Introducing Water Safety Plans

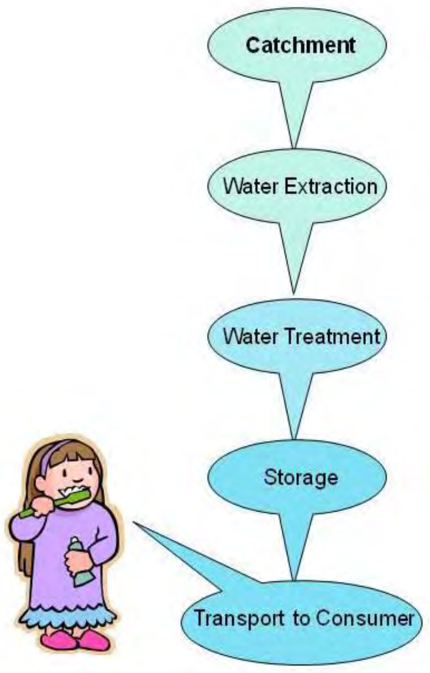
For small-scale piped water distribution systems

Introduction

A central water supply system (cwss) is characterised by its potential to satisfy the water-needs of a group of users via a pipe network. In general small-scale cwss are easier to manage than larger systems. However, this does not imply that the quality of water in smaller systems is higher. Often small-scale systems lack the budget and/or the expertise for water protection measures, adequate treatment of the raw water, or operation/maintenance of the system.

A holistic approach to quality assurance of the water supply system, from the catchment area to the tap of the consumers, is important and includes:

- Assessment and control of source waters to prevent or reduce pathogen contamination;
- Selection and operation of treatment processes to reduce pathogens to target levels;
- Prevention of contamination by pathogens, metals or other substances in the distribution system.



Basic elements of many central water supply networks

Whatever the source is, there should be enough water to sustain the users all throughout the year. The water capacity of a source during several seasons can be estimated by observations and long-term hydrological investigations carried out by experts.

1. Selection of the source water

For the selection of a source several aspects have to be taken into consideration, such as:

Water availability and quality

- Is there enough water available to fulfil the water demand of the community, including dry periods?
- Is the water abstraction in balance with the subsequence delivery of new water?
- Is the quality of the water stable and acceptable – is the water quality and quantity vulnerable for weather events like heavy rainfall or droughts?
- Are possible contaminants removable without complicated and cost intensive treatments?

Type of water source

- The source of a water supply system can derive from several types of water, such as groundwater, spring or surface water (e.g. river).
- Different sources of water have varying qualities and different needs of treatment. If groundwater is well protected against pollutants often no treatment is needed.
- On the contrary surface waters have to be treated in any case.

Location of the water source - accessibility and protection

- The location of the source, e.g. a well, should be chosen in an area where the risks of infiltration of contaminants, e.g. agriculture, are manageable.
- Establishment of different water protection zones should be possible, such as restrictions of human activities.
- The area should be accessible with the equipment required for operation and maintenance of the source.

Removing particles (sand or other particles) **Sedimentation**
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Removing small suspended substances (clay or algae) **Coagulation and precipitation** e.g. with aluminium-sulphate or ferric-chloride
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Removing particles/colloids, odour or colour **Filtration** e.g. sand filter, active carbon filter
↓
Avoiding corrosive properties **Correction of the pH-neutralisation**
↓
Disinfection e.g. with chlorine (chloric gas), hypochlorite, chlorine dioxide or ultraviolet (UV) treatment.

Table 1: Scheme of a simple treatment system for surface water

2. Selection of treatment processes

The type of the treatment depends greatly on the water source, i.e. on the water quality of the raw water. The results of laboratory tests estimate the type and the degree of intensity of the treatment. The treatment's main tasks are to minimise the amount of microorganisms in the supply system, to eliminate particles, and to eventually remove dissolved iron and manganese or other chemicals. Different treatment processes are required to remove different substances. Which kind of treatment finally is chosen depends heavily on the financial and human resources of the supplier. However, the water supplier's task is to deliver drinking water to the consumer, without pathogens and health risks, for a lifetime. Water should be tasty and not corrosive, e.g. through the distribution system or pipes within the households. Water leaving water treatment plants should meet the stringent criteria set by the national and/or EU directive for drinking water.

3. Storage and distribution of water

The conditions of the storage and distribution of water is one of the essential factors to guarantee the quality and availability of water for the consumers. During the storage and distribution safe drinking water may get contaminated by metals or by infiltration of microorganism if the system is not well designed. A well-designed water storage and distribution system should be able to overcome high picks in water usage during day and night, at summer and winter time, and avoid long detention times in the storage and distribution system. Following some elements of a drinking water storage and distribution are summarised.

- Reservoirs, where treated water is stored, allow fluctuations of the demand day and night, and throughout the seasons.
- Reservoirs should be ferment-proof and covered to avoid contamination from pollutants.
- When designing a piped system, sufficient pressure at the point of supply has to be ensured to provide an adequate flow to the consumer.
- For maintaining the microbial quality, it is important to minimise the transit time and to avoid low flows and pressures. The system should not have an excessive capacity resulting in long transit time.
- Low-flow, dead ends and loops should be avoided.
- The materials of the pipes and the water should not allow strong chemical reactions between them.
- Water should contain an estimated concentration of calcium resulting in a protection layer in metal pipes. Most countries established requirements on the quality of material in contact with drinking water e.g. using lead pipes for the construction of a new system is not allowed anymore in many countries.

Appropriate pressure and flow rate

Appropriate pressure should be maintained within a certain range in the whole system whereby the maximum pressure avoids pipe bursts and the minimum ensures that water is supplied in an adequate flow rate to the consumer, even to consumers in the 5^{th} floor of a building. Negative pressure should always be avoided, since it could causes high risks of infiltration of contaminated water in the network. As with the pressure, flow rates are crucial. A flow rate that is too high will result in water being wasted, whereas a flow rate is too low will mean that sanitary fixtures and other appliances in the household will not work properly. Experts should determine the suitable pressure, pipe size and the velocity of water low within the network.

Backflow and intermittent supply

In some situations, the supply is regularly interrupted, sometimes even daily for several hours. Such a situation represents a major challenge to the water supplier to uphold water quality standards.

Backflow is unplanned reversal of flow of water (or water and contaminants) into the supply system. Backflow is caused by a difference in pressure, for example the supply pressure is less than the downstream pressure, allowing water to be pushed in the wrong direction. Different pressures can flow water back into the pipes, which can deteriorate the water quality. In addition by recharging the system surges may dislodge bio films into the pipes, leading to aesthetic problems. The control of hazards, such as stagnant water pools or drains, is important for managing the risks caused by intermittence.

If gravity is insufficient to supply water at an adequate pressure, pumps need to be installed to boost the pressure. Control valves such as pressure reducing valves, non-return valves or throttled valves are designed to optimise the system with respect to pressure, water supply and energy costs. Regular control of pumps and valves is essential to assure the water quality. valves is essential to assure the water quality.

A water tower maintaining
an appropriate pressure day and night

4. Development of a Water Safety Plan for a central piped water supply system

Developing a WSP for a central water supply system contains several modules or steps. The involvement of different stakeholders, e.g. the responsible institution or manager, of the utility is essential. Also, staff for maintenance and operation, consumers or farmers having their fields in the water catchments zones, should take part in the development of an adequate WSP.

4.1. Set up a team

A small-scale centralised water supply system, e.g. for 500 or 1,000 consumers, has many aspects and involves many stakeholders. The establishment of a multi disciplinary team with members like teachers, pupils, citizens, farmers, local authorities and water experts is advisable. As far as possible tasks, activities, and responsibilities of the team and its members should be defined together:

- Identify the required expertise and size of the team,
- Involve multi-disciplinary experts, who will contribute to success,
- Define and report the roles and responsibilities of the team and its members.

4.2. Describe the water system

A description of the whole water supply system is the base for understanding the system and the field of investigation: this includes the current availability of supplies from all sources, the causes of supply problems (e.g. dry streams and wells, pipe breaks, empty dams, damaged or silted up tanks, destroyed roof catchments, etc.) and the systems' status . Furthermore, information on the water sources and the catchment area, the land use in the catchment, details about the treatment, storage, distribution, identification of the users and the water use, and availability of the utility staff are important. For this step in particular the support of the water supplier or local authorities is needed, but field visits from interviewing stakeholders (also citizens) can also provide information. Besides the description and maps, flow diagrams of the utilities are useful instruments for visualising the system.

Step	Description	Responsibility
1	Catchment	Farmer - Utility
2	Transfer - pumping	Utility
3	Primary storage	Utility
4	Settling/sedimentation	Utility
5	Filtration – sand filter	Utility
6	Chlorination – Hypo chlorit	Utility
7	Quality control	Utility
8	Water Meter	Utility
9	Distribution	Utility
10	Water meter	Household
11	In-house network	Household
12	Household use	Household

Table 2: Example of involved stages in a water system - from the catchment to the household level

4.3. Identify hazards, hazardous risks and assess the risks

Each step of the flow diagram that could go wrong, or where hazardous events could happen, has to be identified. This assessment can be done by interviewing, by collecting the experiences of stakeholders and by field visits. Biological, chemical and physical hazards should be assessed, identifying possible points where water could be contaminated, interrupted or compromised. Used materials need to be identified, e.g. by interviews, in case there is suspicion of harmful effects e.g. lead pipes. Laboratory analyses on metals can give additional information.

The water supplier should take water samples before and after the treatment of the water. In any case, at least the quality of the water leaving the treatment system and delivered to the households should fulfil the requirements of drinking water regulated by the drinking water directive.
The causes or indicators of contamination (e.g. leaking pipes, unprotected sources, and discolouration of the water, high turbidity, unusual smell, saltiness, diarrhoea or other possible water-related illnesses within the population) should be identified and reported. Table 3, 4, 5 and 6 give an overview of typical hazards affecting the catchment, hazards associated with the treatment, and hazards within the distribution network. Finally, hazards which could pose a threat to health risks long term, e.g. by chemical pollution or immediate risks by bacteriological pollution, have to be taken into consideration.

4.4. Sanitary surveys and catchment mapping

It is possible to assess the likelihood of faecal contamination of water sources by a sanitary survey of the catchment area. This is often more valuable than bacteriological testing alone because a sanitary survey makes it possible to see what needs to be done to protect the water source. Water samples represent the quality of the water at the time it was collected. Therefore bacteriological testing of water has to be carried out on a regular base. The process of frequent sanitary surveys can be combined with bacteriological, physical and chemical testing to enable field teams to assess contamination and—more important—provide the basis for monitoring water supplies in the post-disaster period. Even when it is possible to carry out bacteriological quality testing, results are not instantly available. Thus, the immediate assessment of contamination risk should be based on gross indicators, such as proximity to

Engine room at the water supplier


After passing kilometres of pipes, the water quality at household level could be decreased and is often not known.

sources of faecal contamination (human or animal); colour and smell; presence of dead fish or animals; presence of foreign matter, such as ash or debris; presence of a chemical or radiation hazard, or a wastewater discharge point upstream. Catchment mapping that involves identifying sources and pathways of pollution can be important tools for assessing the likelihood of contamination.

Many countries developed a guideline for drinking water supply systems on the requirements of water sanitary zones, including allowed activities in the different zones. The implementation of the guideline can be assessed.

It is important to use a standard reporting format for sanitary surveys and catchment mapping, to ensure that information gathered by different staff members and information of different water sources are reliable and comparable.

4.5. Share the collected information with all stakeholders, determine and prioritise the risks

In this stage, it is important to share and discuss the collected information about the water supply system and the identified risks with all stakeholders, including water experts and citizens. Exhibitions and public meetings can be useful instruments. Risks and causes should be prioritised in terms of their likely impact on the capacity and safety of the system. Also the causes of identified risks and problems should be discussed, including aspects about finances and capacity of the water supplier. Is there a budget for adequate maintenance of the system or for the implementation of the requirements of sanitary zones?

4.6. Develop, implement and maintain an improved water supply system

With the results and information of the previous steps, an action plan for short, medium and long-term actions minimising the risks in the water supply system can be developed and implemented. In the action plan monitoring of implementation, results of improvements and adjustment of the WSP should be defined.

Hazardous event	**Associated hazard**
Meteorology and weather event	Flooding. Rapid changes in source water quality
Seasonal variations	Changes in source water quality
Geology	Arsenic, Fluoride, Uranium, Radon Shallow holes
Agriculture	Microorganisms, nitrate, pesticides, slurry spreading
Industry mining	Chemical and microbiological contamination
Transport, roads- railways	Pesticides, chemicals
Housing, septic tanks, pit latrines	Microorganisms, nitrates
Wildlife, recreational use, abattoirs	Microbiological contamination
Competing water use	Sufficiency
Unconfined aquifer	Water quality subject to unexpected change
Well/borehole not water tight	Surface water intrusion
Borehole casing corroded or incomplete	Quality and sufficiency of raw water
Raw water storage	Algae blooms and toxins, stratification

Table 3: Typical hazards affecting the catchment

Hazardous event	**Associated hazard**
Any hazard not controlled/mitigated within the catchment	As identified in the catchment
Power supply	Interrupted treatment- loss of disinfection
Capacity of treatment works	Overloading treatment
Disinfection	Reliability, disinfection by-products
By-pass facility	Inadequate treatment
Treatment failure	Untreated water
Unapproved treatment chemicals and materials	Contamination of water supply
Contaminated treatment chemicals	Contamination of water supply
Blocked filters	Inadequate particle removal
Inadequate filter media depth	Inadequate particle removal
Security, vandalism	Contamination/ loss of supply
Instrumentation failure	Loss of control
Flooding	Loss of restriction of treatment works
Fire, explosion	Loss of restriction of treatment works
Telemetry	Communication failure

Table 4: Typical hazards associated with the treatment

Hazardous event	Associated hazard
Any hazard not controlled/mitigated within the treatment	As identified in the treatment
Mains burst	Ingress of contamination
Pressure fluctuations	Ingress of contamination
Intermittent supply	Ingress of contamination
Opening/closing valves	Reversed or changes flow disturbing deposits Introduction of stale water
Use of unimproved materials	Contamination of water supply
Third party access to hydrant	Contamination of water supply/increased flow disturbing deposits
Unauthorised connections	Contamination by backflow
Open service reservoir	Contamination by wildlife
Leaking service reservoir	Ingress of contamination
Unprotected service reservoir access	Contamination
Security, vandalism	Contamination
Contaminated land	Contamination of water supply through wrong pipe type

Table 5: Typical hazards within the distribution network

Hazardous event	Associated hazard
Any hazard not controlled/mitigated within the distribution	As identified in the distribution
Unauthorised connections	Contamination by backflow
Lead pipes	Lead contamination
Plastic service pipes	Contamination from oil or solvent spillage

Table 6: Typical hazards affecting consumer premises

5. Text sources and further reading

World Health Organisation (WHO), International Water Association (IWA), (2004). Safe Piped Water, Managing Microbial Water Quality in Piped Distribution Systems. Available from: http://www.who.int/water_sanitation_health/dwq/924156251X/en/

World Health Organisation (WHO), International Water Association (IWA), (2008). Water Safety Plan Manual, Step-by-step risk management for drinking-water suppliers. Available from: http://www.who.int/water_sanitation_health/publication_9789241562638/en/index.html