow reciprocating action applied to a steel drill pipe using a lever arrangement, while the driller uses his hand as a flap valve at the top of the pipe to cause it to operate as a pump. As the pipe progresses into the water-filled hole, further lengths of pipe are added as needed.
   - ***Jetting or washboring*** is the only one of the essentially human-powered techniques to use the additional assistance of a motorised pump. Water is pumped down a drill pipe, and the return flow to the surface carries the spoil up the hole, so cleaning it as drilling progresses.

   All four techniques are capable of drilling in mainly unconsolidated (soft) materials, and can be used to construct wells up to 30m deep at very low cost. They lend themselves especially to construction by small entrepreneurs, for both domestic and productive water wells.

BOX 1: Examples of human –powered drilling techniques

1. 'Fadama' drilling programmes, Nigeria

Nigeria's 'Fadama' drilling programs have been on-going since the 1980s and have centered on developing small-scale irrigation through extraction of shallow groundwater with low-cost petrol-driven pumps for shallow tubewells. World Bank funding (US$67.5 million) from 1993-1999 has built on previous achievements and has resulted in a positive impact on farmer income and significant poverty reduction. The economic rate of return of the project was estimated to be 40 percent. Additional benefits were development of a simplified well-drilling technology, training of farmers to help other farmers construct wells, infrastructure for transportation and storage of products, Fadama User Association establishment, and development of an extensive monitoring and evaluation system. Improved welfare of Fadama farmers can be directly attributed to the project.

http://www.worldbank.org/afr/findings/infobeng/infob83.pdf#search=%22fadama%20drilling%20Nigeria%22

2. Enterprise Works, Niger

Hand augered garden wells and domestic wells programme

http://www.enterpriseworks.org/recentprog_irrig_niger.asp

3. Medair, Madagascar

Jetted domestic wells programme (with technical support from a pioneer of this technique, Richard Cansdale)

http://wedc.lboro.ac.uk/conferences/pdfs/31/Mol.pdf#search=%22Cansdale%20jetted%20wells%22

In all three cases, initial periods of technical assistance provided by an external agency have evolved into local small-scale private sector contracting

References

For reports relating to cost effective boreholes in sub-Saharan Africa
http://www.rwsn.ch/prarticle.2005-10-25.9856177177/prarticle.2005-10-26.7220595116

- Carter, RC (2005). Human-powered drilling technologies: an overview.

http://www.rwsn.ch/documentation/skatdocumentation.2005-11-15.5533687184/file#search=%22Cansdale%20jetted%20wells%22

Annex 5.3 Handpump technology

In the late 1970s and through the International Drinking Water Supply and Sanitation Decade of the 1990s, an enormous amount of work was done to develop, laboratory test, and field test handpumps for domestic water supply. The British Government supported the establishment of a dedicated testing laboratory in the UK, and subsequently the World Bank and UNDP financed a great deal of laboratory testing of commercially produced handpump models. The publication in 1986 of Arlossoroff's *"Community water supply: the handpump option"* marked the culmination of this period of trialling 70 different models of mainly commercially produced handpumps (2700 individual units) in 17 countries.

Public domain designs

Around the same time UNICEF in India was developing what would later become the India Mark II pump, probably the most widely used model globally. This led the way among the group of pumps known as "public domain" designs. These are pumps for which the detailed designs and specifications are published (by SKAT in Switzerland), but their manufacture is open to any commercial entity with the appropriate manufacturing facilities. The India Mark II was later joined by the Mark III, the Afridev, and others following the same concept.

Village level operation and maintenance

An important aspect of the technology development which took place at this time was the concept of *Village Level Operation & Maintenance* (VLOM, later extended to VLOMM or Village Level Operation and *Management* of Maintenance). The emphasis of this concept is on community ownership of operation and maintenance, local manufacture, and other factors thought to assure sustainability of handpumps. In some circumstances communities may take complete control of maintenance, although more commonly they act as the first tier of a two- or three-tier system, in which support is provided by the public or private sector or an NGO, or some combination of the three.

The Handpump Technology Network/Rural Water Supply Network

The Handpump Technology Network (HTN) was set up in 1992 to promote development and improvement in water supply handpumps, and to disseminate best practice on related issues. After holding a number of international workshops over a period of several years, HTN formally changed its name in 2004, becoming the Rural Water Supply Network (RWSN). It broadened its scope, while still focusing on groundwater development in Africa through two of its three flagship areas. The three flagships are:

- cost-effective boreholes
- sustainable handpumps
- self-supply.

A key function of RWSN is to hold the detailed designs and specifications for the main public domain handpumps.

Handpump specifications:
http://www.rwsn.ch/prarticle.2005-10-25.9856177177/prarticle.2005-10-26.2582788867

Sustainable handpumps:
http://www.rwsn.ch/prarticle.2005-10-25.9856177177/prarticle.2005-10-26.9228452953

Commercial handpumps and national standards

The promotion of public domain designs has to some extent constrained the development and deployment of commercial handpump models. From the point of view of the (mainly European) private sector, this has been disadvantageous. However, there is little doubt that the development of public domain designs has benefited developing countries, which have largely adopted such models as their national standards

.

BOX1: Rope and Washer pump

Apart from the improvements to handpump technologies which are being continuously made by RWSN (and published though their normal reporting structures), two particular groups of pump technologies are highlighted here.

1. *Rope and Washer pump* (or "rope pump" for short)

The rope pump originated in China and has been developed and commercialised in Nicaragua, promoted in a number of African countries (including Madagascar, Ghana and Uganda), and modified as the "Elephant pump" by Pump Aid (www.pumpaid.org). The rope pump consists of a continuous loop of rope to which washers or loosely fitting seals are attached every 0.5-1.0m. The rope passes over a wheel at the top of the well, and is drawn upwards through a pipe as the wheel is turned. Rope pumps can lift water from depths of 15-30m. The great advantage of the rope pump over many alternatives is its ease of maintenance using locally available and very cheap materials.

2. Canzee and Canlift pumps *(http://www.swsfilt.co.uk/)*.

The Canzee is a piston-less reciprocating pump made from standard PVC pipes and pipe fittings. The pump consists of a pipe-within-a-pipe, each having a simple footvalve made from car inner-tube rubber. The Canzee pump can lift water effectively from 10-12m. The fact that there is no piston seal to wear, and that the footvalves are so readily replaceable, means that this too is a pump which is ideally suited to "true" village level repair, with little dependence on support organisations. The Canlift is a more recent innovation, which can best be described as "*a reciprocating rope pump*". The Canlift pump rod has numerous loose-fitting valves, spaced at intervals, so that water is progressively lifted from one to the next. This pump is still in development, but it has been successfully tested to over 20m lift. Like the Canzee, it too is designed for ease of local manufacture, as well as maintenance at the village level.

Both Canzee and Canlift pumps have the potential to "go public domain", and this option should be pursued.

Challenges

1 With the background just given it might be expected that handpump technology is fully proven, and that little remains to be done to bring about full effectiveness of this group of technologies. On the contrary however, sustainability remains a key challenge for handpumped water supplies. In many countries in sub-Saharan Africa (SSA) in particular, handpump performance is poor. Many (very expensive) boreholes lie idle for want of a simple (or perhaps more challenging) repair to a (quite cheap) handpump.

The failure of handpump sustainability lies with the unrealistic expectations of community "ownership" and maintenance. Communities rarely do truly own their handpump, and they seldom have a culture of preventive maintenance. Moreover, communities have usually been left to take full responsibility for operation and maintenance, with no external support for when hardware or software go wrong. Ad hoc repair is therefore the best that can be hoped for, and any serious breakdown or replacement requires the intervention of an external agency, which may or may not happen.

Possible solutions

Given that the introduction of a technology such as a handpump creates interdependence of users on external (public, private or NGO) support, three broad options are open to enhance the likelihood of handpump operation being sustainable.

1. The full supply and support chain for handpumps needs to be in place and fully functioning. This requires constant attention and monitoring, and is not an easy option.
2. Where possible, technologies which lend themselves better to user-level repair, with little dependence on (but not complete independence of) outside agencies for support should be used. This option is mostly restricted to relatively low lifts, up to say 25m.
3. Migration from handpumps to alternatives such as diesel- or electric motorised pumps (which are well proven), or solar water pumps (which are not yet sufficiently widespread because of their high cost).
   From a technology point of view, the logic would be to ***develop public domain low-lift, "true VLOM" handpump technologies and solar pumping technologies***, in order to permit the second and third strategies for maintenance to be pursued effectively.

Annex 5.4 Solar-powered water pumping

In 1978 the World Bank set a target of 10 million photovoltaic powered water pumps by 2000. By 1998 it was estimated that only 60,000 were in place and a review in 2001 of PVPs installed in Thailand estimated that only half of those installed were still functioning.

Short, TD and Oldach, R (2003). Solar powered water pumps: the past, the present and the future? *Transactions of ASME*. Vol 125, Feb 2003 pp76-82.

Solar (photovoltaic) powered pumping is now considered to be a mature and reliable technology and in low-income countries has the potential to bring sustainable supplies of potable water to millions of people who have limited or no access to a safe water supply photovoltaic powered water pumps (PVPs) seem to have a long way to go before they can begin to meet the needs of those who use them.

Challenges

1. The high capital cost of the components of a solar water pumping system, especially the photovoltaic cells, is invariably a serious constraint to uptake. Many systems have been installed with government or donor finance/subsidy, but contributing to a maintenance fund is often a problem for poor communities and consequently systems may not be sustainable in the long term.

2. Additional components that would increase the efficiency of the pumping system such as automatic solar tracking and power trackers and linear current boosters to allow solar pumps to start and run under low light, not only increase the complexity of the system and make maintenance more difficult but also are usually unaffordable by poor communities.

3. In many countries cloud cover in the rainy season reduces the effectiveness of the solar pumps and therefore back up electricity generation, usually by diesel powered generators, is necessary which also gives rise to additional operation costs.

4. The 'practical efficiency' of photovoltaics is currently around 15%.

5. Often the application of the pump technology ignores the sociological and economic needs of the users, leading to lack of maintenance, inappropriate financing schemes, inadequate system management and, ultimately, failure of the pump. Lack of training and on-going support to enable communities to maintain systems and maintenance costs which are more than the community can afford frequently leads to a lack of sustainability of solar water pumping systems.

Possible solutions

1. There are cases where cost recovery principles have been applied in the supply of solar pumped water to rural communities with a view to achieving long-term sustainability

BOX 1: El Fortin, Choluteca Province, Honduras

In Honduras 47% of the population is without access to clean water.

At El Fortin, Enersol installed a Dankoff Solar TSP 1000 pump that is driven by eight 100W solar panels. The pumping head is 24 metres and the well is about 600 metres from the community. The design per capita consumption is 65 litres/day.

The design principle was to provide a system that met current needs of the community while being affordable and which could be added to in the future if the need arose.

Each of the 39 households has a tap yard connection and there are 2 public tapstands. The system is tiered, so the outlet pipe from the distribution tank for the private tap network is placed 50-100 cm above the tank floor, whereas the public tap outlet is at the floor of the tank. If water is used within the given guidelines, then the private taps always have water. If the community exceeds the allotted amount of water, the water level falls and private users have to use the central, public taps. This signals that the community as a whole is not staying within the recommended usage limits and provides a. powerful incentive to reduce over-consumption and waste.

Enersol charges users a flat monthly fee of US$3.25 per family. This helps recover some of the costs of delivering the water to the village and also to pay for repairs and maintenance.

The villagers have formed a 'solidarity group' that is responsible for collecting the money and depositing it in a special community account.. Enersol and its project partners retain the right to audit the group's account and check that users have been paying properly.

The villagers participated at every stage of the project and were trained to carry out basic maintenance and troubleshooting on the system themselves. Backup technical support is provided by a technician from a local PV company (Soluciones Energeticas).

(Eric Johnson, Long Road to Cost recovery in Rural Water Supply, Sustainable Development International, SD14 4/2). www.enersol.org/documents/costrecovery.pdf

BOX 2: Agua Zarca, Nicaragua

The project was funded by UNICEF, a private consultant and the ENECAL-the Nicaraguan state water company. Cost of the project was US$ 28,180 in 2003 with the community contributing US$ 1,742 (6.1%) to the capital costs. Each of the 52 households (population 364) contributes US$1.27/month towards running costs and the salaries (US$12/month) of 2 technicians.

Before the installation of the solar water pumping system, water was carried 1km from a well and the river 5 km away was used for bathing and clothes washing. Drinking water was frequently contaminated.

Careful attention was given to the technical design of the system. The original technical specification for the project was modified in the light of findings relating to the capacity of the borehole. Pumping was reduced from the planned 34 litres/min to 19 litres/min to ensure a reliable water supply. Similarly a manually-operated tracker was installed to maximise the solar radiation falling on the panels while minimising capital and maintenance costs. The sytem comprises a Grundfos 48Volt DC submersible PD pump powered by a 1.5kW PV- array made of 14 x 105W panels. A battery bank was also installed so that the community could pump at night to compensate for the low recharge rate. A PD (positive displacement) pump had to be chosen, even though the more expensive option, because no AC centrifugal pump could work on such a small discharge

The community participated fully in the project at the design stage and in the construction work which has given them a sense of ownership of the project. It has been found that health and hygiene practices have also improved as a result of the awareness raising during the project implementation and by making a tapstand available in the local school.

Currently the system is being well maintained and the community is making the agreed contribution for maintenance.

http://www.rrasca.org/nicaragua/lib/aguaenglish.pdf

BOX 3: Kaur, The Gambia

The solar water pumping system in Kaur was completed in 1999 and supplies a piped network to 5000 people as well as to two of the three area schools in the village.

There were 5 handpumps and several wells before the solar pumping system was implemented. The system was designed to take 38 public standpipes.

Each household pays 10 Dalasi (US$0.35) a month as a contribution to a maintenance fund and the salaries of the technician and night-watchman. Not only does the technician carry out day- to-day maintenance but both people guard against vandalism of the system.

Another 56 tapstands in compounds have been added to the system by wealthier families (14.6% of the population in the village) who pay 50 Dalasi a month (US$ 1.77) for the facility.

The result is that piped water is only available for 2 hours a day because the solar pumping system cannot match the unplanned demand. Inevitably richer families have more storage facilities for water and can use the water optimally when available to the detriment of the poorer members of the community who have to queue for water at the public tapstands. As a consequence, the solar pumping system has not resulted in a fully equitable water supply even though the public tapstands bring water nearer to poorer peoples' homes than previously.

The water committee is composed of influential and wealthy members of the community (including women teachers) and there is no real representation of the views of poorest in the community.

It is difficult for the community to afford the diesel fuel for the standby generator which is needed in the rainy season when there is reduced solar radiation to power the PVP. It has also proved difficult for the community to raise the money for the future maintenance of the system required by the project agreement. There is a monthly shortfall in the money collected

2. Increasing cell efficiencies (up to 16% achieved with Kyocera polycrystalline silicon solar panels where previously it was 5-6%) and new cell materials and manufacturing processes promise to bring the capital costs of solar powered schemes down significantly over the next decade. Such a lowering of costs brings solar-water pumping within reach of poorer communities.
3. A number of promising materials such as Cadmium Telluride (CdTe) and Copper Indium DiSelenide (CIS) are now being used for PV modules. Advanced CIS (Copper Indium DiSelenide) thin-film technology might in the future provide a real cost breakthrough for solar power. It uses only 1% of the materials used in silicon, and the production process is simpler, with less chance of breakage and no need for expensive hyper-pure silicon. The CIS metal solutions are sprayed onto a glass sheet in layers, much the same way that coated windows are made, eliminating the need for complex wiring and assembly. CIS panels also convert more sunlight to power in shady conditions than silicon panels.

Shell Solar has been progressing the next generation of technologies, including CIS 'thin-film'. The technology recently achieved a 13.5% world record efficiency for thin-film products. BP Solar is financing the development of the new technique for the growth of Silicon ribbon, known as EZ-ribbon, a new physical process with potential for significant reduction in the cost of solar cells and has given €600k funding into a 3-yr research programme with the Faculty of Sciences at University of Lisbon who have been developing the process for some years.

http://www.solarbuzz.com/news/NewsEUTE16.htm

http://www.ecn.nl/en/

Appropriateness of solutions

As with other technologies introduced into poor communities in low-income countries solar water pumping systems need to be 'fit for purpose'. They need to be designed in consultation with all users including women and the poor; be efficient and reliable in operation over the long term and capable of maintenance by the local community. On-going support and monitoring also need to be in place.

Annex 5.5 Household water carrying

In areas where there is reliance on point sources for water supply, water often has to be carried for long distances. Although boys are sometimes involved in water hauling, the burden falls mainly to some 1.6 billion women and girls, and gives rise to many associated problems.

Challenges

1. Distance from the source of water supply and container size directly relates to constraints on the amount of water available for household tasks (cooking, washing dishes and utensils) and hygiene of all family members (bathing and handwashing). Limited availability of water in the home therefore results in negative health impacts and increases the water-related disease burden. JMP describes reasonable access as being '*the availability of at least 20 litres of water per person per day from a source within 1 kilometre of the user's dwelling*.' (WHO, UNICEF, 2000) The Sphere Project suggests 15 litres per day and Gleick (1996) suggested the adoption of 50 litres per day.

Gleick, P H (1996). Basic water requirements for human activities: meeting basic needs. *Water International* Vol 21, pp83-92.

Table 1: Summary of requirement for water service level to promote health

Service level	**Access measure**	**Needs met**	**Level of health concern**
No access (quantity collected often below 5l/c/d)	More than 1000 m or 30 minutes total collection time	Consumption –cannot be measured Hygiene not possible unless practised at source	Very high
Basic access (average quantity unlikely to exceed 20l/c/d)	Between 100 and 1000 m or 5 to 30 minutes total collection time	Consumption –should be assured Hygiene –handwashing and basic food hygiene possible Laundry and bathing difficult unless carried out a source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one on-site tap or within 100 m or 5 minutes collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured Laundry and bathing should also be assured	Low
Optimal access (average quantity	Water supplied through multiple taps	Consumption –all needs met Hygiene –all needs should be met	Very low

100l/c/d and above)	continuously		

From: Howard, G and Bartram, J (2003). *Domestic water quantity, service level and health,* WHO.

2. Water is carried in a variety of bowls, buckets, jerrycans and traditional pots all made of a variety of materials. Water, even from a safe water source, may become contaminated through water being carried in open containers; by containers that are already contaminated; or from dirty hands coming into contact with the water either during transit or in the home.

Trevett, A F (2003). Household water security: the quality component. *Waterlines* Vol 21 No4 April.

Trevett, A F *et al* (2005). The importance of domestic water quality management in the context of faecal oral disease transmission. *Journal of Water and Health* Vol 3, pp259-270.

3. There is the temptation to use sources nearer to home which may be contaminated or more contaminated than water at a distance.

4. Transporting water may take up a third or more of a woman's annual productive time budget (600 hrs/year) and amount to 30 ton.km per year (*i.e.* the equivalent of carrying 30 tons over 1 km each year). The equivalent for men is 30 hrs/year and 2 ton.km per year. (See also Tables 1 and 2 below).

Barwell, IJ *et al* ,1987. *Household time use and agricultural productivity in Sub-Saharan Africa.* London, I.T. Transport.

Time spent collecting and carrying water considerably reduces the time available for:

- adequate care of young children – especially preparation of appropriate food
- household tasks
- growing food
- income generating activities
- schooling
- resting

Table 2: Fetching water (% people collecting water from each source)

Task performed by:	Ethiopia	Uganda		Sri Lanka
		Wet season	Dry season	
Women	40	80	37	80
Girls	45	15	4	10
Men	5	1	25	5
Boys	5	1	4	5
Water vendors	5	3	30	--

Table 3: Daily time budget: fetching of water

Per household	Ethiopia		Sri Lanka	
	Wet season	Dry season	Wet season	Dry season
Daily journeys	2	2	3	3
Total daily travel time	1 hr	1 hr	1.5 hrs	1.5 hrs
Total daily queuing time	0.5 hrs	1 hr	1.5 hrs	3.5 hrs
Total daily time spent fetching water	1.5 hrs	2 hrs	3 hrs	5 hrs

Data from: Bishop-Sambrook and Akhter, 2001 (Development Technology Unit, Warwick University)

5. The physical burden of carrying loads often exceeding 20kg per water container, causes long-term physiological damage to women and children and results in headache and injury to the neck and spine. Women are particularly subject to strain during pregnancy and after childbirth. A substantial proportion of daily food intake is expended on water haulage which further diminishes health where a low calorific diet is the norm and where 45% of women in developing countries suffer from anaemia (World Food Programme, 2006). The resulting lack of energy is particularly acute when food is in short supply during the 'hungry season' before harvest.

Bid, P. *et al* (2002). *Balancing the load: women, gender and transport.* Zed Books, London.

Curtis, V. (1986). *Women and the transport of water*. Intermediate Technology Publications, London.

Possible solutions

A safe source of water within 500 metres of home or on-plot would be the best way to reduce the long-distance water carrying burden. Besides access to hand pumps or tapstands, an often substantial and on-plot supply (even if seasonal) can be provided by rain-water harvesting to supplement other water supplies and mitigate the water carrying burden. This would also have the effect of increasing the availability of water for personal hygiene and household tasks. It is, however, realistic to suppose that in rural areas and small towns, water carrying will continue to be the norm for a majority of women and children who have the greatest responsibility for domestic water collection, storage and use.

What needs to be done:

- Water collection needs to be made more attractive to men in order to share the burden.
- Materials need to be made available to produce lighter-weight, more easily transportable and safer (for the user) design of containers.
- New production methods are required to drive down the unit costs of containers for water carrying and storage
- Affordable rainwater–harvesting and rainwater storage technologies need to be developed to relieve the water carrying burden especially during the rainy season when people are at their busiest in tending to food crops; their hungriest through seasonal food shortages; and the risk of illness (especially malaria, diarrhoea and acute respiratory infections, ARIs) is greatly increased.
- New/innovative designs are required to reduce and/or eliminate the possibility of contamination of water when in transit and during storage.
- Demand for technologies need to be stimulated in order for entrepreneurs to provide water-carrying services even among poor populations.

BOX 1: Intermediate technologies for transport

Water carrying bicycle trailers in Sri Lanka

A locally designed and built bicycle trailer enables women to collect a week's water supply in one trip.

The trailers can carry 200 kg and are used for a variety of purposes and also by men. Local credit schemes provide low interest loans to make the trailers affordable.

http://www.itdg.org/html/transport/expertise.htm

Load carrying bicycles for women in Ghana

Although devised as a solution to the burden of women carrying heavy loads, this scheme which included a purchase loan scheme, was not sustainable as women did not traditionally ride bicycles. Women tended to order bicycles designed for men and to give their bicycles to men in the family who then used them as a status symbol and for leisure purposes. Children also were keen to ride the bicycles. After 18 months, 25 percent of the new equipment was out of use because of lack of maintenance, overloading and inappropriate use.

Where other intermediate transport means were purchased (push trucks) relations between men and women often improved where men helped women with traditionally female tasks.

'Action research to evaluate the impact on livelihoods of a set of post-harvest interventions in Ghana's off-road settlements: focus on Intermediate Means of Transport' by Gina Porter, Frank Owusu Acheampong and Kathrin Blaufuss, University of Durham, June 2003
http://www.dur.ac.uk/child.mobility/

BOX 2: Improved water carrying containers

'Hippo' rollers

http://www.hipporoller.org/ Click on 'what is a hippo roller' (South African-developed version :90 l capacity.

Water is collected in a durable plastic drum made from UV stabilised polyethylene which is pulled or pushed by a handle fixed to the container. The container acts as a 'wheel' which makes transportation easier. The container can withstand transport over rough and rocky ground. The 135 mm diameter opening allows for easy filling and cleaning of the interior.

The containers allow a greater quantity of water to be carried in one journey and reduces the haulage burden. The sealed lid ensures hygienic transport and storage of water.

The container permits effective household level point-of-use water treatment.

'Aquaroll'

http://www.aquaroll.com/English/aquaroll.html (UK version developed for caravanning and camping :29-40 l capacity).

Appropriateness of solutions

Solutions must be affordable and acceptable to local communities and adequate maintenance mechanisms must be in place if adopted technologies are to be sustainable in the long term. It is important to design solutions both from users, entrepreneurs and donor perspectives, where convenience, quality of life, dignity and income are improved as well as health.

Annex 5.6 Rainwater storage

Of the 1.1 billion people 'unserved' - without adequate access to water of sufficient quantity or quality - the majority can benefit from rainwater harvesting for either domestic or productive use, or a combination of the two.

In areas where groundwater and surface water are in short supply – most notably in arid or semi-arid regions – or where improved water sources are distant, rainwater harvesting is often a sustainable alternative. Roof harvesting is the most common method, but other hard surfaces are also used.

Challenges

1. The majority of rural dwellers in low income countries are agriculturalists. The rainy season is the growing season with peak ***demands on labour*** in the fields. It is also the time of greatest food insecurity: food supplies, particularly for the poorest people, are at their lowest, and there is no guarantee of a good crop. Money lenders' interest rates are at their highest and many diseases (vector-borne and diarrhoea) are at their peak. Stored water during the wet season therefore saves the time of water collectors (mostly women and children) at a time when it is most precious.
2. There is limited ability amongst the poor of low-income countries to grow and harvest crops outside of normal agricultural seasons. As a result, household ***food security*** is low (with associated health problems and poor variety of diet) and ***income*** is at a minimum due to low market value of agricultural products during peak harvest seasons.
3. The ***burden of collection*** of water from distant sources throughout the year causes physiological damage to women and children; reduction in quantity of water used (with health implications) and reduced time available for household tasks / education.
4. The ***limited financial and knowledge capacity*** of potential beneficiaries: to afford a rainwater catchment system; and to maximise the productive benefits of collected water.
5. ***Accurate assessments*** of potential numbers of beneficiaries are difficult. The major constraints are:
   - The definition of the 'unserved' currently includes those with any or all of the following: lack of access to water (i.e. distance to source >500m); inadequate quantity; inadequate quality. There are no statistics relating to lack of access to water source only - for productive use, water quality is generally not a concern. Conversely, there will be many currently 'served' who travel up to 500m to an improved source who could benefit from rainwater harvesting,

both to reduce the burden of collection for domestic use and to provide supplementary water for productive use.

- Numbers of unserved are country level statistics whilst rainwater data is often at a more regional or district level. For 40 million unserved (i.e. 4% of the total), there is no rainfall data for the country they inhabit (20 million sub-Saharan Africa, 21 million Europe and Central Asia).
- The extent to which the unserved have potential for rainwater catchment (e.g. galvanized corrugated iron sheet roofs or ability to share a neighbour's roof) is unknown.

Possible solutions

1. Provide or increase storage to meet some or all domestic/productive needs. Variables to consider include storage capacity, rainfall and catchment area (see Figures 1-3). Meeting full domestic needs increases sharply with 15,000 litres storage compared to 10,000 l (408 million compared to 157 million beneficiaries); productive needs met similarly rise sharply with 5,000 compared to 3,000 litres storage (477 million compared to 136 million beneficiaries).

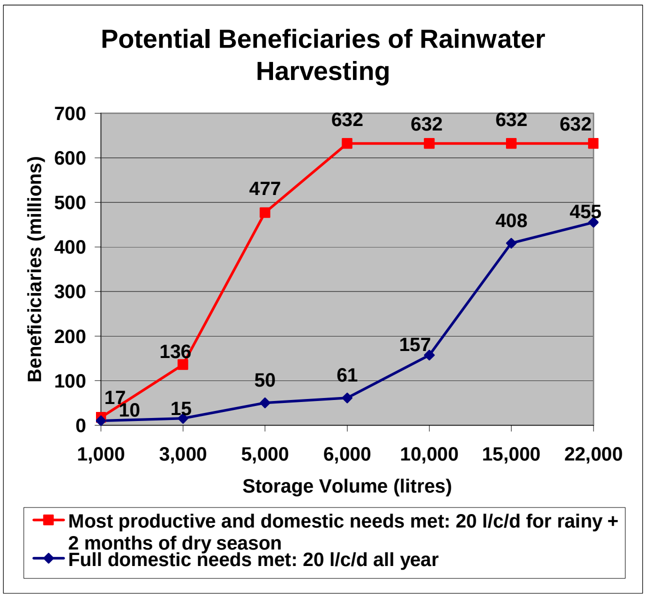
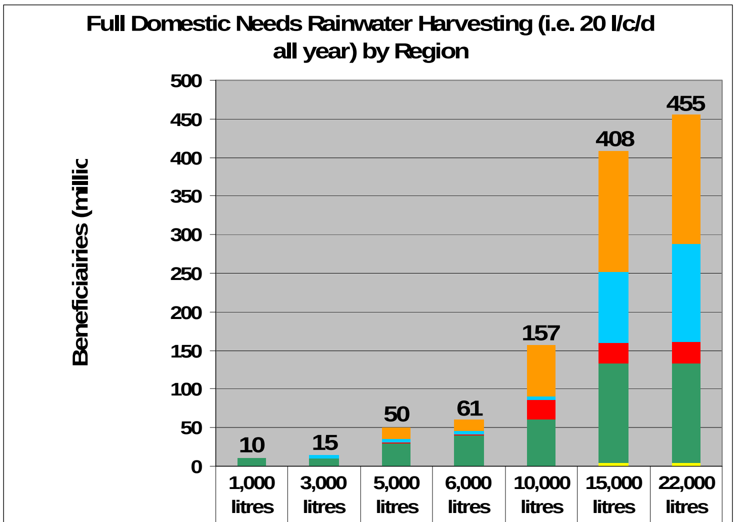


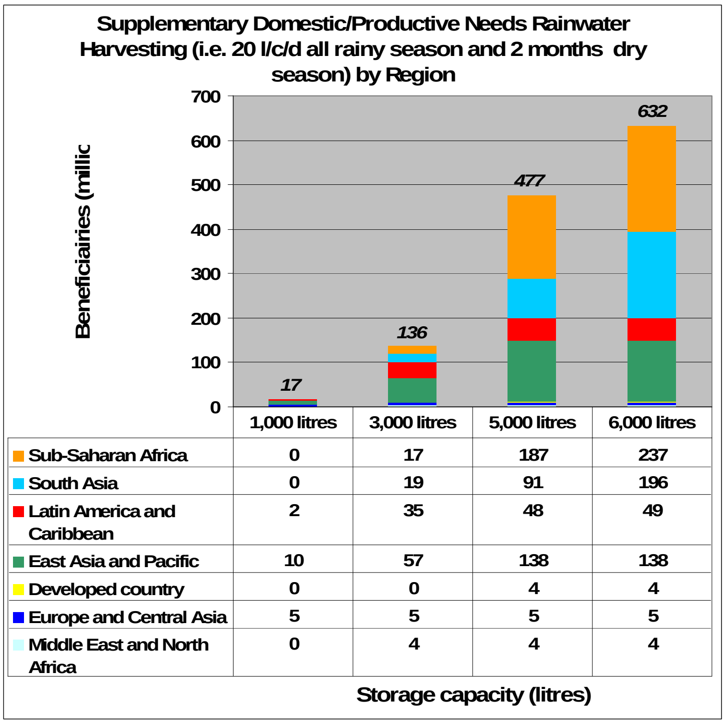
Figure 1: Potential 'unserved' beneficiaries of rainwater harvesting



	1,000 litres	3,000 litres	5,000 litres	6,000 litres	10,000 litres	15,000 litres	22,000 litres
Sub-Saharan Africa	0	1	15	15	67	157	167
South Asia	0	4	4	4	4	92	127
Latin America and Caribbean	0	0	1	3	26	27	28
East Asia and Pacific	10	10	30	39	61	129	129
Developed country	0	0	0	0	0	4	4

Storage capacity (litres)

Figure 2: Full domestic needs by region



	1,000 litres	3,000 litres	5,000 litres	6,000 litres
Sub-Saharan Africa	0	17	187	237
South Asia	0	19	91	196
Latin America and Caribbean	2	35	48	49
East Asia and Pacific	10	57	138	138
Developed country	0	0	4	4
Europe and Central Asia	5	5	5	5
Middle East and North Africa	0	4	4	4

Figure 3: Supplementary domestic/productive needs by region

2. Gathering more accurate data as to the specific number of potential beneficiaries prior to uptake of the following proposed solutions to address point 5 above is critical *(see the detailed Rainwater Harvesting Opportunity Area)*. For example, a specific Government report for China reveals that of the 298 million unserved, only 20 million could benefit from rainwater harvesting (mainly due to the high level of harvesting already present and rainfall patterns). This is taken into account in the figures above, but is unlikely to be mirrored in other areas, especially sub-Saharan Africa, where existing levels of (effective) rainwater harvesting are low.

3. Scale-up of the production of existing (proven) technologies through training existing community structures or individuals (e.g. community based organisations (CBOs), women's groups, health clubs, masons and entrepreneurs) or development of new community structures. For details of the necessary technical assistance and financial support delivered to the above groups through a learning alliance, *see the detailed Rainwater Harvesting Opportunity Area*.

   Technologies may be storage jars or tanks, reinforced or non-reinforced, above or below ground (see **Box 1**). In the absence of significant subsidies, a step by step approach is frequently adopted to meeting water requirements whereby additional relatively small volume jars are added as can be afforded.

   Costs for concrete jars and tanks range from \$100 per m^3 (10 cents/litre) for an un-reinforced ‘Kigezi’ jar in Uganda (\$30 for a 300 litre jar), to \$75/m^3 for a 20m^3 reinforced concrete tank in Uganda (compared to \$20/m^3 for a similar 20m^3 sub-surface ferro-cement tank in China – due to lower labour and material costs).

BOX 1: Differing types of above ground household rainwater storage

Clockwise from top left: construction of 500 litre ‘Kigezi’ jar, Uganda; 150 litre jars, Thailand, 1,000 litre jar, Ethiopia; 5,000 litre tank, Uganda;

4. Centralised production of ‘new’ type of storage. As with solution 3, above, there is a need to reduce the cost of storage either through mass production, subsidy or development of new technologies. Additionally, the development of flat-pack or collapsible storage would significantly assist transport from centralised manufacturing bases to end users - polyethylene (plastic) or bladder tanks are one solution. Currently, small collapsible plastic tanks used for camping are $300/m^3 but only available to 20 litre capacity. Larger, rigid plastic tanks up to 20,000 litres are similar per unit storage.

Appropriateness of solutions

All solutions must be appropriately sized to the runoff available and storage required, with 'first-flush' in place to preserve water quality. Additionally, hygiene promotion is essential if the benefits of improved health are to be optimised. For agricultural production, training and market development is necessary to prevent, for example, local markets being flooded with single products that have little commercial value. Above all, unit costs need to be reduced to ensure the poorest are able to afford rainwater harvesting solutions.

References

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- International Rainwater Catchment Systems Association: http://www.eng.warwick.ac.uk/ircsa/

- Rainwater harvesting: http://www.aboutrainwaterharvesting.com/

- Rainwater harvesting systems: http://www.irc.nl/page/14666

- WELL fact sheet on domestic rainwater harvesting: http://www.lboro.ac.uk/well/resources/Publications/Publications%20list.htm

Annex 5.7 Urban water supply technologies

There is a wide variety of means by which low-income urban households access water services although the conventional expectation for urban water is for a buried supply pipe to connect a tap/number of taps in a house to the utility serviced distribution mains. The alternative normally allowed for by public utilities is for water to be made available at a standpost some distance from the house. There is, however, a range of possibilities for supplying water to the poor in urban areas which needs to take account of different methods of piped connection to the house.

Challenges

1. Utilities frequently fail to take account of the needs of poor and very poor customers and fail to differentiate their supply service, both in terms of technology and subsequent pricing, to meet the needs of those customers.

2. Utilities serving slums often do not recognise the value of marketing, that is, targeting product, price and place to suit the particular market segment.

3. Many slum areas do not have ‘legal’ status and therefore water utilities are reluctant to serve such areas. This often means that water supplies are then controlled by ‘mafia’ style entrepreneurs instead with the result that many poor people pay more for their water than wealthier households with metered connections.

4. The quality of water supply services is often of a low standard with intermittent supply and a lack of potability of the water which ideally requires additional treatment before consumption.

5. Many poor people in urban slums dependent on water vendors for their water supply. Such water is more expensive than a piped supply, of dubious quality and limits the water available for household tasks and personal hygiene because of the need to afford both the water and the containers in which to carry the water.
6. Using water at standposts for bathing, laundry and other sanitary functions lacks privacy and dignity and is often unsatisfactory.

7. Tankers necessarily require household storage to discharge into which can be relatively expensive and which allows vendors to require payment for full loads only, irrespective of the amount of storage available, and therefore to be able to charge more for the water delivered by selling non-delivered water again.

8. The health costs of not having access to water are considerable but such costs are rarely examined. All water carrying either by household members and/or vendors increases the possibility of further contamination of water. The lack of quality

control on water sold by vendors, even in bottles or bags, may also contribute to ill-health from contaminated supplies.

9. There is a reluctance to move towards a non-conventional piped supply, that is a cheaper form of household connection, which may well not meet conventional technical standards (for example depth and quality of pipes or sizing for fire hydrant requirements) but which suits the convenience needs of households and promotes good health and hygiene practices whilst enabling the utility supplier to charge cost-reflective tariffs for a better service.

BOX1: Nigeria

In Abuja, the Federal Capital Territory Water Board installed 860 pre-payment meters in 2003 to ensure customers that "you will not only get equitable billing for your water consumption, but that you can also participate by determining how much water you want to consume and when".

A member of the Federal House of Representatives pays 3000 Naira per week at 100 Naira (US$ 0.78) per 1000 litres for his household's water needs.

Elsewhere in Nasawara State, water vendors pay a utility company a non-refundable 50,000 Naira deposit and water is sold to them on a franchise basis and costs 5 Naira for 20 litres. The water vendors then sell the water at 20 Naira per 20 litre container to those who have no access to a piped supply.

http://www.irc.nl/page/6077

Possible solutions

1. Solutions to serving the poor in slums require utilities to move beyond traditional approaches to water supply to extend services to those who may be settled illegally so that the poor may accrue health benefits as well as saving time and money in gaining access to safe water supplies.
2. Solutions may incorporate access to water via standposts outside of the home where water may be used at the standpost or transported to the home. More formal arrangements can include having multiple taps to facilitate access by more users at once to reduce queuing times, washing areas, 'lifting steps' to facilitate head carrying of water containers, storage tanks so as to guarantee availability even when the supply is intermittent, and in some examples access to those tanks through handpumps, thereby limiting wastage and overuse whilst capturing any available low-pressure piped water in the below-ground tank. As an alternative to public standposts, yard taps can be sited within a few metres of a group of homes making access easier for household groups which also affords greater privacy and dignity.

BOX 2: Dhaka , Bangladesh

9 million people (30% of the population) live in informal settlements, mainly slums. Most slum dwellers are illegal squatters on government owned land and the Dhaka Water Supply and Sewerage Authority (DWASA), is only able to provide connections to land owners, on presentation of a 'holding number' related to their plot. Slum dwellers therefore find themselves outside the official system. The denial of services to the urban slum has encouraged a parallel growth of an informal market where the consumers pay an unregulated and high price for water while DWASA is deprived of the revenue and the illegal operators make large profits.

Since 1992 Dusthya Shasthya Kendra (DSK, a local NGO), has been working with WaterAid and other agencies to connect local communities to the water supply network on a paying basis. From 1997 an integrated programme of water supply, sanitation service, drainage and footpath development, and hygiene promotion has been implemented with the active participation of the community.

There are now 150 water points serving 110,000 people transferred to community management. Loans are usually for 50,000 Taka (US$ 90) repayable by the community over 2.5 years. Water charges are either monthly (US$0.93) or on a pay and use basis (US$0.08/$m^3$. DWASA has reduced the security from 7500 to 1000 Taka for the water points.

Recently provision has also been made for washing menstrual clothes which affords women privacy and dignity.

Image and report from:

http://www.adb.org/Water/Actions/BAN/BAN_WaterAid.pdf#search=%22Rokeya%20Ahmed%22

3. Bulk water points provide closer/larger diameter access to water mains to facilitate speed of filling vendor carts and tanks. Adequate drainage of surplus/spilled water is even more critical for a bulk water filling point than for standposts.

4. Franchised transported water distribution has the potential to provide water in bulk for household storage at a reasonable price to those without a household supply as well as drinking water of monitored and controlled quality in bottles and plastic bags.

5. In many very low-income urban communities the access widths may preclude vehicles and therefore vehicular damage to water pipework. Thus surface pipes with flexible household-managed connecting pipes to yard taps and/or surface yard tanks are highlighted as being the cheapest means of achieving the convenience and low cost of piped water supply in low-income high-density housing areas - far better than standposts but cheaper (and therefore more affordable if the utility recognises those savings) than conventional distribution systems. Running pipes

along the surface of the ground can also facilitate leakage detection with leaks being immediately visible.

The various types of plastic pipe, particularly the polyethylenes (HDPE, MDPE, PEX etc) are ideal for flexible, above ground connections between distribution main and homes, easily made by householders themselves, as demonstrated by the many illegal connections made from such materials. The advantage of self-connection, perhaps from a delivery point on the edge of a (smaller) slum, is that it reduces costs to the utility by transferring the responsibility for negotiating rights-of-way and easements to the householder. The reduction in bureaucracy can lead to significant savings, making such systems affordable. Similarly, where it is appropriate to bury connection pipes, householders (groups of householders) can excavate and reinstate more cheaply than utility employees.

6. The most common form of charging for water is by volume consumed as measured by a water meter but metering can add one quarter to one third to the water bill.

- **Individual metering:** Some low-income households actually value having their own personal water meter and even more surprisingly their own personal bill. As in richer countries, where utility bills are seen as proof of identity and/or residence, slum dwellers also value that recognition. To reduce costs of metering one technique is to install rows of household water meters at the edge of, or in a convenient location in, the low-income housing area. Householders make their own flexible pipe connections to their own distant meter (or on occasion collect water from their meter by bucket) whilst the utility reduces costs by not having to provide individual house connections in difficult areas and reduces the costs of meter reading.
- **Shared metering:** A variation on remote metering is group or street metering where a group of householders share out the bill from a single meter, taking responsibility for equitable payments by whatever mechanisms they chose, thereby reducing costs. This approach depends upon the utility allowing for reduced tariffs as a result of reduced costs and not using the incremental block tariff approach which would quickly disadvantage groups of

households. There is a similar challenge when standposts are metered with tariffs collected through 'kiosk vendors' or community appointed on-sellers. If no allowance is made within the incremental block system the poor end up paying commercial/industrial rates for water. As ever, the technology is only effective in conjunction with suitable approaches. One variation on this idea for standposts is for householders to agree to buy tokens from a local shop-keeper adjacent to the metered standpost, contributing a token per container filled. This ensures that cash is received in advance and removes the expensive (time-consuming) task of trying to get poor households to contribute towards a monthly group water bill long after that water has been consumed.

- **Pre-paid metering:** The use of pre-paid meters is increasing. Originally using some form of coin-in-the-slot mechanical device, electronic versions are now available and have been well-received by customers (if not by NGOs) in, for example, South Africa (see also Box1 above). Householders value the opportunity to manage their spending on water, buying top-ups as they can afford it and, just as for their similar popularity in mobile phones, being able to prevent excess use (and unaffordable bills) by accident or theft.

7. Some societies, having achieved almost universal coverage and community acceptance, have ensured reduced costs for consumers by not having meters. Instead water is charged through a fixed payment for access. This solution is widely practised, as an unacknowledged default, by utilities which only supply water for one or two hours per day (thereby limiting all in that area to a similar consumption) and by utilities which fail to maintain their meters (remarkably common) and then charge a fixed amount.

- **Flow restrictors and volumetric controllers:** .Meter costs can be removed by design through the use of flow restrictors and volumetric controllers. Flow restrictors, sometimes known as trickle devices, allow a limited flow and therefore avoid excess use by some consumers making it possible to charge fairly a fixed tariff to all. However, flow restrictors come with the need for household storage which adds to the cost and in areas where supplies are intermittent and/or pressures are low the inability to access sufficient water usually leads to householders arranging to bypass the flow restrictor.
- **Ground tanks with float valves and limited supply hours during each day** so that customers receive a fixed amount for which they can pay an adequate tariff but without the expense of a meter is another alternative strategy for charging. An intermediate approach is a volumetric controller, in effect a meter but one which does not need to be read and billed separately. Both these systems can be used where water is paid for cash in advance, very appropriate in slums where there are no addresses to send bills to and little means of enforcing payment.

8. The development of pre-paid meter and volumetric controller technology, along with adaptation of tariffs to suit those consumer groups, warrants further attention.

Appropriateness of solutions

Technologies used to supply water in urban slums do not work in isolation from the acceptance of the community of customers – these cannot be technical solutions to social problems, only aids to enabling fair customer involvement and responsibility.

Annex 5.8 Household water treatment

Household water treatment (HWT) technologies are used to remove turbidity, pathogens and/or chemical compounds from small quantities of raw water to provide individual households with safe water mainly for drinking and cooking purposes.

The impact of HWT technologies could be significant, as many people have turbidity and contamination problems in drinking water (up to 100% of people without access to improved water- 1.1 billion people). The impacts on health and economy (local enterprise, improved work productivity and reduced spending on health) could be felt in a relatively short-term. Arsenic, iron and fluoride removal technologies could also have impacts for tens of millions people living in areas with chemically contaminated water.

Challenges

1. In many low-income countries water quality is often poor with regard to, turbidity, bacteriological and chemical contamination. The levels of contamination in drinking water give rise to a range of water-related illness and disease. HWT can remove pathogens, harmful chemical compounds and turbidity in water and hence improve people's health, dignity and quality of life.
2. Some technologies have more limitations than others: boiling has a high cost as well as being environmentally unsustainable; SODIS and household chlorination have potentially high margins of error in terms of water quality; moringa seed extract is cheap or free in some places and very effective at reducing turbidity but only removes some pathogens and therefore has a limited impact on health.
3. From a user point of view HWT technologies need to be reliable and effective at maintaining water quality over time. For example - water quality can drop if filters or lamps are not cleaned / changed regularly.
4. Technologies are often cumbersome to use and expensive for the poor especially to buy and run. Filtration rates of filters, or maintenance of UV lamps can discourage people from using technologies and even with locally produced technologies which may be relatively affordable there are capital and/or running costs to be met.
5. Both the technologies and spares for technologies which are needed on a regular or intermittent basis (e.g. UV lamps, ceramic candles, chemicals) need to be easily available and affordable. Effective supply chains are frequently absent.
6. Users must be able to perceive benefits to themselves and their families in terms of health and even the prestige that comes with ownership of the technologies.
7. Mechanisms need to be in place to support users in their use of the technologies and also for evaluation and monitoring purposes.

Possible solutions

1. Technologies for HWT include: chemical coagulants/disinfectants such as PUR, biological sand filtration, ceramic filters, technologies for removal of arsenic, iron and fluoride, household ultra-violet (UV) disinfection, solar disinfection (SODIS), household chlorination, natural coagulants such as Moringa seed extracts, and boiling. (See table below and **Boxes 1-5**).

   PUR can only be produced in specialised factories, with appropriate machinery and skilled workers. But it can be used anywhere where water turbidity and contamination is problematic in both urban and rural contexts. Its uptake is dependent on price and the efficiency of the local supply chain. Adequate ways of disposing of the sachet and the sludge to avoid adverse environmental and health impacts need to be promoted.

   Production of biosand and household ceramic filters can be taken anywhere, using mostly locally available resources. They can be produced by skilled artisans, at the village level (CBOs, women group, NGOs), or at a larger scale in a factory. For ceramic filters, quality control is necessary to ensure the quality of candles to achieve good results. Biosand and ceramic filters can be used in both rural and urban contexts, the main issue being their price and the availability in local shops of new ceramic candles to replace the used ones.

   Arsenic, fluoride and iron removal technologies can also be produced and used locally, in both urban and rural contexts. As some techniques require chemicals (alum, etc), these need to be available.

   UV lamps are produced in factories, and require electricity. Their use would be mostly for urban areas.

2. Since 2003 the Household Water Treatment and Safe Storage (HWTS) Network set up under the auspices of WHO has been concerned with the microbial quality of water and in reducing diarrhoeal diseases and more recently with arsenic and fluoride removal. The Network provides an overarching view of HWTS and facilitates the sharing of experience with the different technologies and their implementation. http://www.who.int/household_water/en/

Appropriateness of solutions

To encourage scaled-up use of HWT technologies by communities and to be sustainable in the long term, the technologies need to be: simple to use; require low operation and maintenance (O&M); be cheap (in terms of money but also time); provide income or save income for households (money or time); and potentially give some prestige to their owners to encourage wider uptake. The technologies should also be effective at improving water quality with a low margin of error to give positive health impacts.

These HWT technologies have already been widely used in many countries, by different organisations but the main issue is to ensure the availability of good quality, affordable products.

	What?	Why, why not?	How it works	Impact	Cost[2]	Sustainability
Biosand filter	Household biological sand filters – locally produced.	Improved water quality (bacteriological, chemical, turbidity) No reduction in burden of collection (adds slightly to burden if slow filtration rate). No improvement of water quantity.	Slow sand filtration of contaminated supply; concrete poured into steel mould; fixed outlet pipe.	Approximately 100% of those with inadequate access to improved water (i.e. 1.1 billion).	$20 per filter: $8 cement, UPVC pipe, steel mould; $12 locally available materials.	Minimal operation and maintenance costs; durability (20 years+); locally produced, un-reinforced concrete; low cost; replicable (through training CBOs such as women's groups).
Ceramic filters	Filters with ceramic candles	Reduce pathogens and turbidity. Spare candles must be available. Slow filtration rate.	Water is poured in a container, is filtered through ceramic candles and falls into a reservoir.	Approximately 100% of those with inadequate access to improved water (i.e. 1.1 billion).	Ranging from 4 US$ for a 12 litre filter, 1.6US$ for a ceramic candle in Nepal to 25 and 6 US$ respectively elsewhere.	Easy maintenance but fragile technology. Candles are difficult to find, sometimes too expensive.
Arsenic, fluoride and iron removal	Various household low-technologies including filters or chemical treatments can remove arsenic, iron and fluoride.	Improved drinking water quality, depending on raw water quality.	Highly depends on techniques (see more details below).	80 million people have arsenic in their drinking water source. 23 countries have fluoride problems, 62 million people are affected in India alone.	Depends on techniques (see more details below).	Usually relatively low maintenance and low cost, but some chemicals might be needed.
Tablets, PUR	Coagulants associated with disinfectants, sold in tablets or powder.	Reduce turbidity and kill pathogens.	A dose is mixed to a volume of water. Suspended solids coagulate and fall, pathogens are killed through disinfection.	People having turbid and contaminated water.	US$ 0.03 / sachet (for 10 litres).	Imported, difficult to find in shops.

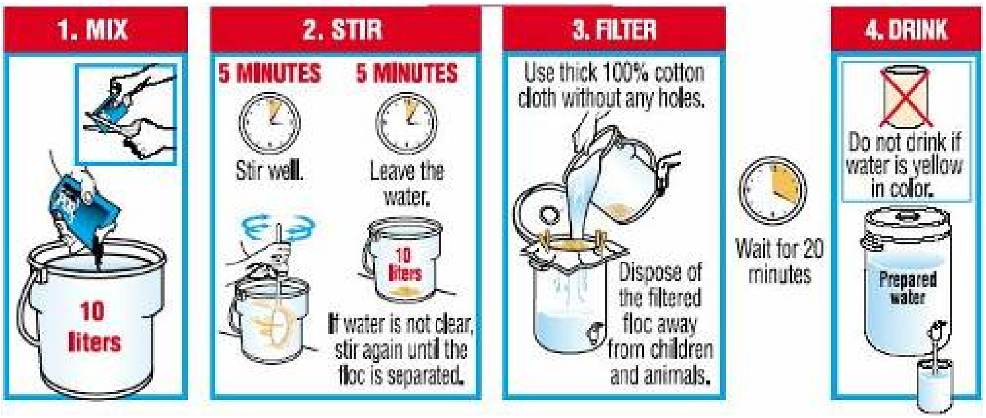
[2] Indicative costs only.. Actual costs per litre of treated water vary according to location and local cost of technologies or their components.

	What?	Why, why not?	How it works	Impact	Cost[3]	Sustainability
Ultra-violet lamps	Lamps emitting UVs to disinfect water, by batch or in flow.	Effective at killing pathogens if used properly but need for electricity and periodic replacement. Does not work to treat water with high turbidity or iron, sulfites and nitrites.	The lamp can be placed in a container with water, or above a thin water flow. Long and intensive enough radiations kills pathogens.	People having contaminated water with relatively low turbidity, low iron / sulfite / nitrite contents. People must have access to electricity.	US$ 10 to 100 per household per year.	Usually imported technology, with need for some maintenance and periodic replacement.
Solar disinfection	Disinfection of water using solar energy or UV lamps.	Kills some pathogens.	Water is poured in max. 1.5 litres transparent recipients exposed to sunlight for 1-2 days.	People having non-turbid but contaminated water in sunny, warm regions.	Cost of transparent containers and time spent.	Easy O&M, low-cost, replicable, but very time-consuming.
Household chlorination	Disinfection with chlorine tablets, granules or bleach.	Improves water quality and prevents household contamination. Risks of under or over dosing.	Chlorine is dosed (volume, chlorine demand) and mixed to water. Minimum 30 minutes contact time is required.	People having non-turbid but contaminated water.	Chlorine is usually relatively cheap.	Chlorine is often available (bleach), relatively cheap. Dosing is not easy.
Moringa seeds extract	Coagulation of suspended solids with natural seed extract.	Reduces up to 95% turbidity and 50% pathogens.	Water is mixed with a seed extract which coagulates with suspended solids. Water is collected after settlement or filtration.	People having turbid and contaminated water.	Cost of local seeds.	Affordable, local.
Boiling	Disinfection through heating. Fuel needs to be available (wood, coal, gas, etc).	Kills 100% pathogens, but disinfection does not last in time.		Regions where water biological quality is bad and fuel is easily found.	Link to fuel availability.	Very expensive, time and energy consuming.

[3] Indicative costs only.. Actual costs per litre of treated water vary according to location and local cost of technologies or their components.

BOX 1 : Chemical coagulants / disinfectants such as PUR

PUR was developed by Procter & Gamble (P&G) in collaboration with the US Centers for Disease Control and Prevention (CDC). This product contains a chlorine disinfectant for killing bacteria and providing residual protection and an iron salt coagulant for removing suspended matter, protozoa, and viruses. It also contains a buffer, clay and polymer to provide good coagulation and flocculation. Each 4 gram sachet treats 10 litres of water (see usage instructions below). PUR can result in removal of more than 99.99% of bacteria, intestinal viruses and protozoa. In randomized controlled health intervention studies, PUR has been proven to reduce diarrhoeal disease incidence by up to 90%, with an average of about 50%. To achieve the best health impacts, safe water storage containers and appropriate hygiene practices are required. According to the raw water quality, users might dislike the residual chlorine taste. PUR produces residual sludge, which, together with the sachet, has to be disposed of safely.

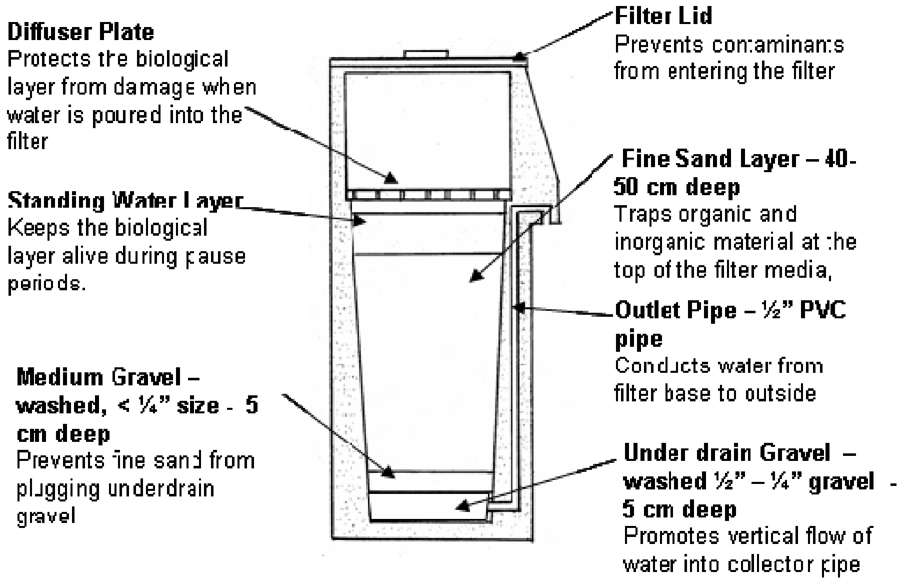


http://www.pghsi.com/safewater/pdf/aquaya_SOP%20Nov_05.pdf

Note: other chemical coagulants / disinfectants products such as Halopure: http://www.vanson.com/prodhalopure.asp , are based on similar processes and can also be used at the household level. Moreover, other chemicals such as Quaternary Ammonium Silanes (QAS) are emerging in the water sector, with potential use at both communal and household levels (see annex on communal water treatment for more information on QAS).

BOX 2: Biosand filters

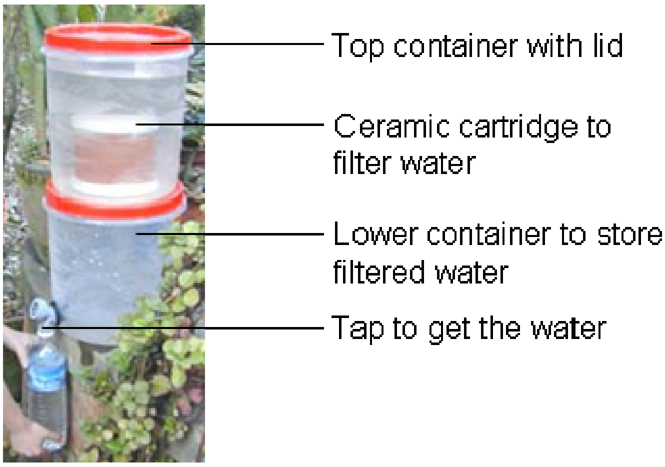
Biosand filters are small slow sand filters, enabling households to remove turbidity (by filtration through sand) and pathogens (by biological digestion) from contaminated water supply. They consist of a concrete or plastic container filled with sand and topped with a diffuser plate and a lid. Users pour the water in the top container, it filters through sand and goes out through an outlet pipe (see figure below), the filtration rate being around 1 litre/minute. Once installed, it will take 2 or 3 weeks for a biological layer to grow below the surface of sand. This layer digests pathogens, disinfecting water naturally. Biosand filters reduce faecal coliform contamination by 70-100%, iron, nitrite, chloride contents by 95%, and removes 95% of turbidity. They do disinfect water but do not provide residual protection against further contamination. However, they provide safe storage, and do not give any taste to water. Biosand filters have to be cleaned from time to time (every 6-12 months).



BOX 3: Ceramic candle filters

Ceramic candle filters consist of 2 containers on top of each other. The top one contains a filter made of porous ceramic. Good quality ceramic candle filters have micron or submicronic ratings and are impregnated or coated with colloidal silver to prevent biofilm formation on the filter and excessive microbial levels in the product water. Users pour water in the top container and then put the lid on it. Water slowly filters through the ceramic candle and goes down to the second container, from which it can be abstracted using a tap. Depending on the quality of candles, these filters can remove 90-100 % turbidity and up to 99,99% bacteria, protozoa, helminth eggs. The efficiency of ceramic filters against viruses depends on the quality and the maintenance of the candles. As for biosand filters, ceramic filters disinfect water but do not provide residual protection against further contamination. They provide safe storage of water, and do not give any taste to water. Ceramic media filters require regular, gentle cleaning with water only (every 2-3 months) to remove accumulated material and restore normal flow rate. Candles have to be replaced regularly (6-12 months).

Example of inexpensive ceramic candle filter used in Nepal



BOX 4: Household level arsenic, iron and fluoride removal technologies

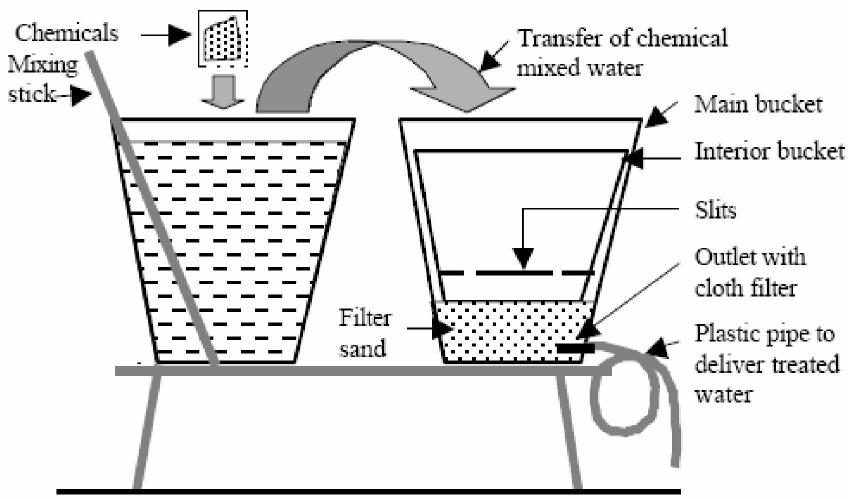
WHO drinking water quality guidelines suggest that the maximum permissible level of arsenic, fluoride and iron are respectively 10µm/l, 1.5mg/l (both for health reasons) and 0.3 mg/l (for reasons of taste only, iron is not dangerous to health). In many countries or regions, groundwater – and sometimes surface water – have much higher concentrations, leading to long term health problems but also inconvenience for end-users (people sometimes prefer bacteriologically contaminated water rather than water with iron colour and taste). When there is no easy alternative water source (such as rainwater harvesting), these chemical compounds should be removed.

http://www.who.int/water_sanitation_health/dwq/arsenic2/en/index1.html

Arsenic removal

A number of household technologies have been designed to remove arsenic from drinking water.http://www.unu.edu/env/Arsenic/Sutherland.pdf#search=%22DPHE%20DANIDA%22
These include:

- Oxidation of arsenite to arsenate: passive oxidation and sedimentation in a traditional household storage container, solar oxidation in transparent bottles.
- Co-precipitation and adsorption: to remove trivalent arsenite effectively, there may need to be a precursor oxidation stage to form arsenate. The arsenate can be removed effectively by the addition of a chemical coagulant such as alum or ferric chloride. These compounds set in train a series of chemical reactions which lead to the formation of flocs onto which arsenate may be adsorbed and removed by sedimentation and/or filtration. The Bucket Treatment Unit developed by DPHE-DANIDA utilises these principles. It has been progressively modified to improve its effectiveness. The figure below shows a similar technology, developed by the Stevens Institute.



- Sorptive filtration media: these are filter media that have an affinity for arsenic. Sorptive media generally have to be chemically regenerated to maintain their effectiveness and have to be regularly replaced. Examples of sorptive media include activated alumina and iron-coated sand. Activated alumina has been extensively tested in Bangladesh.
- Ion exchange: A similar process to sorptive media filtration relying on a reversible adsorption using a synthetic ion exchange resin. The liquid generated by regeneration is hazardous and needs proper disposal. An ion exchange resin has been tested with promising results in Bangladesh.

BOX 4 (continued)…

- Membranes: membrane techniques are capable of removing impurities of differing particle size depending upon the membrane type and operating conditions. Low pressure nanofiltration and reverse osmosis techniques have been applied to the removal of arsenic from groundwater – at household scale. The capital costs are high relative to alternative technologies.

Fluoride removal

- Coagulation-flocculation: Alum can be used to generate settleable flocs under alkaline conditions. The Nalgonda technique uses alum and lime and a pair of linked buckets – one for the flocculation/sedimentation reactions and one for storage of treated water. Sludge has to be disposed safely.
- Sorptive filtration media / ion exchange: another approach is to filter water down through a column packed with a strong adsorbent, such as activated alumina, activated charcoal, bone charcoal, rocks or soils (bauxite, magnetite, kaolinite, serpentine, clay or red mud, broken brick pieces), ion exchange resins. When the adsorbent becomes saturated with fluoride ions, the filter material has to be backwashed with a mild acid or alkali solution to clean and regenerate it. The effluent from backwashing is rich in accumulated fluoride and must therefore be disposed of carefully to avoid re-contaminating nearby groundwater.

Iron removal

Various techniques, similar to the ones described above, could be used at the household level to remove iron from water, but more recent and appropriate techniques have been designed for use at the community level. Iron removal will therefore be described in the communal treatment annex.

BOX 5: Household UV lamps

Pathogens can be inactivated if drinking water is exposed to strong and long enough UV radiations. UV disinfection is usually accomplished with "low pressure" mercury lamps, operating at relatively low partial pressure of mercury, low external temperature (50-100 ºC) and low power. Most low-pressure mercury lamp UV disinfection systems can efficiently disinfect essentially all waterborne pathogens. However, natural organic matter, certain inorganic solutes, such as iron, sulphites and nitrites, and suspended matter (particulates or turbidity) will absorb UV radiation or shield microbes from UV radiation, resulting in reduced microbial disinfection. Another concern is the ability of bacteria and other cellular microbes to repair UV-induced damage and restore infectivity, a phenomenon known as reactivation. Some lamps are designed to be submerged into the water to be disinfected, while others are suspended above a thin flow of water.

UV disinfection with lamps has the advantages of being effective for inactivating waterborne pathogens, simple to apply at the household and community levels, and relatively low cost, while not requiring the use of chemicals or creating tastes, odors or toxic chemical by-products. The disadvantages of UV disinfection with lamps are the need for a source of lamps, which have to be replaced periodically (typically every year or two), the need for a reliable source of electricity to power the lamps, the need for period cleaning of the lamp surface to remove deposits and maintain UV transmission (especially for the submerged lamps), and the uncertainty of the magnitude of UV dose delivered to the water, unless a UV sensor is used to monitor the process. In addition, UV provides no residual chemical disinfectant in the water to protect against post-treatment contamination, and therefore care must be taken to protect UV-disinfected water from post-treatment contamination, including bacterial regrowth or reactivation.

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Annex 5.9 Community-level water treatment

Community water treatment (CWT) technologies aim to remove turbidity, pathogens and/or chemical compounds from large quantities of raw water to provide households with safe water, directly at source or through piped networks. This group encompasses various technologies: coated treatments, conventional and natural coagulants, sedimentation technologies, various types of filters, treatments for removal of specific chemicals, aeration technologies, membrane treatments, desalination and disinfection technologies.

Most of these technologies have been developed and used for a long time without significant changes. Their high capital cost is difficult to reduce, as they rely on proven technologies. Their management is often problematic because of the need for maintenance, spare parts, chemical products, etc. For these reasons, conventional coagulants (alum, ferric chloride, etc), sedimentation tanks, aeration technologies, large-scale seawater distillation, and ozone disinfection will not be developed further in this Annex..

There could be opportunities to reduce running costs, using simpler technologies such as filtration rather than chemical treatments, or replacing imported chemical coagulants by local natural ones. More recent technologies such as membranes or desalination could benefit many more people if their costs (capital and running) could be reduced, and their operation and maintenance simplified.

When water is delivered at source (e.g. protected well or borehole with handpump, protected spring), water is sometimes already safe to drink (no turbidity, no contamination). The only treatment that could apply to such cases is disinfection, to ensure water is free of pathogens and leave a protective residual. In some other cases, water can be treated at source to protect end users from pathogens and suit their requirements in terms of colour, taste, smell (turbidity, iron). When water is delivered through a piped network, it needs to be treated not only to protect end users, but also to protect the network itself (avoidance of blockages, fouling).

Challenges

1. Water treatment is expensive and complex, and sometimes does not prevent water contamination (e.g. when unexpected chemical or biological contamination occurs).
2. Both capital and running costs of CWT technologies are highly dependent on the quantity and quality of water to be treated and on local circumstances.
3. Effective water treatment is dependent on local technical, financial and institutional capacity as much as technologies.
4. As CWT encompasses various technologies with very different goals and applications, it is difficult to evaluate how many people could benefit from them, either directly or indirectly.
5. Land needs to be available especially for slow sand filters

Possible solutions

Each technology has a limited spectrum of applications, which not only depends on the quality of raw water but also on the local technical, financial and institutional capacity. (See also **Boxes 1-7** below).

1. Simple and multi-stage filtration systems are suitable in urban, small towns and rural contexts provided space is available.

   Sand and gravel filtration systems have relatively high capital costs, which are difficult to reduce (price of cement, pipes, etc). However, their running costs are quite low as they do not rely on any chemicals and may also be gravity operated which reduces the energy requirement Operation and maintenance are relatively easy, compared with processes involving chemicals, but need to be carried out regularly by trained people, otherwise water quality will not be reliable.
2. The application of communal treatments for arsenic, iron and fluoride are limited to areas in real need of them. Various technologies have been designed for rural communities and small towns (iron or fluoride treatments to be attached to handpumps), or for small towns and urban contexts (chemical treatments using coagulants). Communal arsenic, iron and fluoride treatments usually involve chemicals and regular cleaning. They are therefore relatively difficult to operate, maintain and sustain. An exception to this is the iron/arsenic removal technology relying on aeration and filtration: capital cost is relatively low (US$ 2000) and running costs are only 1 hour labour every 1 to 4 weeks.

3. The use of natural coagulants such as Moringa seed extract in communal treatments is limited to small towns and urban contexts, but the production and transformation of seeds could be done in rural areas with linkage to income generation.

   Using Moringa instead of - or in conjunction with - conventional coagulants would certainly be cheaper and supply would be easier (since the seeds can be produced locally). However, operation would remain complex.

4 Coated anti-microbial treatments (QAS) are ‘blue-sky’ technologies. Their application is not clear yet, but depending on their price mainly, they have a potential use in all contexts. High investment would be necessary to adapt, field-test, produce and distribute them. Local production is unlikely in the near future.

5. Membrane treatment costs are currently very high, and the technologies are difficult to operate, maintain and sustain (need for high skills, high-tech equipment, pre and post-treatments, supply for spare membranes). However, since these will undoubtedly play an important role in future water treatments, their price and complexity will probably decrease. It might however take a long time before membranes are available and sustainable in low income countries. Membrane treatments could be of benefit in mainly urban contexts, and potentially small towns, but certainly not rural areas.

6. Desalination technologies such as solar distillation can easily be built locally, but their application seems to be limited to rural areas and small towns, because of the need for land. Initial high capital costs are counterbalanced by low O&M costs.

7. Theoretically, disinfection should be carried out systematically and water quality needs close monitoring for disinfection of communal water supplies to be reliable. Various simple chlorination technologies can be produced locally for hand dug wells, boreholes, and piped networks. If not available, chlorine itself can be produced locally (liquid sodium hypochlorite) with water and salt, using small electrical bleach generators. The acquisition or local manufacture of chlorine is still often a prohibitive cost for poor communities

   UV systems would be more applicable to small towns and urban areas, depending on the availability of UV lamps and spares, as well as electricity.

BOX 1: Filtration technologies

Various types of filter rely on two treatment processes : physical filtration of water through sand or gravel (to remove turbidity, organic and inorganic matter, etc), and biological digestion of organic or chemical matter (pathogens, iron, etc).

***Rapid Filters* (RF)** are relatively small filters, usually made of gravel or coarse sand, and aim at removing suspended solids and / or iron and manganese (prior aeration, is required). See also Box 2 communal treatments for iron below.

They can work either with gravity or be pressurised, and need regular backwashing with clean water to maintain acceptable filtration rates and product water quality.

They are not effective enough on their own at removing pathogens .

Coarse Gravel Filters (CGF) consist of two or more layers of gravel or coarse sand, and aim at reducing turbidity and bacteriological contamination. They have to be designed carefully according to the raw water quality and its variation (seasonal, etc). They need to be cleaned very regularly to avoid clogging. This can be done manually or hydraulically (with clean water), or both.

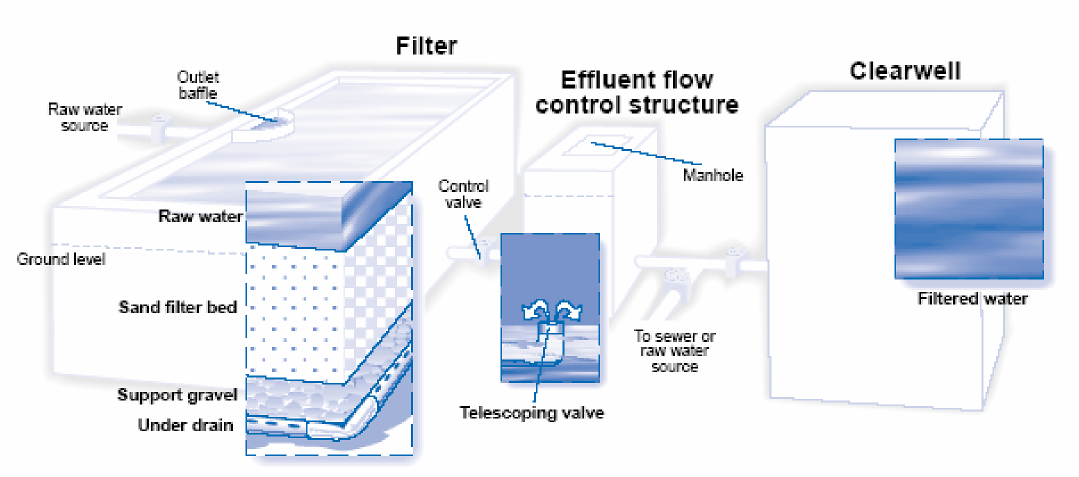
Slow Sand Filters (SSF) are large filters filled with sand to reduce turbidity but above all bacteriological contamination (See below). .They are based on the formation of a biological layer in the top few centimetres of the filter, which digest pathogens and organic matter. It takes several weeks for this biological layer to grow and be effective, while filters have to be cleaned after several months (scraping the 1-3 first centimetres of the filter, with occasional resanding).

Apart from when they are being cleaned, SSFs must be operated continuously to remain effective therefore at least two SSFs are needed in a treatment plant. This increases the already considerable spatial requirements for the location of SSFs..

SSFs are not effective at treating very turbid water; water with high concentrations of iron and manganese; very heavy microbiological contamination, low temperature water or low dissolved oxygen levels. In some cases, SSF there is a need for pre-treating the water by sedimentation, RF, CGF or other technologies.

The combination of several of the above filters is called Multi-Stage Filtration (MSF). An example of MSF would be a treatment plant with raw surface water flowing through one or more CGFs, then a SSF, with a final disinfection before distribution. MSF is effective for treating contaminated water without using chemical products (except maybe chlorine for post-treatment disinfection) and with relatively simple operation and maintenance. It is therefore an interesting solution for small and medium-sized communities.

BOX 1 (continued): Slow sand filter (SSF)



BOX 3: Natural coagulants

Several seed extracts have been used, historically, as coagulant. These include those of apricots, almonds, peaches, etc. The most famous natural coagulant is *Moringa*. The *Moringaceae* family has 14 known species. Half of these species are common, but the *Moringa oleifera*, horseradish or drumstick tree, is the most planted throughout the tropics due to its many uses (vegetable, oil tree, honey tree, fodder, fuel crop, ornamental, and medicinal). Depending on seed quality and the process used to prepare them, their extract has been used as a coagulant at the household level, to reduce high turbidity and bacteriological contamination, although the latter is less effective. Some studies show that *Moringa* can be used as primary coagulant, or as co-coagulant (coupled with alum) in small treatment plants, to reduce running costs and dependences on unreliable availability of chemicals.

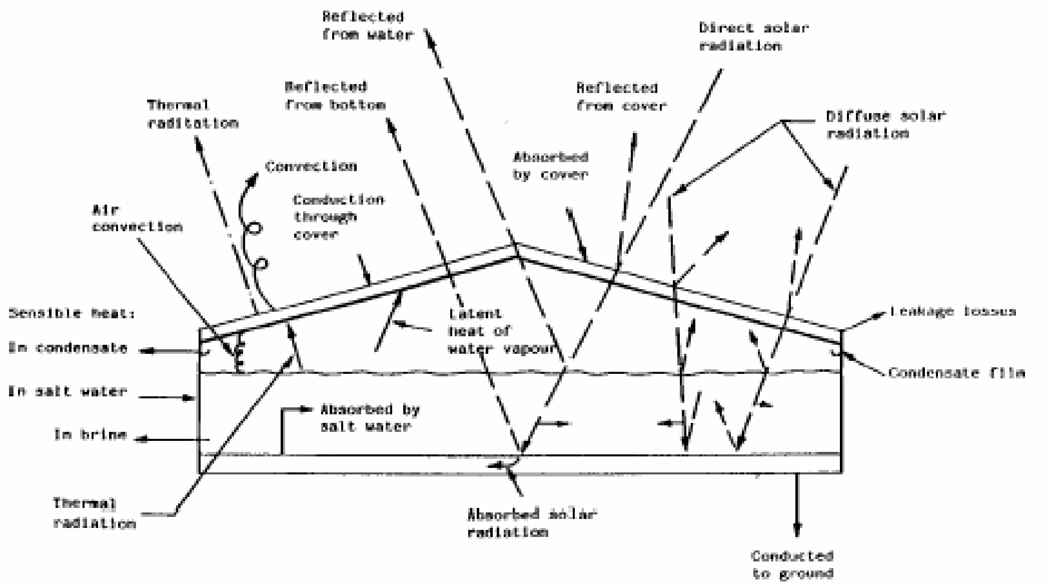
BOX 5: Membrane treatments

Membrane treatments can remove either very small particles or molecules and ions from water. Depending on the size of the particles to be removed (salt from seawater or brackish water, nitrate, iron and manganese, etc), specific membranes are used for reverse osmosis, nanofiltration, ultrafiltration, and microfiltration and rely on the same principle. Membranes are basically very fine filters in which the raw water needs to be highly pressurized to let (usually only part of) it pass through the membrane without the unwanted material. Depending on the raw water quality and the type of membrane used, pre-treatment may be necessary to avoid bio-fouling, scaling or other damage to the membranes. Post-treatment may also be necessary to make the water harder, more alkaline, disinfected, etc. Electrodialysis is another membrane treatment but is an electrically- based process removing ions and charged particles on a membrane which has a specific electrical charge.

BOX 6: Desalination technologies

Desalinating seawater or brackish water can be achieved by three processes: distillation, reverse osmosis or electrodialysis. The latter two have been mentioned in membrane treatments. Distillation at a large scale in treatment plants (multi-stage flash, multi-effect and vapour compression distillation) requires huge amounts of energy, with difficult operation and maintenance, and is not applicable for treating small volumes of water.

For small-scale desalination distillation can be carried out using solar energy (see Figure 1 below representing a solar still). Incident solar radiation is transmitted through the transparent cover of the still and is absorbed as heat by a black surface in contact with the water to be distilled. The water is thus heated and gives off water vapour. The vapour condenses on the cover, which is at a lower temperature, and runs down into a gutter from where it is fed to a storage tank. The main problem relating to this technique is the land requirement ($2m^2$ of still are required to produce on average 5 litres/day). This space requirement does not change whether the raw water is seawater or brackish. Operation can be difficult but maintenance is minimal.



BOX 7: Disinfection technologies

Disinfection technologies are mainly used to disinfect communal drinking water supplies by chlorination, radiation by ultraviolet (UV) light. Treatment with chemicals such as ozone, iodine, bromine, potassium permanganate, silver ions is not usually feasible in many developing countries because of lack of availability of the chemicals and high running costs.

Chlorination is the most widely used method for water disinfection. Chlorine, either in its liquid, solid or gas forms is usually cheap and easily available. With correct dosing and sufficient contact time with non turbid water chlorine kills most pathogens, although a few protozoa are resistant. Chlorination also provides a residual that can protect water from further contamination. Underdosing is ineffective, and overdosing is unpleasant for end-users (taste, smell) and can have negative impacts on health. Chlorination can leave some carcinogenic disinfection by-products (such as trihalomethanes), when raw water carries some organic materials. The public health risks of drinking contaminated water, however, largely outweighs the risks of cancer. Various simple chlorination devices have been designed and have proved effective for various types of communal water supplies, from wells to piped networks.

Rigorous training in dosing and monitoring needs to be carried out if chlorination is to be reliable for disinfection purposes.

Low-pressure mercury vapour UV lamps can also be used to disinfect non turbid water. The operation principles have already been described in the annex for household water treatment, there is no difference when UV lamps are used at the communal scale.

Electricity is needed to operate these lamps and thus a reliable electricity supply is required .

Appropriateness of solutions

1 Treatment processes and technologies have to be adapted to the local institutional, technical and financial capacity, which is not always easy. To avoid these problems, it is always better to protect sources (spring boxes, aprons around wells and boreholes, etc) to ensure the best raw water quality rather than having to treat it. However, sometimes, treatments cannot be avoided.

2. Another approach is to provide water which aims at providing larger quantities of raw or only partially treated water for domestic and other purposes, rather than providing high quality water only for domestic purposes a small proportion of which is generally used for drinking and cooking purposes.

3. Each of the numerous CWT technologies described is relatively context specific. This is especially true for arsenic, iron and fluoride removal technologies, desalination and membrane treatments, for which applications are relatively limited compared to disinfection or filtration technologies. It is essential to understand that water treatment is often a source of “problems” in the long-term (O&M, spares and chemicals supply, running costs, etc) and that technical choices have to be made very carefully, in relation to specific local technical, but above all financial and institutional capacity.

4. Communal filtration systems and disinfection technologies could have huge health and economic impacts, virtually all over the world. Although more limited, communal arsenic, iron and fluoride removal technologies could also have health impacts for tens of millions people living in areas where water is chemically contaminated. Other technologies such as Moringa coagulation, coated anti-microbial treatments, membranes and desalination technologies could have significant health – and potentially economic – impacts, but would need previous research and / or massive investments to benefit the poor.

5. Apart form maybe coated anti-microbial treatments, which are very new in the water sector, none of the technologies described above appear to have significant associated risks. It should however be mentioned that some processes, such as arsenic removal technologies or other chemical treatments, can produce concentrated toxic sludge that need to be disposed of in a way that does not have adverse impacts on health or the environment.

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Annex 5.10 Improved on-site sanitation

The majority of people living in both rural and urban areas of the developing world still do not have adequate sanitation facilities or services. It will be many years before most such people can be served by any form of 'off-site' sanitation, in which their waste is removed by water-borne sewerage to be treated and disposed of. In many situations such a technology will never be feasible, because of cost or lack of water, but this remains the misguided aim of many sanitary engineers.

Therefore **on-site** sanitation technologies, in which human waste is safely contained and, in some cases recycled as a fertiliser, remain the only choice for many. The basic forms of on-site technology that may provide a safe method of disposal of faeces are:

- **Simple pit latrine:** A hole in the ground with a platform and a superstructure to provide privacy;
- **VIP latrine** [Ventilated improved pit latrine]**:** A pit sealed at the surface with a concrete slab; roofed superstructure built to provide a dark interior; ventilation pipe connected to the pit, located outside the superstructure, with flyscreen on top; the vent-pipe greatly reduces smells and flies;
- **Pour-flush latrine**: Pit sealed at the surface, generally with a concrete slab, with a shallow bowl providing a water seal; waste flushed by hand into pit below;
- **Composting latrine** [also sometimes known as 'ecosan']**:** Sealed container below a slab and superstructure collects faeces; sometimes urine is collected separately, and/or ash or other material containing carbon is added to promote decomposition; decomposed excreta are removed and used as fertiliser;
- **Septic tank:** Waste is flushed from a toilet to an underground tank; solids decompose; liquids flow from the surface of waste into the ground.

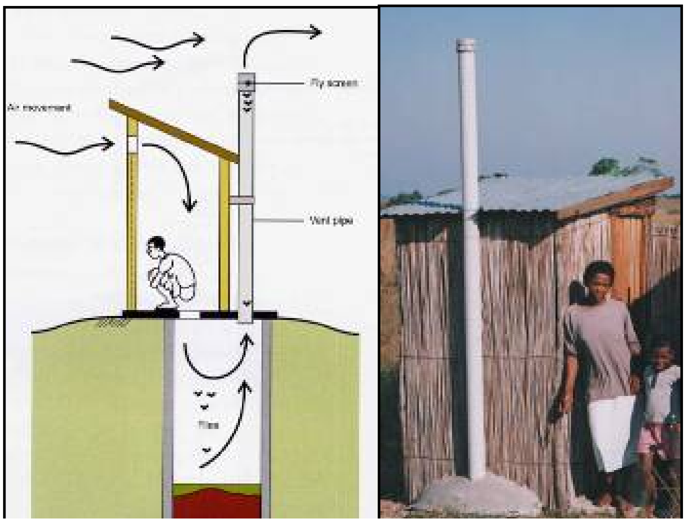

Figure1: A VIP latrine

Simple pits, VIP latrines, pour-flush latrines and septic tanks all dispose of liquid waste by infiltration into the ground. Solids are contained in the pit or tank and are removed when the pit or tank is full, or the pit is sealed and a new one is excavated.

Simple pit latrines are often unpleasant and therefore not used by all members of the household, or they are dirty, facilitating the spread of disease; both conditions endanger health. These can be improved by addition of a small concrete slab, a ‘sanplat’, over the existing platform, which helps users to keep it clean. VIP latrines are promoted, mainly in Africa, where water is often in short supply and is not used for anal cleansing. Pour-flush latrines are mainly used in South Asia, where water is used for analcleansing. Composting latrines are not widely used, except in East Asia, partly because of widespread taboos about handling faecal waste.

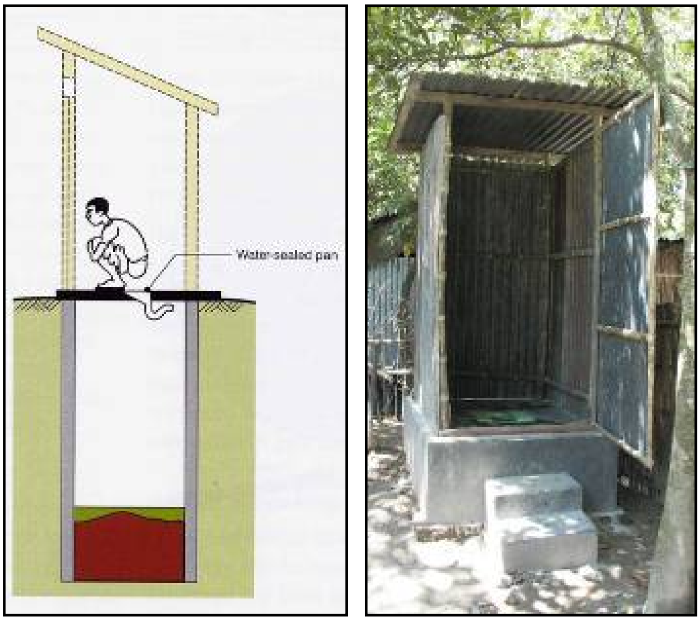

Figure 2: A pour-flush latrine

On-site sanitation is not permitted in urban areas of many countries, but is clearly the only way in which facilities will reach the majority of the urban poor in the next few decades. Conventionally trained engineers are also resistant to promoting such technologies. Lobbying is needed to overcome these hurdles.

Challenges

1. Approximately 2.6 billion people do not have a safe sanitation facility; they are either using unhygienic, dangerous latrines or defecating in the open. This has huge impacts on individual and community health and is degrading.

2. Many households, especially in urban areas, apparently want improved facilities; but there are often gender differences in demand.

3. Too often households cannot afford, or do not want to pay the full cost of the technologies on offer, even the relatively low-cost forms of VIP or pour-flush latrine.

Possible solutions

A range of options is needed, all aiming to provide a hygienic facility, including a floor that can be easily kept clean, a screened vent-pipe for 'dry' latrines, and a pour-flush bowl for 'wet' ones. Composting may also provide a solution, but generally requires a considerable change of attitude amongst users in order to be adopted.

What is needed:

1. Low-cost, locally applicable components for easily maintained latrines that are pleasant to use, to increase hygienic use of on-site sanitation.

2. Reduced cost alternatives to the reinforced concrete slab, such as the smaller, flat concrete *sanplat* or the domed, unreinforced concrete slab, have been developed, promoted and used with dry latrines, but there is potential for further improvement at minimal cost. Low-cost alternative designs for the VIP latrine have been developed and promoted, but these have not spread widely. The plastic pour-flush bowl has revolutionised the spread and use of pour-flush latrines in South Asia. Such affordable technology needs to be spread throughout Asia, where water is available and used, and similar solutions need to be developed for incorporation into dry latrines in Africa.

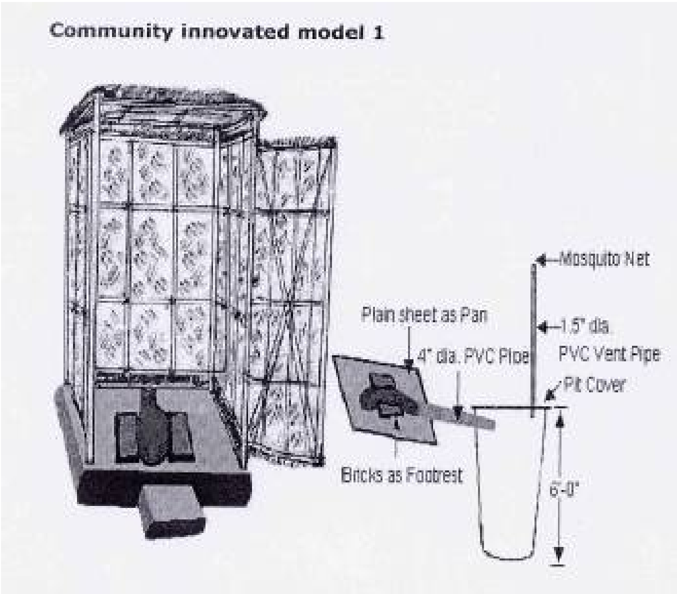

Figure 3: A locally adapted pour-flush design (Kar, 2003)

3. Development, where necessary, dissemination and promotion of low-cost alternative floor components, including plastic floors as an alternative to concrete, and plastic pour-flush bowls, throughout Asia, and of similar technologies, including alternative floor slabs, low-cost superstructures, vent pipes and fly-screens, for dry latrines in Africa, hygienic, on-site sanitation should become available to a much wider group of households, in both rural and urban areas, than at present. If such latrines are affordable and can be easily maintained in a hygienic state, they will be used by most of the population.

Appropriateness of solutions

1. Low-cost, sanitary latrines are needed by at least 2 billion of those living in both rural and urban areas of the developing world; if appropriate, affordable floor components, superstructures and ventilation pipes can be developed, made, disseminated and taken up widely so that adequate latrines are built and used, the toll of sanitation-related disease and all the social impacts of lack of access to a decent sanitation facility, which particularly affect women and girls, and those living with a disability, should be greatly reduced.
2. Very low-cost floor, ventilation and superstructure components are key to increasing the spread of sanitary latrine construction and use by billions of poor people throughout Africa and Asia.

   Development costs are unknown at present – but the principle is to produce a structurally sound latrine floor that can be easily kept clean, a cost-effective superstructure and, in Africa, an effective ventilation pipe, for as little cost as possible, both for pour-flush latrines and for dry latrines. Many different materials have already been tested by various programmes. The intention should not be to find a 'one-size-fits-all' solution, but rather to assemble a range of proven technical solutions, which can be promoted, taken to scale, locally produced, and adopted very widely at locally affordable cost. The aim should be a latrine built for US$5 plus family labour and a small amount of local, semi-skilled labour. Subsidies should be minimised although the poorest may still need assistance.
3. Sustainability of solutions is essential. The development of appropriate components must be carried out with local manufacturers in different countries and regions of Africa and Asia, and the testing and installation carried out with local artisans. Further artisans will then need training in order for the appropriate solution to spread. Different solutions will be needed by different socio-economic groups. Flexibility and responsiveness must be key to success.

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Annex 5.11 School-friendly sanitation

The provision of sanitation in schools needs to be considered as a package of technologies ('hardware') and approaches ('software'). As a package, school sanitation includes not only latrine provision but of equal importance is water supply and hygiene education in schools. Without 'child-friendly', 'girl friendly' and, above all, hand washing and sanitation facilities in good working order in all schools, children cannot put appropriate hygiene behaviours into practice. The significance of children as agents of change in their families and communities and amongst their peer group (child to child) with regard to the adoption of improved hygiene behaviours also needs to be recognised in all school sanitation and hygiene programmes.

Challenges

1. Approximately half of primary schools in developing countries lack water supply and 75% lack sanitation. This translates into 300 million primary school children without school water supply, 450 million without school sanitation and 600 million who could benefit from hygiene education (UNICEF School Sanitation and Hygiene Education, January 2006). A similar lack of provision exists in secondary schools.

2. Where facilities do exist they are often poorly maintained. The latrines photographed below were all in use in schools in the Gambia in 2005. Such conditions do not encourage improved hygiene behaviour among school children.

3. Water supply is needed in schools to encourage the practice of hand washing with soap. Even where a handpump or tapstand is installed there are often no separately provided facilities to make hand washing convenient. Similarly, soap for hand washing is often considered to be too expensive to be provided out of school budgets or is stolen if made available.

4. Lack of access to safe water and sanitation at school and in the home affects a child's ability to enroll and stay in school (this especially applies to girls), causes poor health, irregular school attendance and diminished performance.

5. Female teachers are in the minority and so there are very few staff who can deal sensitively with hygiene issues for girls especially with regard to menstruation management.

6. There is a lack of an integrated approach to school sanitation which frequently leads to a lack of hygiene education and promotion in the school curriculum and no linkages to the local community to reinforce appropriate hygiene behaviours in the home environment.

Possible solutions

1. The ***School Sanitation and Hygiene Education*** programme (SSHE) launched as a concept in 2000 by UNICEF and IRC, is also championed by the World Bank's School Health Initiative and other international organisations, and promotes an integrated approach to school sanitation. An extra dimension has been added to SSHE by the incorporation of the Focusing Resources on Effective School Health (FRESH) framework which was also begun in 2000.

   UNICEF funding[4] in over 70 countries for school sanitation programmes together with workshops and the output of guidance notes and learning materials to facilitate an integrated approach to school sanitation has helped to provide, improve and maintain appropriate facilities for water supply, handwashing and sanitation facilities in schools as well as to provide hygiene education for children and resources for their teachers (http://www.irc.nl/page/4480)

[4] UNICEF spent US$ 160 million in 2004 on water, sanitation and hygiene (12% of UNICEF programme expenditure) http://wwwa.house.gov/international_relations/109/tob062905.pdf

Box 1: SSHE in Bangladesh

In its commitment over the next five years (2005-2010) to the expansion of SSHE to another 7,000 primary schools and 300 secondary schools in Bangladesh UNICEF is also strongly encouraging the Government and development partners to incorporate the construction of appropriate facilities in schools into relevant Sector Programmes to ensure that all children attending schools in Bangladesh have access to adequate water supply and sanitation facilities by the year 2010.

Compared with the world average of 20 to 30 students per latrine, the current (2006) average provision in Bangladesh is one latrine to 152 pupils with the worst case of 479 pupils per school latrine in a country with 78,000 primary schools.
http://nation.ittefaq.com/artman/publish/article_25183.shtml

2. The provision of ***'child-friendly'*** facilities is necessary if children are to be able to practise improved hygiene behaviours. In addition to providing suitable latrines, child- friendly facilities need to include the provision of hand washing facilities as well as the setting up of maintenance programmes which also incorporate daily cleaning.

   Zomerplaag, J., Mooijman, A (2005). *Child friendly hygiene and sanitation facilities in schools: indispensable to effective hygiene education*. IRC and UNICEF
   http://www.irc.nl/content/download/10474/154194/file/Child_Friendly.pdf

3. Appropriate and well-maintained facilities backed up with hygiene education which encourages improved hygiene practices among children can help to improve child health by reducing the incidence of parasitic worm infections, acute respiratory infections and diarrhoeal disease in particular. School attendance and academic performance tend to improve as a result.

   Curtis, V and Cairncross, S (2003). Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. *The Lancet Infectious Diseases*. Vol 3, May, pp275-281.

   Luong, T V (2003). De-worming school children and hygiene intervention. *International Journal of Environmental Health Research.* Vol 13, Supplement 1, June, ppS153-S159.

4. The provision of '***girl-friendly'*** facilities can improve the school attendance of girls whereas inappropriate provision for school hygiene, sanitation and water has long contributed to their absenteeism. A study for UNICEF Bangladesh, for example, found that enrolment of girls in school increased by 11% with sanitation provision.
   http://wedc.lboro.ac.uk/conferences/pdfs/26/Sen.pdf155

   In order for school sanitation facilities to be 'girl-friendly', they must afford privacy and dignity. Facilities must be separate and not adjacent to those for boys but not so isolated that girls feel unsafe or are likely to be harassed or assaulted. In particular, facilities for washing and sanitation need to be suitable for menstrual hygiene and management if personal hygiene and health are not to be negatively affected. There is also a case for investigating the possibility of providing pads and sanitary products in schools to promote menstrual hygiene and management.

5. The provision of suitable ***handwashing facilities*** in schools is often overlooked but if schoolchildren are to wash their hands satisfactorily before eating and to prevent infection after using a latrine then they need adequate facilities to do so. Facilities need to be separate from the handpump or standpipe and close to the latrines for older children. For younger children it may be more appropriate for handwashing to take place near or in the classroom where children can be supervised. The use of soap in handwashing has been shown to reduce diarrhoeal infections by 42 - 47%. Without soap, handwashing is not as effective for removing pathogens. Soap, however, is expensive and often not supplied or is stolen and alternatives such as ash and sand, although traditional hand cleaning agents, may not be acceptable to the children. The waste-water from hand washing facilities needs to be managed to avoid water-logging of the ground which may then provide a breeding ground for mosquitoes.

   For more handwashing devices see http://www.schoolsanitation.org/BasicPrinciples/HandwashingFacilities.html

Appropriateness of solutions

Integrated school sanitation solutions must be appropriate for the age, gender and culture of the children concerned and adequate maintenance mechanisms must be in place if technologies and improved hygiene behaviours are to be sustainable in the long term. It is important to design facilities from the users' perspectives taking into account convenience, well-being and dignity as well as likely improvements to health. To achieve the greatest impact the technologies must of necessity be backed up with appropriate hygiene education in the school curriculum by teachers with specific training and using interactive teaching and learning methods. In this way the children can transfer their learning to their home environment and family members.

An overview of some SSHE projects is given at: http://www.irc.nl/page/9489

Annex 5.12 Latrine emptying

On-site sanitation is needed by most people living in poverty in urban areas of Africa, Asia and Latin America – a total of 1 billion people now living in slums, rising to 1.5 billion by 2020. On-site sanitation is likely to be widely needed in urban areas of the developing world for at least the next 50 years. During that time, densely populated slums are projected to continue to grow. Simple, cost-effective means of emptying pit latrines and transporting the sludge for safe disposal are needed.

Challenges

1. Pit latrines are widely used in poor urban areas and, because of population density are heavily used, fill up rapidly, and cannot be easily moved to new locations. Latrines therefore require emptying in urban areas, but this is foul and degrading work, that can be costly, if carried out manually. The resulting sludge needs to be removed and disposed of safely. Cost-effective mechanical means of emptying are needed, especially for densely-populated areas where trucks, which are difficult to maintain, cannot reach. Safe disposal of the resulting faecal sludge is often not assured and means are needed for this.
2. Trucks with mechanical pumps are conventionally used for this work, but are expensive to purchase, operate and maintain and cannot reach latrines in densely-populated areas where lanes are narrow. The Vacutug and MAPET mechanical and hand-operated pumping systems have been developed in East Africa for this purpose but have not yet spread widely.

Possible solutions

1. Some further local development, and widespread introduction, dissemination and promotion of low-cost, alternative methods of pumping and transporting sludge throughout poor urban areas of Africa, Asia and Latin America, on-site sanitation should become more effective and viable in densely-populated, low-rise areas. Such work has already been shown to be a viable economic enterprise in several locations [eg Kibera, Nairobi, Kenya (WSP-Africa, 2005); Dhaka, Bangladesh (WaterAid Bangladesh, 2004)], although capital equipment costs currently tend to be subsidised. Costs therefore need to be rationalised in order to ensure sustainable, entrepreneurial services.
2. Care must be taken with safe disposal of faecal sludge resulting from pit latrine emptying. Collaboration is needed with local authorities or local utilities who are responsible for wastewater management, to find suitable disposal routes for latrine sludge. The economic viability of the envisaged pit emptying operations can easily be jeopardised if it is necessary to transport the resulting sludge over long

distances. A cost-effective disposal plan must therefore be integrated into any planned operation.

3. Existing pilot projects using the Vacutug in Kenya and Bangladesh suggest that the technology can be cost-effective and therefore economically sustainable. In order to be environmentally sustainable this service needs to be linked with safe disposal of sludge, which is often provided, inadequately, by local municipal authorities.

4. A technical and socio-economic survey of existing pit-emptying technologies and services, including the Vacutug and MAPET in both East Africa and South Asia, needs to be undertaken in order to determine what works and what are the constraints to further spread of the technology and service. Based on the results of such a survey, a strategy for development of appropriate equipment and the manufacturing, operation and maintenance facilities needs to be developed and implemented for many areas of Africa, south, east and south-east Asia and Latin America. Such services can clearly provide a useful source of entrepreneurial employment. Training in business skills would be a useful component of any development of a latrine emptying service.

Appropriateness of solutions

1. With improved pit latrine emptying the toll of sanitation-related disease and all the social impacts of lack of access to a decent sanitation facility, which are particularly serious for women, girls and those living with disabilities, should be greatly reduced. At the same time, the degrading work of manual removal of faecal sludge will be greatly reduced. Small, local businesses could be established to manufacture, operate and maintain machines and the services that use them, spreading sustainable livelihoods, through a valuable service, to numerous people.

2. Many urban environments are heavily contaminated and would benefit enormously from improved pit latrine emptying and disposal. At present, if such facilities are available, they are either provided manually by people to whom the job is appallingly degrading (eg the Bhangi *untouchable* lower-caste in India, or the mostly Christian or Hindu ‘coolies’ in Pakistan), or they are provided by local government or private companies at unaffordable expense, using large trucks that cannot access many areas.

3. Development costs are unknown at present – but the principle would be to develop machines, based on existing examples in both Africa and Asia, that are affordable to local entrepreneurs and a sustainable service that is affordable to local residents. Economic studies would be an essential component of any development of pit emptying technologies.

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Annex 13: Bio-additives

Modern waste water treatment plant incorporates bacterial populations for the removal of organic matter during the water treatment process. The process is often facilitated by bio- additives.

Broadly speaking modern treatment systems classify into two types: fixed growth and suspended growth.

- Fixed growth systems are so-called because bacterial populations grow on large naturally aerated (aspirated) surfaces such as rocks or plastic media while digesting ('oxidising') the organic material arriving in the sewage flow: 'Trickling Filters' are a typical example of fixed growth systems.
- In suspended growth systems, forced aeration (oxygenation) causes biological flocs to form which are 'suspended' in the flow rather than fixed on a surface: these flocs reduce organics in the same way. The well-known 'Activated Sludge'[5] system (first proposed in 1914) is a prime example.

Both types of system can be brought up to full performance more quickly by mixing a small amount of live sludge with the settled sewage before the aeration stage: this is known as 'seeding'. In fact Activated Sludge systems are so-called because a small proportion of the living sludge produced is re-introduced upstream of aeration: it can be considered as a constant 'seeding' of the system. The remainder of the sludge is normally sent to special tanks for (anaerobic) digestion producing more stabilised solids for disposal, while the ('supernatant') liquid is run-off for further treatment.

However, neither type of system can resist 'shocks' without a reduction in performance or even complete failure. Such shocks may be in the form of sudden changes in the strength of sewage arriving:. In general too low a temperature slows down bacterial activity, and sudden changes or failures in aeration rates can seriously damage bacterial colonies. Many other shocks such as chemical or pH changes can also cause reduced performance or failure.

Challenges

1. Most wastewater treatment systems only work to optimal performance when all flow parameters are 'balanced' and steady.
2. In many low income countries and particularly in urban slum areas the accumulation of faecal waste in the absence of effective sewerage poses major hazards to health.
3. Substitutes for traditional, expensive sewage disposal in need of sophisticated operation and maintenance need to be found use in low income countries.

[5] http://en.wikipedia.org/wiki/Activated_sludge

Possible solutions

1. The practice of bio-augmentation (the use of bio-additives) is often proposed for rectifying systems which are failing. Several companies[6] propose proprietary mixtures of dried bacterial cultures, and/or enzymes, and/or nutrients, based on the logic that a sudden strong inoculation of the 'correct' bacterial species will help return the system to its full performance more quickly: the 'dominant' colony argument.

   Frequent dosing with such wetted and incubated mixtures is also often proposed for performance maintenance and enhancement. The make-up of such mixtures is often proprietary and secret, and arguments can proliferate when the product has been paid for but is found/thought to be ineffective, with the reasons for lack of efficacy being highly debatable.

   It is now generally accepted that treatment systems that are maintained at optimal design conditions will not actually benefit from bio-augmentation. It is cheaper to ensure that systems are well-designed and well-managed in the first place. Bio-augmentation in this situation is not a 'silver bullet': it is frequently ineffective.

2. There are specific situations in which bio-additives can be appropriate, such as in the reduction of Fats, Oils, and Greases (FOG) in wastewater flows and drains, and in the 'bio-remediation' of ground contaminated by such substances as PCBs (polychlorinated biphenols) and hydrocarbons. This is a more focused side of this young industry, but it also fraught with difficulty. It is indeed possible to digest such contaminants provided it is possible to get the microbes to the contaminant in the presence of sufficient oxygen. The physical engineering of this is often far more expensive than the actual microbial treatment.

3. The possibility of using bio-augmentation to promote the reduction in sludge solids in the highly anaerobic environment of pit latrines is clearly interesting.
   The usable life of a pit latrine depends on how fast it fills up, and this depends on how fast liquid escapes into the surrounding earth, and how efficiently solid waste is digested into further liquid or gases. Digestion will potentially degrade up to 40% of sludge solids. Commercially available bio-additive products aim to boost one or more of the three usual components required for successful digestion: of microbes, enzymes, and nutrients.

[6] typical example: http://www.bioremediate.com/contactus.htm

BOX 1: Use of bio-additives in pit latrines

ıdy in 2001 for OXFAM concluded that ‘some’ bio-additives did increase digestion, creating 5% extra capacity within the trial buckets. But 15% more space was found simply by stirring the sludge to release trapped gaseous digestion products. Concentrations of polluting coliforms in the escaping liquids (half of the trial buckets were perforated to mimic a pit latrine environment) were not found to increase with either of these space-saving approaches. All trial buckets were found to have an acidity (pH5) which would have prevented the final digestion phase, methanogenesis.

two main conclusions were that a pit latrine should be:

- sited in a soil trough which liquids can easily percolate and at a location where exposure to sunshine is maximised (anaerobic digestion proceeds best between 30-38ºC), and
- managed for enhanced digestion by seeding with mature sludge, and by monitoring temperature and pH, and then where appropriate stirring to release trapped gases and adding lime or ash to maintain pH > 6.5.

The research also recommended that pit latrines should include seeding of new latrines with appropriate mature sludges as they have performed as well as commercial products. **It also noted that: ‘given the scope for rapid developments in biotechnology, however, this position should be kept under review’.**

Redhouse, D (2001). Less lump per dump: prolonging the life of pit latrines. Unpublished MSc thesis, Cranfield University.

BOX 2: Exciting possibilities for anaerobic digestion

Collaborative research at Rhodes University, South Africa on the enzymology of anaerobic bio-reaction (digestion) has been in progress for several years.

The research illustrates the enormous complexity of the bio-reactions which need to be understood, and shows why 'simple' commercial guesstimates of microbial/enzyme/nutrient mixture requirements are extremely unlikely to be based on adequate research on this particular form of digestion.

From work based primarily on investigation of the enzymology of anaerobic bio-reactors designed for the accelerated digestion and hydrolysis of primary sewage sludge under sulphate reducing conditions, the low-cost high-efficiency the Rhodes BIOSURE process was established.

Further work has focused on the hydrolases of the hydrolytic or fermentative group of bacteria, which has found that the activities of all the enzymes (except for alpha-glucosidase) are dramatically enhanced in the presence of sulphide which is produced by sulphate reducing prokaryrotes, which are bacteria that live in symbiosis with the hydrolytic, acidogenic, acetogenic and methogenic bacteria in anaerobic digestion. Results indicated that there was an 80% reduction in solids and a 97% reduction in chemical oxygen requirement (COD) when two particular hydrolytic enzymes were added as a mixture. But the same enzymes used alone had little or no impact on sludge solubilisation

The group has therefore made very interesting discoveries which could lead to 'greater methane yields, lower sludge liquors, and a significant reduction in the requirements for and costs of digested sludge dewatering and disposal'. This clearly has implications for extending the life of pit latrines, as well as the possibility of considerably reducing the costs in conventional wastewater treatment plants.

Roman, H.J., Burgess J.E. and Pletschke, B.I. (2006). Enzyme treatment to decrease solids and improve digestion of primary sewage sludge. *African Journal of Biotechnology* [online]. Vol 5 , No 10 pp 963-967.
http://www.academicjournals.org/AJB\contents\2006cont\16May.htm.

4. The Rhodes University research team have now moved into what they believe to be 'blue sky research' looking at the effect that sulphide plays on the digestion of various forms of cellulose, the most abundant form of biomass on the planet, and also the other forms cellulose. **Although this is strictly fundamental 'blue-skies' research, the potential of applying any resultant discovery to waste treatment under anaerobic conditions could be enormous.**

The following is a detailed summary of the progression of this work:

Previous research performed by our group investigated the enzymatic processes underpinning the treatment of solid sludge waste under biosulphidogenic (sulphate reducing) conditions. These research projects were funded by the Water Research Commission of Southern Africa (WRC project # K5/1170), with the aim of optimising biosulphidogenic bioreactor conditions for the accelerated hydrolysis of solid waste. Hydrolases and hydrolysis of the complex organic polymers (cellulose, lignocellulose and lignin) constituted the rate-limiting step. The activities of all the hydrolases studied (proteases, glucohydrolases and lipases) were dramatically enhanced in the presence of sulphide (Pletschke et al., 2002; Watson et al., 2004;Whiteley et al., 2003,Whiteley et al., 2004). However, this work was performed on crude batch bioreactor systems, and this was extended to include a biochemical study of the degradation of organics under more clearly defined enzymatic conditions, to confirm the stimulatory effect of sulphide on the hydrolases per se.

Funding is currently being received for a current National Research of South Africa (NRF) focus area grant (NRF GUN # 2069258) **to investigate the effect of sulphur containing compounds** (sulphide, sulphite and sulphate) **on the activity of the hydrolases in the cellulosomes of hydrolytic bacteria such as Clostridia, Acetovibrio, etc., known to be critically involved in the hydrolysis of complex organics under anaerobic digestion conditions.**

Appropriateness of solutions

Bio-augmentation and bio-remediation in general will have a future, but considerably more research work will be needed for anything more than straightforward problem-solving. Although not touched on in this Annex, there are unresolved regulation issues concerning the use of certain types of microbial cultures in some situations.

There is a provisional South African Patent Application filed by Rhodes University covering their methods of use of enzyme additives in pit latrines and municipal waste treatment sites, although the group have considered abandoning this Patent Application due to lack of interest in South Africa from funders. It may be that the appropriate technology backers have not been identified, or its presentation to such backers may not have been well researched, prepared, and delivered.

This whole area of research work on enzymes seems to have steadily produced incremental forward steps probably on relatively low budgets, and it seems probable that the individuals concerned are well suited to the job of making further progress. They are already in some collaboration with at least one overseas organisation.

Such 'blue-skies' work has the potential to lead to something very worthwhile in the field of wastewater and effluent treatment, quite possibly also yielding an affordable process for prolonging the life of pit latrines in the developing country context.

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Annex 5.14: Hygiene hardware

Technologies for personal and household hygiene ideally provide people with convenient and effective ways of protecting themselves as well as their food and water from contamination by pathogens (through insects, soil, faeces etc). These technologies can be grouped as follows: soaps and equivalents, hand-washing devices, body-washing facilities, laundry facilities, technologies related to menstrual hygiene, cooking facilities, and technologies aimed at preventing nuisance, contamination and infection by insects.

Soaps and hand washing devices have potentially high positive impacts on health and are described below. Although very important, body-washing facilities (showers, bathrooms, solar or electrical water heaters), cooking facilities (off-ground dish drying devices, devices to cover the food) and insect-related technologies (fly traps, mosquito nets, insect repellents) will not be considered further, as various technologies, including local, low-cost ones, already exist and need only to be promoted and/or made cheaper and more easily available. Although the same can be said about laundry facilities, these will be included in the discussion relating to technologies for menstrual hygiene and management.

Challenges

1. Hygiene is a matter of health but also convenience, dignity and prestige. Many people are aware of the importance of hygiene, but may not have access to convenient and effective hygiene-related technologies. Some people also lack hygiene awareness concerning contaminated water, sanitation, menstrual hygiene, danger of insects, etc. Technologies related to behaviour change and hygiene promotion are discussed in a separate annex.
2. Although more appropriate, more convenient, less expensive technologies might be designed and promoted to improve hygiene and health, significant impacts will not be achieved without associated supporting hygiene/health education and promotion. Although fundamentally important, these ‘approaches’ are outside the scope of this ‘technology analysis’ and are dealt with in the ‘Approaches’ landscaping document under ‘Demand stimulation’.

Possible solutions

1. Conventional soaps come either in solid or liquid forms, and are used together with water to wash away dirt and soil, but above all pathogens, from the hands and body.

   Traditional alternatives include sand, mud or ash, which can produce the same abrasive effect as soap and which clean quite effectively when used with water. Their use is, however, not very widespread and highly dependent on culture.

Most soaps are made from a mixture of sodium (soda) or potassium (potash) salts (lyes) and animal or vegetal oils or fats with other additives to give perfume, colour and skin softening properties. Soap can be manufactured on a large scale in factories, but also at a much smaller scale by village entrepreneurs (often women). In small-scale production in developing countries, people usually use locally available oils or fats together with potassium from ashes.

See also: Soap making. (ITDG Technical brief)
http://www.itdg.org/docs/technical_information_service/soapmaking.pdf

Solid soap is usually produced in bars but for convenience of use and storage at hand washing facilities, soap-on-a rope is ideal. Soap bars can potentially be produced and used anywhere, the main issue being their price and availability. Currently, soap is often not affordable for the poorest and supply chains may be unreliable.

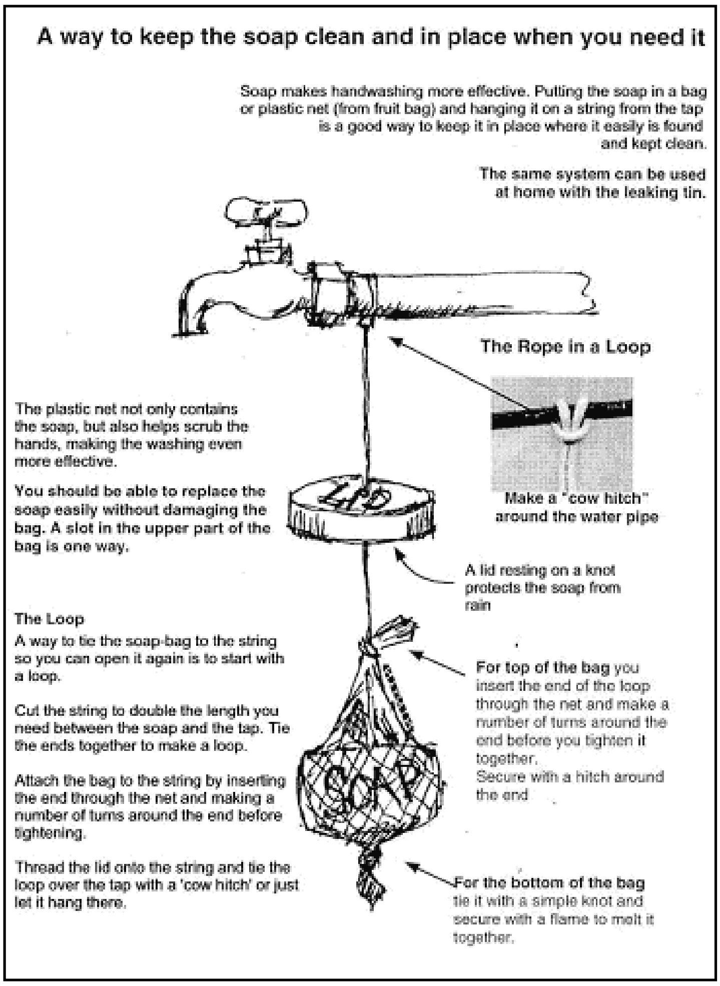

Figure 1: Soap on a rope

From: http://www.schoolsanitation.org/BasicPrinciples/HandwashingFacilities.html

2 More modern alternatives are antiseptic handrubs which are waterless agents with disinfectant properties that decrease the number of microorganisms present. Most alcohol-based hand antiseptics contain either isopropanol, ethanol, n-propanolol or a combination of two of these products. Because these handrubs do not remove organic material, they cannot be used if hands are visibly soiled. Moreover, they are very expensive and can cause pathogens to develop resistance. Conventional soaps used with water are therefore recommended for cleaning hands. There is the possibility that non-water requiring soaps could be impregnated into a piece of biodegradable cloth or paper to act as a barrier between the mother's hand and the child's faeces when cleaning the child after defecation. The environmental risks associated with the use of waterless, bactericidal soaps needs to be given due consideration.

For non-water requiring soap see also:
Article: http://www.pulsus.com/Paeds/07_08/lang_ed.htm
Sanitaire: www.sanitear.com
Cuticura: http://www.expresschemist.co.uk/product_6770_CUT636P.html

3. Hands should always be washed, using soap and running water, after using the toilet, cleaning babies or tending to someone who is sick, before handling or cooking food, and before eating. For households who do not have access to tap water, both the quantity of water used for hand washing and the fact that their water is not "running" can be problematic. Various devices have therefore been designed to enable people to wash their hands effectively with small quantities of running water. Three designs, among many, are presented in Figure 2 below: the famous 'tippy-tap', another device designed by CSIR (South Africa), and finally the Captap, designed by Steve Harries for Oxfam GB (Liberia). All these designs allow users to wash their hands with soap/mud/ash, without touching the tap again after use and therefore avoid further contamination of the hands.

Hand washing devices such as the tippy tap or the Captap can be produced anywhere as they rely on widely available recycled and generic materials. The CSIR hand washing dispenser is a manufactured product and made out of plastic for fixing to recycled plastic bottles. Depending on its price and acceptance, it could be used anywhere as well.

		
The Tippy tap is made out of a recycled plastic container filled with water and hung with a rope. It is intended only for household use.	The Captap is quite similar to the Tippy tap but can be used for communal purposes because of its larger capacity. It uses 200 to 300 ml of water per hand washing.	CSIR Hand washing dispenser is a plastic, industrially made tap intended for households. It can be fixed to a recycled plastic bottle for water dispensing.

Figure 2: Handwashing devices

For more information on handwashing devices see also:
http://www.schoolsanitation.org/BasicPrinciples/HandwashingFacilities.html

Tippy taps: http://www.cdc.gov/safewater/publications_pages/tippy-tap.pdf and http://www.rehydrate.org/dd/dd54.htm#page6
Dispenser: http://wedc.lboro.ac.uk/conferences/pdfs/30/Wilkinson.pdf
Captap: http://wedc.lboro.ac.uk/conferences/pdfs/31/Harries.pdf

4. The issue of menstrual hygiene and related laundry facilities is often overlooked although, in developing countries, very few women can afford commercially available sanitary protection during menstruation. Some use washable pads, but most women, including the poorest, use pieces of cloth. Whatever is used to absorb menstrual blood has to be disposed of safely or cleaned and dried in a hygienic, convenient and acceptable environment. Women using washable pads or cloths often do not have access to light, and facilities might not be suitable for washing and drying sanitary protection for reasons of privacy, dignity and hygiene and because taboos are often associated with menstruation in many cultures. Many adolescent girls miss school when they have their periods or may even drop-out of school at puberty and many women encounter difficulties in working during menstruation, because of lack of adequate facilities.

   Disposable sanitary towels or tampons have to be made in factories and are too expensive to be sold widely in the developing world. Environmental issues surrounding their disposal are also a concern. However, washable sanitary towels, sponges or cups could be produced in factories at more affordable prices.

   It seems very little has been done to address the issue of menstrual hygiene. The NGO BRAC is reported to have set up small factories in Bangladesh and employ young girls to make washable sanitary towels that are distributed by health workers. Similarly a WaterAid supported project in Dhaka has set up facilities which provide women with privacy in which to wash and dry clothes used for menstrual management. Some ideas have been proposed by the NGO Social Junction to design composting facilities for menstrual cloths next to latrines. More research would be useful on the design of appropriate laundry / composting facilities or washable sanitary protection and especially to address the needs of poorer women.

See also:

http://www.schoolsanitation.org/Resources/Readings/Bharadwai-2004-Menstrual.doc

http://www.irc.nl/content/download/19159/239102/file/JunctionSocial.pdf

http://www.mooncup.co.uk/

http://www.who.int/reproductive-health/publications/towards_adulthood/30.pdf

Low cost sanitary protection including BRAC's production in Bangladesh
Dr. Munir Ahmed, Program Coordinator
Health and Population Division
BRAC
Tel: 880-2-9881265
Fax: 880-2-883542

http://216.239.59.104/search?q=cache:2QVgKX_BJhgJ:intra.un.org.in/km/Solution%2520Exchange-Consolidated%2520Replies/Maternal%2520and%2520Child%2520Health%2520Community/mch04-%2520Low%2520Cost%2520Sanitary%2520Napkin.doc+brac+bangladesh+sanitary+napkins&hl=en&gl=uk&ct=clnk&cd=9

Appropriateness of solutions

Solutions relating to handwashing, need to be affordable and widely available and useable. The technologies need to be culturally acceptable and in the case of menstrual hygiene products and facilities, in particular, need to offer dignity and privacy to women and girls.

Most importantly all technical solutions for handwashing need to be strongly linked with hygiene promotion on a continuing basis in order to sustain improved hygiene behaviours in the long term.

Annex 5.15: Hygiene promotion tools

The purpose of this Annex is to briefly address the issue of technologies which may be useful in hygiene promotion and education. It should be noted, however, that hygiene promotion is very much ‘approaches’ oriented dealing as it does with issues of perception, dignity, gender and culture as they impinge on hygiene behaviours relating to sanitation, water sources and use, food, and environment. Hygiene promotion ideally builds on what people ‘know, do and want’ and, like hygiene education, often tends to be tacked on as an afterthought in water and sanitation programmes, given low priority, time and resources. (Reference is made to hygiene promotion and education in the ‘Approaches’ landscaping document under ’Demand stimulation’).

The international agencies such as WHO and UNICEF together with NGOs such as WaterAid have come to emphasise the need for hygiene education and promotion as an integral part of all water and sanitation programmes rather than as afterthought or ‘bolt-on’ extra to such programmes which has tended to be the case in the past. The Participatory Hygiene and Sanitation Transformation (PHAST) programme, for example, was developed in 1993 from experience of implementing water and sanitation programmes in east Africa) by WHO’s joint initiative with UNDP and the World Bank Water and Sanitation Programme. With the aim of integrating sanitation and drinking water projects, the World Bank Water and Sanitation Programme has also financed hygiene promotion programmes in countries such as India (Water and Sanitation Program -South Asia, 2000), Burkina Faso and Zimbabwe.

International agency policy and other publications example: UNICEF Water, Environment and Sanitation Technical Guidelines Series
http://www.unicef.org/wes/index_documents.html

Country study example: Sidibe, M and Curtis, V (2002). Hygiene promotion in Burkina Faso and Zimbabwe: new approaches to behaviour change. World Bank, Nairobi, Kenya (Water and sanitation program filed note,7) http://www.wsp.org/publications/af_bg_bf-zm.pdf

Hygiene promotion basics: http://www.lboro.ac.uk/orgs/well/resources/fact-sheets/fact-sheets-htm/hp.htm

PHAST: Simpson-Hebert, M *et al* (1997). *The PHAST initiative: participatory hygiene and sanitation transformation. A new approach to working with communities. WHO*, Geneva.
http://www.who.int/water_sanitation_health/hygiene/envsan/phast/en/index.html

The ultimate aim of hygiene promotion and education is to encourage behaviour which will help to prevent the scourge of water and sanitation-related disease. The success rate is variable. If the approaches to hygiene promotion and education are to succeed then the technologies used for hygiene promotion and education need to be widely available, appropriate and effective for all end-user groups in a variety of localities.

Challenges

1. Access to appropriate learning materials and mass-communication media pose major problems in developing countries. This is mainly due to many people being too poor to be able to afford access to mass media such as radio and television, and educational resources through the Internet but also it is due to unreliable or non-existent power supplies in many areas, especially rural areas. In addition, many people, especially the older poor, have low levels of literacy which debars them from information in written learning materials although illustrated resources can be useful to them. Any advertising hoardings are usually located in urban areas or on the road between urban areas which reduces their effectiveness in reaching a large proportion of the population for hygiene promotion purposes.
2. Modern channels of communication such as television and radio, mobile phone technologies and the Internet are not the main means of communication for many people who tend to rely on traditional face-to-face communication methods (word of mouth, social gatherings etc).
3. Television programming in developing countries often relies on imported programmes rather than in-country production which therefore results in programme content which audiences cannot realistically relate to. In programming and advertising hygiene promotion is not given as high a priority as more obviously health-related issues such as vaccination and HIV/AIDS.
4. Many learning materials used in hygiene promotion and hygiene education are not adapted to the local situation and people. Many hygiene education materials are poorly produced (not visually stimulating) and very didactic rather than interactive and therefore fail to encourage active learning. Such materials have a limiting effect on the potential for hygiene behaviour change through hygiene promotion and education.
5. Often because people cannot see the effects of unhygienic behaviours they cannot understand the need to change their behaviours

Possible solutions

1. Unreliable power supplies in developing countries could be overcome by the use of wind up radios. (See **Box 1** below) If a mass market could be developed the unit cost would be reduced and therefore the price would be more affordable for more people who would then have access to radio programmes addressing issues of health and hygiene .
2. Television is a major means of reaching vast numbers of people. In the absence of reliable power and the fact that comparatively few people can afford to purchase their own televisions, community-owned televisions with individual generators might be a possibility for extending access to soap operas, advertisements and the like which aim to promote improved hygiene behaviours.

3. Where more traditional means of communication are the norm for adults and children puppets may be used as the technology in drama and theatre to convey motivational messages for hygiene behaviour change.
4. Videos addressing hygiene issues could be made for use at social gatherings, in schools and health clubs. Local participation in the video production would help to maximise local interest and foster the uptake of improved hygiene practices.
5. IT kiosks which have already been set up could additionally provide learning materials available on CD_ROM and via the Internet to promote improved hygiene behaviours. (See **Box 2** below).
6. New Partnerships for Africa (NEPAD) was established in 2001 with the mandate to manage the structured development of the ICT sector in Africa, including an e-schools initiative which is a capacity building project for e-learning. Although there are many constraints to providing ICT in schools (budget, power supplies, no computer-literate teachers etc) with time, hygiene promotion and education could become possible using interactive computer-based learning materials and the internet.
7. Paper-based materials for hygiene promotion can be produced fairly cheaply but often these are generic in style and content and do not reflect local needs, behaviours and culture. Other visual aids similarly need to be appropriate for local use. Learning materials for school children need to be interactive to stimulate interest and learning. In the field, posters drawn with group in-put and local visual aids provide a reliable basis for any hygiene promotion.
8. If people are able to see 'germs' on their hands and utensils and to see changes in contaminated water that has been treated, the benefits of behaviour change become evident. Phosphorescent powder or even 'glitter' can demonstrate dirty hands, simple water quality testing results and water clarification demonstrations are all useful aids for 'seeing is believing'. Such demonstrations can quickly lead to one group acting as an agent of change in a locality to bring about improved hygiene practices.

Appropriateness of solutions

Technologies are only a part of the solution for hygiene promotion which remains an essentially approaches-based subject. Any technologies which support the approaches for hygiene promotion equally need to be acceptable to local communities but also affordable. Very often extremely simple technologies used for hygiene promotion are effective in bringing about behaviour change provided the message is right.

BOX 1: Wind up radios

In 2001 it was estimated that 205 million Africans had access to radio. While TV signals are often confined to urban areas most of Africa can be reached by radio. The lack of a reliable power supply and the relatively high cost of batteries means that mass-produced (and therefore cheaper) wind-up radios have great potential uptake. Radio is proving to be a cheap and effective means for the dissemination of health-related information including hygiene promotion at national and community levels in many countries and for encouraging community dialogue on health-related issues. Wind up radios would give increased access to such information and help to promote behaviour change through more people having access to broadcasts.

Skuse A (2004) *Radio broadcasting for health: a decision maker's guide.* DFID
http://www.comminit.com/pdf/RadioBroadcastingForHealth.pdf

Wind up radio :http://www.ogormans.co.uk/windup.htm

BOX 2 ICTs in rural India

People in more than 2000 villages in rural India within 30 kms radius of a town are connected to the Internet through kiosks which provide a range of communications services. Each kiosk is run by a local entrepreneur, costs $1000 to set up and needs to earn $70 per month to break even

Such kiosks, among other things currently provide agricultural information, but could also provide hygiene information accessible in local languages and with locally produced resources which would help to make hygiene information more relevant to local circumstances.

Connecting Rural India towards Prosperity', by Ashok Jhunjhunwala, UN Department of Economic and Social Affairs ICT Task Force Series 4, 2003
http://www.id21.org/zinter/id21zinter.exe?a=0&i=r3aj1g1&u=44ad6e68

Annex 5.16: Acronyms

Organizations and networks

BP	British Petroleum
BRAC	NGO, Bangladesh
CAPNET	Capacity Building for Integrated Water Resources Management
CSIR	Council for Scientific and Industrial Research (South Africa)
DANIDA	Danish International Development Agency
DFID	Department for International Development, UK
DSK	Dusthya Shasthya Kendra (NGO, Bangladesh)
DWASA	Dhaka Water Supply and Sewerage Authority (Bangladesh)
GW-MATE	World Bank/Global Water Partnership Groundwater Management Advisory Team
HTN	Handpump Technology Network
IDE- India	International Development Enterprises -India
IRC	International Water and Sanitation Centre, The Netherlands
ITDG	Intermediate Technology Development Group (Now Practical Action)
JMP	Joint Monitoring Program on Water and Sanitation (WHO/ UNICEF)
MIT	Massachusetts Institute of Technology
NEPAD	New Partnerships for Africa
RWSN	Rural Water Supply Network
SKAT	Swiss Resource Centre and Consultancies for Development
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
WSP	Water and Sanitation Program
WHO	World Health Organization
WHYMAP	Worldwide Hydrogeological Mapping and Assessment Programme

Terms

AC	alternating current
ARI	acute respiratory infection
CdTe	cadmium telluride
CBO	community-based organization
CDT	capacitive de-ionisation technology
CGF	coarse gravel filters
CIS	copper indium di-selenide
CWT	community water treatment
DNA	deoxyribonucleic acid
'Ecosan'	ecological sanitation
GIS	geographic information system
GPS	global positioning system
HDPE	high density polyethylene
HWT	household water treatment
HWTS	household water treatment and safe storage
ICTs	information and communication technologies
IWRM	integrated water resource management
MDG	millennium development goals
MDPE	medium density polyethylene
NGO	non governmental organization
O&M	operation and maintenance
PCB	polychlorinated biphenyls
PD	positive displacement (pump)
PEX	cross-linked polyethylene
PHAST	Participatory Hygiene and Sanitation Transformation
POU	point-of-use
PV	photovoltaic
PVC	polyvinyl chloride
PVPs	photovoltaic powered water pumps
QAS	quaternary ammonium silanes
R&D	research and development
RF	rapid filters
SODIS	solar water disinfection
SSA	sub-Saharan Africa
SSF	slow sand filters
UV	ultra violet
VIP	ventilated improved pit (latrine)
VLOM	village level operation and maintenance
VLOMM	village level operation and management of maintenance
VP	vapour compression
WPM	water point mapping
WS&H	water, sanitation and hygiene