**STRATEGIA, NETHERLANDS**

**PRINSES BEATRIXLAAN 58**

**2595 BM, THE HEGUE, NETHERLANDS**

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**SUBMITTED BY:MABOR MAYOM AKEC**

**Email: jabrilchol@gmail.com**

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1. **List and briefly describe the measures by which the success or otherwise of a public–private partnership providing water supply services can be assessed.**

In cities across the world it has usually been the case that a municipal (public) authority takes responsibility for urban water supply. There are now variations in this service provision. In many countries, private businesses (or operators) have joined in partnership with public authorities to provide water in arrangements called public–private partnerships. This study session explores the concept of public–private partnerships and their application in urban water supply.

**Public–private partnerships**

In the major towns and cities of Ethiopia water is supplied by water utilities (also known as Town Water Supply Enterprises) but **public–private partnerships** (PPPs) can be helpful. A public–private partnership is any collaboration between public bodies, such as a municipality or even the government, and private companies. The belief is that private companies are more efficient and better run than bureaucratic public bodies, and the management skills and financial acumen that they bring will create better value for money for customers.

The incentive for the private companies is the profit that can be generated. PPPs have become popular, to the extent that the number of people served by private water operators in developing and former Communist countries increased from 94 million in 2000 to more than 160 million in 2007 **(Marin, 2009)**. Philippe Marin's report, *Public–Private Partnerships for Urban Water Utilities*, which was a review of PPPs in urban water utilities in developing countries, was undertaken because of the interest generated in these arrangements. At the time of the report (2009), about 7% of the urban population in the developing world was served by private water operators. There are different ways in which PPPs can be set up but the sections that follow now briefly consider the factors that Marin covered in his report.

**Access**

Marin found that where most of the investment for expansion of access was provided by the public partner rather than the private operator, access to piped water increased. The finance provided by the public partner is thus crucial if the aim is to increase the number of people with access to water.

**Quality of service**

Marin reported that often water PPPs substantially improved service quality, in particular by reducing water rationing (for example, in Guinea, Gabon, Niger and Senegal). This had the advantage of improving drinking water quality because a constant flow of water through the piping system reduces the risk of infiltration of unclean water from the soil around the pipelines.

**Operational efficiency**

The three main indicators of operational efficiency (water losses through leakage, etc., payment collection and labour productivity) were also studied by Marin.

*Water losses*

Any water lost is a loss in income, and so, perhaps predictably, Marin found (in line with other researchers) that private operators were effective in reducing water losses, some reducing non-revenue water to less than 15% (which Marin states is similar to that of some of the best-performing water utilities in more developed countries).

*Payment collection*

Not surprisingly, because of the financial benefits to the private partner, it was found that the introduction of a private operator markedly improved the payment collection rate.

*Labour productivity*

There was strong evidence that the introduction of private operators resulted in an improvement in **labour productivity**. This is the amount of work undertaken by each employee. Many of the public water utilities studied were over-staffed, and the PPPs when set up were followed by significant redundancies, ranging from 20% to 65% of the labour force. Besides the over-staffing issue, layoffs were often motivated by a need to change the overall profile of the workforce and to hire more skilled people **(Marin, 2009**).

Marin concludes by saying that the biggest contribution that private operators can make in a PPP is in improving operational efficiency and service quality. Improving service quality results in customers becoming more willing to pay their bills, and increasing operational efficiency results in increased income; both of these factors lead to more money being available for investment in expansion of services. In turn, expansion of services results in more customers and consequently increased income, which again can be invested to bring access to water to even more people.

**Assessing the performance of a PPP**

The performance of a PPP (and indeed a public water utility) can be assessed through the following parameters **(Athena Infonomics, 2012):**

- *Accessibility*: What proportion of the population have access to water? Is the distance to the water point less than 1 km or 30 minutes' walking time? **(Pickering and Davis 2012)**, using survey data from 26 sub-Saharan countries, found that the further away a water source was, the less water was used; when the distance was more than 30 minutes away, households collected less water than was necessary for basic needs.
- *Affordability*: Is the cost of the water needed less than 5% of the household's income?
- *Cost recovery*: Is the cost of providing the water being recouped?
- *Minimisation of non-revenue water*: Is this reduced to no more than most 15%?
- *Water quality*: Is there adherence to national standards?
- *Operational efficiency*: What is the quantity of water supplied per capita? What is the duration of water supply in hours per day?

These parameters can be used to evaluate whether a PPP is beneficial, with data from before the partnership's creation being compared with data after the PPP has been running for, say, a year.

**PPP for bill payment**

In Ethiopia, a public–private partnership called 'Lehulu' (which means both 'for all', and 'for all services', in Amharic), established jointly by the Ethiopian Ministry of Communications and Information Technology and a private company, was launched in early 2013. Its remit was to allow easy payment of bills from the Ethiopian Electric Power Corporation (EEPCO), EthioTelecom, and Addis Ababa Water and Sewerage Authority (AAWSA). Based on the 'build–own–operate–transfer' model, this was said to be the first such institution in Africa, and has the potential to create more than 450 jobs (Kifiya Financial Technology, n.d.). In the build–own–operate–transfer model of PPP, a private firm sets up a system, owns and runs it for several years, and then transfers it to the public sector.

**Other possibilities for PPPs**

According to (**François Munger (2008)**) the most common public–private partnership arrangements in the water sector in developing countries take the following forms:

- Management contracts, where the private firms look after the management, operation and maintenance of the entire water system or part of it (for example, the distribution network) for a limited period of time (approximately five years) in exchange for a performance-related fee.
- Lease contracts, where the private firms maintain and operate the water supply system, at their own risk, deriving revenue from the water tariff, for a fixed period (six to ten years). Investment is financed and carried out by the public sector.
- Concessions, where the private firms provide a service at a given standard for a fixed time (20 to 30 years). The private firms operate, manage, and make the investments, carrying the commercial risks. For example, in countries where

hand pumps are common, a private company may take on the role of supplying pump mechanics and spares to keep hand pumps operational.

- Build–own–operate–transfer contracts, as mentioned earlier, are where private firms construct new water treatment plants and run them for a number of years before handing them over to the public sector.

**Microenterprises**

A **microenterprise** can be defined as a small business that employs fewer than ten people and is started with a small amount of capital. Water supply is an area in which microenterprises operate in a number of different ways, as you will discover later in this explanation.

**Selling water at public taps**

Public taps are one way of distributing water. The water is sold to people by volume, and customers come to the public tap with water containers. Although many of the public taps are owned and run by the public utility, some are microenterprises: the water is bought from the water utility by the tap attendant and then sold on to consumers at a higher price. A survey of public taps in Addis Ababa **(Howard, 2005 )**found that water was being sold at a price up to eight times the cost of buying directly from the water utility! Public taps are open for only a few hours each day, which can sometimes result in long queues.

**Selling water using tankers**

Private sellers also supply water through the use of water tankers licensed by the government. This happens in areas not served by a piped water distribution system. The tanker usually has a capacity of 20,000litres and the water is pumped into water storage tanks at the households, which usually have a capacity of about 3000 litres.

**Water vendors**

In a survey of three poor areas of Addis Ababa **(Sharma and Bereket, 2008)**, it was found that 17% of the respondents obtained their water from water vendors who had originally purchased the water from the public water utility (the Addis Ababa Water and Sewerage Authority). The water vendors in cities are usually people who have private taps in their homes or yards and who sell water from these. The price at which the vendors sold the water to the end users was again about eight times the price paid for the water, corroborating the findings of **(Howard (2005). Sharma and Bereket )**found in their survey that most people would have preferred to have their own private tap but the high initial cost of a private connection was prohibitive. If this could be paid in small instalments, 90% of those keen to acquire a private tap would take up the option. In Kombolcha, in Amhara Region it is possible to do this, with the set-up cost being paid in four instalments. There is scope for a private–public partnership here, with private companies providing the administrative arrangements to collect the instalments. There are also water vendors who sell water from horse-drawn or donkey-drawn carts;

**Selling water at kiosks**

(**Sharma and Bereket (2008)** )Found that the price of the water at kiosks which is about three times the cost of water from the water utility. Water kiosks are common in the countries of sub-Saharan Africa, and water is brought from the kiosk owner's home to the kiosk and sold. Alternatively, if the kiosk is near the home of the owner, a hose connection to the house tap enables water to be sold direct. In a typical day a kiosk can serve 500–3000 people bringing their own water containers.

**Selling water-related services**

As part of the water industry, several microenterprises have emerged to supply plumbing services such as fixing leaks, extending pipelines around a house or compound, and selling and installing plumbing systems (such as tanks, pipes, latrines, WCs, etc.)

2. **Give six possible causes of water emergencies, three due to natural causes and three due to humans.**

   Water scarcity or water crisis or water shortage is the deficiency of adequate water resources that can meet the water demands for a particular region. Whenever there is a lack of access to potable and fresh water for drinking and sanitation, the situation means that the water is scarce. Water scarcity thus pertains to a situation where there is water shortage, water crisis, and the lack of access to quality water.

   The concept of water scarcity may also refer to the difficulty in obtaining fresh water sources and the deterioration and depletion of the available water sources. Some of the contributing factors to water scarcity are climate change, water overuse, and increased pollution. Many areas around the globe are affected by this phenomenon, and about 2.7 billion people experience water scarcity each and every year.

   According to the United Nations (UN) 2013 report on *water for life*, more than **1.1 billion people** lack access to clean drinking water. As more people put ever increasing demand on existing water resources, the cost and effort to build or even maintain access to water will increase. With the current consumption rate, two-thirds of the world's population may face water shortages by 2025.

   According to Science Daily,

“Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region. It already affects every continent and around 2.8 billion people around the world at least one month out of every year.”

Causes of Water Scarcity

1. **Water Pollution**

   Water pollution is yet another cause of water scarcity. The sources of water pollution include pesticides and fertilizers that wash away from farms, industrial and human waste that is directly dumped into rivers without treating it in water treatment plant. Oil spill on the ground, waste water leakage from landfills can seep underground and may pollute the groundwater making it unfit for human consumption.

2. **Overpopulation**

   The rapid increase in human population combined by massive growth in industry sector have have transformed water ecosystems and resulted in loss of biodiversity. As population is increasing at an ever increasing rate, the demand for new resources will result in additional pressure on freshwater sources.

3. **Agriculture**

   Agriculture uses majority of available freshwater. The sad thing is that about 60% of this water gets wasted due to inefficient agriculture methods and leaky irrigation systems. In addition to this, pesticides and fertilizers are washed away in rivers and lakes that further affect human and animal population.

b. What are the options for safe water supply during a water emergency

**A disaster** is a natural or manmade event that causes physical loss or damage, social and/or economic disruption and threatens people’s lives either directly or indirectly. A community1 confronted with a disaster will need to react in order to save the lives of its members and prevent suffering as much as possible. However, the disaster may stretch beyond the capacity of a community and cause an emergency.

**An emergency** is a situation of hardship and human suffering arising from a disaster, which develops if the organizational infrastructures in place cannot cope with the situation. In an emergency the affected population will need external assistance to ease the hardship and suffering to a bearable level and to minimize mortality and morbidity levels. Disaster and emergency response operations may be very different, depending on a wide range of aspects, such as:

• Scope and duration of the response needed: ranging from only required immediately after the event for a small number of specific aspects, to broad interventions required for several years after the event;

• Presence of local and national authorities;

• Level of operational capacity and effectiveness of authorities;

• Degree of effective response of local authorities and other local actors/leaders;

• High security risks in area (especially in conflict areas);

• Logistical and resource problems for agencies and authorities involved;

• Location of affected populations (i.e. displaced, partly displaced or not at all);

• Availability of water sources and their quality and quantity. From a technical point of view drinking water systems used in response to an emergency may not differ much from similar systems used in development situations.

For a comprehensive methodology for the selection of drinking water systems for both survival and longer-term supply in response to emergencies reference is made to **(House and Reed (1997). De Veer (1999)** ) Suggests quality systems for the operation of a number of different drinking water systems in camps; (**Davis and Lambert (2002)** )provide a comprehensive overview of drinking water techniques used in emergency response operations.

**Water tankers**

The provision of drinking water by tankers is a solution for survival supply when time is very limited and other systems cannot be realized within the time limits. Water supply by tankers is only possible when certain requirements are fulfilled. Usually these requirements can be met locally. Otherwise trucks, repair facilities, etc. have to be brought in by road or air from elsewhere. Water supply by tankers is almost always planned and managed by specialized external agencies because of the complexity of its management and the high costs. This is not, therefore, a solution for longer-term water supply, although examples exist where large water tanker operations have continued for many months. Water tankers are also often used to supplement other water services.

**Water intake, storage, treatment and distribution systems**

Water transport and distribution systems constructed in response to a disaster/emergency situation follow the same principles as those constructed under normal conditions. They may differ in certain details due to the factors also the choice of a specific type of system may be dictated by the special circumstances prevailing in an emergency. Construction of water transport and distribution systems in response to a disaster/emergency is usually done through paid labour, while in development situations much more use is made of voluntary labour from the beneficiary community.

The common reasons are that, following a disaster, social coherence among the affected population is less than in "normal" communities, there is lack of a common feeling of responsibility, and people may believe that the facilities will not be beneficial to them for a long time. These factors can make it more difficult to mobilise beneficiaries on a voluntary basis. This is not a rule, though, and exceptions do exist. Intake If the water source is surface water then a temporary intake structure can be created by building a small weir made of bags filled with sand.

The end of the inlet pipe needs to be covered with some kind of filter (netting) and positioned in the river directly upstream of the weir. The pumping equipment can be whatever is commonly available in the country; straightforward technology gives the best chances for reliable functioning. A source caretaker (a paid staff member) is required to make sure that the pump does not operate when the water level is too low.

Advantages of simple intake structures are that the materials required can be easily obtained locally or flown in quickly, construction requires little time and can be done without highly skilled technicians, management is easy, costs are low and the structures can be dismantled easily. Upgrading of the system may involve the use of floaters attached to the inlet, in case the water level rises, and small diversion structures to cope with flow variations in the river.

Wherever possible, the water catchment area should be protected to minimize the risks of pollution. Human settlement, agricultural and livestock activities should be prevented as much as possible anywhere near or upstream of the intake. Part of the source assessment should be the identification of present or potential pollution sources upstream of the intake. If pollution threats are found, then the intake may have to be positioned further upstream (beyond the polluting source), or another reliable and safe water source needs to be found, or the people need to be settled elsewhere.

A diversion structure for a stream intake Source: (**Davis, J. and Lambert, R. 2002 )**Pipes the quickest response is achieved by using pipes that are locally available even if they are not an ideal solution. Flexible hoses are suitable for survival supply. They usually have to be brought in from abroad but can be flown in and are easily transported over land, can be installed on site very quickly (rolled out) and connect easily to other types of pipe.

**Public standposts**

In most disaster/emergency response operations water distribution is through public standposts. Private connections are not common unless existing systems are used. Special connections will be needed to public facilities such as field hospitals and health posts, feeding centres and market places. These facilities have their own water requirements, which should be included in the calculation of the total water demand and the design of the water supply.

For public standposts, usually push taps, also called self-closing taps, are used. These are robust taps that close automatically under their own weight after a user stops pushing the weight up. The taps help in this way to diminish water wastage, if users do not close the taps due to negligence. Sometimes people do keep the taps open on purpose by attaching a piece of rope between the weight and the pipe above. They may do so for instance if they want to use the water for irrigation, small industrial activities (beer brewing), etc. Particularly in situations where water of drinking water quality is scarce - which is usually the case in disaster/emergency situations – this practice should not be allowed and needs to be strongly controlled. Each standpost should have a voluntary caretaker elected by the people using the water from it.

The caretakers should be trained, monitored and guided by higher-level staff. Proper selection and training of caretakers can be quickly arranged, even in survival supply systems. It is, for instance, important to have the beneficiaries discussing the character and qualifications of the person they need as a caretaker. If this is done well, people often choose women to be caretakers. It is worthwhile to pay regular attention to and motivate the caretakers. This can be done by organising small workshops for them that may also provide good feedback to the programme, and by giving them small incentives (e.g. soap) once in a while. It is also important to give them a recognised status and acknowledge the work they do, for instance by inviting them to meetings and not taking their work for granted. But the main assurance that things will go well at the tap stand is regular supervision by higher-level staff.

**Spring protection**

Where springs are a suitable source they can be quickly protected by installing a minifilter. If the amount of storage in the collection pit with the filter layers is small it is better to have an open outlet instead of a tap at the collection point to avoid possible build-up of back-pressure with the danger of the spring diverting to an alternative route. Instead of a tap that may break easily if used heavily, a simple wooden plug can be used. Drive a small bar horizontally into the ground to mark the level of the groundwater before disturbing the site. The bar will show the level below which the filter element with the outlet pipe has to be placed.

The spring site should be cleaned and vegetation cleared. Care must be taken not to disturb the underlying impermeable layer; the spring could be lost by the diversion of groundwater away from the original eye. Ensure good drainage at the collection point. Fence the area 10 m around the spring to prevent contamination from beneficiaries and/or their livestock in the immediate surroundings of the spring. If the catchment area is in danger of contamination a larger area may have to be fenced (and/or guarded).

**Rainwater catchment**

Rainwater can be collected from roofs – these can also be tents or plastic sheeting - or ground surfaces. To avoid contamination plastic sheeting can be laid on the ground to catch the water. Rainwater can be an important source for survival supply, but the problem is that one cannot be sure that sufficient rain will fall just during the days it is required. Also, those who catch the water need to have sufficient storage capacity. Disinfection is usually needed to ensure good quality of drinking water. This can be done by using chlorine tablets, solar disinfection or boiling. Boiling is often not a feasible option because of lack of firewood and the flat taste of the water. See also chapter 19 on disinfection technologies.

**Household facilities**

In disaster/emergency situations affected households always need drinking water containers for fetching water and for storage in their house or shelter. Often people have lost these items during the disaster and they need to be made available. An important criterion is that the containers can be well closed and easily carried, by children as well as adults. Typical containers are

1. Collapsible containers of 5-15 litres with a narrow neck and screw cap: easy to transport to site quickly and in large numbers, but often with a very short life time; they can break easily, sometimes even within days. These containers usually are not available locally and have to be brought in from abroad.

2. Jerry cans (usually plastic) of 15-25 litres with a narrow neck and screw cap. They have a long lifetime but are often difficult to transport to site in large numbers. Often these jerry cans can be purchased locally at low cost.

3 A bucket of 15 litres with a cover with a small hole plus attached push cap. Because the buckets can be stacked inside each other they can be more easily transported to site in large numbers quickly. While they are quite durable, they are expensive and not available locally. The form (round) makes them less easy to carry and the cover may get lost.

It may also be necessary to provide households with chlorine tablets, particularly when the water cannot be purified centrally and where water is contaminated to a dangerous level. Proper instructions and regular follow-up are of utmost importance to prevent people using too little or too much chlorine or even consuming the chlorine tablets thinking it is some kind of medicine.

It is useful to try to size the tablets such that only one is needed for the size of water container that people have available. However, the amount of chlorine may change over time, the size of the containers people have may vary and the disinfecting capacity of the chlorine tablets may differ. If households are to boil their drinking water they should have access to sufficient amounts of fuel wood. This can have large environmental implications.

3. **You are about to set off to conduct a sanitary inspection of an abstraction point at a river.**

Inadequate maintenance of the microbial quality of groundwater in peri-urban areas of developing countries is compounded by many factors, including high-priced microbiological infrastructure and the low level of socio-economic conditions (**Butterfield & Camper 2004.** )As a result, peri-urban communities consume water of unknown quality, which may put them at an unacceptable risk of infection by enteric pathogens (**Hutin et al. 2003.**) This situation calls for simple, feasible and easy-to-perform methods to help peri-urban communities understand, react to and subsequently manage the quality of well water.

Sanitary inspection, which identifies actual and potential sources of contamination of groundwater abstraction points, was proposed by the World Health Organization **(WHO 1997)** as part of the comprehensive and complementary risk-based assessment of drinking water quality **(WHO 2004; Luby et al. 2008**). This proposal supports the operation and maintenance of water points by providing clear guidance for remedial action to protect and improve the water supply **(Luby et al. 2008. The WHO (1997)**)established a format for sanitary inspection forms consisting of a set of questions which have "yes" or "no" answers (cf**. Supplementary Table S1)**. The questions are structured such that "yes" answers indicate that there is a reasonable risk of contamination and "no" answers indicate that the particular risk appears to be negligible. Each "yes" answer scores one point and each "no" answer scores zero points. At the end of the inspection, the points are totalled, yielding a sanitary inspection risk score. A higher ROC score represents a greater risk that drinking water is contaminated by faecal pollution from the area immediately surrounding the well **(Lloyd & Batram 1991; WHO 1997; Godfrey et al. 2006; Luby et al. 2008; Vaccari et al. 2009; Parker et al. 2010.)**Limited data exist on the performance of such sanitary inspection tools **(Lloyd & Batram 1991; Godfrey et al. 2006; Luby et al. 2008; Vaccari et al. 2009; Parker et al. 2010**)**,** especially in most developing and tropical countries like Tanzania. Moreover, the few existing investigations are based on a small set of standard faecal indicator bacteria (SFIB) such as faecal coliforms, *Escherichia coli* and enterococci and are thus potentially prone to an indication bias or limited to a more holistic picture of the actual faecal pollution situation (e.g. recent versus past faecal pollution). This is especially significant in tropical environments where SFIB may originate from non-faecal sources (such as soil) and proliferate in aquatic habitats under favourable conditions, thus resulting in detection at levels that may not reflect the actual extent of faecal contamination **(Solo-Gabriele et al. 2000; Byamukama et al. 2005; Ishii & Sadowsky 2008.** )Consequently, there is a need for investigations concerning the performance of ROC scoring in tropical environments based on robust faecal pollution diagnostics. The aim of this study was to evaluate the predictive capacity of ROC scoring, based on simple-to-perform sanitary inspections according to the WHO guidelines, regarding the extent of bacterial faecal pollution in well water in a peri-urban area of a tropical, developing country. The analysis was based on a selection of wells representing environments ranging from low to high presumptive faecal pollution risk. To integrate the information regarding the extent of bacterial faecal pollution, a multi-parametric data set including SFIB, alternative faecal indicators (i.e. *Clostridium perfringens* spores and sorbitol-fermenting Bifidobacteria) and physicochemical parameters were investigated. We hypothesised that ROC scoring would accurately predict risk levels for bacterial faecal pollution in Tanzania, a tropical and developing area, thus representing a useful tool for well-water quality management.

## MATERIALS AND METHODS

It is important to note that the study published by **(Mushi et al. in 2010 )**is based on the same field investigation described in this work. **(Mushi et al. 2010 )** Focused on the ecology of sorbitol-fermenting Bifidobacteria (SFB) in streams and groundwater in a tropical environment; using lumped data from the collected well water samples. owever, the current study focuses on the ROC scoring based on a detailed analysis of the same wells in a variety of locations and over a span of three months.

### Selection of the wells

Wells were selected using weighted random sampling from the peri-urban area of Dar es Salaam, Tanzania (6.2°S, 39.2°E). The approach covered well environments ranging from low to high presumptive faecal pollution risk based on the stratified randomisation according to (**Byamukama et al. 2005.**) Wells W1, W2 and W3 are situated in heavily vegetated areas without nearby stagnant water, septic tanks, pit-latrines, human residences or anthropogenic activities. Residents travel approximately 200–300 m from their houses to collect water from these wells. Well W4 is situated approximately 100 m from human residences. Ponding was evident around the well. Neither septic tanks/pit-latrines nor fences were observed within 30 m of the well. Wells W5 and W6 were situated close (approximately 3–5 m) to roads. Septic tanks and pit-latrines were observed at approximately 15 m from the well.

Ponding was evident at approximately 10 m from the well, as the drainage channel was faulty. Although wells W1–W6 were well-constructed, no apparent protective measures had been taken against anthropogenic activities. Wells W7, W8 and W9 were chosen as they are situated in a highly populated area with poor sanitary infrastructure. These wells are poorly constructed and poorly protected. The walls of the wells are cracked, with broken platforms that allow growth of algae on the walls and influx of stormwater and runoff. The drainage channels are dirty and broken, allowing ponding. Some of the wells are close to roads and surface runoff, or are within 5 m of poorly constructed septic tanks/latrines situated uphill of the well site. A map of the well locations is given in **(Mushi et al. (2010))**

### What would you take with you?

Certain basic data are needed to identify where sanitary surveys are required:

• population data for each town, village, and community;

• information on water sources;

• summaries, from past studies, of data for water quality;

• identification of sources for which no water-quality data is available;

• summaries of health records on the incidence of illnesses associated with water quality and sanitary conditions;

• correlation between outbreaks of illnesses, and water source and quality; and

• any water-treatment methods being used. Sanitary surveying and water-quality analysis (either in a laboratory or in the field) are complementary activities; they are both important, and both have limitations

**Explain four things you will be looking for during your inspection**.

In carrying out a sanitary survey, an inspector is identifying potential risks to the quality of the water but she or he should also take the opportunity to make constructive criticism, leading to positive improvements. It should not be an opportunity to indulge in destructive criticism. Undertaking a sanitary survey should be considered:

• when new water sources are being developed, to assess the water quality and any treatment needs;

• when comparing water sources for potential development;

• when contamination is suspected, to identify the likely cause;

• when there is an epidemic of a waterborne illness, to identify the likely cause;

• to interpret results from water quality analysis, to establish how the water became contaminated;

3. **Explain briefly why a Water Safety Plan is necessary**

What is a water safety plan? -A water safety plan is a methodology to improve the operations and management of a water supply system. The goal proposed by the World Health Organization is to improve the management and operations of the existing water supply systems and if necessary to make capital improvements in order to comply with health-based standards.

The WSP methodology presents a paradigm change in that the water utility companies now focus on the entire chain of the water supply system, from the water source—for example, aquifer or surface water—to the point of household use. Traditionally, the water utility companies have only focused on the system from the point of extraction to the water meter. Likewise, another change in the paradigm is that the WSP process advocates for more operational monitoring in addition to monitoring of treated water quality.

The methodology recommends an intense effort to identify and understand how hazards affect the system, the development of control measures to mitigate these hazards, and the implementation of a operational monitoring system to verify the functionality of control measures throughout the entire water supply chain. Sustainability NWC Ministry of Health & Env; (Nat'l & Parish level) NEPA Water Resources Authority National Irrigation Commission Pesticides Control Authority Spanish Town Team Composition PAHO

It requires collaboration from a variety of professionals: water supply system operators, lab personnel-chemists and microbiologists, engineers, environmental health scientists, health professionals, public relations-media and regulatory agency personnel. (Ask the participants who they are? [For example: are they engineers, chemists, biologists, etc.]) In many of the communities where the CDC works the Water Safety Plan team includes community members because it is the community that has responsibility for managing their own water supply; or, community members have responsibility for the transport, storage, and disinfection of their own water supply. Without a clear understanding of their tasks team members often times lose interest and the sustainability of the entire water safety plan is threatened. A system description that is too general will not be useful for the process.

Describe the System PROVIDE DESCRIPTION, SCHEMATICS, ETC. (sources, treatment works, distribution network) Once the water safety plan team is formed the first task is to describe the water supply system In the experiences of the CDC in Latin America, facilitators tried to collect data that not only described the water supply system, but also the sanitation system; and, since data that describes water quality are oftentimes scarce or incomplete, epidemiological surveillance data were also collected to understand how water borne diseases associated with water, sanitation and hygiene were affecting the community.

The following are some examples of the data that were collected in Aguas Verdes, Peru and Huaquillas, Ecuador The Facilitators:

•Used GIS maps that showed the layout of the water distribution system

•Used AutoCad maps from the municipalities to define the limits of the communities served by the water supply systems.

•Obtained reports on the Zarumilla watershed that contained descriptions of the agricultural practices

•Requested databases with epidemiological surveillance data, and

•Searched for data to describe the coverage of the water supply and sanitation systems.

Describe the System LIST WATER QUALITY STANDARDS Final Water/Distribution pH 6.5 - 8.5 Turbidity 0.2 mg/L Total/Faecal Coliforms none Another important task is to collect the available surveillance data on water quality. Oftentimes there are several agencies that have responsibility for collecting water quality data and it is rare when this data is aggregated, analyzed collectively, and action taken to address operational deficiencies. An activity of the water safety plan team could be the analysis and organization of all existing data that describe water quality (Give example from a local experience).

Describe the System ASSESS EXISTING WATER QUALITY Color in Final & Distributed Water 0 15 30 45 60 75 Dec-06 Jan-07 Feb-07 Mar-07 Apr-07 May-07 Jun-07 Jul-07 Aug-07 Sep-07 Oct-07 Nov-07 Dec-07 Date Color (Hazens) WTP Lot 8 Lot 23 Here we have an example from Spanish Town, Jamaica.

The water safety plan facilitators collected data and during conversations with the water service provider they realized that no one had ever analyzed the data. Therefore, it was apparent that no one was using the data in an efficient manner to inform system operators about the water quality. It is recommendable to use collected data for decision-making.

Why collect the information if an analysis plan does not exist, or there is no intention to make decisions based on the analyzed information? Describe the System DESCRIBE POINT-OF-USE PRACTICES (where appropriate) To ensure the safety of drinking water, go beyond the tap & consider point-of-use practices. Storage Treatment Handling In many communities in Latin America and the Caribbean, water supply systems do not provide a continuous supply of water.

Therefore households must collect, and in some cases transport, handle, and store their water in way to protect the quality of their drinking water. Therefore the traditional practice of assuring drinking water quality only to the point of the water meter is considered outdated and the focus of the water utility company now includes the management of household drinking water. Given that the household handling of drinking water is not a traditional responsibility of the water service provider, it is recommended to include new partners to work at the household level. Positive total coliform detections HOUSEHOLD TAP STORAGE TANK DRINKING CONTAINER 11/47 (23%) 8/22 (36%) 31/73 (42%) 30/47 (64%) 19/22 (86%) 66/73 (90%) Positive E. Coli detections: Describe the System (Linden, Guyana) Why is it necessary to monitor the household water use? Here we have an example of a problem that can occur at the household level.

In Linden, Guyana the water supply system operates intermittently and the community cannot count on a continuous supply of water. Therefore, the residents have to store their drinking water. To better understand the contaminants that can affect water quality at the household level a household survey was conducted that collected data on the consumers perception of water quality, the handling and storage of drinking water, and the use of alternative water sources.

The surveyors also collected water samples from household taps, household storage tanks, and household drinking water containers. The water samples were sent to the laboratory for microbiological analysis. These are the results. These findings demonstrate that water quality degrades as water is being inadequately stored and handled at the household level.

Given that the problems associated with continuity will not be resolved in the near future, the water safety plan team has started to develop a support program to train residents on disinfection, and the proper handling, maintenance and storage of their drinking water. (Explain and define the adequacy of supply indicators [quantity, quality, coverage, continuity, and cost] and the importance of these concepts for a water safety plan.).

Identify Hazards HAZARD Physical, biological or chemical agents that can cause harm to public health. Examples:  Industrial effluent discharge to surface water (chemical)  Leaking septic tanks contaminating groundwater (microbial)  Disinfection byproducts in treated water (chemical)  Termite mounds built upon the water distribution system pipes (chemical, microbial, physical) HAZARDOUS EVENT An event that introduces hazards to, or fails to remove them from, the water supply (i.e. source of hazard) of the water safety plan relies on all of the information collected during the system description. Upon describing the system one has to determine what are the points in the water supply chain where hazards (physical, biological and chemical agents) can enter the system and what are the hazardous events that allow the contamination to occur. Here we have some common examples of hazards and hazardous events;

Identify hazards/hazardous events Hazardous Event (Source of Hazard) Associated Hazard Poorly trained operators in adequate water treatment (chemical, physical & microbial concerns):

Identify Hazards The findings or data from the system description ultimately become the inputs for the Module three. If the system description is too general then there will be a lack of specificity when trying to describe hazards and hazardous events. (Share a local example of a hard and hazardous event) Another example from Aguas Verdes, Peru was a situation where the sanitation pipes collapsed in a very poor zone with a large number of squatter households.

In this settlement there were a large number of clandestine connections to the water supply system and during low pressure events sewage was able to enter into the water supply system. In your opinion what is the hazard, and what was the hazardous event? Perhaps the hazardous event was the decision of the mayor to allow the illegal construction of households on top of the water and sewerage infrastructure, which prevented timely repairs.

Assess control measures & risk control measures activities, processes & policies applied to reduce or mitigate risk. Examples:  Minimum offset distances between latrines and water bodies Fencing around a wellhead  All water treatment processes  One way (check valves) to prevent cross contamination After identifying the hazardous events that affect the system, module 4 recommends the development and validation of control measures (control measures are activities, processes, and policies applied to reduce or mitigate the hazards). Some examples of control measures are:

•Minimum offset distances between latrines and water bodies

•Fencing around the wellhead

•All water treatment processes

•One way (check valves) to prevent cross contaminations  identify and assess existing control measures: Assess Control Measures & Risk Hazardous Event (Source of Hazard) Associated

Hazard Existing Control Measures Limitations & Effectiveness of CMs Poorly trained operators Inadequate water treatment (chemical, physical & microbial concerns) Operator training program (lead by plant supervisors) Supervisors not adequately trained; infrequent training and high operator turnover In some systems the control measures do not exist and the water safety plan team will need to develop and implement new control measures. In other systems the control measures already exist however they are not effective.

A very important task is to evaluate the limitations and the effectiveness of the control measure and to adjust the measure as necessary. In our example from Jamaica, the facilitators determined that the control measures were not effective because the supervisors were not adequately trained, the trainings were infrequent and there was problem with staff turnover. ASSESS RISK (qualitative & semi-quantitative methods for assessing risk) Assess Control Measures & Risk For each hazard, assess risk by considering:

1) The likelihood that the hazard will occur (e.g. certain, possible, rare)

2) The severity of consequences should the hazard occur (e.g. insignificant, major, catastrophic)

3) The feasibility of quickly and effectively reducing the risks associated with the hazard. One has to also consider the risk classification when they are evaluating the hazards, hazardous events and the level of effectiveness of the control measures. The level of risk should motivate the treatment plant operators and supervisors to take action. Therefore, a water safety plan team can use the following criteria to evaluate the risk level.

•The likelihood that the hazard will occur (e.g. certain, possible, rare)

•The severity of consequences should the hazard occur (insignificant, major, catastrophic)

•The feasibility of quickly and effectively reducing the risks associated with the hazard, Assess Control Measures & Risk Hazardous Event (Source of Hazard) Associated Hazard Existing Control Measures Limitations & Effectiveness of CMs Risk Poorly trained operators Inadequate water treatment (chemical, physical & microbial concerns) Operator training program (lead by plant supervisors) Supervisors not adequately trained; infrequent training and high operator turnover High Lets continue with our example from Jamaica We have determined that the hazard in this case is the inadequate disinfection of drinking water; the hazardous event is that the operators have not received adequate training; we know that the control measure already existed but was not functioning effectively because the supervisors did not have adequate training to train the plant operators, the trainings for operators were infrequent, and staff turnover had resulted in personnel without the capacity to do the job.

Using the classification criteria we determined the risk is high, because the lack of disinfection could immediately impact the health of consumers.

Develop improvement plans define corrective actions hazardous event (source of hazard) corrective actions responsible agency target timeline poorly trained operators External expert to lead a "train the trainer" program for plant supervisors; supervisors to perform operator training annually; create an operator certification program Water provider Train the trainer:

The water safety plan team will need to make decisions that will describe the implementation of operational monitoring activities, such as:

•What is going to be monitored

•How will it be monitored

•The moment and the frequency of monitoring

•Where it will be monitored

•Who will conduct the monitoring

•Who will receive the results of the monitoring system Among other questions Some of the challenges in this stage of the process are:

•The cost increases related to additional monitoring

•The resistance of staff to adopt new practices

•The lack of expertise to analyze and organize the collected data. Define Verification Monitoring monitor treated & delivered water (for compliance with health-based standards) Distribution System Monitoring Parameter Acceptable Range

When?

Where?

Sampled by Whom?

Tested by Whom? To whom (externally)

are results shared?

How often?

pH 6.5 - 8.5 Weekly Points 1-20 Operators Central lab Central Board of Health; monthly Turbidity 0.2 mg/L Weekly Points 1-20 Operators Operators Central Board of Health; monthly Coliforms None Weekly Points 1-20 Operators Central lab Central Board of Health; monthly Verification of the effectiveness (Compliance monitoring) of the water safety plan includes three main activities:

1) Compliance monitoring: Is the drinking water that is delivered to consumers safe?

2) Internal and external auditing of operational activities, and

3) Consumer satisfaction. In some countries the infrastructure is setup so that external monitoring is the responsibility of a regulatory agency which works collaboratively with the ministry of health. (Give a local example). In Peru, for example, the regulatory agency for potable water(Superintendencia de Agua Potable [SUNASS] in Spanish) works together with the Ministry of Health through the regional health directorates to conduct internal and external auditing.

Prepare Management Procedures Define & document actions to be taken under normal operating conditions & in emergency situations. Update/define standard operating procedures (manuals & treatment plant posters, etc.) update/define emergency response plans after defining the monitoring of the control measures and improving the compliance monitoring, the facilitators need to update the standard operating procedures to include all of the new changes. A WSP is a data-driven process  Actions taken are only as relevant as the data driving the process the implementation of a water safety plan can result in

•New commitments to face the hazards that affect the water supply system.

•A team that is aware of the system and its vulnerabilities

•New collaborations one should take into consideration that a water safety plan depends on reliable data. If the data do not reflect the reality of the system, then it will be difficult to take the appropriate corrective actions to improve the system.

5. Distinguish between the two types of maintenance at a water utility and give reasons why one of them is Better

Water utilities are part of the organizational structure for water supply in towns and cities. In Ethiopia each woreda has a Council, and each town in the woreda has its own Town Council. Under each Town Council there is a Town Water Board, and under it is the water utility, which may also be termed the Town Water Supply Enterprise. In some towns the water utility is also responsible for the collection and disposal of sewage, in which case it is referred to as the Town Water Supply and Sewerage Enterprise and reports to the Town Water Supply and Sewerage Board. The water utilities have a duty to provide the water supply (and sewerage services) promptly, at appropriate cost, and with a high quality.

The Town Water Board is a committee made up of individuals who are specialists in water treatment and supply, representatives of other sector offices such as Health and Education, and other **stakeholders** (in this context, representatives of people who would be affected by the water utility's actions). Importantly, two members of the Board are democratically elected community representatives. At least one of these has to be a woman. The term of office of the Board members is five years.

The function of the Board is to ensure the effective performance of the water utility. In particular it is responsible for ensuring that the water delivered to the public conforms to quality standards. The Board is also responsible for determining the utility's vision, mission, aims, objectives and values, together with approval and monitoring of the utility's budget and work programme, recruitment of the utility's General Manager, and approval of appointment of Heads of Department.

- The Planning Department plans for the growth in services provided.
- The Commercial and Customer Care Department handles queries and complaints from commercial and domestic customers.
- The Engineering Department is responsible for major engineering works, such as refurbishment or expansion of facilities.
- The Corporate Affairs Department takes care of public relations and communications such as publicity campaigns to encourage efficient use of water.
- The Rural Water Supply Department ensures that water supply is extended to cover the rural population.

- The Operation and Maintenance Department ensures the smooth running of the water treatment and supply system.
- The Water Quality Assurance Department monitors the quality of delivered water to ensure that it is up to standard.
- The Human Resource Management Department looks after the recruitment and training of staff.
- The Finance Department manages the water utility's budget and makes sure that all financial transactions are recorded, and that revenue is collected for water supplied.
- Finally, if relevant, the Sewerage Department looks after the sewer network and sewage treatment. (Note that sewage is the water-carried faecal waste from toilets, sewers are the pipes carrying this waste and sewerage refers to the infrastructure that conveys sewage. It encompasses components such as receiving drains, manholes, pumping stations and screens.)

While all the above departments are important, an effective and efficient Operation and Maintenance Department is vital to ensure that people receive good-quality water continuously each day. This function will be the focus of the next section.

### The basics of operation and maintenance

**Operation and maintenance** of a water supply system refers to all the activities needed to run the system continuously to provide the necessary service. The two words are very frequently used together and the abbreviation 'O&M' is widely used. The overall aim of operation and maintenance is to ensure an efficient, effective and sustainable system **(Castro et al., 2009**). 'Efficient'means, being able to accomplish something with the least waste of time, effort and resources; 'effective' means being successful in producing the intended result and 'sustainable' means able to be maintained at the best level over time – in this case, the supply of water.

### Operation

**Operation** refers to the routine activities and procedures that are implemented to ensure that the water supply system is working efficiently. The activities that contribute to the operation of a water utility are undertaken by technicians and engineers who have responsibility for controlling the functions of the system.

The components of the system that they look after, such as the treatment plants, process units and all the equipment and facilities (for example, offices and laboratories) are called the **assets**. For each asset there will be operating guidelines to follow. For instance, a water pump should only be operated for a limited number of hours per day and this must not be exceeded, otherwise it will be exposed to overheating and eventually to failure. The pump should also be run long enough to fill the service reservoir. If not, there will not be enough water for distribution to customers.

**Maintenance**

**Maintenance** refers to planned technical activities or activities carried out in response to a breakdown to ensure that assets are functioning effectively and requires skills, tools and spare parts **(Carter, 2009)**. There are two types of maintenance:

- *Corrective or breakdown maintenance*: this is carried out when components fail and stop working. Breakdown is common in many utilities in Ethiopia and occurs as a result of poor preventive maintenance (explained next).
- *Preventive maintenance*: this is a regular, planned activity that takes place so that breakdowns are avoided. Examples of preventive maintenance would include servicing of equipment, inspecting equipment for wear and tear and replacing as necessary, cleaning and greasing moving parts of equipment, and replacing items that have a limited lifespan. Preventive maintenance is important because it ensures that the asset fulfils its service life. It also prevents crises occurring and costly repairs (in terms of time and money) being needed.

Regularly checking the electrical parts, the components of the switch/operating board and inspection of power lines are tasks that can be regarded as preventive maintenance. If the pump fails due to operational problems or lack of preventive maintenance, it will have to be repaired or replaced – an example of breakdown maintenance.

Preventive maintenance ensures that the different components of the water supply system perform correctly over their service life (their expected lifetime). This in turn avoids the occurrence of a major fault or breakdown in the water supply system that calls for corrective maintenance that is many times more expensive. In some cases, the problem may require full replacement of a costly item of equipment, which also takes a significant amount of time to achieve. As a result, the service level of the water supply system will reduce or even be interrupted over the period of maintenance, causing significant inconvenience to users and reducing the income of the water utility.

Utilities should always ensure that an adequate level of preventive maintenance is in place for all of their assets in the water supply system. This requires that adequately skilled persons are employed as operators or maintenance crew, and that they are provided with the proper tools. A strict and regular schedule of work is also required to ensure that preventive maintenance is carried out at the appropriate time. The next section considers strategies and plans for maintenance.

## 6.3 Maintenance strategy

Utilities with a strong focus on the preventive maintenance of assets can save substantial time and costs, avoid service interruptions, and increase their revenue.

A good maintenance strategy will detail:

- how the maintenance activities will be organised (on a regional and area basis)

- how maintenance will be carried out (using own technicians, or outsourcing to skilled technicians outside the utility, or both)
- clear descriptions of how the assets are expected to function with proper maintenance
- information and documentation requirements, for example a log of parts replaced, inspections made, recording of any incidents (unexpected events)
- prioritisation of assets for routine inspection and maintenance (the more important items, such as main pumps, needing more frequent inspection and maintenance).

At times key decisions have to be made to replace old or damaged equipment. Adept utility managers plan and decide in advance which assets require replacement and when. These decisions may be made based on past experience or on the opinions of individuals, although this may be unwise because experience and opinions vary from one individual to another. One technique that can assist in making objective decisions uses the concept of life-cycle cost. (An objective decision is one based on facts, unlike a subjective decision, which is one based on personal feelings or opinions.) The **life-cycle cost** of an asset is the sum of its one-time, non-recurring costs (for example, its purchase and installation costs) and its recurring costs (such as its operating cost, maintenance cost and disposal cost) over the life of the asset.

The solid line shows the trend for an asset with a low purchase cost but high operating cost over time, whereas the broken line shows the trend for an asset which has a high purchase cost but low operating cost over time. Note that both graphs show cumulative costs (the total costs accumulated over the time period shown). The graph demonstrates that a high initial cost does not mean an asset has the highest life-cycle cost. Similarly, a low initial cost does not mean lowest life-cycle cost. Utility managers and technicians can use graphs such as these to help take decisions when replacing assets or acquiring new ones.

### Maintenance plans

Maintenance plans are prepared based on the maintenance strategy that has been formulated. The plan will outline the maintenance activities, their timing or frequency and the information needed for the record for each asset. It will also take into account the current condition of the asset, and its **criticality** (degree of importance) for the water supply system. Based on the plan, activities such as inspections, parts replacement and preventive maintenance will take place.

- Retta is drawing up a maintenance schedule for various items at his water utility. In terms of criticality, how should he rank the following items?
  - The computer used for billing customers.
  - The pump at the water intake.
  - The vehicles used by the leak detection team.
  - The control system for the rapid gravity filter.

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