Water safety plan manual
Module 3 supplementary tool: possible threats to the supply of safe drinking-water

This tool is intended to support the practical application of the guidance presented in the *Water safety plan manual: step-by-step risk management for drinking-water suppliers, second edition* (WHO & IWA, 2023). Refer to Module 3 in the manual for detailed guidance.

WSP teams can use this tool to help identify possible threats to water safety, which will inform the identification of hazards and hazardous events (Module 3).

This list is not comprehensive – it is given to stimulate thinking of potential hazards and hazardous events in a particular water supply. WSP teams should decide which threats are relevant to their water supply and adapt the list as required.

When completing Module 3, threats should be converted to hazardous events using the template shown in the box below. Hazardous events are specific for each water supply, so the examples given may not apply to the water supply under consideration.

How to describe hazardous events

A clear and concise way to describe a hazardous event is to use the convention:

X happens because (of) Y

where **X** is the effect on the water supply and **Y** is the cause.

For example:

*Microbial contamination enters distribution pipes (**X**) because of unsanitary pipe repair practices (**Y**).*

In addition to what happens, **X** will often describe the stage of the water supply when it occurs (e.g. source water, network pipe, informal settlement). **X** may also include the hazard type (e.g. microbial contamination, arsenic, pesticide).

Identifying **X** (the effect) and **Y** (the cause) allows the WSP team to understand and assess the associated risk, and to identify appropriate control measures in Modules 4 and 5.

For more comprehensive guidance on threats related to climate change and equity considerations, refer to Climate-resilient water safety plans: managing health risks associated with climate variability and change (WHO, 2017) and A guide to equitable water safety planning: ensuring no one is left behind (WHO, 2019), respectively.

Source threats[1]

Surface water

- Raw or inadequately treated sewage from human settlements
- Industrial effluents – organic, chemical, biological pollutants
- Animal access, leading to faecal material in the waterbody upstream of the abstraction point
- Agricultural activities (e.g. related to application of fertilizer, manure, pesticides, herbicides)
- Cyanobacteria ("algal") blooms in surface-water sources (e.g. lakes, reservoirs)
- Solid waste/refuse disposal sites
- Biosolids storage or spreading sites
- Roads near intake (e.g. accidents, run-off)
- Major spills (accidental and deliberate)
- Animal husbandry in catchment
- Development/construction activity
- Mining activity
- Forestry or logging activity
- Landslides
- Human activities in open reservoirs and waterways (e.g. bathing, clothes washing, recreation, fishing)
- Severe weather events (e.g. flood, drought)
- Increased temperatures
- Increased rainfall, run-off, flooding or snowmelt
- Fires (e.g. bushfires)[2]
- Volcanic eruptions
- Deforestation
- Erosion
- Abstraction-related threats (e.g. clogging of, or damage to, intake structures, including screens)

Example of a surface water threat converted to a hazardous event

Threat: Raw or inadequately treated sewage from human settlements

Conversion to a hazardous event: Source water is contaminated by pathogens (X) because the domestic sewage treatment plant in the catchment is overloaded and discharges poor-quality effluent directly into the surface-water source close to the intake (Y).

Groundwater

- Naturally occurring chemicals (e.g. arsenic, fluoride, iron) and radioactivity
- Agricultural contaminants (e.g. pesticides, nutrients)
- On-site sanitation and sewerage systems
- Chemicals from extractive, industrial and human settlement activities
- Reduced yields (e.g. declining groundwater tables from over-extraction for irrigation or natural causes)
- Salt-water intrusion
- Run-off from surface contaminants into poorly constructed or maintained wellheads
- Backflow into groundwater source

[1] For desalination systems, refer to Safe drinking-water from desalination (WHO, 2011).

[2] Also referred to as forest fires or wildfires.

- Animal access, leading to faecal material at abstraction point
- Severe weather events (e.g. heavy rain, flood, drought)
- Changes in groundwater quality in dry conditions and reduced recharge (especially relevant in groundwater sources that are currently of low quality)
- Abstraction-related threats (e.g. surface water entering well heads after intense run-off or flooding events)
- High water level (reducing natural contaminant attenuation processes)
- Earthquakes (disruption of aquifer)
- Low pH
- Oxidation–reduction reactions in deep wells
- Casing material not suitable for corrosive water

Example of a groundwater threat converted to a hazardous event

Threat: Naturally occurring chemicals

Conversion to a hazardous event: Groundwater contains arsenic above the national drinking-water quality standards (X) because of naturally occurring geological, physical and chemical conditions of the groundwater and substratum (Y).

Water treatment plant threats

This list is for conventional treatment consisting of coagulation, flocculation, sedimentation, filtration and chlorination. Although some of these threats will occur with other treatment process configurations, specific threats associated with other treatment systems should also be considered.

General (applicable to many of the individual processes)

- Inadequate backup for essential equipment (e.g. spare parts, duty/standby equipment)
- Inadequate human resources
- Insufficiently trained operators
- Interruption to the treatment process
- Power failure
- Poor water quality during accidents and emergencies
- Inappropriate plant design
- Flow rates in excess of design capacities
- Inadequate site security
- Inadequate process control or monitoring
- Rapid changes in source water quality or quantity
- Failure of automated alarms and monitoring equipment
- Presence of raw (untreated) water bypass valves (allowing untreated water to bypass the treatment plant and enter the distribution network)
- Contamination during water sampling
- Contamination during maintenance

Example of a water treatment plant threat converted to a hazardous event

Threat: Inappropriate plant design

Conversion to a hazardous event: Hazards are insufficiently removed or reduced (X) because treatment is not well suited to the prevailing source water quality and flow variations (Y).

Coagulation, flocculation and sedimentation

- Malfunction in alum/polyaluminium chloride (PAC) or other chemical dosing
- Improper alum/PAC dosing rate
- Suboptimal pH control
- Exhausted chemical supply
- Incorrect chemical used
- Poor-quality chemicals used
- Inadequate mixing of chemicals
- Insufficient contact time for floc formation
- Improper mixing speed for floc formation
- Malfunction in floc removal mechanism (e.g. scrapers)
- Improper storage of chemicals
- Use of out-of-date chemicals
- Poor calibration of dosing or testing equipment
- Improper selection of coagulant and flocculant
- Dosing pipe clogging
- Dosing pipe leakage

Example of a coagulation, flocculation and sedimentation threat converted to a hazardous event

Threat: Exhausted chemical supply

Conversion to a hazardous event: Harmful microorganisms are not removed from raw water (X) because the supply of coagulant is exhausted, resulting in no dosing of the treated water (Y).

Rapid sand filtration

- Improper or exhausted media
- Infrequent filter backwashing
- Ineffective filter backwashing (e.g. over-frequent backwashing mixes filter layers, filter bed is not completely fluidized during backwashing)
- Filter backwashing using untreated water
- Inadequate filter inspection and maintenance
- Return of backwash water to the head of the plant without sufficient treatment
- Insufficient filter ripening periods
- Incorrect valves and pipe configurations
- Biofilm growth

Example of a sand filtration threat converted to a hazardous event

Threat: Insufficient filter ripening periods

Conversion to a hazardous event: Filtered water exceeds desired turbidity (X) because filtered water is released to filtered water storage before stable performance is achieved after filter backwash (Y).

Chlorination

- pH too high for effective chlorination
- Turbidity too high for effective chlorination
- Chlorine under-dosing (microbial threat)
- Chlorine over-dosing (chemical, acceptability threat)
- Insufficient contact time for pathogen inactivation (e.g. flow short-circuiting or flow rate in excess of design limits)[3]
- pH or temperature change affecting Ct value
- Dosing equipment malfunction or poor dose control
- Poor calibration of dosing or testing equipment
- Incorrect dose calculation
- Chlorine supply exhausted
- Expired chlorine used
- Chlorine of poor quality used (e.g. not for potable use or outside of specification)
- Inappropriate chlorine storage (e.g. in direct sunlight)
- Formation of disinfection by-products[4]

Example of a chlorination threat converted to a hazardous event

Threat: pH is too high for effective chlorination

Conversion to a hazardous event: The effectiveness of chlorine dosing is compromised (X) because the pH of dosed water is above the pH range for effective chlorination (Y).

Distribution and storage threats

Post-treatment storages (e.g. tanks, reservoirs)

- Open tanks or reservoirs
- Access by animals/birds (e.g. through unscreened vents, holes or gaps in tank roofs, cracks in concrete roofs)
- Unauthorized access (e.g. vandals)
- Leaching from construction materials, fittings or liners and internal corrosion
- Entry of run-off from storage tank roof
- Entry of contaminated groundwater (for underground tanks)
- Entry of contaminated surface water (for uncovered reservoirs or underground tanks)
- Contamination during sampling
- Contamination during maintenance
- Sediment build-up and resuspension
- Biofilm growth build-up on internal surfaces and subsequent release (e.g. liners, floating covers)
- Cyanobacterial blooms resulting in metabolites (e.g. taste/odour compounds, toxins)
- Improper cleaning practices
- Inadequate site security
- Long water detention times (excessive water age)
- Flow short-circuiting

[3] For effective disinfection of drinking-water at the point of disinfection, WHO recommends a minimum contact time of 30 minutes where the residual chlorine concentration is ≥0.5 mg/L and the water is pH <8.

[4] Attempts to control disinfection by-products should not compromise effective disinfection.

Note: Where raw water storage is in place before water treatment, some of the above may also be applicable.

Example of a post-treatment storage tank/reservoir threat converted to hazardous event

Threat: Access by animals and birds

Conversion to a hazardous event: Microbial contamination from the entry of birds and small animals (X) because of faults or gaps in tank air vents (Y).

Pipe network (including pump stations)

- Depressurization events
- Unintentional cross-connection (e.g. wastewater, stormwater or greywater pipes)
- Illegal or unauthorized connections
- Leaching of chemicals from pipelines or fittings materials (e.g. solders, joint compounds)
- Change in water chemistry causing internal corrosion
- Poor pipeline repair or installation practices and return-to-service procedures
- Inadequate design controls
- Abnormal flow conditions (e.g. flow reversals, sudden flow rate increases)
- Sediment accumulation and resuspension
- Biofilm build-up and release ("sloughing off")
- Disinfection residual not maintained throughout network
- Exposed pipework
- Excessive detention time in network (increased water age)
- Contaminants drawn into system due to a combination of:
    - low pipeline pressure (e.g. intermittent operation);
    - presence of subsurface contaminants (e.g. sewers, drains, garbage pits, pit latrines); and
    - breaks, loose joints or leaks in pipeline
- Backflow (e.g. from users' tanks or hose connections, industrial processes using high-pressure pumps for process controls)
- Contamination from water tankers, water carters
- Contamination from use of public tap stands (standpipes)
- Power failure at pump stations
- Contamination during maintenance
- Mechanical pump failure

Example of a pipe network threat converted to a hazardous event

Threat: Contamination from use of public tap stands

Conversion to a hazardous event: The condition of the container collection area is unhygienic (X) because of poor maintenance of the tap stand area (Y).

User-level threats

- Water transported or stored in open or unclean containers
- Water transported or stored in unsafe containers (not suitable for potable water)
- Household storage tank not regularly cleaned
- Household storage tank vulnerable to access by birds or animals (e.g. open rooftop tank)
- Poor hygiene practices (e.g. dirty hands and utensils)
- Improper or inconsistent household treatment practices
- Absence of backflow prevention device (see "Pipe network", above)
- Poor management of private systems (e.g. pipe network or storages in high-rise buildings or body corporate systems)
- Use of less safe alternative water sources

Note: See threats above for storage tanks under "Distribution and storage threats" that may be applicable to storage at the user level.

Example of a user premises threat converted to a hazardous event

Threat: Poor hygiene practices

Conversion to a hazardous event: Water stored at the household is microbially contaminated (X) because of use of a dirty utensil (Y).

Special consideration: informal areas

Hazards, hazardous events and risks are magnified in informal settlements. For example, population densities are high, sanitation is often poor, non-revenue water rates are high, and often residents receive water from water kiosks, water carters or tap stands. Management of water systems in informal settlements is often poor. Hence, the likelihood of hazardous events occurring is much greater. Examples of specific threats in such settings are provided below.

Poor sanitation due to:

- open defecation;
- overflowing sewers, pit latrines, bio-toilets and storm drains;
- open drainage; and
- poor solid waste management.
- poor hygiene;
- poor reporting and communication of leaks and other failures;
- limited access, restricting maintenance and repairs; and
- limited governance, planning and operation.

Inadequate supply due to:

- lack of storage;
- high leakage rates;
- high cost of laying pipes;
- poor quality of pipe materials;
- illegal connections;
- inadequate protection of standpipes;