Environmental Guidelines for Small-Scale Activities in Africa (EGSSAA)

Chapter 16: Water Supply and Sanitation

Contents

Good sanitation and hygiene practices are key to preventing contamination of water resources.

At the same time, good facilities and practices provide few health benefits if the water resource remains contaminated.

Therefore, water supply and sanitation projects and hygiene promotion should be viewed as interdependent activities. Implementing them at the same time leads to the

Sector overview

Adequate, safe water: a basic need. To remain healthy, human beings need an adequate, year-round supply of high-quality water. Many debilitating or even fatal illnesses are spread by contamination of the water supply with human fecal matter containing disease-causing viruses, bacteria, and parasites. In addition, there is a high opportunity cost to the lack of safe water., especially for women and children.

- Children are more likely to become ill, and women are the primary caregivers for ill family members.
- Women and girls carry out most water collection, and many spend long hours doing so. Time spent collecting water could be spent in more productive activity, such as food production or, especially in the case of children, education.

However, infrastructure alone will not result in improved health. It is necessary to integrate provision of water supply and sanitation facilities with sanitation and hygiene promotion activities to ensure sustainability of the infrastructure and correct and consistent hygiene behaviors to reduce waterborne diseases.

The basic need is not met. Unfortunately, over one-third of the world's population, nearly 2.5 billion people, have inadequate access to sanitation, and over 1 billion people do not have access to enough safe water. Overall, polluted water affects the health of 1.2 billion people every year and contributes to the death of 15 million children under five every year. Vector-borne diseases, such as malaria, kill another 1.5 to 2.7 million people per year, with inadequate water management a key cause of such diseases

This EGSSAA Chapter was prepared by The Cadmus Group, Inc. for International Resources Group, Ltd. (IRG) under USAID Africa Bureau's Environmental Compliance and Management Support (ENCAP) Program, Contract Number EPP-I-00-03-00013-00, Task Order No. 11. Its contents are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

The YACUPAJ project: community participation promotes sanitation

The YACUPAJ project in Bolivia (1991–94) integrated many of the features analysts have found in successful sustainable projects:

Respond to demand. To participate in the project, communities had to ask for it. The first stage of the project in every community was to strengthen and expand this demand through a coordinated education and demonstration program.

Community management. Community members took part in managing the entire project. They defined their needs, set the level of participation, chose the project type, and shared costs.

Involve women. Steps were taken to engage women as active participants in every stage of the project.

Install appropriate technology. Facilities were simple, low-cost, and easily maintained by users.

Local construction and maintenance. Family or community personnel constructed household latrines. Local masons were trained in latrine construction and as hygiene promoters.

Promote hygiene. Hygiene was promoted through education and training. Promotion was identified as a key activity for ensuring effective and sustained use of the services.

Monitor sustainability. State and private institutions remained involved after the project ended to monitor sustainability.

The results:
Communities provided over 50% of the funding, even though they were the poorest in the country.

A sustainability study in 1995 showed 82% of latrines still in use.

Trained masons continue to build latrines with direct responsibility to client families and no external support.

Attitudes toward latrine use have improved dramatically.

See Soto (1998).

(*UNEP Global Environmental Outlook Report 2000*). In Africa alone, over 300 million people lack either sanitation or adequate water, and frequently both.

Significant international focus and investment during the "Water and Sanitation Decade" (1981–1990) brought water to 80 percent of the world's population and sanitation to 50 percent. During the 1990s, however, no additional gains were made, and population growth led to an increase in the absolute numbers of people without safe water or sanitation.

Water resources in general are poorly managed, especially in the developing world. For example, many urban areas in developing countries lose more than 50 percent of distributed water through leaking pipes. The water and sanitation technologies used in the developed world, such as extensive sewer systems and large wastewater treatment plants, are frequently too costly or impractical for developing countries, although this has not necessarily discouraged attempts to implement them. Rural populations and the rapidly

The Hakitagata Bakyara Twimukye Hot Springs near Kisoro, Uganda are believed to have special medicinal properties. Disease sufferers are living in makeshift huts at the source. Water quality downstream may be harmed by the effluent from this site.

growing peri-urban and urban poor are disproportionately under-served.

Water supply, sanitation and hygiene are closely related. Good sanitation and hygiene practices are essential to preventing contamination of water resources. At the same time, good hygiene practices and sanitation facilities provide few health benefits if the water resource remains contaminated. Therefore, water supply and sanitation projects and hygiene promotion should be viewed as interdependent activities. *Implementing them at the same time leads to the greatest health benefit and is considered a best practice in the sector.*

ESDM Approach to Small-Scale Water and Sanitation Projects: General Guidance

Environmental issues. Water and sanitation projects are intended to improve environmental health conditions for beneficiaries. However, poor design, construction or implementation or activities in this sector can result in **environmental failures** that eliminate or offset the intended benefits. These failures range from heightened risks to human health, to damage to ecosystems and economic activities, to depletion and degradation of water resources available to neighboring and downstream communities.

Environmentally sound design and management (ESDM) of activities in all sectors requires design and management to anticipate and avoid or otherwise mitigate these impacts.

Participatory approaches for environmental soundness and sustainability. Environmental soundness depends significantly on community participation and commitment:

- Operating practices and maintenance are essential to environmental soundness, and this usually requires continuing involvement by the community. (For example, after the NGO leaves, communities must continue to protect source waters, maintain latrines, etc.).
- In addition, beneficiaries must actually *use* the latrines, water supply points, etc. and adopt complementary behaviors (like hand-washing after defecating) for environmental health benefits to be achieved. Both require changes to behavior that are sustainable only with education and commitment.

For these reasons, ESDM in the water and sanitation sector requires a participatory approach. Over the past three decades, experience has shown that water and sanitation activities are most effective and sustainable when they adopt a participatory approach that (1) acts in response to genuine demand, (2) builds capacity for operation and maintenance and sharing of costs, (3) involves community members directly in all key decisions, (4) cultivates a sense of communal ownership of the project, and (5) uses appropriate technology that can be maintained at the village level. Also important are educational and participatory efforts to change behavioral practices.

This guidance is intended for application to a variety of **small-scale** rural and urban water supply and sanitation activities that PVOs and NGOs may help design or manage. Large-scale water projects are not considered here. Representative small-scale activities/technologies are listed in the sidebar.

Representative small-scale water and sanitation activities/technologies

Water sources
pond and spring improvements
hand-dug wells
small-diameter boreholes
wells with hand pumps
roof rainwater catchments
small dams and seasonal impoundments
Rivers and streams

Water distribution
Simple spring-fed gravity feed water distribution systems
Well or surface water source pump with storage tank and piped distribution to standposts or individual yard taps or connections,
Extensions of existing urban water lines into unserved or under-served peri-urban zones

Water use points
showers
clothes-washing basins
cattle troughs
hand washing taps

Individual latrines
Ventilated improved pit (VIP)
Composting latrines
Dehydrating latrines
Pour-flush latrines
Simple pit with or without cover

Community latrines
(see technologies above)

Sewerage
Small-scale septic and leach field systems
Settled and simplified sewers
Water stabilization ponds
Constructed wetlands
Water borne sewage to primary/secondary treatment
Ecological sanitation (urine diverting toilets, arborloo latrines)

Potential Environmental Impacts of Water and Sanitation Activities and Their Causes

As noted above, while water and sanitation projects are intended to improve environmental health (and provide numerous other benefits), they may cause adverse environmental impacts that can offset or eliminate these intended benefits.

This section discusses these potential adverse impacts. Summary tables appear at the end of the section.

Debilitating disease and death. Water supply and sanitation projects may cause increased incidence of infectious water-borne diseases such as cholera, non-infectious disease such as arsenic poisoning, and water-enabled diseases such as malaria, schistosomiasis or bilharzia.

- contamination of surface and groundwater supplies with infectious organisms from human excreta is especially serious. Contamination may be caused by poorly designed, operated or maintained sanitation facilities, such as sanitation systems that transfer sewage to receiving waters without treatment, or pit latrines located in areas with high water tables.
- Infectious diseases may also be spread by improper use of wastewater to grow food crops.
- Failure to test new sources of water, especially groundwater, for possible natural or industrial chemical contaminants, such as arsenic, mercury, fluoride and nitrate, can have devastating consequences.

These adverse impacts may occur in both urban and rural areas. Increased population densities and the lack of facilities can increase the negative impact in peri-urban areas.

This well near Tamale, Ghana has poor drainage and thus significant potential for adverse health impacts. Possible impacts of stagnant water include increase in vector-borne diseases and soil erosion/sedimentation.

Native plants and animals harmed and associated land, water, and coastal ecosystems degraded. These impacts most often arise from water diversion, construction or decommissioning activities in or near a watercourse, or from fecal contamination of water. Numerous impacts on ecosystems are possible:

- Construction of facilities in sensitive areas (wetlands, estuaries, etc.) can destroy flora or fauna or their habitats, leading to loss of biodiversity, reduction of economic productivity and loss of aesthetics and recreational value.

- Water-supply projects can also deplete fresh water. Increased consumption of water can reduce water flows and cause loss of habitat, wetlands and wildlife downstream.
- Water supply projects can erode soil from pipe leakage or poor drainage at taps. Soil erosion may cause sedimentation in receiving waters, which may reduce the capacity of ponds and reservoirs, increase flooding, or substantially alter aquatic ecosystems by changing streambed, lakebed and estuary conditions.
- Contamination of receiving waters with human excreta or animal manure can cause nutrient enrichment, depletion of dissolved oxygen and other changes that disturb natural ecosystems and reduce the vigor, abundance, and/or diversity of plants and animals that live either in the water or on land. Disease-causing microorganisms from excreta and manure may also contaminate fish or shellfish, creating health hazards.

Fresh-water resources depleted. This may occur when projects do not adequately assess the quantity of available surface and groundwater (including typical seasonal and annual variations.) Other causes include poor mechanisms for regulating withdrawals and use of water, and insufficient monitoring and maintenance of leaks.

- Depletion of surface water sources destroys the resource itself, damages aquatic life, reduces economic productivity, diminishes downstream use, and curtails recreational possibilities.
- Overdrawing wells and boreholes can alter groundwater flows, reduce groundwater levels, or cause aquifers in coastal or island areas to experience salt-water intrusion. All can lead to loss of drinking water sources and reduced economic productivity. Aquifer depletion and falling water tables can also lead to land subsidence (sinking of the land's surface).

Both these situations increase the cost of future water supply systems. In addition, depletion of water resources may lead to poorer water quality, health impacts, and elevated costs of potable water supplies in downstream or down-gradient locations.

Increased disease transmission from standing, stagnant water.
Poor design, operation and/or maintenance of water supply improvements can lead to pools of stagnant water near water taps, water pipes and storage tanks. Improper or ineffective practices for disposing of excreta and solid waste make this problem worse.

These pools form an excellent breeding place for disease vectors (mosquitoes that carry malaria, etc.). They can also increase transmission of water-related diseases, especially when the wet spots are clogged or contaminated with solid waste or excreta.

Table 1: Potential Environmental Impacts of Water Supply Projects and Their Causes

Problems	Possible Impacts	Possible Causes
1. Depletion of fresh water resources (surface and groundwater)	Destruction of the natural resource Destruction of aquatic life Loss of economic productivity Loss of recreation areas Land subsidence Increased cost of water supplies in the future or in down-gradient locations	Overestimation of water supplies Underestimation of water demand Over-pumping of water resources Lack of information on resource yields Waste and leakage of potable water Poor water pricing policies and practices, leading to excessive use, waste and leakage
2. Chemical degradation of the quality of potable water sources (surface and groundwater)	Concentration of pollution in surface water sources Salt water intrusion Poorer quality water, with associated health problems Increased water treatment costs in the future or in down-gradient locations	Depletion of surface and groundwater resources (see above) Reduced stream flows Runoff/drainage from improper solid and liquid waste or excreta disposal
3. Creation of stagnant (standing) water	Increase in vector-borne diseases Contamination of standing water with fecal matter, solid waste, etc., leading to health problems Soil erosion/sedimentation	Drainage systems lacking or poorly designed Leakage from pipes/wastage from taps Lack of user/operator concern for stagnant water
4. Degradation of terrestrial, aquatic, and coastal habitats	Alteration of ecosystem structure & function and loss of biodiversity Loss of economic productivity Loss of natural beauty Loss of recreational values Soil erosion/sedimentation	Improper siting of facilities (within wetlands or other sensitive habitats, etc.) Poor construction practice Leakage/wastage from pipes and taps Increased population density/agricultural activity because of new water systems
5. Supply of contaminated water	Arsenic poisoning Mercury poisoning Water-related infectious diseases	Failure to test water quality before developing the water resource Lack of ongoing water quality monitoring Inadequate protection of wells and water supply points Biological nitrite/nitrate and / or pesticide contamination

Source: Adapted from Alan Wyatt, William Hogrewe and Eugene Brantly (1992). ***Environmental Guidelines for PVOs and NGOs: Potable Water and Sanitation Projects.*** **Water and Sanitation for Health Project, USAID.**

Table 2: Potential Environmental Impacts of Sanitation Projects and Their Causes

Problems	Possible Impacts	Possible Causes
1. **Contamination of surface water, groundwater, soil, and food by excreta, chemicals and pathogens**	Increased disease transmission associated with excreta (diarrheal, parasitic, etc.) Malnutrition caused by above diseases Higher infant mortality Reduced economic productivity Health problems from use of chemically contaminated water Increased cost of down-gradient water treatment for domestic and industrial uses	Failure to use sanitation facilities Disposal of excreta or wastewater directly on land or into surface water without adequate treatment Improper siting of sanitation facilities near water supplies Inadequate protection of groundwater Improper operation of sanitation facilities Failure of sanitation facilities due to lack of maintenance Improper use of wastewater in food production
2. **Degradation of stream, lake, estuarine and marine water quality and degradation of land habitats**	Health problems from contact with contaminated water Fish or shellfish contamination (health hazards, lost economic productivity) Nutrient contamination (eutrophication) Alteration of ecosystem structure and function; loss of biodiversity Reduced economic productivity Soil erosion and sedimentation	Failure to use sanitation facilities Disposal of excreta or wastewater directly into sensitive areas without adequate treatment Improper operation of sanitation facilities Failure of sanitation facilities due to lack of maintenance Improper siting of facilities (within wetlands or other sensitive habitats, etc.) Poor construction practice

Source: Adapted from Alan Wyatt, William Hogrewe and Eugene Brantly (1992). *Environmental Guidelines for PVOs and NGOs: Potable Water and Sanitation Projects.* Water and Sanitation for Health Project, USAID.

ESDM of Activities & Programs: Best Practices

As noted above, avoiding the potential adverse impacts of water and sanitation activities and achieving ESDM in this sector requires a **participatory approach** to activity/program design and management.

In addition, **good technical design** is required. Each design choice has potential impacts, and appropriate measures must be used to avoid or otherwise mitigate these impacts.

This section provides some basic, general elements of best practice drawn from lessons learned in the field over more than 30 years. Some concern the participatory approach and some concern issues of technical design.

Best Practices For Water and Sanitation Projects

- Use others' experience
- Concentrate on the human component
- Use a promotional program, especially for sanitation, to build demand
- Participatory approach
- Cost sharing
- Integrate water supply, sanitation and hygiene promotion
- Use existing community organizations
- Economically self-sustaining design
- Provisions for operation and maintenance

A low cost alternative to a hand pump—a privately owned shallow well with a trap door cover near Segou, Mali. Note that water retrieved may require treatment to achieve desired quality according to end use.

The next section (environmental mitigation and monitoring) sets out the potential impacts of specific technologies and activities, and specific mitigation measures to counter them.

Both the general best practices and the technology- and activity-specific measures in the next section are necessary to achieving ESDM. As in other sectors, these issues should be addressed early in the design process.

Best practices applicable to both water supply and sanitation projects

- **Take advantage of the experience of others**. A number of excellent and detailed guidelines, manuals, sourcebooks, and checklists provide clear and concise guidance on developing water supply and sanitation projects. In most cases these are available via the internet.

  Many of these resources, most with URLs, can be found in the Resources and References section at the end of these guidelines.

- **Concentrate first on preparing and developing the human component of the project** and use a demand-focused approach. Projects will be welcomed and supported by the local community only when they perceive a need. Cost sharing, especially for operation and maintenance, should be encouraged because of the positive effects it has on ownership, community support, and long-term sustainability. However, there may be some instances, such as emergency relief situations, where cost-sharing may not be possible. Cost sharing can be in-kind, such as community clean up days for drainage ditches, or community supplying locally available materials (sand, wood, etc). This type of commitment indicates genuine household-level demand for the project, as does an interest in adopting hygienic behaviors.
- **A promotional program/social marketing must accompany infrastructure development**. Water supply and sanitation projects that fail to improve hygiene behaviors generally achieve little or no improvement in public health. Community participation (discussed below) and awareness building are essential to achieving these changes. Improving hygiene practices requires sensitivity to the community's cultural and social preferences. Realism must be applied in this process—it may take years for the community to adjust to new practices.

  Reaching school children is often an effective strategy, but efforts to bring about behavior change must focus on all other family members as well. Sanitation practices of infants, as well as those of pre–school age children, the elderly, the sick and the disabled, generally do more to contaminate water supplies and spread disease than those of healthy adults.

  Understanding local hygiene behaviors and social-cultural beliefs that limit options is an essential first step in design. For example, in some cultures sanitation facilities for men and women must be strictly segregated even at the family level, so that a single latrine per family is inadequate. In other cases there may be the belief forbidding defecation in roofed structures.

  Resources exist to help design programs to improve hygiene behavior. See *Sanitation Promotion* (Simpson-Hébert and Wood, 1998), *PHAST step-by-step guide: a participatory approach for the control of diarrhoeal disease* (Sawyer et al., 1998), and *Sanitation and Hygiene Promotion Programming Guidance* (WHO, 2005). The Resources and References section at the end of this guideline provides a summary description and access information for each.

- **Use a participatory approach, including choice of technology** that actively engages the community in all stages of the project, including planning and development of management systems, establishment of user fees, construction, operation and maintenance, and possible future decommissioning. This will lead to appropriate design, enhance adoption of new behaviors and help generate the levels of community commitment and support needed for proper maintenance of the project.

  An essential part of the process is to give families and communities a selection of generally appropriate technology and design options to choose from, instead of beginning the project with a predetermined technology.

Offer technology alternatives that can be operated and maintained locally/at the village level (VLOM). Confirm that spare parts and necessary expertise are readily available. The VLOM (village operation and maintenance) is widely used to bring operation and maintenance of communal hand pumps down to the level of the users, but it must be part of a well-established system of community management, training, and technical support when repairs require outside expertise

- **Use some form of cost sharing to minimize subsidies**. When households share the cost of building latrines they feel a sense of ownership and responsibility for the project. This can reduce overall costs, increase correct usage, and improve maintenance.
- **Integrate water supply, sanitation and hygiene promotion interventions**. If these elements are treated individually, the fecal-oral route of disease transmission will not be broken and public health benefits from infrastructure investments will be limited.
- **Draw upon existing community organizations instead of starting new ones.**
- **Design the program so that it will be economically self-sustaining**. Generally, this requires cost recovery mechanisms such as user fees, taxes or levies to finance operations, monitoring, maintenance and repairs, along with a sustainable management structure for collecting these monies and overseeing their use.
- **Include a system for sustaining operation and maintenance** as part of overall program design. The failure to ensure ongoing operation and maintenance is one of the most common reasons projects fail. The system should include a mechanism for training local residents to operate, monitor, maintain and repair the improvement and to keep up institutional memory, for example, maintaining a pool of community members trained in operation and maintenance.

Best Practices—Water supply

- Calculate yields and extraction rates
- Appropriate scale and capacity
- Assess water quality
- Periodic testing
- Minimize downstream impacts
- Promote improved hygiene behaviors

Best practices for water supply projects

- **Calculate yield and extraction rates** in relation to other area water uses and available supply. This is necessary to avoid depleting the resource or adversely affecting aquatic ecosystems and/or communities down stream/down gradient.

  These calculations should take into account historic and projected upstream/up-gradient and downstream/down-gradient supply and demand for water. Projects tapping groundwater should also consider depth to water table and groundwater hydrology.
- **Design improvements with an appropriate scale and capacity**. Estimate current and projected water quantity and availability based on current water sources and existing uses, baseline measurements on quantity of water available (including seasonal fluctuations), current and historic use data (household, agricultural, and institutional), population data and forecasts, current and projected

demand up and down stream/up and down gradient, and actual water use for similar projects in the past.

If possible, data on typical water leakage rates in other existing water schemes should be examined. Demand projections should take into account the likelihood that the project will attract additional users.

- **Assess water quality** to determine if water is safe to drink and to establish a baseline so that any future degradation can be detected.

  Ideally tests should be performed on the chemical, biological and physical quality of the proposed water source. At a minimum arsenic and fecal coliform tests should be conducted. *USAID requires testing for arsenic for all USAID-funded water supply projects, as there is currently no way to determine which locations may contain natural arsenic deposits.*

- **Maintain periodic testing**. *Ongoing testing is the only way to determine if a water supply is or has become contaminated* (other than by observing dramatic and sustained increases in water-borne disease).

- **Minimize downstream/down-gradient effects of intervention**, perhaps by establishing some form of communication with downstream parties.

Selected Water Quality Standards for Human Health

- Arsenic < 0.01 mg/L
- Total Coliforms = not detectable in any 100mL sample
- Lead < 0.01 mg/L
- Copper < 2 mg/L
- Nitrate (as NO_3^-) < 50 mg/L
- Nitrite (as NO_2^-) < 0.2 mg/L for long-term exposure
- Fluoride < 1,5 mg/l

Reference: WHO, *Guidelines for Drinking-Water Quality (3rd Edition)*, 2004. http://www.who.int/water_sanitation_health/dwq/gdwq3/en/index.html

Factors to consider for siting wells

Location:

- Locate the well at the highest point on the property.
- Avoid positioning down slope from potential sources of contamination, including surface water flows and flooding conditions.
- Locate the well in a site easily accessible for maintenance.
- Define a sanitary protective area around the wellhead that is kept in its natural state.

Potential Contaminants:

- Yield and quality of water supply will depend on soil type (which determines filtering capability and transmissivity).
- Course gravel, limestone, and disintegrated rock can allow contaminants to travel quickly with little opportunity for natural purification.
- **Distance to nearest point of potential contamination** is site and aquifer specific. The following MINIMUM distances from potential sources of contamination are best practice for sites with sand-like filtering capabilities:
    - 150 ft (45.7 m) from a preparation area or storage area of spray materials, commercial fertilizers, or chemicals that may cause contamination of the soil or groundwater.
    - 100 ft. (30.5 m) from a below-grade manure storage area.
    - 75 ft (22.9 m) from cesspools, leaching pits, and dry wells.
    - 50 ft (15.2 m) from a buried sewer, septic tank, subsurface disposal field, grave animal or poultry yard or building, privy, or other contaminants that may drain into the soil.
    - The distance between a septic tank leach field and a down-gradient well should be greater than 100 ft (30.5 m) if the soil is coarser than fine sand and the groundwater flow rate is greater than 0.03 ft/day (0.01 m/day).

Source: Driscoll, Groundwater and Wells, Second Edition.

Best Practices—Sanitation

- Promotion sanitation to create demand
- Match demand, customs, preferences and ecosystem
- Assess local water quality
- Minimize downstream impacts
- Minimize hardware subsidies
- Consider natural treatment before mechanical options

Best practices for sanitation projects

- **Develop a hygiene promotion strategy** that takes into account the current hygiene behavior (handwashing, latrine use, water collection, transport, and storage) of all users, including women, infants, children, the elderly and the infirm and, as well as any social/cultural religious factors that may hinder changing behavior.
- **Design improvements to match demand, user customs and preferences, climate, and abundance of water**.
- **Test water quality downstream/down gradient** from the proposed site before construction of infrastructure to establish a baseline. Testing after completion of project will provide necessary information for mitigation purposes.

  Elements to test for include fecal coliform, total suspended solids (TSS), biological oxygen demand (BOD) and nutrients. Maintain ongoing testing to monitor for contamination.

- **Minimize downstream/down-gradient effects of intervention**. See box below on Sanitation and Hydrology.
- **Consider appropriate natural treatment systems instead of mechanical systems**. These tend to be preferable for small-scale activities as they generally cost less, do not require highly skilled labor, and can frequently be manufactured locally. Also, supplies for maintenance and repair are likely to be more readily available.

  There are many proven natural treatment options. Examples include double-vault batch composting toilets, double-vault batch dry toilets, upflow anaerobic filters[1], biogas reactors[2], confined-space constructed wetlands, subsurface wetlands, floating aquatic macrophytes, stabilization ponds and ecological sanitation (urine diversion and arborloo systems).

Sanitation and Hydrology

Preventing microbial contamination of groundwater sources depends on several factors:

- Type of latrine – the rate of flow of pathogen-containing liquid from latrine pits to the soil beneath is proportional to the quantity of liquid in the pit (static head). Dry latrines present the smallest risk of groundwater contamination.
- Water table – a latrine pit must be above the water table during all seasons. 1.5m below the surface is the minimum depth necessary to ensure the pit contents remain dry. The greater the distance between the base of the pit and the water table, the more time is required for pathogens to seep from the pit into the groundwater, thus allowing more pathogens to die-off naturally.
- Soil type – Clay, silt, and fine sand soil types all have grain sizes small enough to act as natural filters for microbial contaminants (<0.2mm). Certain clay soils can also absorb viruses.
- Distance to nearest water source – the risk of contamination of a surface or groundwater source by a latrine depends on the distance to the source, the direction and velocity of the flow of water in the soil (hydraulic gradient), and the soil/rock permeability. 30m is considered the minimum separation for most soil types.

Balancing these factors to determine the best combination of siting and sanitation technology should involve input from engineers and/or hydrologists. For more information, see S. Sugden, *WELL Factsheet: The Microbiological Contamination of Water Supplies*, 2004. http://www.lboro.ac.uk/well/resources/fact-sheets/fact-sheets-htm/Contamination.htm

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[1] [2] The reference to upflow anaerobic filters and biogas reactors both require pumping, so they are not truly “natural treatment systems”.

ESDM of Activities and Programs: Specific Mitigation and Monitoring Measures

The table in this section (overleaf) matches impacts and mitigation measures to specific water and sanitation activities/technologies.

Achieving ESDM requires that these impacts are considered and the corresponding mitigation measures adopted when the impacts are potentially significant. Note that in many cases, the mitigation measures are good practices.

In general, USAID IEEs or subproject review documents should note and assess the potential impacts listed here and specify corresponding, appropriate mitigation measures.

An "enviroloo" (dry composting toilets) mandated by the Department of Public Works in the Northern Province of the Republic of South Africa (2002)

Table 3: Impacts and mitigation measures for specific water and sanitation activities and technologies

Activity/ Technology	Potential Impacts *The activity or technology may. . .*	Mitigation measures *Note: Measures apply to the project phase specified: planning and design (P&D), construction (C), or operation and maintenance (O&M).*
General		
Site selection (P&D)	Damage sensitive ecosystems or endangered species (P&D)	Survey for, and avoid, wetlands, estuaries or other ecologically sensitive sites in the project area. Identify nearby areas that contain endangered species and get professional assessment of species' sensitivity to construction at site (P&D)
Construction of buildings and structures (C)	Damage sensitive ecosystems or endangered species (C) Cause erosion and sedimentation (C)	Follow guideline on Construction in this manual (P&D) (C) Train and monitor workers on best practices in construction of buildings and structures (P&D) (C) Gather data on soil type, slope and topography to determine the potential for significant erosion (P&D) Use silt screens, straw bales or similar erosion control measures (C) Avoid damaging vegetation (C) Revegetate areas damaged during construction. Do not remove erosion control measures until revegetation is complete (C) Use proper bedding materials for pipes (P&D) (C)
Soakways and drains	Cause erosion (O&M) Alter the natural flow of rainwater runoff (O&M) Create pools of stagnant water (O&M)	Use riprap (cobbled stone), gravel or concrete as needed to prevent erosion of drainage structures (P&D) (C) Monitor and keep drains and soakways clear (O&M)
Water Supply Improvements		
Hand-dug wells, seasonal ponds, improved springs, ground-level catchment and similar structures	Contaminate water with human pathogens (O&M)	Include focus on proper use and maintenance of the improvement as part of behavior change and education program (P&D) Construct spigot or similar system that prevents people from touching impounded water with their hands or mouths (P&D) (C)
	Contaminate water with animal manure (O&M) Create pools of stagnant water (O&M) Exhaust water supply (not applicable to improved springs or hand-dug wells) (O&M)	Use fencing or equivalent that will keep live stock from grazing uphill or up gradient of the water supply improvement (P&D) (C) Do not allow animals to drink directly from the water source (O&M) Monitor drains and soakways and keep them clear of debris (see entry on soakways and drains above for more detail) (O&M) Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves and similar structures (O&M) Put in place a system for regulating use, such as a local warden or appropriate pricing (P&D) Give the community training in operating the improvement (P&D) (O&M) Monitor water levels in wells or impoundment structures to detect overdrawing

Activity/ Technology	Potential Impacts *The activity or technology may. . .*	Mitigation measures ***Note: Measures apply to the project phase specified: planning and design (P&D), construction (C), or operation and maintenance (O&M).***
		(O&M)
Wells	Provide water contaminated with nutrients and bacteria from animal waste (O&M) Create pools of stagnant water (O&M) Change groundwater flow (O&M) Create saltwater intrusions (O&M) Deplete aquifer (groundwater) (O&M) Cause land subsidence (impact from many wells) (O&M)	Don't let animals graze or be watered up-gradient from wellhead (P&D) (O&M) Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves and similar structures (O&M) On islands and coastal areas, keep withdrawals within safe yield limits to avoid overdrawing, possible salt water intrusion and contamination of the well (P&D) Put in place a system for regulating use, such as a local warden or appropriate pricing (P&D) Include a focus on proper use and maintenance of the improvement as part of the behavior change and education program (O&M) Monitor water levels (O&M)
Standpipes	Create pools of stagnant water (O&M) (This problem can be more severe when water table is high, clay soils are present, or population/tap density is high)	Ensure that spilled water and rainwater drain to a soakway or equivalent structure and do not accumulate and create stagnant standing water (C) Monitor and repair leaks from cracked containment structures, broken pipes, faulty valves and similar structures
Treatment systems		
Pit latrine	Increase transmission of vector-borne diseases (O) Contaminate groundwater supply with pathogens (O) Contaminate water supplies, damage water quality and/or transmit disease at other locations if waste is not properly handled and treated during or after servicing (O)	Devote adequate attention to identifying and addressing social barriers to using latrine (P&D) Use the ventilated improved pit latrine design that traps insect vectors (P&D) Evaluate depth to water table, including seasonal fluctuations and groundwater hydrology. The size and composition of the unsaturated zone determine the residence time of effluent from the latrine, which is the key factor in removal and elimination of pathogens. Pit latrines should not be installed where the water table is shallow or where the composition of the overlying deposits make groundwater or an aquifer vulnerable to contamination (P&D) Ensure that a reliable system for safely emptying latrines and transporting the collected material off-site for treatment is used. This should include use of a small pit-emptying machine such as the vacutug that relies on an engine-driven vacuum pump. The vacutug was tested for UNCHS in low-income areas of Nairobi, Kenya, and was found to give workers much greater protection from disease than conventional methods. See Wegelin-Schuringa, *Small Pit-Emptying Machine: An Appropriate Solution in Nairobi Slum,* for more details) (O&M) Ensure that collected material is adequately treated and not directly applied to fields or otherwise disposed of improperly (O&M)

Activity/ Technology	Potential Impacts *The activity or technology may. . .*	Mitigation measures *Note: Measures apply to the project phase specified: planning and design (P&D), construction (C), or operation and maintenance (O&M).*
	Cause injury to people or animals	Properly decommission pit latrines. Do not leave pits open. Fill in unused capacity with rocks or soil.
Composting toilets	Increase transmission of vector-borne diseases (O)	Maintain humidity of composting material above 60% and supplement excreta with generous quantities of carboniferous material (dry leaves, straw, etc.). The pile should then remain aerobic, odor-free and insect-free (O&M)
	Contaminate groundwater supply with pathogens (O)	Construct sealed vaults to hold composting material if using fixed-batch systems. If using movable-batch systems check removable containers for leaks before installing (O&M)
	Cause disease transmission to field workers and consumers of agricultural products (O)	Test samples from active chamber and mature chamber after fallow period for *Ascaris* eggs and fecal coliforms (O&M) Allow sufficient residence time in mature chamber. This may vary from 6 months in warm climates to 18 months in cooler climates (O&M) Ensure that the systems will be properly operated and maintained so that the soil amendment taken out after the treatment period is truly sanitized (O&M)
Dry toilets	Increase transmission of vector-borne diseases (O) Cause disease transmission to field workers and consumers of agricultural products (O)	Maintain humidity of composting material below 20% and supplement excreta with alkaline material (ashes or lime). The pile should then remain both odor free and insect free (O&M). Generous applications of ashes will help ensure that pathogens are destroyed. pH is the most important factor for sterilization (O&M) Construct sealed vaults to hold dehydrating and curing material (C) Ensure that the systems will be properly operated and maintained so that the soil amendment taken out after the treatment period is truly sanitized (O&M) Test samples from active chamber and mature chamber after fallow period for *Ascaris* eggs and fecal coliforms to assess level of sterilization (O&M) Allow sufficient residence time in mature chamber. This may vary from 6 months in warm climates to 18 months in cooler climates (O&M)
Septic tanks	Contaminate groundwater supply with pathogens (O&M)	Evaluate depth to the water table, including seasonal fluctuations and groundwater hydrology. If water table is too high, line the tank with clay, plastic sheeting or some other impermeable material to prevent leakage (P&D) (C)
	Contaminate surface water supplies with nutrients, biological oxygen demand (BOD), suspended solids (SS) and pathogens. (Septic tank effluent generally contains relatively high concentrations of pathogens, BOD, and SS) (O&M)	Avoid direct discharge of effluent to waterways if possible. Direct discharge to waterways with sufficient volume and flow to assimilate the waste may be acceptable. It is better to add a secondary treatment, such as passing effluent through an anaerobic filter, followed by discharge to an absorption field, or better yet, a constructed wetland (P&D)
	Contaminate water supplies, damage water quality and/or transmit disease at other locations if waste is not properly handled and treated during or after servicing (O&M)	Ensure that a reliable system for safely removing sludge and transporting the collected material off-site for treatment is available. This should include use of a mechanized (probably vacuum-based) removal system (P&D) (O&M) Ensure that collected sludge is adequately treated and not directly applied to fields or otherwise improperly disposed of (See Sludge management below) (O&M)

Activity/ Technology	Potential Impacts *The activity or technology may. . .*	Mitigation measures *Note: Measures apply to the project phase specified: planning and design (P&D), construction (C), or operation and maintenance (O&M).*
Upflow anaerobic filters	Damage ecosystems and degrade surface water quality. Sludge has high concentrations of nutrients, BOD, and solids (O&M) Cause disease transmission to field workers and consumers of agricultural products (Sludge may still contain pathogens) (O&M)	Treat sludge before secondary use (see Sludge management below). Do not allow disposal in or near water bodies (O&M) Provide workers servicing, transporting, and otherwise exposed to sludge with appropriate protective clothing including, at a minimum, rubber gloves. Train workers to wash hands and faces frequently with soap and warm water and make both available. (See Wastewater and sludge use in agriculture and aquaculture below) (O&M)
Settled and simplified sewers	Damage ecosystems and degrade surface water quality (O&M) Transmit diseases to field workers and consumers of agricultural products (O&M)	Ensure that collected sewage will be treated, e.g., in a wastewater stabilization pond, and not simply discharged to a river or stream or used directly in agriculture or aquaculture. This is especially important for simplified sewerage, since there is no interceptor tank (P&D) (O&M)
Biogas reactors	Damage ecosystems and degrade surface water quality (O&M) Transmit diseases to field workers and consumers of agricultural products (O&M)	Do not allow disposal of digested slurry in or near water bodies (O&M) Follow WHO or other national or international guidelines for use of sludge in wastewater in agriculture and aquaculture (see Sludge and wastewater reuse below) (P&D) (O&M)
Wastewater stabilization ponds **(anaerobic, facultative, aerobic)**	Damage ecosystems and degrade surface water quality (O&M) Transmit diseases to field workers and consumers of agricultural products (O&M)	Avoid discharging single (facultative) pond systems directly into receiving waters. If this is unavoidable, construct hydrography-controlled release lagoons that discharge effluent only when stream conditions are adequate. Install secondary treatment such as a constructed wetland, if possible (P&D) (C) (O&M) Use two-, three- or five-pond systems if possible (anaerobic, facultative, (maturation)) (P&D) Allow only restricted uses for agriculture and aquaculture of effluent from all but five-pond systems (O&M)
Reed bed filter	Contaminate groundwater or surface water (O&M)	Evaluate depth to the water table, including seasonal fluctuations and groundwater hydrology. If water table is too high, line tank with clay, plastic sheeting or some other impermeable material to prevent leakage (P&D) (C)
Subsurface wetland	(See reed bed filter above)	
Free water surface wetland **Floating aquatic macropytes**	Provide breeding ground for disease vectors (O&M) Introduce invasive non-native species (O&M)	Use plant and animal species that are native to the region. Avoid introducing water hyacinth, water milfoil, or salvinia, which have proven extremely invasive outside of their natural range (P&D) If using water hyacinth, maintain dissolved oxygen at 1.0 mg/L, frequently harvest and thin plants and/or add mosquitofish (*Gambusia affinis*) to the wetland or use other plant species such as duckweed, water lettuce (*Pistia stratiotes*), water milfoil, or salvinia (*Salvinia spp*.) (O&M)
Slow-rate overland flow	Contaminate groundwater or surface water (O&M)	Use where growing season is year round. Requires vegetation (P&D) (O&M) Use only where soil textures are sandy loam to clay loam (P&D) (O&M) Use where groundwater is >3 ft. below surface (P&D) (O&M)

Activity/ Technology	Potential Impacts *The activity or technology may. . .*	Mitigation measures ***Note: Measures apply to the project phase specified: planning and design (P&D), construction (C), or operation and maintenance (O&M).***
Slow-rate subsurface flow	Contaminate groundwater or surface water (O&M)	Use only where soil textures are sand to clayey loam (P&D) Use only where groundwater is >3 ft. below surface (P&D)
Rapid infiltration	Contaminate groundwater or surface water (O&M)	Use only where soil textures are sandy to loam (P&D) Use only where groundwater is >3 ft. below surface (P&D)
Sludge management	Damage ecosystems and degrade surface water quality (O&M)	If possible, choose treatment technologies that do not generate sludge, such as wastewater stabilization ponds (P&D) Compost sludge, then use as soil amendment for agriculture (O&M)
	Cause disease in handlers and processors (O&M)	Provide workers with appropriate protective clothing, including rubber gloves, boots, long-sleeved shirts and pants. Train workers to wash hands and faces frequently with soap and warm water and make both available (O&M)
Wastewater use in agriculture and aquaculture	Cause disease in field workers and consumers of agricultural products (O&M)	WHO guidelines recommend (1) treat to reduce pathogen concentrations, (2) restrict use to crops that will be cooked, (3) use application methods that reduce contact with edible crops, and (4) minimize the exposure of workers, crop handlers, field workers and consumers to waste (P&D) (O&M) Wastewater used in aquaculture should have $<10^3$ fecal coliforms per 100 ml to minimize risk to public health. (*See Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture: Measures for Public Health Protection*, 1989, WHO, Geneva (P&D) (O&M) http://www.who.int/environmental_information/Information_resources/documents/wastreus.pdf

Resources and References

Guidelines for Water Supply and Sanitation Programmes

- *Guidelines for the Development of Small Scale rural Water Supply & Sanitation Projects In East Africa.* Warner. D, Abate. C July 2005. http://www.encapafrica.org/documents/Wat0509_e.pdf

  In order to respond to the growing needs for safe drinking water and appropriate means of household sanitation, Catholic Relief Services is determined to provide the best possible technical, social and economic support to rural communities of East Africa. These guidelines are the result of the combined efforts of many individuals, both within CRS and other organizations, to assist in the planning and implementation of CRS country programs in water and sanitation in the region.

- *FID Guidance Manual On Water Supply and Sanitation Programmes* (1998). United Kingdom Department for International Development (DFID). http://www.lboro.ac.uk/well/resources/Publications/guidance-manual/guidance-manual.htm

  An excellent general resource designed to assist DFID staff and partners in developing effective and sustainable water supply and sanitation programs. Comprising three chapters and appendices, it takes the reader from an overview of the sector, through specific development perspectives, to detailed recommendations for each stage of the project cycle.

- *Best-Practice Sourcebook On Water, Sanitation, and Environmental Health* (2000). CARE (in press).

- *Standard Methods for the Examination Of Water and Wastewater,* 20th *Ed.* (1995). Washington, D.C.: APHA. http://www.standardmethods.org/

  This comprehensive reference covers all aspects of water and wastewater analysis techniques. Standard Methods is a joint publication of the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF).

- *Assessing Demand for Water Supply and Sanitation Projects.* (2000). Sarah Parry-Jones. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  An exploration of the issues surrounding a demand-responsive approach to water and sanitation service provision, with a discussion of the relative merits of the most commonly used demand assessment tools.

- *On-Site Sanitation In Areas With a High Groundwater Table.* (1999). Sarah Parry-Jones http://www.lboro.ac.uk/well/resources/fact-sheets/fact-sheets-htm/lcsahgt.htm

  In areas that experience a seasonally high groundwater table or that are prone to flooding, constructing affordable on-site sanitation facilities can be very problematic. It is a challenge that affects many countries worldwide. This technical brief provides practical guidance on some sanitation options in such conditions. More details on each option outlined can be found in the references in the further reading section.

- *Private Sector Participation In the Water and Sanitation Sector: Public-Private Partnership and the Poor* (1999). Mike Webster and Kevin Sansom. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  A review of existing work examining the impact of Public-Private Partnerships (PPP) in the water and sanitation sectors on service delivery to the poor. Important gaps in current knowledge are also identified.

Web sites

- WELL - Research Centre Network for Water, Sanitation and Environmental Health. http://www.lboro.ac.uk/well/

  The WELL website is a focal point of information about water, sanitation and environmental health and related issues in developing and transitional countries. They publish a wide-variety of guidance documents, including factsheets, studies and technical briefs.

- IRC International Water and Sanitation Centre. http://www.irc.nl/

  Since its foundation in 1968, the IRC International Water and Sanitation Centre (IRC) has facilitated the sharing, promotion and use of knowledge so that governments, professionals and organisations can better support poor men, women and children in developing countries to obtain water and sanitation services they will use and maintain. The website contains a vast array of references, training courses and documents. Of particular interest is the interWater Guide to Organizations available at http://www.irc.nl/page/126.

- Water Supply and Sanitation Collaborative Council. http://www.wsscc.org/

  Established in 1990 at the end of the International Drinking Water Supply and Sanitation Decade. Its purpose is to maintain the momentum of the Decade, by providing a regular way for water and sanitation sector professionals to exchange views and experiences and develop approaches to foster more rapid achievement of the goal of universal coverage

- NETWAS: Network for Water and Sanitation. Hosting the International Training Network for Water and Waste Management (ITN - Africa). http://www.netwas.org/

  A network of regional and international training institutions, launched in 1984 by the World Bank's Water and Sanitation Program to support training in low-cost water supply and sanitation. ITN Centers provide training, disseminate information and promote local applied sector research on low-cost water supply and sanitation options. The Network links affiliated institutions serving Asia and Africa in Ouagadougou, Burkina Faso (serving countries in francophone West Africa); Kumasi, Ghana (Ghana); Harare, Zimbabwe (Zimbabwe); Nairobi, Kenya (Ethiopia, Kenya, Tanzania, and Uganda); Dhaka, Bangladesh; Calcutta, India (India); and Manila, Philippines (Philippines). New centers are under development.

- Water and Sanitation Program Knowledge Network http://www.wsp.org/

  The Water and Sanitation Program (WSP) is an international partnership of the world's leading development agencies concerned with improving sector policies, practices and capacities to serve poor people. Administered by the World Bank, WSP provides targeted support to national and local governments, local communities, and their support organizations.

Disease Prevention and Control

- *Cholera and Other Epidemic Diarrhoeal Diseases Control* (1996). Prepared by the Robens Institute, University of Surrey, UK. Geneva: WHO. http://www.who.int/csr/resources/publications/cholera/WHO_EMC_DIS_97_6/en/index.html

- *PHAST Step-By-Step Guide: A Participatory Approach for the Control of Diarrhoeal Disease* (1998). R. Sawyer, M. Simpson-Hébert and S. Wood. Geneva: WHO. English: http://whqlibdoc.who.int/hq/1998/WHO_EOS_98.3.pdf French: Available for purchase at http://www.who.int/bookorders/francais/detart2.jsp?sesslan=2&codlan=1&codcol=93&codcch=131

- *Sanitation Promotion* (1998). Mayling Simpson-Hébert and Sara Wood, eds. Water Supply and Sanitation Collaborative Council (WSSCC) Working Group on Promotion of Sanitation. Geneva: World Health Organization (WHO). http://whqlibdoc.who.int/hq/1998/WHO_EOS_98.5_pp1-140.pdf and http://whqlibdoc.who.int/hq/1998/WHO_EOS_98.5_pp141-277.pdf

  A valuable resource consisting of a number of short sections that can be used independently. A "Checklists" section (pp. 141-153) includes checklists for planning better sanitation projects, sanitation in emergency situations, hygiene behavior-change, and suggestions for addressing gender issues. Other sections focus on building political will and partnerships and on conducting promotional programs including subsections on principles and guidelines, empowerment, checklists, and promotion through innovation.

- *Promoting Change in Environmental Health Behaviour* (1999). Ben Cave and Valerie Curtis. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  A literature review focusing on the potential effectiveness of approaches to environmental health promotion in developing countries, and appropriate expectations and targets for change in health behavior.

Provision of Drinking Water

- *WHO Guidelines for Drinking Water Quality: Training Pack.* (2000). World Health Organization, Protection of the Human Environment. Geneva: WHO. http://www.who.int/water_sanitation_health/dwq/dwqtraining/en/index.html

  These training materials cover a wide range of topics and include 23 sessions - both presentations and practical sessions. Each presentation in the materials includes a session plan, a background paper and overhead transparencies. Each practical session provides guidance as to how such sessions might be delivered and the materials required.

- *On-Line Bore-Well and Hand-Pump Installation Tutorial.* Lifewater Canada. http://www.lifewater.ca/ndexdril.htm

- *Water Quality Assessments: A Guide to The Use Of Biota, Sediments And Water In Environmental Monitoring*, 2nd edition (1996). Deborah Chapman, ed. Published on behalf of UNESCO, WHO and UNEP. London: E & FN Spon. http://www.who.int/water_sanitation_health/resourcesquality/wqa/en/index.html

Sanitation References

- John Kalbermatten, Richard Middleton and Roland Schertenleib. *Household-Centered Environmental Sanitation.* Vision 21. http://www.wsscc.org/pdf/publication/hces.pdf

  An amplification of the HCES Model, developed following the Wageningen Meeting. It includes more detailed descriptions of the "zones" and the decision-making processes in different circumstances. Likely to be the model for environmental sanitation planning and implementation in the coming years.

- *Guidelines for Wastewater Reuse In Agriculture And Aquaculture: Recommended Revisions Based On New Research Evidence* (1999). Ursula Blumenthal, Anne Peasey, Guillermo Ruiz-Palacios and Duncan Mara. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  The implications of some new studies for the setting of international guidelines for using wastewater in agriculture and aquaculture are considered, along with the wastewater treatment and other health protection measures needed to achieve these guidelines.

- *A Guide to the Development Of On-Site Sanitation* (1992). R. Franceys et al. Geneva: WHO. http://www.who.int/water_sanitation_health/hygiene/envsan/onsitesan.pdf

- *Community-Based Technologies for Domestic Wastewater Treatment And Reuse: Options For Urban Agriculture* (1999). G.D. Rose. International Development Research Centre (IDRC). http://www.p2pays.org/ref/03/02008.htm

  This document provides information on urban wastewater management. It specifically discussed issues involved in wastewater resrouce recovery, wastewater management, project planning and implementation. It also includes a good discussion of wastewater treatment technologies such as on-site treatment, anaerobic treatment systems, water-based treatments, and sludge management.

- *Health Aspects Of Dry Sanitation With Waste Reuse* (2000). Anne Peasey. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  A review that collates current knowledge of health risks associated with dry sanitation technologies and the problems associated with their use and maintenance.

Guidance for Operation and Maintenance

- *Operation and Maintenance of Rural Water Supply and Sanitation Systems: A Training Package for Managers and Planners* (2000). Prepared by François Brikké. WSSCC Operation and Maintenance Network and IRC International Water and Sanitation Centre. Geneva: http://www.irc.nl/redir/content/download/2548/26132/file/OME_OM_TrainingPackage.pdf

- See http://www.who.int/docstore/water_sanitation_health/wss/o_m.html for links to the following guides:

  - Selected case studies on operation and maintenance of water supply and sanitation systems. These case studies describe different operation and maintenance (O&M) experiences in a variety of countries, in both rural and urban settings. They are a useful source of information for improving O&M practice.
  - Tools for assessing operation and maintenance status of urban and rural water supply (2000). These comprehensive guidelines show how to assess O&M performance in both rural and urban areas.
  - Operation and maintenance of urban water supply and sanitation systems: a guide for managers. This publication examines factors which may prevent existing urban water supply systems from working efficiently, and provides guidelines and solutions for optimization.
  - Leakage control: source material for a training package. Materials trainers can adapt for use in local training courses, covering all aspects of leakage control, divided into individual modules for ease of use.
  - Upgrading water treatment plants (2001). Summarizes many different field experiences with efforts to improve the quality of water and to upgrade the capacity of water treatment plants. It provides a practical approach to improving the performance of water treatment plants.
  - Management of operation and maintenance in rural drinking-water supply and sanitation: a resource training package. This package contains resource material for training courses aimed at improving the management of O&M in rural areas.
  - Models of management systems for the operation and maintenance of rural water supply and sanitation systems. This document evaluates the factors which influence the development of O&M management systems for rural facilities. It describes models in eight representative countries and offers guidance to planners and designers in selecting the best approach.

- Linking technology choice with operation and maintenance. This document helps users make more appropriate technology choices by providing information on the O&M implications-particularly the costs-of selecting a specific technology.

Case Studies

- *Provision of Water and Sanitation Services to Small Towns* (2000). Jeremy Colin and Joy Morgan. http://www.lboro.ac.uk/well/resources/well-studies/summaries-htm/%23brief323.htm

  This report describes and analyzes the findings of rapid investigations in two small towns in Uganda and two in the Southern Indian state of Kerala.

- *Sanitation Programmes Revisited* (1999). Darren Saywell and Caroline Hunt. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  A comparative analysis of two notable African sanitation programs, focusing on a historical analysis (investigating how, when and why the programs developed in the way they did) and an understanding of critical issues common to each program, including demand assessment, sanitation promotion, community participation, responsibility for service provision, finance and cost recovery, and health aspects of promotion.

- *Lessons Learned From Village-Level Operation and Maintenance* (VLOM) (1999). Jeremy Colin. http://www.lboro.ac.uk/well/resources/well-studies/well-studies.htm

  A literature review of sector experience of the Village Level Operation and Maintenance Management (VLOM) approach to rural water supply.

- *Learning What Works: A 20-Year Retrospective View on International Water And Sanitation Cooperation* (1998). Maggie Black. World Bank. English:. http://www.un.org/esa/sustdev/sdissues/water/InternationalWaterDecade1981-1990_review.pdf

  A detailed history of water supply and sanitation programs and lessons learned.