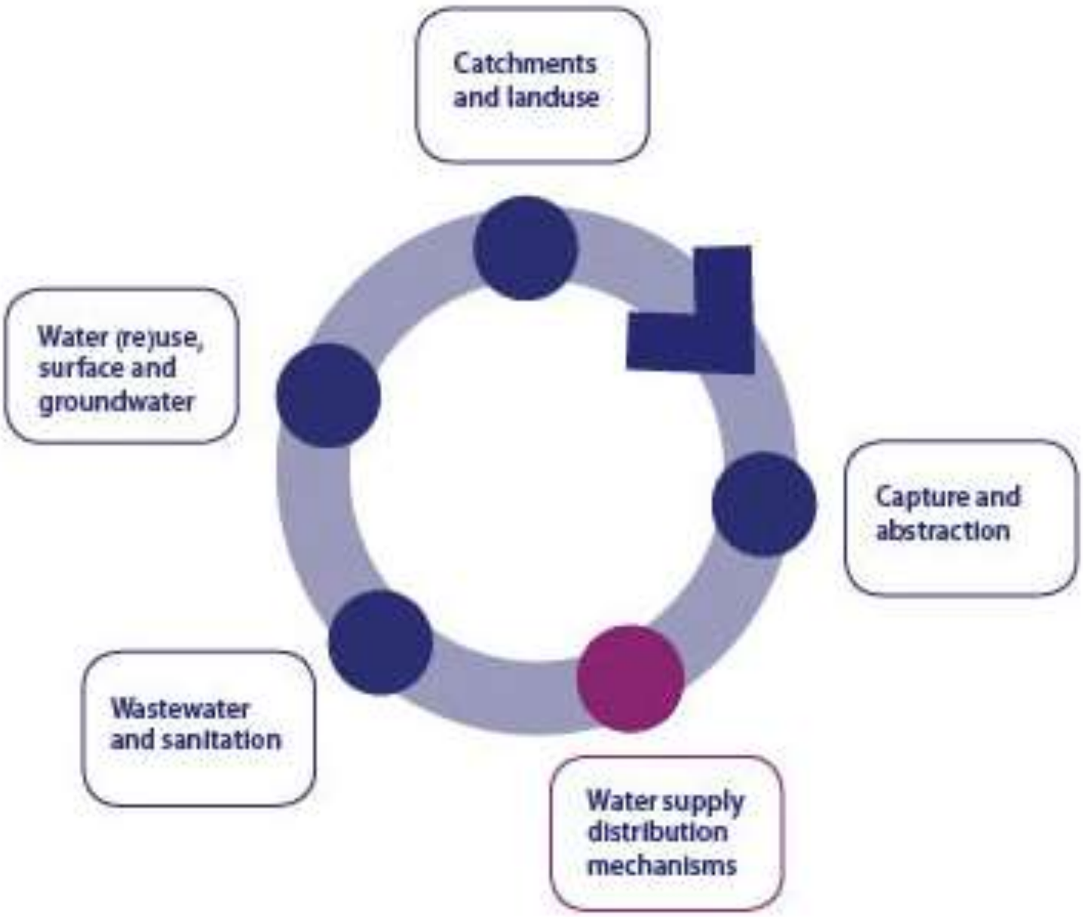
Guided Learning to develop Water Safety Plans for urban water utilities in Ethiopia



Guided Learning to develop Water Safety Plans for urban water utilities in Ethiopia

These Guided Learning modules have been developed to support the S2TAB project to reach out to water utilities in Ethiopia to benefit from the experience of the project partners. The concept of guided learning has been applied in different locations in Ethiopia.

The development of the modules has been a collaborative effort under guidance of Jan Teun Visscher with key inputs from Girma Senbeta and Simon Chevalking from MetaMeta. Implementation of the modules was initiated late in 2018 with water companies in Oromia with the first testing workshop in November.

March, 2019

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Preface

Significant progress has been made in the provision of safe water supply both in urban and rural areas in Ethiopia in the past 20 years. The comprehensive Water Sector Policy and the Water Sector Development Plans of the Government of Ethiopia have been very instrumental for making progress, but still very important challenges exist related to ensuring access to safe drinking water. This includes expanding safe water coverage but equally important ensuring sustained access to and performance of existing water supply services taking into account possible effects of climate variation. The challenge is to provide higher levels of service to a growing population in a sustainable manner.

The 5th WASH Multi-stakeholders' Forum (MSF-5, Nov 2012) identified the introduction of Water Safety Plans (WSP) as one of the important activities to be taken up in the water sector in Ethiopia. This approach which explores water safety from source to point of use looking at all risks including those posed by climate change. Good progress has been made since 2012 led by the Ministry of Water, Irrigation and Energy. Progress includes the development of three key documents:

- National Climate Resilient Water Safety Plan Strategic Framework (MoWIE, 2015-a)
- Climate resilient water safety plan implementation; Guidelines for Urban Utility Managed Piped Drinking Water Supplies (MoWIE, 2015-b)
- Climate resilient water safety plan implementation: Guidelines for Community Managed Rural Drinking Water Supplies (MoWIE, 2015-c)

With these documents in place the next step is to help ensure that responsible actors actively pursue the development of water safety plans. This requires a strong effort to build the capacity of water companies to improve their service delivery for which WSP are a crucial approach. Building capacity in water companies in Oromia is one of the activities envisaged in the S2TAB project as to allow them to benefit from the experience of the project partners among others in the development of water safety plans for Addis Ababa and Adama.

Taking into account the limited impact of class room teaching as well as the relatively high turnover of staff an innovative approach to capacity building is chosen. In this approach, training activities are embedded in the daily routines of staff. Key to the approach is that participants in the course obtain a set of training modules as a document, complemented by the same course package and additional resource materials in electronic form. The self-learning modules comprise key information, specific field assignments with 'learning-by-doing' exercises and a question and answer section where participants can check their own progress. The training is arranged in short modules each of which addresses a main issue that needs to be understood by participants, some practical exercises that can be implemented at the place of work and questions to review the level of learning.

Together the modules build up towards making a WSP for the water supply system were participants are involved. The exercises are implemented by participants and shared with the course facilitators through internet, normal mail and/or face to face contact. Facilitators will come to the place of work of the small groups of trainees and will go with them into the field to jointly review the main field assignments. The main premises underlying the approach is that practical, problem-based learning can make a difference in the performance of staff and can support them to providing a WSP to their company that is revised by external advisors and can be directly implemented. The modules can also be used to support new staff joining the company and in that way help to reduce the negative impact of high turnover of staff.

I. General introduction to the course

Considerable efforts have been made in Ethiopia to improve water and sanitation coverage. As a result the number of improved water supply systems is growing but management and maintenance of these facilities is not well developed putting their sustained functioning at risk. A review of the service levels in 16 small and medium towns in four regions of Ethiopia showed for example that the number of people with access to improved water services is high, but only a small part of them (9%) has a service that meets the standards set in the Ethiopian government's Growth and Transformation Plan (GTPII) in terms of reliability, quality, quantity and travel and queuing time. The study stresses that these limitations in service delivery pose a huge challenge particularly for water supply delivery in small and medium towns, also taking into account their quickly growing population (Adank et al, 2017).

One important strategy of the Ethiopian government to cope with the situation is the development of WSPs. With such plans the possible water pollution risks and performance problems which can have adverse health effects on consumers can be identified and mitigated where feasible. The concept of WSP, as promoted by WHO focuses particularly at ensuring the safety of drinking water from existing and new water systems (piped supplies, as well as point water sources) through a comprehensive risk assessment and management approach. Promising experiences have been obtained with this approach resulting in WSP that vary in complexity according to the situation. WHO (2012) states that whereas their focus is on water systems, complementary measures such as household water treatment and safe household storage may be important as well.

In many municipalities in Ethiopia the population has access to multiple water sources and their use may vary over the year depending on water availability. This makes the situation more complex as not only the risks related to the water supply system will need to be checked, but also whether it is relevant to explore the risks related to other water sources in terms of water quality and quantity and also look at the users' part of the chain in terms of collection and storage as well as household water treatment.

Management and staff of water companies and municipalities are key actors to meet the challenge to provide safe water supply as they are very well aware of the local situation and the performance of the water systems. The practical training course set out in this manual is meant to help these actors to cope with the development and implementation of a WSP for their water system. This 120 hour course is being implemented in a guided self-learning mode over a period of three months. It comprises the following course modules:

1. ***Water safety plan introduction*** which introduces de participants to the framework of the process, the steps involved and the description of the water supply system
2. ***Risk assessment in the water chain*** which includes learning about a hazard and risk based approach using sanitary inspections as well as water quality testing.
3. ***Validating and monitoring control measures*** which helps participants to obtain an overview of the situation and find the gaps to cope with the highest risks
4. ***Practical Mitigation measures*** which includes identification, formulation and prioritization of mitigation measures based on priority risks
5. ***Towards Water safety plan implementation*** which includes completing of the plan, monitoring measures and a management and support programme

At the end of the course participants will be able to: Present the risks involved in the water supply system of their company adopting an approach that explores these risks from source to tap and they will be able to explain the WSP for the system.

II. How to go about the course

This training course has been established to help participants to acquaint themselves with water problems that may be present in their water supply system and to enable them to, jointly with other actors and users, find possibilities to improve upon the situation that can be embedded in a WSP. At the end of the course they will have explored the water supply situation and will have developed a WSP that caters for the management of relevant risks, whilst taking into account the overall context where people may not exclusively use the piped water supply but also may revert to other water sources.

The course follows an innovative approach of guided self-learning, where participants can access training modules, resource materials and resource persons, in different ways. The access may be through a paper based approach, electronic devises or the Internet. Participants will learn in their work environment and have face to face contact with fellow participants, course facilitators and resource persons. A proposed structure and possible timing of the course are shown below. Timing is based on an on average availability of one day per week. A shorter period can be used if participants have more time available per week or are already having considerable experience.

Possible course structure and timing

Module	Activities	Timing of completion
Preparation	Formation of teams of trainees Agreement with water company Development of a description of the water system by trainees	Prior to introductory workshop
Introductory workshop	Identification of trainer per team Establish contact arrangement with trainer Review Module 1 and key concepts of module 2	Start: two day meeting; (alternative is to visit trainees in their company)
Module 1	Revisit module 1,and revise the information on the water supply system with the team and complete assignment	End of week 2
Module 2	Review module 2, meet with team, review the components of the water supply system and submit assignment (as an alternative you can submit the assignment together with assignment in module 3	End of week 3
Module 3	Review module 3, meet with team, review and validate the existing priorities and control system measures and adjust as needed; submit assignment, (together with assignment of module 2 if that was not yet discussed) and meet with facilitator	End of week 5
Module 4	Review module 4, meet with team, submit assignment	End of week 7
Module 5	Review module 5, complete assignments, complete the plan and the monitoring system; discuss with management and meet with facilitator	End of week 9
Final review	One day meeting to present and discuss results	Week 10; alternative is that each team presents in their company
1. All assignments can be done in the water supply system of your company, but some may require visiting the catchment area and the distribution network.		

The course includes field assignments in which participants will work in small teams. Assignments in principal can be done in the area of their water supply system and may include interviewing for example water users.

Module 1 Water safety plan introduction

This module provides an introduction to water safety planning for urban water systems in Ethiopia. At the end of this module the participant will:

- *Be able to explain the objective and the steps involved in the development and implementation of a WSP*
- *Have provided a description of a water supply system including an indication of possible other water sources users may be accessing*

1.1 Introduction

There are few issues that have greater impact on our lives than the management of water. Water is a basic requirement for human life; we need water to stay alive and maintain basic health and sanitation. We need it to grow our food, to maintain our industry and economy and to sustain our environment. Safe drinking water in adequate quantities is a prerequisite for the health and wellbeing of the population and to sustain development.

Access to safe water in Ethiopia is a complex issue particularly in smaller communities. It is not a straightforward engineering problem. It is about people and much less about technology. Men, women and children may have different views about their water supply and its quality, and they, knowingly or unknowingly, interfere with their water supply systems. The water supply may range from a polluted river or an open well to a piped water supply with house connections and treatment. Although some of these supplies may be unacceptable to outsiders, they may be well appreciated by the local user. People create their own ‘world view' and have their own perception of their situation which is shaped by history.

In many places we see that people continue to use traditional water sources even after a piped supply is installed for example because they do not like the taste of piped water, they may have to walk further, wait longer or have to pay. This behaviour may be particularly happening in and after the rainy season when more water sources may be readily available. Hence the challenge of water providers is not only to provide safe drinking water in adequate quantities to consumers but also to do this in competition with other potential water sources.

"Everyone living in a specific place has access to some form of water supply or even multiples water sources and has a perception about their quality"

WSP are very important for water providers as water safety planning, the process of regularly upgrading their WSP, helps them to provide safe water to consumers. A WSP is a comprehensive risk assessment and risk management approach to identify and address existing or potential problems that may affect service delivery. It is an effective strategy to ensure water safety from catchment to the point-of-consumption (WHO, 2011). Essential components for safe and secure drinking water include:

- ***A comprehensive risk assessment*** of water supplies from catchment to consumer – assessing all risks along the chain that may result in a health risk and/or a breach of the required standard
- ***Effective operational monitoring*** of critical points along the chain to detect pollution, equipment failure or chemical dosing faults; followed by prompt and effective corrective actions where problems have been identified
- ***Effective management*** of the supply during normal and abnormal conditions, regular and accurate reporting of system performance and staff trained and resourced to perform their tasks

The need to establish WSP is stressed in the National Climate Resilient Water Safety Plan Strategic Framework (ref ….) and the Urban utility managed climate resilient Water Safety Plan implementation guidelines (ref …) developed by the Ministry of Water, Irrigation and Energy. Adding the issue of climate stresses the importance to adopt a longer term approach to both risk assessment (particularly in relation to water sources and water source quality) and water safety planning as a continuous process to keep the water supply safe. It also has implications for the expertise that needs to be taken into account in the development of WSP. Normally WSP teams consist of water supply operators, managers, technical specialists and health specialists. In relation to climate change such teams may require additional support in obtaining and interpreting climate-related information (WHO, 2017).

A WSP focuses on the identification of the main risks in the water supply cycle from source to consumer and in establishing suitable solutions to avoid these risks that may have adverse effects on water quality and quantity. A WSP is about risk prevention, putting water quality testing in context. Conventionally spot samples are taken at particular times and particular locations including water taps. In response to results action may be taken but then consumers may already have been affected. So water testing is needed, but as part of a risk prevention approach.

In summary a WSP is a way to minimise risks by:

- Knowing your water supply system thoroughly
- Identifying where and how problems could arise
- Putting barriers and management systems in place to stop the problems before they happen
- Making sure all parts of the system work properly

A WSP is a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer

It is important to realize that a water supply system is not static. It changes over time because:

- The community may grow which my imply that systems need to be expanded
- The technology may gradually reduce in performance because of wear and tear if not properly maintained and managed. This may go unnoticed for some time and may make people to turn to other sources. Another problem may be that when a new system is built, people no longer maintain the traditional systems and then get into trouble if the new system breaks down.
- Users may adopt new habits that affect their water consumption. Introduction of new systems (water flush toilets, showers etc.) may increase water consumption whereas water saving devices may reduce consumption. Also communities may start to use water for productive use.
- The environment may change possibly affecting the availability and/or quality of the water. This may include lowering water tables because of over abstraction of water or climate change but also deterioration in water quality because of erosion, use of fertilizers and pesticides, or changes in groundwater composition.

The dynamics of a water supply system need to be recognized and taken into account to ensure long term sustainability of the system. This stresses the need adopt a water safety planning approach and to ensure adequate monitoring to assess if the situation is changing.

Sustainable water supply

The main challenge is not to build or improve a water supply system, but to ensure that it is sustained over time. Too many systems have been built that do not operate according to standards. Adank et al, (2017) found in a survey of the service levels in 16 small and medium towns in four regions of Ethiopia that only 9% of the users received the service that meets the standards set in the Ethiopian government's Growth and Transformation Plan (GTPII) in terms of reliability, quality, quantity and travel and queuing time.

This is a serious situation where WSP will be very useful, but also other issues need to be taken into account particularly related to the long term financial situation and the availability of an adequate support system. Revenues from the water system need to provide for the cost of management, operation, maintenance and repairs. A point that is often overlooked is that a piped water supply still may have to compete with other water supply systems such as water ponds, wells etc. particularly if people do not have to pay for these other water sources. If people are not really aware of the benefits of a safe water supply, for example in avoiding cost related to diarrheal disease, they may only consume water from the piped system if they do not have alternatives. This in turn implies that less revenue is available for the piped system. So it is very important to obtain a good overview of the water use habits and available water sources.

1.2 Steps involved in water safety planning

The development and implementation of the WSP approach involves a number of steps that are outlined in Table 1.1.

Table1.1 Steps involved in water safety planning

1. Set up a team (staff/stakeholders) and decide about the process to develop the WSP
2. Describe the present water supply system from catchment through distribution
3. Identify all the hazards and hazardous events that can affect the safety of the water
4. Assess and prioritise the risk presented by each hazard and hazardous event
5. Consider if effective control measures or barriers are in place for each significant risk
6. Define the monitoring system for each control measure
7. Draft management procedures and verification plan
8. Develop supporting programmes
9. Finalize WSP document including communication procedures
10. Implement, monitor (including reporting) and regularly review WSP

Based on WHO (2009)

Although the stages depicted in Table 1.1 are sequential (i.e. to be done one after another in a sequence), they can be undertaken by teams of people working in parallel, looking at different aspects of water supply. It is essential to understand that water safety planning is not a one of process as risk and hazards may change over time. Hence an annual review of the WSP is required and may be needed earlier in case of unforeseen events happening. One aspect to take into consideration is that potential risks may change because of climate variability induced adaptions in environmental and social systems, which can impact the nature of the hazards and exposures ordinarily considered and introduce new hazards. This may impact the likelihood and severity of the consequences arising from the hazard or hazardous event which need to be reflected in the WSP.

1.3 Set up a WSP team

Setting up a WSP team requires careful consideration as it has to allow obtaining all necessary information about the water supply system from the catchment to the taps of consumers, whilst also looking at alternative water use. This will include details of the catchment (sources of contamination, climate variation risks), the abstraction point, the pipes (sizes, construction materials, etc.), the treatment plant, the distribution system (piping material, possible weak spots, etc.) and the taps.

The expert team should include not just technical experts but also local staff and possibly a person of the municipality or staff from organizations involved in water catchment management. The most feasible approach may be to set up a relatively small core team that consults with other relevant persons possibly including farmers, forestry workers, landowners, representatives from industry, local government, and consumers. Collectively the core team should have the basic skills required to identify hazards and determine how the associated risks can be controlled as will be discussed in module 2. Taking into account that smaller and medium size water supply systems may have staff limitations it should be considered to consult with experts for specific risks such as climate related issues instead of adding these to the team.

The team needs to be able to take actions forward and therefore it is crucial to have support of senior management in the formulation and implementation of a WSP. This support will allow making resources available to make adjustments in the system and to introduce changes in working practices to control risks. Such resources and changes will need to be approved by senior management such as the Town Water Board.

To develop the team you can consider the following steps (see Table 1.2):

- List the staff from your utility, their expertise and their role in the team; verify that they have the time available to participate as often the same staff is scheduled to participate in several activities including training by external actors
- Identify missing expertise and explore if you can obtain this by involving staff from other organizations including the municipality
- Discuss with management how missing expertise can be sourced
- Identify which other stakeholders you need to involve (as part of the team or in a consultative capacity)

Table 1.2. Team composition

Name	Organization	Role in team	Contact Number	Email

1.4 Description of the water supply system

Making a good description of the water supply system provides the basis for the identification of hazards and the assessment and management of risks. In most cases this information will be readily available and will only need reviewing to ensure that it is up to date. As a start it is necessary to provide an overview of the main characteristics of the water supply system and its users (see Table 1.3).

Table 1.3. Basic information about the water supply system

Name	
Location	
Type of water source(s)	
Number of boreholes Number of water intakes*	
Design capacity l/s	
Age	
Average production m^3/day	
Type of water treatment	
Water storage tank (overhead) m^3	
Number of water pumps	
Length of distribution system (km)	
Number of house connexions	
Number of standpoints	
Operating hours / day	
* Chose the option that relates to the system; if you have both ground water and surface water than you need to indicate both	

The next step comprises the preparation of flow diagram that shows all the major elements of the water supply system (Figure 1). The main objective of the description is to have a clear understanding of the main components of the water supply, i.e., how the water supply system is designed and functioning from catchment to point of use. The description includes the catchment area, type of the source (s), intake, treatment plant, reservoirs, distribution system with primary, secondary and tertiary pipe networks, pump stations, valve boxes, bulk water meters, public stand posts and/or household connections. Information may be readily available in the office but it will be necessary to validate the information in the field and visually inspect the main features of the system and assess their condition. This inspection can be done in the next step of the process which comprises identification of hazards and risks.

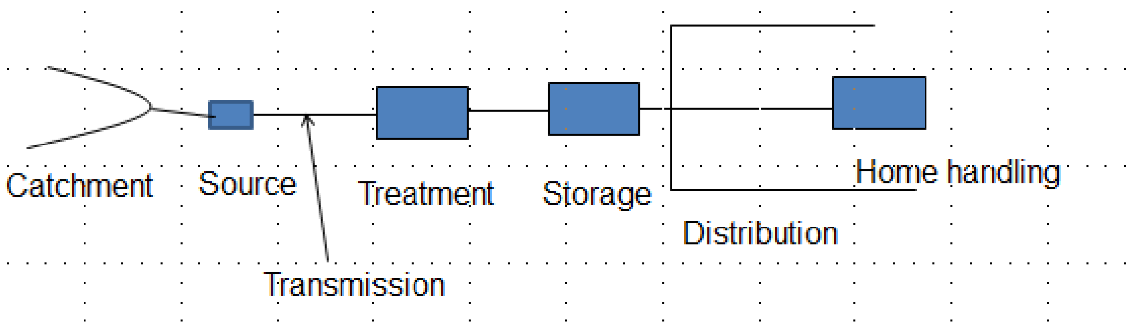

Figure 1.1. Profile of the water supply system

1.4.1 The water catchment

Understanding the water catchment in relation to the water source is a necessity to be able to identify possible hazards caused by contamination or changes in runoff patterns. In the case of groundwater sources it is important to know about the recharge areas of the ground water

1.4.2 Water source and water intake

The system may draw water from a single or multiple sources which may include: surface water (river, lake), ground water (deep borehole, a spring), and rainwater. So it is important to describe the water source and provide an indication of its performance. For surface water sources the description should include, the location and the water intake structure and for groundwater the description should include the characteristics of the well (including location, depth, water level) and the pumping system.

1.4.3 Transmission main

In many systems a transmission main takes the water from the water intake or the borehole to the water treatment plant. Details of the transmission main to be presented include the length, diameter, type of material and age.

1.4.4 Treatment system

The description of the system should include the type of treatment process(es), the lay-out and dimensions of the system, the flow rates, main operating devices, the age, consumption of chemicals and data about system performance.

1.4.5 Storage reservoir(s)

Usually the water is stored after treatment in a water storage tank which may be a ground tank or an elevated tank. The description should include the location, the volume, dimensions and age of the tank and the resident time of the water. The latter is particularly important if chlorine is dosed at the tank entrance. The description should also include the water main that transports the water from the treatment plant to the storage reservoir.

1.4.5 Distribution systems

The drawing of the distribution system needs to include the primary, secondary and tertiary pipe networks, pump stations, valve boxes, bulk water meters, public stand posts and/or household connections.

1.4.6 Household water storage

It is also important to briefly describe whether water is stored at home indicating the types of containers that are being used and to provide an indication of the percentage of households that have such devices.

1.4.7 Alternative water sources

The last point to include in the description concerns alternative water sources the population may be using (during part of the year). This point is often overlooked, but may be critically important. Such sources may include ponds, open wells, springs, rivers and rainwater, which should briefly described including location, availability throughout the year, users and the way they are using the water. To help improve upon the local conditions it will be necessary to get insight in the water culture, the way in which people deal with water and the water sources and systems they use as just providing a safe piped water supply is usually not sufficient to ensure safe water access for the population.

1.5 Self Evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers (section 1.9) and review the module again if you had many mistakes.

Q1. Why is a Water Safety Plan necessary?
A: A water safety plan is needed to guarantee that the water that is provided is safe to drink
B: To make sure that people take water from the water system and not from other sources
C: To reduce the risk involved in taking water from the water supply system

Q2. People with access to a water supply system that has a WSP drink safe water
A: Yes
B: No
C: May not be the case

Q3. Once a WSP has been developed we do not have to worry about the system.
A: Correct: WSP are looking at longer term risks including climate change and so the planned interventions cover for the risks for a period of several years
B: Not correct: We need to review the WSP every year
C: Not correct: We need to review the WSP at least every year and in case of calamities

Q4. Which of the following answers is correct? (Multiple answers possible)
A: A WSP team needs to include a climate change expert
B: A WSP team needs to include operational staff from the company
C: In most cases a WSP team needs to consult with different experts
D: A WSP team needs to include water users

Q5. Which of the following answers is correct? (Multiple answers possible)
A: A WSP is a management tool
B: A WSP may include changes required in the organization
C: Decisions by the WSP team can change the organization
D: A WSP has direct relevance for the water users

1.6 Assignment

In this section you will find the assignments related to this module. Preferably you first do this assignment for yourself and then you discuss with your training group and make one collective answer.

1. Make a brief description of the main components of your water supply system including a flow diagram.

2. Make a drawing of all possible water sources which the community may use in your service area and the purpose for which they are being used.

3. List the main problems involved in your water supply system

Action: *Copy the collective answers of your group to questions 1, 2 and 3 and submit this to your trainer through the means of communication you have agreed upon.*

1.7 References and further reading

This section includes the references for the section as well as some publications that may be interesting to gain more insight in the issues that are being discussed

- Adank, M., Butterworth, J., Godfrey, S., and Abera, M. (2016). Looking beyond headline indicators: water and sanitation services in small towns in Ethiopia. Journal of Water, Sanitation and Hygiene for Development 6(3) August 2016
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- WHO, (2017). Climate-resilient water safety plans: Managing health risks associated with climate variability and change. Geneva: World Health Organization

1.8 Answers to self evaluation questions

Q1. Answer C is correct; a WSP aims at reducing the risk involved in taking water from the water supply system by looking at all the hazards related to the system. Answer A is not correct because a WSP does not guarantee that the water is safe, it reduces the risk that it is not safe. Answer B is not correct as people may continue to use other water sources in addition to or in parallel with the water supply system for which the WSP has been developed.

Q2. Answer C is correct as a WSP does not imply that the water is safe; it just reduces the risk that the water from the piped system is not safe to drink. In addition it should be noted that people may use alternative water sources (for example because of cost involved) instead of the piped supply.

Q3. Answers C is correct as a WSP needs to be updated and this can be done annually, but that may not be sufficient. In the light of unforeseen changes or disaster situations it may indeed be necessary to review the WSP even earlier.

Q4. Answer B and C are correct. In many cases it will not be feasible to have specialist expertise on the core team, but this can be overcome by consultation at strategic moments. With respect to answer D, users need to be consulted but usually are not formally included in the team, although it may be worthwhile to consider having a user representative on the team.

Q5. Answers A, B and D are correct. Concerning answer C the WSP team provides information to management but does not decide about the implementation of the plan. That is done by management.

If you failed to provide several of the correct answers, then review this module again.

Module 2 Risk assessment in the water chain

This module provides an introduction to assessing the hazards and risks involved in a water supply system from source to tap (the water chain). It also explores some key water quality parameters and a practical approach to risk analysis using sanitary surveys. At the end of this module participant will:

- *Be able to differentiate between hazards and risks*
- *Have identified main water safety risks in a water supply system*
- *Be able to present key water quality aspects and related hygiene risks*
- *Have undertaken a sanitary survey of a water supply system*

2.1 Introduction

Safe, adequate, accessible and reliable drinking water is essential for human health. A person needs, on average, a daily intake of water that ranges from 1.8 to more than 10 litres, depending on the conditions. Someone doing hard labour in the sun requires much more water than a person resting in the shade (Cairncross and Feachem, 1983). People need also water for other purposes including their livestock and possibly for (small plot) irrigation and (small scale) industry.

Water can cause the person to become ill, as it may contain:

- Microbiological contamination that can lead to diseases such as diarrheas and dysenteries caused by bacteria, viruses or protozoa, enteric fevers and worm infestation.
- Chemical contamination causing diseases such as fluorosis and arsenic poisoning, as now reported from several countries.

The problem is that we cannot see most chemical and/or bacteriological contamination. As a result many people judge the water just by their senses (pleasant in taste, cool, free from visual contamination, free from odour) and others just take whatever they can get or are used to. In all of these cases however this water may cause disease if it contains contaminants.

The water people obtain for drinking purposes should be free of chemical substances and micro-organisms that can result in rejection or disease among users, or in deterioration of the water supply system and domestic utensils. Clean water can be ensured by selecting water sources that are not contaminated or by removing contaminants by water treatment. Yet the provision of clean water may not be sufficient. Water from point water sources such as tap stands will be transported from the source to the point of storage at homes. During transport and storage water may come in contact with contamination (dirty containers, hands that are not washed etc.). This implies a considerable risk of contamination during transport and storage that depends on the “water culture” of the users.

To develop a WSP all potential risks need to be explored that may affect the delivery of safe water to the consumers. This implies that a systematic assessment of the total water chain from catchment to consumer is needed. An important tool for this assessment is the sanitary inspection or sanitary survey as will be explained in this module. The WSP approach allows to establish the most important biological and chemical hazards related to the water supply and to identify control measures to reduce the risk that these hazards represent for consumers.

2.2 Important water quality issues

People may take the water they need from different types of water supply systems, and can only survive for a few days without it. Based on the type of source we can make a distinction between:

- Groundwater based systems,
- Surface water based systems, and
- Rainwater based systems

Important differences exist in the quality of surface water, ground water and rainwater. Rainwater is usually clean but may pick up impurities from the surface from which it is collected. Groundwater may comprise excess chemicals, but is usually free from harmful bacteria and viruses unless the water is polluted for example by nearby pit latrines or during abstraction, by repairs of pumps and water infiltration in the well. Most surface water is contaminated with harmful bacteria and viruses and may also contain other contaminants such as herbicides, pesticides and excess chemicals. For more details see Smet and van Wijk (2002).

It is often overlooked that people may use different water supply systems in parallel or at different moments. Hence providing safe piped water supply may need to include exploring with the users whether they do not also use 'possibly contaminated' water from other sources.

The water quality determines whether the water can be used for specific purposes such as drinking water, personal hygiene, cattle and/or irrigation. Drinking water must be free of substances that may create disease, and preferably with a taste, smell and temperature that is pleasant for the users. Water quality can be described in terms of the physical, chemical, and biological characteristics of the water as will be explained in this section. The information is kept concise and primarily relates to community water supply. It also takes into account that in many locations water quality testing may not be feasible for example for lack of equipment. In case you do have such equipment than you may want to look at the more comprehensive overview that can be found in the resource materials for this section such as the WHO guidelines for drinking water quality, volume 3: surveillance and control of community supplies, which includes also procedures for water sampling

2.2.1 Physical aspects

The physical aspects of drinking water concern taste, odour and appearance. These aspects often determine whether consumers drink and like the water and this is also influenced by their experience and customs. Standards are available (Table 2.1) which if complied with will usually lead to consumers' acceptance of the water.

The physical aspects may also be an indication for possible risks that may be associated with the water. A bad smell for example may be caused by contact with waste or waste water. High turbidity is an indication that soil particles but also possibly other contaminants may be present in the water. Colour may for example be an indication of the presence of decomposed organic materials or of high iron content.

People may also be reluctant to drink water that has a strong smell of chlorine whereas other users consider this as a positive sign that the water has been treated.

Table 2.1 Ethiopian standards for the physical characteristics of drinking water

Characteristic	Maximum permissible level
Odour	Unobjectionable
Taste	Unobjectionable
Turbidity (NTU)[1]	5
Colour (TCU)[2]	15

Turbidity is the cloudiness of a fluid caused by particles (suspended solids) that are generally invisible to the naked eye, similar to smoke in air
The **colour** of a water sample is caused by both dissolved and particulate material in water, and is measured in **Hazen Units** (HU).

2.2.2 Chemical water quality

There are few chemical components that produce an acute risk for users, except for situations where accidents occur in industry or through the spraying of pesticides and herbicides. In such cases, the water is often rejected by the consumers. Chemical pollution may, however, bring a chronic health risk associated with long periods of exposure, as can be seen from the incidence of arsenic or fluoride poisoning which may lead to dental fluorosis (Figure 2.1) or even more serious forms such as bone fluorosis.


Figure 2.2 Dental fluorosis a sign of long term exposure to fluoride

Detailed guidelines are available for example from WHO and from the Government of Ethiopia concerning the maximum concentration of chemicals in drinking water. We have included a few indicators in Table 2.2, but a more elaborated list is beyond the scope of this module as it would need support from qualified laboratories. If you want to learn more on these aspects that it is suggested that you look at the resource materials that come with this module. Here the idea is to just give a brief indication of the situation focusing on some parameters that seem most relevant in your daily context and that can support you in developing a practical WSP.

Literature shows that water quality across Ethiopia is highly variable. It ranges from fresh waters in many of its rivers, springs and wells to more saline waters and waters with high concentrations of fluoride especially in the Rift zone. Areas with high nitrate concentrations are found in shallow groundwater and particularly in urban areas because of leaking septic tanks (BGS, 2001). Iron and manganese may be a problem in different areas, but these are not so much a direct health problem but may cause stains in clothing and a brown or greyish colour of the water and create an unpleasant taste. It may also make the water less suitable for cooking as rice may turn black. Still a health problem is associated with this because people may dislike the taste and may for example use polluted surface water instead. Nitrates may be a problem in some areas mainly due to pollution stemming from agriculture but also septic tanks and latrines. For healthy individuals high nitrate levels are not a problem, but it may be a risk for babies under 6 month. Another potential risk is entailed in the discharge of waste water from industry, but this often concerns complicated toxic waste and will require specialist research to detect the problems and possible solutions.

Table 2.2 Guideline values for Ethiopia for some constituents in drinking water (MoWR)

Constituents	MoWR guideline
pH	6.5 – 8.5
F^- (mg/L)	3.0
Mn (mg/L)	0.8
Fe (mg/L)	0.4
Total coliform/100 ml	0
E. Coli	0

2.2.3 Biological water quality

The contamination of a water source with excreta from people or animals introduces a great variety of bacteria, viruses, protozoa and helminths (parasitic worms) (Figure 3). Insufficient protection of water sources, or inadequate treatment, handling and storage, puts the community at risk of contracting infectious diseases. An important problem is that the risk of bacteriological contamination may not be perceived by users as the pollution is often not visible. Local people may value the taste and appearance of the water, but not its bacteriological quality unless they understand the risks.

The problem with the microbiological quality is that you cannot see it and you cannot be sure that a water source is free of pollution. Another problem is that there are many bacteria and viruses but only few of them are pathogens (harmful bacteria and viruses that can cause disease). It is however impossible to just measure the pathogens as these are very divers and often present in small numbers only. So an approach has been adopted that assumes that when water has been in contact with excreta from human beings and warm blooded animals there is a considerable change that this water may not only include harmless bacteria but also some pathogens. This approach makes the situation less complex as now we just need to look at an **indicator,** a bacterium that can tell that the water has been in contact with faeces.

Indicator bacteria

The coliform organism is commonly used as indicator for the presence of water pollution. It is a very common group of bacteria that by itself is not considered to cause disease but is a good indication of potential pollution as members if this group of bacteria are present in large numbers in human excreta. Two indicators are being used: ***Total Coliform*** and the ***Termo tolerant Coliform*** (which used to be referred to as Faecal Coliforms) (WHO, 1997).

Total Coliform is measured by taking a water sample and incubating this for 48 hours at 35 ^{o}C. This test measures the presence of coliform bacteria, and therewith establishes a potential risk of contamination. Yet many of these organisms are not exclusive to human excreta, but live in the soil. Hence this indicator has important limitations.

It is therefore better to look at **Termo Tolerant Coliform (TTC),** mainly comprising Escherichia coli, a subgroup of the total coliform group that are exclusively or almost entirely exclusively present in faeces of people and warm-blooded animals” (Cairncross and Feachem, 1983). These bacteria are always excreted in large numbers by people and animals, irrespective whether they are healthy or sick”. The test involves incubating a sample for 24 hours at 43.5 ^{o}C

Two general types of analyses are possible to enumerate TTC:

- MPN - Most Probable Number
- Membrane Filter - MF

If you do not have access to equipment to carry out these tests themselves then it will be necessary to take a water sample and transport it packed in ice to a laboratory where it should reach within 6 hours to start testing. The sample needs to be representative for the source you want to test and you need to avoid that you pollute the sample during sampling. Another important point is to use proper sterile containers for the sample and clearly indicate the time and location of the sampling. If you do not have such containers you can use a bottle with a cap, but you will need to disinfect this bottle preferably by boiling it for 10 minutes. Further information on water sampling and testing is not included in this manual but more can be found including detailed sampling and test procedures in the resource materials.

It is necessary to underscore that often tests may not be needed or may have little value by themselves. If you see that water is in direct contact with excreta (for example an area with open field defecation directly draining into the water source), then it is obvious that Coliforms are very likely to be found if you would test the water. So it is better (and cheaper) to only test in situations where you think that the water might be safe to drink but do not feel totally sure. Furthermore test results are only indicative as they relate to the specific moment in which the sample was taken. A sample taken just after a rainy day may give very different results from one taking in a dry period. To cope with this difficulty WHO has introduced the concept of sanitary inspections.

2.2.4 Sanitary Inspections

When visiting a water supply system, a well, a handpump, a piped supply, or a water container in a house, it is often possible to spot possible deficiencies that could lead to the pollution of the water in the system. Buckets to collect water may be left on the ground next to well, surface water may leak into a storage tank because it is cracked, and people may take water out of the container touching the water with their hands. These are all examples of possible contamination which you can spot yourself. This type of assessment is the basis for the sanitary inspection or sanitary survey, which is a technique that records visible problems, enabling fieldworkers to assess the possible risk of contamination in a specific water system.

A sanitary inspection (sanitary survey) consists of a systematic review of possible hazards that may occur in the water supply chain from catchment to consumer (catchment area, water source, water supply system and household water storage and use) (Lloyd, B. and Helmer, R. 1991). The advantage of a sanitary inspection is that it just needs common sense and no equipment. It will allow getting an impression of possible contamination and this impression may be compared for example with information that may be available about possible problems with diarrhoea from users or local health staff. Another point is that after some training, inspections can be carried out (several times per year) by staff of the water company as one element in water supply monitoring.

Sanitary inspections will provide insight in the sources of contamination and risks involved. They are the basis to establish corrective actions in the system, the community, and community habits, to eliminate or reduce the hygiene risks.

Sanitary inspections and water quality testing

Sanitary inspections and water quality analysis (2.2.5) are complementary activities. Whereas the sanitary inspection identifies potential hazards, the water quality analysis establishes the level of contamination at the point and time of sampling. The sanitary inspection is essential for the interpretation of the results of the water quality analysis and to prioritize remedial actions. The difficulty with water quality analysis is that it is just a snap shot and therefore may not at all be representative for the situation.

Furthermore it may be quite difficult in many situations to find the necessary equipment and chemicals to do the testing, whereas the sanitary inspection combined with users' information is always feasible. On the other hand it is not sufficient to estimate water quality risks related for example with chemical substances such as Fluoride. Furthermore the regulations in Ethiopia prescribe that water supply systems need to meet certain water quality criteria which makes water quality testing a necessity, particularly when developing a new system.

Climate conditions may have an important influence on water quality. Particularly in micro-catchments changes, for example, because of rain can be of short duration and may be difficult to detect with occasional water quality testing. The sanitary inspection can be of great help in such case. Waste water discharge often is more critical in the dry season when less water is available. First rains after a dry spell can severely enhance the microbial and chemical contamination of a water source and increase turbidity levels.

The community is an important source of information. They know about changes in water quality during and over the years in terms of turbidity, colour and taste (salinity, iron). Also they may be able to give an indication of the incidence of water borne diseases in the community. Hence their information can help to confirm the findings of a sanitary inspection. One would expect a high incidence of diarrhoea if the sanitary inspection shows that there are considerable sanitary risks from the source and/or inadequate hygiene habits.

2.2.5 Water quality parameters

Ethiopia has comprehensive water standards that are based on the WHO guidelines. But the WHO (2005) suggests that these types of standards are too complex to adhere to in rural areas and municipalities with limitations in infrastructure. WHO (1997) presents a much less prescriptive approach, which combines the use of a few water quality parameters and the implementation of sanitary inspections.

The water quality parameters in the minimum WHO approach to community water supply include:

- Turbidity
- E. coli counts (the indicator discussed in section 2.2.3)
- residual chlorine (if chlorine is applied)
- pH (if chlorine is applied)

Even these very few parameters are still difficult to measure on a regular basis. Hence an approach may be to sample only regularly those systems that are susceptible to pollution or are the water source for large populations. For other schemes, the quality of water is monitored through sanitary surveys, and water quality testing is only carried out when pollution is suspected or an outbreak of water-borne disease is reported.

Another important aspect is to view the water quality in the context of local conditions. In an area where there are numerous other potential routes of disease transmission, the impact of less stringent water quality norms may be lower than in very clean environments.

2.3 Water supply hazards and risks

Identifying hazards and assessing risks are important aspects of preparing a Water Safety Plan. A **hazard** is something that is known to cause harm. Bartram et al. (2009) define a hazard as ‘a physical, biological, chemical or radiological agent that can cause harm to public health’. **Risk** is the likelihood or probability of the hazard occurring and the magnitude of the resulting effects (Risk = Likelihood x Severity) (see Box 2.1).

To clarify the difference we can use the following example. If you are driving a car one **hazard** is that you run out of fuel. What is the **risk** involved. In the first place the occurrence of the hazard may be small provided you observe the fuel meter. So this is the first part in the **risk assessment,** the evaluation of the frequency that it may occur. The second part is the evaluation of the potential harm if the hazard will happen. The latter depends on the specific circumstances. If you normally drive your car in a town it may be easy to find fuel so the harm is small and as the frequency is small as well the risk is small. Yet if you normally drive in remote areas or in the desert the potential harm of running out of fuel is much higher, it may even get you killed. Hence in that case even though the frequency may be small the risk may be high.

Box 2.1 Hazards and risks in water supply systems

Hazards are harmful microorganisms (bacteria, parasite, protozoa, and/or virus), or chemicals (fluoride, arsenic, lead, etc.) or physical (turbidity etc.) and/or lack of water that might affect health of the consumer or affect the water supply system.

Hazardous events are unfavourable conditions that may allow hazards to enter into or affect the water system and therewith interfere with the delivery of water safe for human consumption.

Risk is the probability of the hazardous event occurring and the magnitude of the resulting effects (risk = likelihood of the hazard x severity of its possible impact)

It is important to never assume that people see potential health risks the way you see them. People living all their life in a polluted environment may be so accustomed to it that they do not appreciate possible health hazards. Children seeing that mothers handle faces of babies as if they are harmless are likely to adopt this behaviour as well.

Managing hazards implies confronting situations that pose a level of threat to life, health, technologies or environment. Most hazards are dormant or potential, but once a hazard becomes 'active', it can cause harm. The risk involved in a hazard (and the management attention it merits) depends on the likelihood that it can become active and the seriousness of the damage it can cause. To establish the risk involved in a hazardous event in a water supply we need to explore:

- The hazardous event
- The likelihood of its occurrence, and
- Its potential impact on water quality or quantity

Howard (2002) distinguishes three categories of factors that need to be explored:

- Hazard factors; Potential sources of faecal material or chemicals situated so that they may contaminate the water supply (e.g. the location of a waste dump in relation to the water source).
- Pathway factors; Potential routes by which contamination may enter the water supply (e.g. eroded backfill areas of protected springs, cracks in well covers, or leaking pipes).

- Indirect factors; Factors that represent a lack of a control measure to prevent contamination (and therefore increase the likelihood of a hazard or pathway developing). The absence of a fence, for example, will not lead directly to contamination, but may allow animals or humans to gain access to the source and create either a hazard (through defecation) or a pathway (through causing damage to the source or its immediate surroundings).

Assessing hazards and risks implies that the water supply chain (Figure 2.1) needs to be reviewed very carefully while taking into account possible problems in the design, construction, operation and maintenance of all components in the water chain (catchment area, wells, pumps, pipes, storage vessels at homes etc. These may all influence the type of hazardous events that may occur and the associated risk (in particular the likelihood of occurrence).

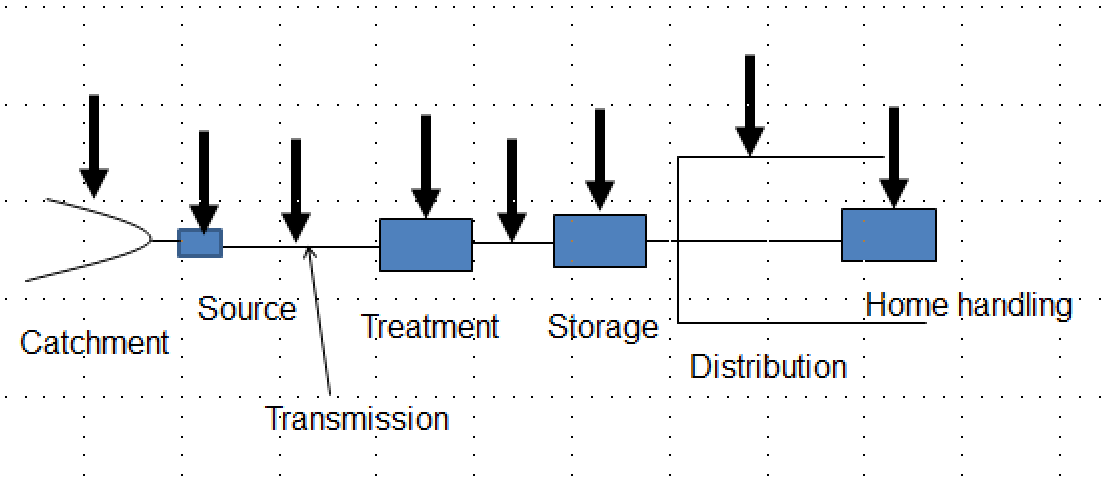

Figure 2.1 Example of a water supply chain (arrows indicate potential risks)

The sanitary inspection is the main tool to assess the risks, but it is not a one off activity as risks involved in hazardous events and pathways may vary during the year and change over time. For instance in rural areas microbial contamination may peak at the start of the rainy season but then rapidly diminish as the reserve of faecal material diminishes. Man-made interventions in catchment areas may cause erosion and change of runoff patterns which may negatively affect springs in terms of quality and quantity.

The sanitary survey also needs to take into account problems caused by the technology and inadequate maintenance. This may for example result in lower production levels of pumps which may lead to longer waiting times at collection points. Users than may go to alternative (polluted) sources or buy water from vendors (forcing them to spend more on water). As such problems may be the result of poor management and financing, also these aspects need to be explored as will be discussed in more detail in the other modules in this course.

2.4 Risk identification and management

For the development of the WSP all the hazards that may occur in the supply chain from collection to use need to be identified (Figure 2.1). The overview of hazards and the level of occurrence will provide insight where to focus our interventions.

Some of these interventions are very feasible to implement in existing systems, but some hazards need to be or can better be addressed at the design stage. This may include, for example, choosing a protected water source with good quality water, or including a very robust water treatment system.

2.4.1 Managing hazards related to water catchment and water source

Looking at managing hazards related to water sources implies posing a number of questions. The first question to pose is: Where is the water coming from?

For both ground and surface water we need to understand the hazardous events that may be present in the water catchment area. For a surface water source this may be more easy to identify and possibly to control. That is, if it concerns a catchment area that is nearby. For larger rivers and lakes a more comprehensive approach with many more actors will be needed. For groundwater a similar situation exists as in some case the recharge area where rainfall percolates into the ground may be nearby, whereas in other cases the ground water may come from much further away. For areas that are closer it may be feasible to introduce protective measures such as restrictions on, say, fertiliser or pesticide use. Hence in relation to the water source we need to identify:

- The main microbial, chemical and physical contamination hazards
- The main pathways that exist for contamination to enter the source
- The main actors involved and in what way do they contribute to the risk
- Possibilities to reduce or block hazards and/or pathways

A good approach to help identify possible hazards in a catchment area is a ***transect walk***, a systematic analysis of the catchment area where the water is coming from by walking along a straight line to explore the situation. A transect walk in the catchment area by an experienced person or team may be very important to assess possible risks that may affect the long term water availability or water quality. If the water catchment is not well protected and signs of deforestation, overgrazing and erosion are visible the water source may be at risk. Furthermore farming using fertilizers and pesticides may also negatively affect the water quality of the water sources and may lead among others to increase in nitrate levels which may generate a risk for small babies.

Some water systems have multiple water sources and in that case risks need to be identified for each of the sources and abstraction points. The orientation is to use the description you already made in module 1 and add information on the water source(s) including the behaviour over the year (dry and wet season) looking also at climate variability which may result in extreme weather events that may affect the source water quality and quantity. The WSP team can use information from the climatic zone assessment report. It is necessary to explore changes (comparing historic and current data) that may have taken place for example in flow discharge of the source and water abstraction for the water supply system.

When the catchment area is known and interventions are feasible in this area it will also be relevant to briefly describe the nature of the land and its use, including anticipated development in the future looking particularly at issues such as waste water discharge, intensive agriculture use etc. and the possible load of microbiological and chemical hazards that may be involved. It is also important to identify possible prevailing action that is in place such as soil and water conservation interventions.

Present the water quality data available from the water supply source(s) and the way their quality is seasonally affected and possible longer term trends due to changes in the watershed and/or climate variation.

Define for each of the intake related components of the water system the risks that are at stake. These issues will be water scheme specific, but may be quite generic in similar water systems in the same area.

Once the risks are identified it may be possible to take specific action to prevent or strongly reduce them. A number of possible actions for different water sources are presented in Tables 2.3 and 2.4.

Table 2.3. Action to prevent or reduce sanitary risks in existing groundwater sources

Hazard and pathway	Remedial action
Pollution of aquifer "upstream" of the water source by infiltration	Avoid or remove latrines, cattle ponds and pools close to the water collection point. The 'safe distance' needs to be assessed locally as it depends on the travel time of harmful bacteria or chemicals and the direction of flow of the ground water.
Changes in run-off patterns because of interventions in the catchment area	Identify zones that need to be protected in the catchment area and ensure adequate protection; avoid: overgrazing, deforestation, spraying with chemicals etc.
Direct infiltration of pollution in the source	Ensure fencing of springs to avoid erosion of the protective cover (back fill). Review system components (spring box, well cover etc.) for possible cracks and repair them Ensure disinfection of the deep well after cleaning or pump repair Disinfect the source after pollution has occurred (which may be shown by an outbreak of diarrhoea)
Wells running dry and/or salt water intrusion	Avoid possible over-pumping of groundwater in the area as this may cause a fall in the water table. In some areas it may also result in salt water intrusion. Another option to look into is to enhance recharge of the groundwater for example by improvements in the catchment area or by building of subsurface dams

Table 2.4 Action to prevent or reduce sanitary risks in existing surface water sources

Hazard and pathway	Remedial action
Pollution of water source "upstream" of the point of collection	Avoid, remove or reduce, waste water discharge, cattle grazing, human intervention and agricultural activities that may affect the water quality and water availability. Adequate water catchment protection is a good start to ensure good water quality, but almost always some form of treatment of the surface water will be needed
Changes in run-off patterns because of interventions in the catchment area	Identify zones that need to be protected in the catchment area and ensure adequate protection; avoiding overgrazing, deforestation and inadequate land management. Construct bunds and implement other protection and corrective measures if erosion is increasing.
Direct infiltration of polluted water in the water intake and water transmission pipe	Ensure fencing of the water intake. Review system components (water intake and transmission pipe) for possible cracks and leakages and repair them Close intake if water quality deteriorates (dead fish, bad smell, strange colour etc.)

2.4.2 Managing hazards related to transmission main and water treatment

In many systems a transmission main takes the water from the water intake or the borehole to the water treatment plant. This pipe needs to be checked for possible infiltration problems due to cracks and leakages.

The water treatment system depends on the type and extent of source contamination. The orientation is to use the description you already made in module 1 and add information on the performance of the system and on possible risks. The conventional water treatment system commonly used for surface water includes sedimentation, coagulation/ flocculation, filtration, and disinfection before distribution. For each of these processes performance data need to be provided including the effect of water treatment, the way treatment processes are controlled and information on standards that are used to decide that the treatment process is properly functioning. Another part of the assessment has to do with the collection and review of details of the standard operating procedures (working manuals).

It is necessary to assess whether the hazards that were identified in the water source and the water main can be controlled by the water treatment system. Hazards related to water treatment may include running out of chemicals and interruptions in energy supply. Another group of hazards are related to (lack of) maintenance and spare parts management. The third group of hazards are related to the knowledge and experience of the team that is operating the treatment plant.

In summary it needs to be explored:

- Whether the treatment processes are adequate to produce a water that is attractive and low in sanitary risk;
- What are the main hazards that need to be addressed in terms of microbial and chemical contamination during the treatment process?
- What are the main pathways that exist for (re)contamination of the water during treatment and storage?
- Who are the main actors involved and in what way do they contribute to the risk?
- Can hazards and/or pathways be reduced or blocked

This assessment is specific for each water treatment system and provides the basis for identifying possibilities to take specific action to prevent or strongly reduce the risks. A number of possible actions for different water sources are presented in Table 2.5.

Table 2.5 Action to prevent or reduce risks in water treatment and related storage

Hazard and pathway	Remedial action
Inefficiency of water treatment processes	Monitor the treatment processes and take action when required indicator levels are not met Ensure adequate operation and maintenance Explore if the operator occasionally by-passes the water treatment system, explore why and try to solve the problem
Problems with overdosing chemicals in treatment	Over dosing of chemicals such as alum sulphate or chlorine may not represent a direct health hazard, but it can be dangerous as people may reject the water and use polluted sources instead. Monitor as feasible and take immediate action if problems are encountered or users complain. It will be needed to be critical. In some systems in Ethiopia it is common practice to disinfect deep borehole once a month. The question is whether this is actually needed particularly if you also use disinfection in the storage tank
Ineffectiveness of	Monitor chlorine level at strategic locations. Review functioning of the

disinfection process	equipment and chlorine dose if indicator levels are not met
Direct pollution of treated water	Review system components (tanks, pipes, boxes and valves) for possible cracks or other damages and repair them Ensure that safe water is used for possible priming of pumps and cleaning Avoid the use of unclean equipment, boots etc. in O&M Carry out repairs in a hygienic way and if possible disinfect afterwards Disinfect the clean water pipes and storage tank if pollution has occurred (which may be shown by an outbreak of diarrhoea)

2.4.3 Managing hazards related to water storage and distribution

Usually the water is stored after treatment in a water storage tank which may be a ground tank or an elevated tank. The tank and all pipes need to be checked for possible problems. Points of attention also include manholes and manhole covers, vent pipes and cracks which may allow rodent access and entry of contamination caused by birds. Furthermore it may be required to check the contact time if the tank is used as a contact tank for chlorine and if growth of microorganisms is present and tanks are regularly cleaned. It is important to check the performance in terms of stored volume over the time of the day and particularly whether the tank runs dry.

From the tank the water is distributed to the users. Three main situations can be identified:

- **A piped water supply system**, which is a convenient system that may entail some hazards primarily related to the intrusion of polluted (ground) water through leaks into the system. This situation is more critical in systems that provide intermittent water supply. Another hazard may be the existence of cross connections with pipes that contain polluted water.
- **Manual transport by users** often in open containers with a considerable risk of contamination by hands and dirt.
- **Mechanized transport by water vendors** which often is not well controlled. Risk involved may be considerable because of poor handling of the water, but also water may be collected from polluted sources

Hence it is important to provide a good description of the distribution system flow, type, age, length, size and type of the materials used as well as the locations were the pipes are laid in low areas prone to high water tables or flooding. In part information about the distribution system primarily relies on review of the secondary data (system design) and information from operation workers to update the network system map and identify possible/probable areas of problem and associated risks. Here it will be useful to involve water users as well as these may have insights in the different means of transport including for example on possible pipe bursts. A related point is the need to check for possible back flow of contaminated water from consumer’s premises during period of supply interruption (back siphonage) and equally important to check for illegal connections as these may entail risks as well.

Once the hazards are known it may be possible to take specific action to prevent or strongly reduce the risks. A number of possible actions for different water distribution options are presented in Tables 2.6 and 2.7.

Table 2.6 Action to prevent or reduce sanitary risks in piped water distribution

Hazard and pathway	Remedial action
Water pressure is not maintained during 24 hours	Maintain continuous pressure on the pipes to avoid infiltration by improving efficient water use (leakage control

	and reduced consumption) to improve water pressure conditions If 24 hours supply is not feasible test water quality at taps in strategic locations particularly after periods of low or no water pressure Ensure water treatment at home in case water quality test confirm possible hazards
Pipes are buried and pass through water logged areas or close to waste drains	Improve drainage and/or reinstall the pipes in areas that pose a risk Test water quality at taps in strategic locations Ensure water treatment at home if needed
Water is contaminated because of repairs of the distribution system	Carry out repairs in a hygienic way and if possible disinfect afterwards (this issue should be covered in the standard operating procedure relate to repairs) Inform users that the water supply will be interrupted for a given period (to allow them to store water) and tell them that they will need to treat the water at home (boiling) during the first day after the repair of the system.

Table 2.7 Action to prevent or reduce sanitary risks in water transport

Hazard and pathway	Remedial action
The water may be polluted at the point of collection; water vendors for example may collect water from polluted sources	Explore where the water is being obtained Test the water if possible and particularly if you suspect contamination or users report high incidence of diarrhoea Encourage that water is only collected from ‘safe water sources’ Inform the users that the water is polluted Encourage water treatment at home
Water is contaminated by users during transport	Explore how people handle the water Introduce safer containers with less risk of pollution Inform the users about the risks and show better ways of handling the water Inform about water treatment at home for weaker family members
Water is contaminated by vendors during transport	Explore how vendors handle the water and if feasible test the water Introduce safer ways of handling the water to reduce the risk of pollution Explore possibilities of disinfection of the water by vendors Inform the users about the quality if the water of vendors Inform about water treatment at home for weaker family members

2.4.4 Managing hazards related to water storage at home

A considerable risk may also be present at the end of the water chain when storage containers are dirty, poorly managed or water is withdrawn in an unhygienic way. Whereas this part is the responsibility of the users it is important to at least explore it in the context of the development of WSP as users may jeopardize all the efforts made to provide safe water at the tap.

Once the risks are clear users can be informed about specific action they can take to prevent or strongly reduce the risks. A number of possible actions are presented in Table 2.8.

Table 2.8 Action to prevent or reduce sanitary risks in household water storage

Hazard and pathway	Remedial action
The water may be polluted prior to the storage	Explore whether the water comes from a safe source and if the risk of recontamination in water transport is low (test if possible); Encourage use of water with lower risk either by using water from safer sources and safer water transport or by water treatment at home
Storage container may be polluted before water is stored	Explore maintenance of the water container and encourage cleaning preferably with a disinfectant.
Pollution may enter the water in the storage because the storage is not properly closed or water is taken out in an unhygienic way	Ensure that the water storage container can be properly closed to avoid that pollution (dust, flies, rodents) may enter Encourage users to keep storage containers closed Encourage users to draw water from the container either with a clean ladle but even better if the container has a tap.

A related point is that in some systems it still may be difficult to ensure that water with a low hygienic risk is provided to the users. If that were the case it is essential to inform the users how they can obtain access to safe water for human consumption. Some users may be in the advantageous position that they can afford to buy bottled water, but this is often very expensive. For many other people the only feasible option then becomes to treat the water at home by boiling or by using other treatment processes to reduce the health risk involved.

2.4.5 Alternative water sources

The last point to include in the description concerns alternative water sources the population may be using (during part of the year). This point is often overlooked, but may be critically important. Such sources may include ponds, open wells, springs, rivers and rainwater. Hence it is needed to explore with the users whether they have access and actually use possible alternative water sources and what hazards these systems implicate, as just providing a safe piped water supply is usually not sufficient to ensure safe water access for the population.

2.5 Risk prioritization

Risk is the likelihood that a hazard affects the water supply system and the severity of the effect. Risks can be prioritised if the likely hood of a hazardous event and the severity of the associated impact are known. A method of undertaking a risk assessment quantitatively is to use a risk matrix as shown in Table 2.9 (Bartram et al, 2009). The severity of the impact of a hazard (ranking as shown in Table 2.10) and its likelihood can be multiplied together to arrive at a number that indicates its risk score.

Table 2.9. A risk matrix for risk assessment.

Effect	No/minor impact 1	Serious impact 3	Very serious impact 5
Likelihood[1]			
Rare (1) < 1% of the time, cases, connections	1	3	5
Moderate (2) 1 – 20% of the time, cases, connections	2	6	10
Likely (3) > 20% of the time, cases, connections	3	9	15
Risk levels: low risk < 3; medium risk 3 – 6; high risk 7 – 10; intolerable risk > 10			

[1] The likelihood depends on the situation that is being assessed and may be established in terms of time, number of events per year, number of connections etc. The idea is to establish a reasonable level of likelihood tobe able to prioritise risks.

Adapted from Bartram et al, (2009) Based om British Standard 8800 1996

Table 2.9 Ranking of possible impact

Impact	Definition
Minor	Minor water quality impact (not health related) or disruption in operation affecting few customers; insignificant rise to complaints
Serious	Minor water quality impact (aesthetic impact, not health related) affecting many customers, clear rise in complaints, community annoyance, minor breach of regulatory requirement
Very serious	Major water quality impact (health-related), illness associated with the water supply, large number of complaints, significant breach of regulatory requirement

The risk rating can then be assessed in terms of risk level and different risks can be compared. Table 2.9 gives an indication suggesting that if an intolerable risk exists this needs to be taken care of immediately. But also risks with the indication of significant and moderate need to be taken into account as these risk levels will need to be reduced.

To illustrate the application of a risk matrix we show the following example.

Hazardous event 1: The treatment plant runs out of chlorine. The hazard is that water is contaminated as it is not disinfected. Running out of chlorine is rare in a well-managed system but the health impact will be very serious hence a score of 1*5 = 5. By repeating the exercise for other hazards and comparing risk scores, a prioritised list can be drawn up that ranks the risks in order of importance. Unfortunately, budgets are often limited and because of this many of the smaller risks are disregarded.

Table 2.11 gives an indication of the priorities that need to be addressed on the basis of the risk assessment based on BS 8800 1996

Table 2.11 Tolerance levels with guidance on necessary action

Tolerance level	Guidance on necessary action and timescale
Very low risk	These risks are considered acceptable. No further action is necessary other than to ensure that the controls are maintained.
Low risk	No additional controls are required unless they can be implemented at very low cost (in terms of time, money and effort). Controls should be maintained, but actions to further reduce these risks are assigned low priority.
Medium risk	Consideration should be given as to whether the risks can be lowered, where applicable, to a tolerable level, and preferably to an acceptable level, but the costs of additional risk reduction measures should be taken into account. The risk reduction measures should be implemented within a defined time period. Arrangements should be made to ensure that the controls are maintained, particularly if the risk levels are associated with harmful consequences.
High risk	Substantial efforts should be made to reduce the risk. Risk reduction measures should be implemented urgently within a defined time period and it might be necessary to consider suspending or restricting the activity, or to apply interim risk control measures, until this has been completed. Considerable resources might have to be allocated to additional control measures. Arrangements should be made to ensure that the controls are maintained, particularly if the risk levels are associated with extremely harmful consequences and very harmful consequences.
Intolerable risk	These risks are unacceptable. Substantial improvements in risk controls are necessary, so that the risk is reduced to a tolerable or acceptable level. The activity should be halted until risk controls are implemented that reduces the risk so that it is no longer very high. If it is not possible to reduce risk the activity should remain prohibited.
Based on BS 8800 1996	

Example 2: Hazardous event: Heavy rain in a catchment area (frequency 2 times a year = moderate level 2); Hazard is that suspended solids load increases as slopes in the catchment area are not protected. The high load of suspended solids interferes with the treatment process and the water supply needs to be stopped for several hours, which implies a serious impact leading to a score of 2*3 = 6 and if it needs to be stopped for several days the impact will be very serious, leading to a score of 2*5 = 10.

A Water Safety Plan considers all the stages in the supply of water, and therefore it involves:

- Management of the catchment (which may require interventions of other organizations) and or the water intake to prevent contamination of the source water
- Removal or elimination of contaminants during treatment of the water
- Prevention of contamination of the water after treatment (during distribution, storage and handling).

Water Safety Plans put the emphasis on controlling risks where they are likely to arise, rather than having a treatment plant deal with cases of contamination after they have occurred. Preventing a problem from occurring is much better than having it occur and then trying to minimise its impact

2.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers (see section 2.9). In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. Is cold crystal clear water safe to drink?
A: Yes
B: No
C: May not be the case

Q2. Indicate which of the following statement is correct. (Several may be correct)
A: Groundwater is bacteriologically safe
B: The physical characteristics of water include Odor, Taste, Turbidity and Color
C: Ethiopian water sources may have very high levels of fluoride and nitrates
D: Bacteriological contamination of water supplies is a problem in Ethiopia

Q3. A sanitary inspection
A: Consists of a systematic review of all the hazards that are potential and actual causes of contamination of the supply.
B: Consists of a systematic review of all potential and actual causes of contamination in combination with water quality testing
C: Is carried out only once when the best water source is being identified for a community

Q4. A good sanitary survey only needs to be carried out once to clearly identify the risks involved in hazardous events and related pathways.
A: Yes
B: No

Q5. An experienced researcher may carry out a sanitary survey without asking information from the local community and water users.

A: Yes

B: No

Q6. Indicate which of the following statement is correct. (Several statements may be correct)

A: Changes in run-of patterns in a catchment area may imply changes in the sanitary risks

B: Low water pressure in pipes are an important hazard and may lead to transmission of water related diseases

C: Users may contaminate safe water during transport and storage

D: Water treatment at home is needed in many households in Ethiopia

2.7 Assignment

In this section you will find the assignments related to this module. Preferably you first do this assignment for yourself and then you discuss with your training group and make one collective answer.

1. Complement the description of the main components of your water supply system including a flow diagram from module 1.

2. Make a list of all possible hazardous events related to your water supply system and assess and prioritize the risks involved.

3. Conduct a sanitary survey of the main components of the system (this assignment can be distributed among team members who perhaps can work in pairs whilst possibly involving external advisors for example in the review of the catchment area)

Action: *Provide results of the assignments to your trainer.*

2.8 References and further reading

Bartram, J., Corrales, L., Davison, A., Deere, D., Drury, D., Gordon, B., Howard, G., Rinehold, A., and Stevens, M. (2009). Water safety plan manual: step-by-step risk management for drinking-water suppliers. Geneva; WHO

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WHO, 1997. Guidelines for drinking water quality. Volume 3 Surveillance and control of community supplies. Geneva: WHO. http://www.who.int/water_sanitation_health/dwq/gdwq2v1/en/index2.html

WHO (2008) *Guidelines for drinking-water quality: Training materials.* Geneva: WHO

2.9 Answers to self evaluation questions

Q1. Answer C. The cold clear water may not be safe as chemical and bacteriological pollution may not be visible. So it will depend on the water source, possible hazards in the water supply system and in the handling and storage at home.

Q2. Answers B, C and D are all correct Answer A is not correct as groundwater may contain Fecal coliforms if the source is not well protected

Q3. Answer A. The sanitary inspection looks at the potential and actual causes of contamination of the supply and is complementary to water quality testing. It is not carried out once but on a regular basis as a monitoring tool.

Q4. Answer B. A sanitary survey is not a one off activity as risks involved in hazardous events and pathways may vary during the year and may change over time. Important differences may exist for example between the wet and the dry season. Also situations may change over time. Water tables may be falling because of over-pumping and water catchment areas may change because of overgrazing of cattle or deforestation. People may invade the area etc.

Q5. Answer B. Communication with the users and people living in the catchment area is an important part of a sanitary survey. They know about activities that take place in the area, which may be related to specific seasons. They know if the water sometimes becomes turbid. They know if they receive water intermittently or at low pressure etc.

Q6. All answers need to be marked as they are all correct

If you failed to provide several of the correct answers, then review this module again.

Module 3 Validating and monitoring control measures

This module introduces the validation of control measures and the development of new ones.

At the end of this module the participant will:

- *Be able to explain what is meant with validation and monitoring of control measures*
- *Has reassessed the risks of the system they are working with taking into account the effectiveness of existing control measures*
- *Have identified what control measures are missing and developed at least one example of a new control measure*

3.1 Introduction

In the previous module we looked at the different risks that are in place, but several of them may already have been identified earlier and control measures may be in place to reduce these risks. When we look at **control measures** we look at activities or processes to prevent or eliminate a water safety hazard, or reduce it to an acceptable level (also known as 'barriers' or 'mitigation measures').

Hence it is essential to explore these measures in relation with the risks that have been identified. What needs to be done is to **validate the control measure**. This implies to obtain evidence that the control measures can effectively control the hazard and reduce the risk. When existing control measures are not effective or completely absent for certain risks than new or additional control measures will be required. Hence the assessment of the effectiveness of existing control measures will allow the WSP team to determine clearly where additional control measures are required.

Validation of controls may involve a variety of methodologies including for example catchment surveys, sanitary surveys of the water supply system, water quality testing, and testing procedures in practice. Based on the assessment indicated in module 2 a table can be established with what can go wrong in the different components of the system and the related risk (table 3.1)

Table 3.1 Initial risk assessment and existing control measure

Process	Hazardous event	Hazard	Risk level[1]	Existing control	Effect[2]	Reason	Risk level[1]
Catchment	Poor land management	Microbial Chemical Physical	M	Orientation of farmers	S	Few adopt better land management techniques	M
Treatment	Failure of chlorine equipment	Microbial	H	Routine maintenance Option for manual dosing	G	If power or pump fails dosing can be done by hand and gravity supply	L

1) Risk levels: L = low; M = medium; H = high; IN = intolerable.
2) Effectivity existing measure; G = good; N = Not functioning; S = Somewhat

The table provides the basis to establish which of the risks still will need to be controlled by new or improved measures. Risks should be prioritized in terms of their possible impact on the delivery of safe water. Some risks may require modifications in the system to meet water quality targets others may be reduced by improving routine activities.

3.2 Control measures

A wide variety of control measures may exist in the water chain from catchment to consumer. They comprise the full range from short-term mitigation measures to medium- and long-term mitigation measures. Existing measures may include measures in the catchment area, in the treatment and distribution system as well as activities related to water uses (Table 3.2). The effectiveness of the control measures should be checked against pre-determined targets or 'critical limits'. These targets may be expressed as upper and/or lower limits.

Table 3.2 Possible control measures

	Location	**Control measure**
1	Catchment	Stop free rooming of cattle
2		Covering and protecting of springs
3		Restricting use of catchment area (code of using chemicals etc.)
4	Treatment	Controlling stock of chemicals (guaranteed minimum)
5		Stand-by generator
6		Operators' competency
7	Distribution	Mains repair procedures
8		Non-return valves
9		Pressure monitoring and recording
10	Users	Information when water quality is at risk (advice boil the water)

Part of the control mechanisms may be embedded in standard operating procedures (SOP), which maybe common practice to a water supplier. The problem may be that these procedures may have been developed by consultants perhaps even without staff consultation and may in fact be just text on paper. It may well be that whereas procedures exist responsibilities may not have been clearly allocated. Hence it is essential to review the actual implementation of these SOP and to explore where they are effective and were they can be made more efficient to ensure that the company can respond quicker to incidences.

3.3 Standard operating procedures

A Standard Operating Procedure (SOP) is a set of written instructions that document a routine or repetitive activity that is to be implemented by an organization (EPA, 2007). SOPs are important to ensure the quality of the day to day activities of the organization as it provides staff with the information to perform a job properly, and facilitates consistency in the quality and integrity of a product or end-result. Organizations may also use other terms for this type of procedures such as protocols and instructions, and they may also use worksheets.

SOPs document the way activities are to be performed to facilitate that they conform to technical and quality system requirements and to ensure proper data management. They may be very important to reduce the risk involved in different hazards. They may detail for example how to go about water disinfection including steps to be taken when some of the equipment fails. SOPs are intended to be specific to the water company whose procedures are described and aim to assist the company to maintain their quality control, ensure compliance with prevailing regulations and ensure provision of good quality water.

SOPs need to be written properly and need to be followed. This implies that management needs to ensure that they are readily available at the place of work and they need to review and re-enforce their implementation. It is important to include in the SOP how its effectiveness will be monitored as an input to the regular monitoring system that is needed for a water company.

3.4 Developing standard operating procedures

It is very important that SOPs are simple, short and unambiguous. In the development of SOPs it is necessary to take into account that they should provide detailed work instructions and therewith can also be used in staff training. SOPs may relate to routine operations such as water treatment, disinfection, disinfection of systems after repair etc. but may also include a number of emergency related procedures for example in case of a flooding event.

SOPs need to be written by individuals or a team knowledgeable with the activity and the organization's internal structure and who may actually perform the work or use the process (see for the SOP format Box 3.1). The procedure should have sufficient detail to allow it to be implemented by someone with limited experience but with a basic understanding. The minimum experience for performing an activity should be mentioned in the procedure.

The draft SOP needs to be tested by involving individuals other than the original writer. The most convenient approach is to give the draft SOP to staff that have to implement the procedure asking them to put it in practice. The finalized SOP should be approved by the immediate supervisor of the procedure and by management. To remain current SOPs need to be reviewed perhaps every 1 to 2 years and also whenever procedures are changed. In the latter case SOPs should be updated (possibly only the section that deals with the part of the process that is adjusted) and reapproved. An SOP should be withdrawn if it describes a process that is no longer followed.

Box 3.1 Annotated outline of an SOP

- Title and date of issue
- Registration number and number of pages (so it is easy to check if document is complete)
- Introduction (purpose of the work or process, appropriate regulatory information or standards, scope to indicate what is covered and links to other SOPs)
- Responsibility (who is / are responsible for implementation)
- Procedure (The steps and materials involved in the procedure including as needed a possible recovery process after the intervention)
- Monitoring (how to know that procedure was effective – including indicator to monitor)
- Reporting / registration of the event (official report to the appropriate person / unit)

3.5 Monitoring and reporting

One common problem is that SOP and other safety measures are developed, but not necessarily implemented properly. This implies that it is important to have some key indicators that can be monitored in relation with the SOP and other safety measures. This may concern indicators that measure the outcome of the SOP or the safety measure, for example the chlorine content of the clean water storage is always above the minimum acceptable level. It may also relate to reports being prepared on SOP implementation in combination with occasional spot-checks. It needs to be clear to whom reports need to be submitted and staff should also be aware of the possibility that their activity may be evaluated which may include repeating the procedure under supervision to ensure that they follow all the steps.

Effective monitoring needs to be simple and depends on the hazardous events that have been identified. Monitoring is essential for risk management and should allow demonstrating that the control measure is effective or action is taken in a timely manner if targets are not reached. To establish the monitoring process it will be necessary to clarify:

- What will be monitored and how this will be done (including frequency and location)
- Who will monitor
- Who will analyse the result and propose that action is taken
- The person that will take action

For each of the relevant risks routine monitoring needs to be instated preferably based on simple observations and tests, such as volume of chemicals in store, turbidity, pressure, and absence of cracks, rather than complex microbial or chemical tests. For some control measures, 'critical limits' may need to be defined and for these measures it will need to be clear, as much as possible, what action needs to be taken if results are not within these critical limits, as often this will imply that urgent action needs to be taken including for example notifying the health authorities (Table 3.3).

Table 3.3 Example of a control measure that needs to be monitored

Control measure	Hazard	Desired level (limit)	Location (where)	When	Who	What action
Ensuring chlorination	Microbial contamination	Chlorine 0,5 - 1,5 mg/l	Outlet reservoir	At least Daily	Operator	Follow SOP chlorination

Monitoring needs to be reported properly to allow for internal and external audits, but reports need to be very simple comprising a minimum number of data to avoid bureaucracy and additional workload. So better to use simple forms where boxes can be ticked. We can distinguish between operational monitoring, the checking of key indicators related to system performance, such as residual chlorine, turbidity, pH, integrity of screens, stock of spares etc. and monitoring of the control measures.

Monitoring of control measures in first instance implies that they are reported upon by the actor that is to take the action. For example for the control measure: ensuring chlorination it needs to be checked from the operational data whether the levels were outside the prescribed limits. If that is the case the responsible person as indicated in the SOP has to take action and report. In addition management needs to check at times if prescribed limits were passed and whether appropriate action was taken.

3.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. Control measures may include?

A. Restricting use of catchment area
B. Purchasing chlorine from a company
C. SOP of disinfection process

Q2. Indicate which of the following statement is correct. (Several statements may be correct)

A. Validate of a control measure implies to obtain evidence that the control measures can effectively control the hazard and reduce the risk.

B. An SOP needs a registration number, a date, and needs to be updated at least every two years

C. All SOPs are control measures to ensure that good quality water is being provided

Q3. When we look at control measures we look at activities or processes to prevent or eliminate a water safety hazard

A. This statement is correct

B. This statement is not correct

3.7 Assignment

1. Develop a list with all SOPs that exist in your company
2. Identify which of them are control measures for which risk
3. Review if these control measures actually control the risk to a sufficient low level (For this analysis you can divide the SOPs among your team)
4. Indicated which control measures are lacking (based on the risks established in module 2 and the control measures validated in point 3 of this assignment
5. Develop or improve one SOP that controls a risk

3.8 References and further reading

- Dabbak, B. (2017). Hakatere Water Supply Water Safety Plan New Zealand; Ashburton District Council
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3.9 Answers to self-evaluation questions

1: **Answers A and C are correct**. Answer B just purchasing chlorine is not a control measure but a regular activity.

2**: Answers A and B are correct**. Answer C indicates that al SOPs are control measures, but that is not correct. SOP are a description of different type of routine as well as emergency activities. Not all of these however are control measures. Some are just routine operations for example in administrating a new connection in the system

3: **Answer A is correct**. When we look at control measures we look at activities or processes to prevent or eliminate a water safety hazard

If you failed to provide one of the correct answers, then review this module again.

Module 4 *Practical Mitigation measures*

This module introduces technical improvement options to overcome some of the risks that may have been identified.

At the end of this module the participant will:

- *Be able to present some options to reduce some of the risks in water supply systems which may include working closely with water users*
- *Have identified possible remedial actions in their water supply system including issues where they may need to seek expert advice*

4.1 Introduction

Many water supply systems in Ethiopia have limitations in the way they are being operated and maintained, and staff may have limited skills and resources to overcome problems that are occurring. In theory they may have support from external bodies (usually an arm of local or national Government or an NGO) to provide support for problems beyond their capacity but in practice this may be limited or may not be timely and effective.

WSPs offer an opportunity to explore the hazards and risks before they actually occur and to establish the necessary prevention strategies so staff knows what to do when problematic events occur. Part of the WSP may concern the implementation of practical technical improvements looking at all steps from catchment to consumer. We can distinguish between different categories of problems including:

- Inadequate preventive and corrective maintenance
- Problems as a result of mistakes in the design and/or construction
- Water quality problems
- Water quantity problems

The key issue to problem solving is to get a good understanding of the situation and predict and prevent problems before they occur. An essential activity is to discuss operation and maintenance routines with the operator. You can learn a lot from these discussions and you may find for example that monitoring is not part of the routine and that breakdown maintenance is common, with the big disadvantage that this cannot be planned and so repair may take more time and may come at an inconvenient moment.

It is important to take an action oriented approach from the beginning. The review of the systems will show a number of problems which sometimes may be very serious. It does not seem fair to just leave the community and write a report instead of already exploring possible 'emergency' improvements that can be implemented. In high risk systems for example it can be considered as a minimum to advice consumers that water needs to be boiled, chlorinated or treated by solar disinfection at household level at least for children and elderly people. Or a safe source (a deep well handpump for example) may be identified and the community may prioritize this for drinking water supply leaving the other water sources for other uses. Or the water company can set up temporary safe water selling points.

4.2 Water quality improvement techniques

Water treatment may be needed to as much as possible reduce the potential risk involved in ground water or surface water supply. The level of treatment should maintain harmony with aspects such as: the type of risk existing in the water source and water supply system, and the socio-economic conditions in the community. Five issues are essential to take into account.

- ***Select and protect the best water source you can find***. Water catchment and water source protection is in fact the first step in water treatment as this will allow you to prevent harmful materials entering the water. This may include measures such as banning construction of latrines close to wells etc. Source selection may also be an option to avoid fluoride problems. It is well known that fluoride levels may vary considerably in water sources even if they are close to each other. Prioritizing the 'safest' source for drinking water then may be a feasible option to reduce the problem.
- ***Make sure that possible treatment works.*** If no experience exists with a specific treatment system first try it out or have it tried out carefully before you depend on it. Particularly explore the assurance that possible chemicals and spareparts are readily available.
- ***Disinfection*** requires that the water is already of reasonable quality and does not contain a lot of pathogenic micro-organisms or substances such as organic matter that can interfere with the disinfection process. The essence is to ensure that the water quality is sufficiently good (either by selecting a good water source or providing water treatment) that only a small and rather constant dose of disinfectant is needed to make the water safe to drink.
- ***Avoid recontamination of the water***. Unfortunately recontamination of water after treatment is rather common either through leaking pipes or inadequate collection transport and storage of the water. So measures may be need to prevent this.
- ***Household water treatment***. In case continuous water treatment cannot be secured, or if a high risk exist of water being re-contaminated in the water chain prior to its use than household water treatment needs to be explored as the quickest option. Yet this puts an important challenge to individual households as household water treatment may involve cost and adds a number of routine activities to the daily chores.

4.2.1 Physical Disinfection

Disinfection means the destruction, or at least the complete inactivation, of harmful micro-organisms present in the water. At family level the two principal physical disinfection methods used are boiling of the water and solar disinfection. Ultraviolet radiation is gaining acceptance for community water supply because of the reliability of the components and the declining costs.

Boiling is highly effective as it destroys pathogenic micro-organisms such as viruses, bacteria, cercariae, cysts and helminthes ova. It is recommended to filter the water through a cloth when cloudy and to boil for one minute or a bit longer at high altitude where boiling temperature is lower. On the down side it may be expensive as it involves considerable fuel consumption. Also consumers may not like the taste of boiled water and it takes a long time for the water to cool. Shaking the water when it has cooled down may improve the taste. Particularly for vulnerable groups such as babies, and young children water boiling may prevent a lot of problems.

Solar disinfection (SODIS) (Figure 4.1) works on the principle of combination of UV disinfection and heating. Exposing water to sunlight will destroy most germs that cause disease. This is even more effective at higher temperature. To also effectively inactivate amoeba species the water temperature needs to rise above 50°C for at least an hour. One easy method of treating the water is to expose plastic or glass bottles of water to the sun. The recommended time of exposure is six hours on a sunny day. The amount of time the bottle is exposed to the sun will need to be doubled (two days instead of one) when the water is cloudy. The exposure time should also be increased if the weather is not sunny (rainy season). For greater effectiveness place the bottle on a corrugated-iron roof which will help to increase the temperature.

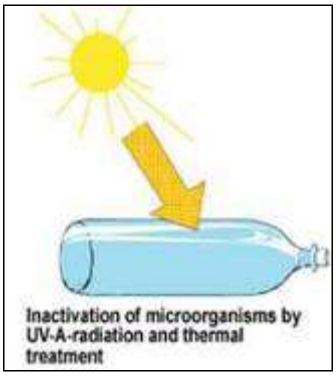


Figure 4.1 Solar disinfection SODIS (Source: www.sodis.ch)

4.2.2 Chemical disinfection

Several chemicals, acting as strong oxidants, can destroy micro-organisms including for example chlorine, ozone and iodine. Here we will focus on water disinfection by chlorination, which is widely used because of its effectiveness, availability and the ability to produce a good persistent residue that can be easily measured and monitored in networks and after delivery to users.

Chlorination of drinking water is carried out in practice through the bubbling of chlorine gas through the water or by dissolving chlorine compounds in the water. At household level the approach is to add a tablet or some chlorine solution to a container of water. Different chlorine compounds are available in the market such as Aquatab, Water Guard, Bishangari, and Pure and come with a description of use on the package.

Chlorine is also used to disinfect wells. Different methods are being used including hanging a container with chlorine compounds in a shallow well. These components will gradually dissolve over time and therewith create a longer term effect. Another method that is applied is the provision of a single dose of powdered or liquid chlorine, after for example a repair or an indication of contamination. An important point here is that it is very important to do a sanitary survey as this may show that there is a continuous risk of contamination because water is drawn with dirty containers or contaminated water infiltrating in the well. Then chlorination is not of much use until the situation is improved. In case of a protected well or borehole where the survey indicates a low risk you would want to seek confirmation by bacteriological testing before deciding to chlorinate. This is even more important when the water is pumped from the borehole to a storage tank with continuous chlorination. If that is the case routine chlorination of the borehole (in some systems they seem to do this every month) is a waste of time and money.

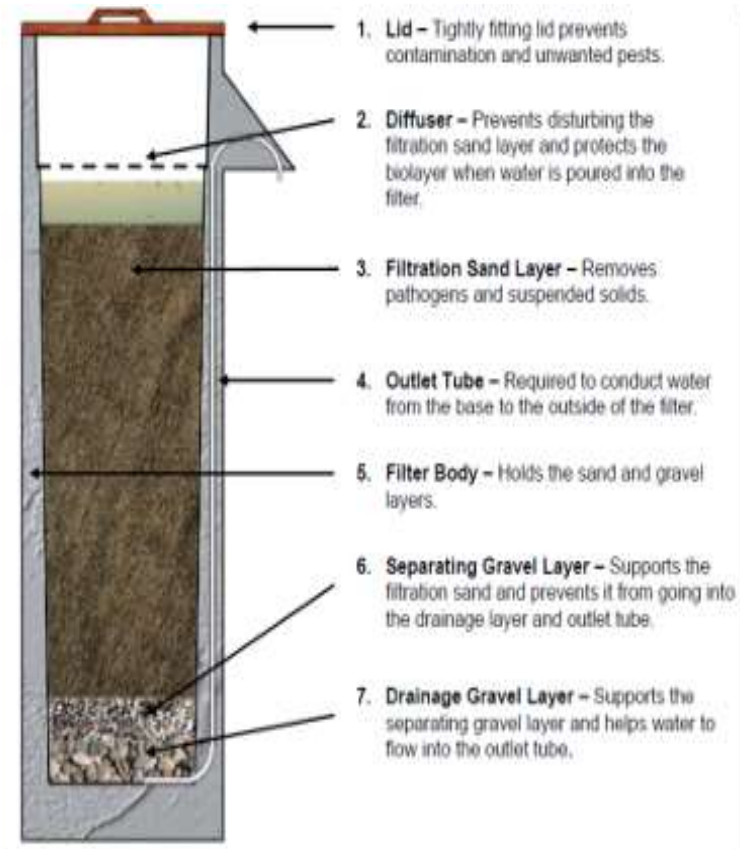
It is essential that the water that is being chlorinated is very low in turbidity and organic content. This is important as the chlorine may react with these impurities thus becoming less effective in killing bacteria and viruses as these may protect themselves by hiding in flocculate material. In case of turbid water this first need to be treated by filtration for example to obtain good chlorination results.

4.3.3 Filtration

One option to improve the transparency of water and partly remove impurities is plain sedimentation. By adding chemicals this process can be further improved. Filtration however gives much better results.

Rapid sand filtration (RSF) is widely used in water supply systems. It is important to mention however that this technology is less suitable for small town water supply as it requires chemicals and a higher level of maintenance. Another point is that RSF systems are only removing part of the micro-organisms, still leaving a considerable risk of transmission of water borne diseases unless the water is properly disinfected after filtration.

Slow sand filtration (SSF) is a very effective treatment. It was one of the first treatment systems that was applied in large water supply systems and is used in many places around the world. In an SSF water slowly passes through a box with sand. After some days a biological film is formed at the surface which comprises a lot of useful micro-organism that contribute to oxidizing organic matter and to the removal of disease causing organisms. The essence of the process is that the water flow is maintained as this provides the oxygen and nutrients the micro-organism in the filter need to do their work.



SSF is also used at household level where they are also called Biological Sand Filters (BSF) (Figure 4.2). Maintenance is easy and comprises of removing the top of the sand layer where most materials have been retained and putting the filter back to work. Also the tube may need to be cleaned. These BSFs do reduce turbidity and remove pathogens but have a limitation in that often the water flow is not continuous which implies that the removal efficiency for harmful organism is not guaranteed. So still some chlorine dosing, solar disinfection or boiling of the water is needed particularly before giving it to young children.

Figure 3.2 Biological Sand Filter

Cloth Filtration is used at household level is cloth filtration. By pouring water through a piece of fine, clean cotton cloth part of the suspended solids and pathogens are removed. This contributes to improving the water quality but is not ensuring the complete removal of the contamination and therefore some chlorine dosing, solar disinfection or boiling of the water is needed. An important advantage is that chlorine and solar disinfection will be more effective as the water is cleaner. The cloth can be washed between uses to restore the straining capacity.

Ceramic filter candles (Figure 4.3) are porous candles which are put in a container with water but also can operate under pressure. Different filter candles are being produced throughout the world, some using the latest techniques to provide a hollow porous ceramic which is fired at a temperature of over 1000°C. The most effective candles have an inner silver coating that kills bacteria that still may pass the candle. This coating however gradually dissolves and therefore the candle needs to be replaced (often after one year in normal use). The most advanced candles use a variety of specialist media to improve taste, odour and appearance as well as to remove chemical and organic pollutants.

Figure 3.3 Modern filter candles

Locally made filter candles may also be available but may be less effective as they may have small (invisible) cracks which may enable some bacteria and viruses to pass through the filter. Hence a risk still remains that the water is not safe unless the silver coating is working and therefore, particularly in the case of locally made filters, still extra measures may be needed for babies and small children.

4.2.4 Fluoride removal

In this course fluoride removal techniques are not discussed as they apply only for specific areas in Ethiopia. It is important however to realize that all fluoride removal techniques are rather difficult to sustain. On the other hand not all sources even within the same communities in fluoride infested areas have similar levels of fluoride. Therefore the first option is to try and select the water sources with lowest fluoride content and reserve these for drinking and cooking water, keeping those with high fluoride for other household chores. An alternative may be to install a treatment system on one of the water collection points and sell water for drinking and cooking separately (and at a higher price to meet cost) from the water that is not defluoridated. For those who face fluoride problems in their area we refer to the study by Haimanot (2005).

4.3 Technical improvements

Technical problems may exist in water supply systems because of design and construction mistakes which as much as possible should be traced back to the source (designer or contractor). Too often such mistakes are the result of mistakes in the design. Also inadequate supervision of construction is a main issue as it may allow contractors to use poor quality materials or to put, for example, less cement and iron rods in the concrete. The problem is that this may very much reduce the life time and the performance of systems and lead to suffering of the users.

Other problems may arise from poor preventive maintenance and repairs particularly in older systems but also from an increasing number of users making that the volume of water is too small to properly satisfy the needs of all users. In this section we will present a few experiences with this type of problems which sometimes can be overcome quite quickly at low cost whereas in other cases larger interventions are needed, that will require external support.

4.3.1 Physical improvements in tanks, wells and springs

In this section a number of suggestions are presented of possible solutions for problems that seem to be quite common.

- **Cracks in storage tanks and wells** often can be repaired quite quickly and even by local masons. It can help to reduce leakage and may reduce the risk of infiltration of contamination. If cracks in tanks are considerable you will need to check for structural problems. Sometimes a quick way to repair is to put chicken mesh wire with a cement coating of some three centimetres on the inside wall and floor of a tank.

- **Leaking overhead tanks** of other materials also need repairs as continuous leakage is costing a lot of resources in pumped systems. A way to calculate the leakage is to fill the tank, close the tap, and measure the fall of the water level over say a period of one to a few hours.

- **Wells running dry** may be caused by falling water tables. An option may be to deepen the well to chase the water table. Yet first and foremost the cause of the problem needs to be assessed. If it results from over pumping for example for irrigation than this may need to be controlled also because irrigation is often very inefficient. Another problem is that deepening sometimes leads to connection with another aquifer which may be of lesser quality. Alternative options may also need to be explored including the construction of a new well.

- **Contamination of wells** may be overcome by properly protecting the well site and the well head.

- **Springs may have important risks,** which may relate to infiltration of polluted water, inadequate protection of the structure or reduced flow because of changes in the catchment area. Different options may exist to improve the spring including repairing cracks and spill ways. Enhancing protection of the area, but also exploring whether measures can be taken in the catchment area that will help to increase water infiltration and reduce run-off. A very important point to take into account is that the intervention should not lead to disappearance of the water. It is always essential to avoid blocking the free flow of water as closing the outlet of the spring will lead to building up pressure in the collecting structure. This may result in the eye of the spring finding another outlet and your structure will become useless.

4.3.2 Improvements in distribution networks

Pressure problems and leakages in distribution networks may be extensive. The risk is that water infiltrates at times of low or no pressure through pipe locations that are leaking and this may cause the water to become contaminated. Often pressure problems may be directly associated with leakages or with lack of control valves to properly distribute the water. There are several options to try to find the leakages even with simple means, but in case of major differences in pressure it will be needed to seek expert advice. In relation to distribution systems you may explore the following:

- **Checking the water loss** (making a water balance) by comparing production and consumption. This involves assessing the water production per day by taking data from the bulk water meter. If no bulk water meter exists but a water tower you may get this information by asking for the pumping hours and by pumping for 10 or 15 minutes into the tower with all outlet valves closed to obtain the pump production per hour). The total then needs to be compared with the volume that is received by the users (either from the water meters or the sales). The difference is the non-revenue water. This includes water loss through leaks, but also because of inaccurate water meters, or illegal connections. The latter may be badly made and therefore may also be a water quality hazard.

- **Reducing water loss** is a challenging task as leakages may not be visible. A visual inspection of network can be useful including being alert on possible leaking taps, wet spots in the ground or differences in vegetation. Also the help of the community is important as they may alert you particularly to visible leaks but also pressure problems. Still this will not help you enough to find the leakages. A better option is to use listening equipment to identify leaks as even small leaks produce a sound. If you do not have access to listening devices you may use an alternative by closing all outlet taps and 'to listen to flowing water' by putting a metal stick through the ground to touch the pipes. This device you can call a 'local listening device' because when you put your ear to the metal bar you will hear water flow if there is considerable leakage. You follow the pipe upstream and repeat the listening and this may help you to detect leakages.

- **Exploring possible meter problems.** This can be started off by comparing the bills of water users. Differences may show up which can be the result of differences in water use (number of users etc.) but also may indicate meter problems. Than the households with 'strange' data (high or low) can be checked. If you find low consumption data but a large family or many users than you need to check the meter. You can do this by replacing the meter temporarily and take it to a test bank, or by putting a temporary additional calibrated meter after the existing one. You may also use a simple approach by tapping a few hundred or even 1000 litres of water and see what the meter indicates. This may be easy if users have water tanks for water storage, but in other cases it may be an option to ask one or more water vendors to help collect this water as they will be able to sell it. An alternative is to replace the meter and check the old one or to put a second water meter after the one you are checking.

- **Low pressure at taps** may be an important problem that may be caused by leakage but also by many people with open taps at the same time, distribution systems with too small pipes or inadequate pressure distribution for lack of control valves. For stand posts this may lead to long waiting lines. One option to tackle this problem is to install storage tanks at the tap points where water can accumulate during periods with low consumption. One added advantage is that the number of taps connected to this tanks can be increased thus allowing more people to get water at the same time. Another advantage is that when a risk of (re)contamination in the piped systems has been identified then it could be considered to put a disinfection device in these tanks.

- **Very high pressure at taps** may also be a problem as it will increase leakage and the number of locations where leaks may occur (thus increasing the risk of contamination when water pressure drops. This problem is quite common in gravity piped systems and may require the installation of pressure break chambers or pipe-reductors.

- **Very different levels of discharge in different taps** is quite common in many systems and is often caused by faulty or absent water regulation valves or by important leakages in some parts of the system. If this is the case probably external support is needed to do a detailed analysis including a calculation of the network to identify the most suitable solutions.

4.3.3 Improvement in pumps

Problems with pumps are common in many places as a result of design and construction failures, falling water tables but mostly because of poor monitoring and maintenance. Particularly lack of preventive maintenance is an issue. This concerns regular maintenance of the equipment and timely replacement of spare parts to avoid systems wearing out /breaking down and may require costly repairs that may take considerable time with water users having to revert to other water sources.

You will need to explore the situation in detail with the operator and management to understand the problems asking among others about age of the system, performance, repairs, availability of fast moving spares etc. It is clearly an issue of finding out what the problems are and not of telling them what to do. It is quite likely that operators have received some kind of training when systems were installed and most likely they did receive instructions for preventive maintenance. So just telling them to do it does not seem to work. The crucial question is why they do not do it and what would it take to change the situation. Monitoring and reporting may help the operator to do a better job.

In this section we will indicate a few common problems with different types of pumps and some suggestions for improvements. It is not the scope of this manual to give detailed information on these improvements or on operation and maintenance and repairs. More information is available on specific systems in the resource materials including for example the manual: Preventive Operation and Maintenance of Water Lifting Devices in the SNNPRS (Abate, B and Migbar Assefe, A., (eds.) 2009). The approach here is to give you some ideas about problems and possible solutions that you could pursue further.

Problems with electrical pumps may be quite varied and may particularly relate to fluctuation in current which may cause burning of pumps. Another very common problem is that performance of the pump may have been dropping because of wear and tear over the years. Lower production may also be caused by lowering water tables. These problems often go in a way undetected because the reduction is gradual and the performance of the system is not monitored and registered. So no data are available to compare.

The electrical part including the switchboard is a crucial part of the system and may have different types of problems including exposed cables that entail a risk of electrocution but also safety fuses that are by-passed, as they switched off the pumps frequently and so the operator gets tired of switching the safety switch back all the time. Yet bypassing safety fuses enhances the risk of pump burning. Checking with the operator gives you a good idea of what is going on and what should be improved. Data on electricity consumption (and particularly changes in consumption) in combination with water production data can provide a good indication of potential problems.

You may benefit for your analysis from the trouble shooting model made by Abate and Migbar Assafe (2009) shown in Table 4.1 which gives you an number of key points to check and to find out what is wrong as well as some possible solutions. It is necessary to take into account that interventions in electrical deepwell pumps often need a specialized organization with heavy equipment for example to lift the pump from the well. Many electrical pumps are not connected to the electricity but to a diesel generator. This implies that the operator also has to provide for preventive maintenance of the generator and to ensure that the pump environment is clean and safe. Also in this case obtaining data on fuel consumption in combination with water production is essential as a possible indication of difficulties, which may include the use of part of the fuel for other purposes. A brief checklist is indicated in Table 4.2 with points to check when looking at generators.

Table 4.1 Trouble shooting for electric deep well pumps

Fault	Cause	Remedy
Electric pump fails to start	switch is set to OFF position	Turn to the ON position
	The motor is not powered	-Check whether motor receives power (fuses burned out, circuit protecting relay activated, defect level gauge or pump cable) - Dry running protection activated due too low water level in borehole
	The motor starter overload tripped out or is defect	Reset the motor starter overload, if it trips out again check voltage. Replace if starter defect
The fuses burnout on start up	Fuse of inadequate size	Replace with proper fuses for the engine
	Insufficient electrical insulation	check insulation resistance, repair or replace
	Damaged power cable / connection	Repair or replace the cable or connection
The overload relay activates after a few seconds or minutes of service	Voltage too low or full voltage is not reaching all the motor phases	Check voltage and contact electricity supplier Check the condition of the electrical equipment -Check the terminal strip is well tightened -check the power supply voltage
	Power draw unbalance between the phases	Check unbalance (see instruction manual) -send pump to authorized service center
	Abnormal power draw	-check that star or delta connections are correct
	Wrong relay setting	check that the setting amperage is correct
	The rotor is jammed or pump fails to turn freely since parts are rubbing	send pump to authorized service center
	Pump fails to turn freely owing to a high concentration of sand	Reduce the flow rate and if needed clean the pump and inspect borehole (clean if needed)
	Electric panel temperature high	Check if relay is set to the ambient temperature Protect electric control panel from sun / heat
The electric pump delivers at poor or no flow rate	Air intake or pump operating in cavitation conditions	Increase installation depth
	Too low water level in the borehole	Check water level; lower pump if feasible but also explore cause for water level reduction
	Motor turns in wrong direction	Inverse two of the three phases
	Check if valve and or non-return valve are partly blocked or disfunct	Disconnect pump and check and if needed send to authorized service center
	Closed sluice valve	Adjust the sluice valve
	Riser pipe or discharge pipe partly blocked by impurities	Check for impurities and clean
	Worn electric pump	send to authorized service center
	Pump head is not sufficient	Replace pump
The electric pump is noisy and vibrates	Plant installed incorrectly drawing water with air	Increase the suction mouth head
	Worn shaft and the guide bearing	send to authorized service center
Frequent start	The differential of the pressure	Increase the differential. But stop pressure must

and stop	switch between the start and the stop pressures is too small	not exceed operating pressure of pressure tank, and start pressure should be high enough to ensure sufficient water supply.
	Water level electrode or level switches in reservoirs not installed correctly / working properly	Check and if needed adjust intervals of electrodes/level switch to ensure suitable time between cutting –in and -out of the pump (installation manual) . If intervals between stop/start cannot be changed pump capacity may be reduced by throttling discharge valve
	The diaphragm tank has a problem	Check diaphragm, adjust pressure (see manual) or replace diaphragm pressure tank

Source: Abate, B and Migbar Assefe, A., (eds.) (2009)

Table 4.2.Checklist for identifying improvement options for generators

Check point	Observation
General impression	If environment and system are dirty it is likely that maintenance is a problem; Particularly check training level, motivation and supervision of the operator
General condition of engine	Check engine oil level, radiator water level (if water cooled), battery water level and possible loose bolts; these are indicators for a possible lack of preventive maintenance
Check possible changes in fuel consumption over time against pump production	May give an indication of problems with the generator or the pump
Check voltage and frequency	Possible fluctuation in voltage and frequency may be very damaging for the pump and if this is the case a review by an expert is needed
Check vibration	This may be caused by engine problems which will require review by an expert
Check color of the smoke	If diverts from normal expert advice is needed

4.3.4 Improvement of household storage and treatment

The household is often a weak link in the water chain as users may easily pollute the water during transport, storage and use. Hence the first action to take is to review the water habits and the risks involved. Is water transported and stored in close containers? Is it withdrawn from these containers in a hygienic way? You may then suggest improvements based on the risks you see and perhaps you can use more careful users to help others. This type of problems need to be discussed with staff from the health authorities and may lead for example to implement a small campaign to improve water handling and household water storage as an action point in the plan.

If the water from the source is not safe or it is not possible to avoid recontamination then it may be an option to introduce solar disinfection or the use of chlorine or at least advice families to boil water for younger children. Also this action may be more in line with the work of the health authorities, but that does not imply that the water company should not take action and inform the users when problems exist.

4.4 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. **An experienced water professional can assess the prevailing problems in a water supply system without asking information from the water users.**
A: Yes
B: No

Q2. **Important water leakages may occur and can be detected by (indicate which answer is correct (multiple answers possible):**
1. Observing and repairing leaking taps;
2. Visual inspection of the area where the network is installed;
3. Making a water balance
4. Making a detailed inspection including the use of a 'local listening device'

Q3. Indicate which of the following statement is correct. (Several statements may be correct)
A: Low water production in a handpump may be caused by worn out washers
B: If water appears only after several strokes of the handle than the pump may have a leaking foot valve or a leaking pipe or cylinder
C: When the water appears only after several strokes than it is very likely that the water table has lowered

Q4. In a water supply system it is important to (several answers possible):
1. Prevent contamination of source waters even if you have water treatment;
2. Treat the water to reduce or remove contamination that could be present to the extent necessary to meet the water quality targets;
3. Prevent re-contamination during distribution, storage and handling of drinking-water

A: Answers 1 and 3 are correct
B: Answer 2 is correct
C: All three answers are correct

Q5. Household water treatment is not needed in systems with chlorination
A: This is indeed not needed
B: This is still very much needed
C: This still may be needed

4.5 Assignment

Take your assignment of module 2.7 and explore possible remedial actions (including seeking expert advice) that can be taken to reduce or avoid the hazards that you have identified in the system that you have reviewed.

4.6 References and further reading

Abate, B and Migbar Assefe, A., (eds.) (2009) Preventive Operation and Maintenance of Water Lifting Devices in the SNNPRS, a general guide line REVISED Final. Addis Ababa: SNV

Brikke, F. and Bredero, M. (2003) Linking technology choice with operation and maintenance in the context of community water supply and sanitation. Geneva: WHO and Delft: IRC http://www.who.int/water_sanitation_health/hygiene/om/wsh9241562153.pdf

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Stevenson, M. (2008) Monitoring Effective Use of Household Water Treatment and Safe Storage Technologies in Ethiopia and Ghana. Massachusetts: MIT

Visscher J.T. (2006) *Facilitating Community Water Supply, from technology transfer to multi stakeholder learning.* IRC, International Water and Sanitation Centre, the Netherlands http://www.irc.nl/content/download/25104/278851/file/TP46_FacilitatingCWS.pdf

WHO, 2008 Household Water Treatment and Safe Storage. Geneva: WHO http://www.who.int/household_water/en/index.html

4.7 Answers to self evaluation questions

Q1. Answer B is correct. Communication with the operator, the WASHCO, the users and people living in the catchment area and supply area is an important part of a sanitary survey. They know about activities that take place in the area, which may be related to specific seasons. They know if the water sometimes becomes turbid. They know if they receive water intermittently or at low pressure etc. If you did not provide the correct answer, then also review Module 2.

Q2. All answers need to be marked. All four options can contribute to the reduction of water loss. The water balance will give you insight in the level of the water loss, the visual inspection may show some problem areas, the listening device will help you to find mayor leakages and dripping taps in fact may produce considerable leakage. Just as an experience put a bucket under a dripping tap and come back an hour later. If you did not mark all answers than better review module 3 again.

Q3. Answers A and B are correct: In fact most problems in handpumps occur because of normal wear and tear of cup seals and washers. Leaking pipes and cracked cylinders are less common, but indeed may occur. Answer C is not correct. A falling water table may cause a reduction in pump flow or the flow may stop entirely if the water level drops below the cylinder. It does however not cause a 'delayed' flow.

Q4. Answer C. All three answers are correct

Q5. Answer C. Even if the water supply system includes disinfection at the source this may not be fully effective to the point of use. So you will need to explore if a risk of recontamination exists. This risk may result from infiltration of impurities in for example pipes which may be common in systems that operate intermittently, but also from water carrying and home storage.

If you failed to provide several of the correct answers, then review this module again.

Module 5 *Towards Water safety plan implementation*

This module completes the steps involved in developing and implementing a WSP which includes completing of the plan, monitoring measures and a management and support programme.

At the end of this module the participant will have:

- *Developed an improvement plan to overcome the priority hazards and risks that were identified*
- *Identified possible support programs that need to be implemented*
- *Completed de WSP document*

5.1 Introduction

Planning and management are perhaps the most neglected aspects of water supply systems in many parts of the world. It is very common that breakdown management is applied combined with the collection of a fee to meet operational cost. Sometimes operators obtain one-off training when systems are being installed with external support. As a result many water supply systems show substandard performance.

The WSP approach can help to change this situation. If significant risks to the safety of water have been identified and control measures need to be put in place an improvement plan needs to be prepared with clear activities, responsible actors, a time frame and (financial) resources. This may include simple action in relation to improving and organizing procedures to capital investment to improve the infrastructure. The plan may include short-, medium- as well as long-term activities which need to be planned with management and may require external support which in turn may have an impact on timing. When resources are scarce careful prioritization should be made in accordance with the risks that were identified. After approval implementation of the plan needs to be monitored, including the timely introduction of new control mechanism. Some improvements may be very easy to implement and no or very low cost. Even if these are not a priority it may be considered to implement these pretty quickly in order to show quick results.

5.2 Development of the improvement plan

The improvement plan needs to cover all risks ranging from medium to intolerable, where priority needs to be given to higher risks as established in module 2. For each of the specific improvement actions that is developed it needs to be clear to what hazardous event it relates, who will be the person that will be responsible to implement the action, what budget is available and when the action needs to be completed (Table 5.1). Preferably the actions are listed in order of importance.

The actions may be very diverse and may include technical interventions, control measures as well as the development or improvement of SOPs. A difficulty may be the availability of (financial) resources, but with a good plan in hand it may be easier to convince external actors that resources are needed. It may also be the case that some of the envisaged measures such as leak detection in fact may reduce water loss and therewith may reduce pumping and chemical cost which represents cost reductions. In this case it may be that management can reorient some resources for that specific action. Other actions may not require financial support such as SOPs but may need staff time to ensure that they can be developed.

Table 5.1 Elements that may be included in an improvement plan

	Specific improvement action	**Arising from** *(relevant hazardous event*	**Responsible party**	**Budget (Birr)**	**Due date**	**Status** *(not yet started, actions undertaken to date, etc.)*
1	Strengthen control of chlorine stock and improve SOP	Risk of microbial contamination of distributed water	Mr. Y	……….	…………	……………….
2	Purchase a new dewatering pump, develop SOP and train staff on new procedures	Risk of physical and microbial contamination from pipeline repair	Mr. X	……….	…………	……………….
3	Improve control of fuel and ensure strategic reserve	Risk of interruption in water supply	Mrs. Y	……….	…………	……………….
4						

5.3 Verification monitoring

With the improvement plan being implemented the water supply system should score better in terms of verification monitoring that assesses whether the system as a whole meets its objectives (Figure 5.1).

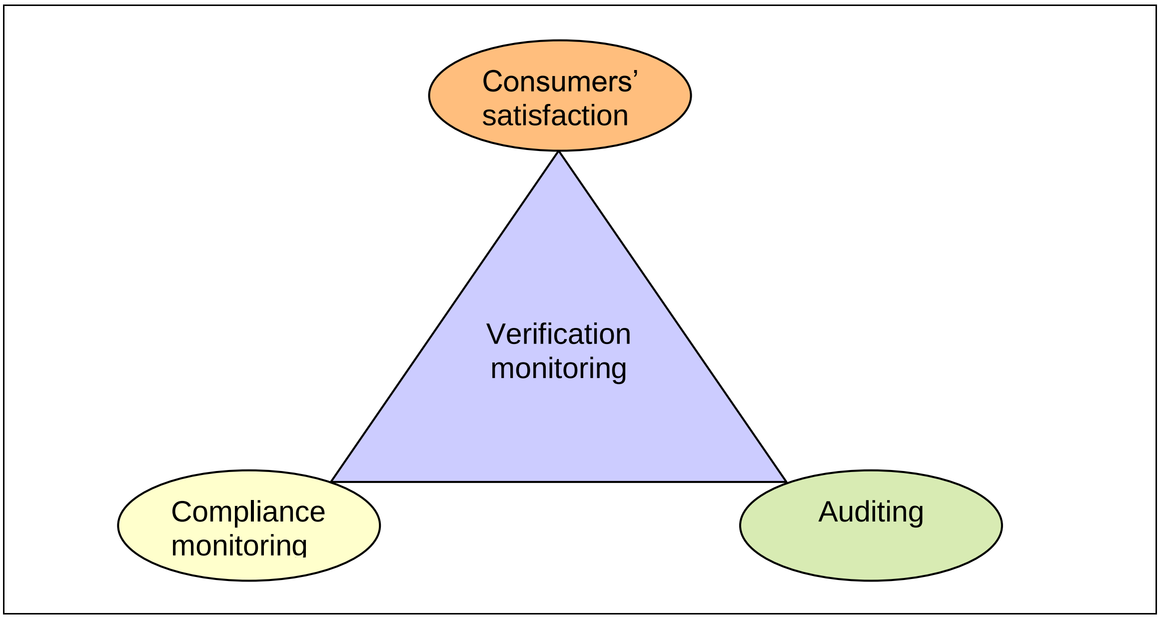

Figure 5.1 Components of verification monitoring based on WHO (2009)

Verification monitoring includes; compliance monitoring being the checking that the system provides water according to standards, and that the WSP is functioning. Internal and external auditing which includes checking the information that is provided, the compliance of operational activities and the effectivity of the WSP. The third element concerns consumer's satisfaction which is very important as it will determine the willingness of the users to support the water company and to pay for the service that is being provided.

5.4 Management and communication

At this stage we can combine the different elements that have been developed and fit these in an overview of the management procedures that apply to the system. It is essential to understand the management that is in place and the way the roles and are being implemented. What are the rules of engagement that are in place? A few key aspects can be distinguished in management

- Who are the actors and what is their role
- Who operates the system
- Who monitors and controls the system (technically and financially)
- Who carries out repairs

This needs to be briefly described in the WSP and may include the roles and responsibilities of the actors involved in the different system components. In addition the SOPs and safety measures can be listed per component, under normal operating procedures, including events that may be more complicated but can be managed without interrupting the water supply. Part of the management procedures concern communication with the users and possibly other actors.

A different issue that needs to be briefly addressed is how management will function under ***emergency conditions.*** This may include for example flooding of the water intake or part of the area may make it impossible to supply water to all consumers. It is good to reflect what can be done in such case so you will be prepared once this happens. In this case communication will be even more important as consumers will need to know what to do with the emergency situation at hand.

Another important issue is that a one-off WSP exercise is not useful as actions will become dated. So at least an annual review of the WSP is needed to ensure that actions are up to date and reflect the developments that are taking place in the system and the catchment area.

5.5 Develop supporting programs

To ensure a good implementation of the WSP it is essential to establish what supporting programmes are needed for implementing the WSP approach. This may entail capacity building, but also issues such as research to optimize system capacity, and calibration of equipment. The process needs to include a review, and as necessary, revision of existing supporting programs and development of additional ones.

Gaps in staff knowledge or skills may impede the timely implementation of the WSP and this may be aggravated by staff turnover. This makes it even more important to clearly document operational procedures so new staff can quickly grasp the approach they have to follow. But equally important is to have training material available such as this manual that staff can consult and review including doing the exercises and discuss results with colleague that have already done the course. .Supporting programmes are activities that support the development of people's skills and knowledge, and commitment to the WSP approach,

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An issue that is often not being considered is how to deal with conflict. This is unfortunate because conflicts are normal and in fact may be having a great potential for growth if the negative energy can be transferred into joint action (Visscher, 2008). So the challenge is not to avoid conflict but to manage it. Conflict avoidance and neglect can worsen the situation. Many conflicts can be dealt with in a positive way through negotiation and joint problem solving. A few key aspects include:

- All parties need to understand the conflict and gain insight in the (subjective) views of the other parties
- Dialogue as the basis for problem solving in which actors listen to each other
- Separating the people (emotions) from the problem, but dealing with both. This aspect may require the involvement of a mediator to facilitate the process. Actors need to learn how to jointly face the problem instead of each other
- Focus on interests instead of positions to open dialogue
- Can problems be turned into opportunities by the actors allowing benefits to be enlarged and better shared?
- Develop multiple solutions to choose from and insisting on using objective criteria, independent of the will of either side, to choose the solution.

If conflicts were identified in the assessment then it is important to include actions that deal with these conflicts and that may include seeking external support.

5.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. An adequate management model:
1. Requires a detailed analysis of the existing system and existing practices
2. Ensures that manuals with all technical specifications are available
3. Includes appropriate monitoring formats for the tasks to be performed

A: Answers 1 and 3 are correct
B: Answer 2 is correct
C: All three answers are correct

Q2. A written report is the most important aspect of a monitoring system.
A: Yes
B: No

Q3. The most important reason to establish a good monitoring format for a water supply system is:
A: The need to have reliable data and a good performance record
B: The need to be able to review the performance of the system over time
C: The need to be able to manage the system

Q4. Verification monitoring; indicate which of the following statement is correct. (Several statements may be correct)

A: Verification monitoring includes compliance monitoring, auditing and assessing consumers' satisfaction
B: The most important issue of verification monitoring is compliance monitoring
C: Compliance monitoring is the part of verification monitoring that includes monitoring of the WSP

5.7 Assignment

Establish with your team:

- An improvement plan for your water company based on the hazards and risks identified including suggestions for distribution of responsibilities, resources involved and timing
- A management plan for normal operating conditions for your water company that includes the WSP
- A brief indication about actions to be taken in case of emergency conditions

5.8 References and further reading

Butterworth, J., Ducrot, R., Faysse, N. and S. Janakarajan (eds) (2007). Peri-Urban Water Conflicts. Supporting Dialogue and Negotiation. Delft, The Netherlands, IRC International Water and Sanitation Centre. http://www.irc.nl/page/38645

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5.9 Answers to self evaluation questions

Q1. Answer A. An adequate management model requires that clear insight is obtained in existing systems and that a good overview is provided of all the tasks and responsibilities, but it is not necessary that all detailed specification of the different technologies are available locally as these will be only relevant for the technicians that will carry out repairs that go beyond the capacity of the company.

Q2. Answer B. In many locations reporting is strongly emphasized, but the main reason of a monitoring system is to generate action when needed. Recording of some data is useful, but it should not be made into a burden as many monitoring aspects do not need to be recorded. So the essence is to establish a monitoring system that clear shows which indicators need to be checked and depending on the results what action need to be taken.

Q3. Answer C. A good monitoring format that clearly describes the indicators to be monitored and the actions required if indicators do not fall into the prescribed levels is crucial to be able to adequately monitor the system. It may also be used for reporting and assessing the performance, but these are not the most important reason. A good monitoring format will help the operator to do his or her job and seek timely support when needed.

Q4. Answers A and C are correct; Based on answer B the system can perform very well, but if consumers are not satisfied the end result will not be satisfactory.

If you failed to provide several of the correct answers, then review this module again.