6

Control measures and priorities

The chapter outlines control measures for catchment protection, water treatment and piped distribution systems. All significant hazards in the water supply process, identified during the hazard analysis (Chapter 5) need to be identified as being controlled, or potentially controlled, by some mitigating process.

6.1 DETERMINE CONTROL MEASURES

In many instances control measures (often referred to as 'barriers') will already be in place, where this is the case they should be assessed to determine if they meet current (i.e. health-based target) requirements.

Control measures are identified by considering the hazardous events that can cause contamination of water, both directly and indirectly, and the activities that can mitigate the risks from those events. Control measures need to be identified at the point of contamination (where the hazardous event occurs) as well as downstream so that the effect of multiple barriers can be assessed together.

> Control Measures are those steps in supply that directly affect water quality and which, collectively, ensure that water consistently meets health-based targets. They are actions, activities and processes applied to prevent or minimise hazards occurring

Flow diagrams are particularly valuable to support the identification of control measures. This is because it simplifies the task conceptually. There are likely to be hundreds of control measures for a large system, or for a water safety plan covering many small systems. For example, control measures would include every point-of-use water treatment unit or each backflow prevention valve. To make the water safety plan simpler to develop, control measures that are alike can be represented on a flow diagram as one process step. One result of rolling up groups of control measures into single process steps is that relatively few key process steps emerge. In some case studies of water safety planning these process steps on the flow diagram are given the name Critical Control Points.

Control measures can be effective in reducing the levels of hazards in a number of ways:

- reducing their entry into the water supply,
- reducing their concentration once in the supply; or
- reducing their proliferation.

As control measures should be applied to the whole water supply process control measures for pathogenic and chemical hazards include those that relate to source protection and those that relate to engineered assets, such as well-head protection, drinking-water treatment plants, disinfection plants, storage reservoirs and backflow protection. Most control measures are non-engineered and, for example, many standard operating procedures include water safety considerations. Adherence to the work practice described in such a standard operating procedure can be considered a barrier to contamination and, therefore, a control measure and form an integral part of a water safety plan.

Source protection programmes are likely to include the most diverse control measures and, in some systems, the greatest total number. In many cases, activities to ensure the barriers are established and maintained may not be the sole responsibility of the water supplier, but may require multi-agency action.

6.1.1 Resource and source protection

Effective catchment management has many benefits. By decreasing contamination of source water, the amount of treatment and quantity of chemicals needed is reduced. This may reduce the production of treatment by-products and minimise operational costs.

Effective resource and source protection include the following elements:

- developing and implementing a catchment management plan, which includes control measures to protect surface and groundwater sources;
- ensuring that planning regulations include protection of water resources (land use planning and water shed management) from potentially polluting activities and are enforced; and
- promoting awareness in the community of the impact of human activities on water quality.

Examples of specific control measures are shown in Box 6.1.

Box 6.1: Examples of source water, storage and extraction control measures

Source water and catchments

- Designated and limited uses
- Registration of chemicals used in catchments
- Specific protective requirements (e.g. containment) for chemical industry or refuelling stations
- Reservoir mixing/destratification to reduce growths of cyanobacteria, anoxic hypolimnion and solubilisation of sedimentary manganese and iron
- pH adjustment of reservoir water
- Control of human activities within catchment boundaries
- Control of wastewater effluents
- Land use planning procedures, use of planning and environmental regulations to regulate potential water polluting developments
- Regular inspections of catchment areas
- Diversion of local stormwater flows
- Protection of waterways
- Runoff interception
- Security to prevent sabotage and tampering

Water extraction and storage systems

- Use of available water storage during and after periods of heavy rainfall
- Appropriate location and protection of intake
- Appropriate choice of off-take depth from reservoirs
- Proper well construction including casing, sealing and wellhead security
- Proper location of wells
- Water storage systems to maximise retention times
- Roofed storages and reservoirs with appropriate stormwater collection and drainage
- Securing tanks from access by animals
- Security to prevent unauthorised access, sabotage and tapping and tampering

6.1.2 Water treatment

After source water protection, the next barriers to contamination of the drinking-water system use water treatment processes. Source waters of very high quality may only require watershed protection and disinfection.

Control measures may include pre-treatment, coagulation-flocculation-settling, filtration and disinfection, examples are given in Box 6.2.

Box 6.2: Examples of treatment control measures

Water treatment system

- Coagulation/flocculation and sedimentation
- Alternative treatment
- Use of approved water treatment chemicals and materials
- Control of water treatment chemicals
- Process controllability of equipment
- Availability of backup systems
- Water treatment process optimisation including:
  - chemical dosing
  - filter backwashing
  - flow rate
  - minor infrastructure modifications
- Use of tank storage in periods of poor quality raw water
- Maintaining security to prevent sabotage and illegal tampering

Pretreatment includes roughing filters, microstrainers, off-stream storage and bank-side filtration. Pretreatment options may be compatible with a variety of treatment processes ranging in complexity from simple disinfection to membrane processes. Pretreatment can have the advantage of reducing, or stabilizing the microbial load to the treatment processes.

Coagulation, flocculation, sedimentation (or flotation) and filtration remove particles, including microorganisms (bacteria, viruses and protozoa). It is important that processes are optimised and controlled to achieve consistent and reliable performance. Chemical coagulation is the most important step in determining the removal efficiency of coagulation/flocculation/clarification processes. It also directly affects the removal efficiency of granular media filtration units and has indirect impacts on the efficiency of the disinfection process. While it is unlikely that the coagulation process itself introduces any new microbial hazard to finished water, a failure or inefficiency in the coagulation process could result in an increased microbial load entering drinking-water distribution.

Various filtration processes are used in drinking-water treatment, including granular, slow sand, precoat and membrane (microfiltration, ultrafiltration, nanofiltration and reverse osmosis) filtration. With proper design and operation, filtration can act as a consistent and effective barrier for microbial pathogens and may in some cases be the only treatment barrier (for example for removing *Cryptosporidium* oocysts by direct filtration when chlorine is used as the sole disinfectant).

Application of an adequate level of disinfection is an essential element for most treatment systems to achieve the necessary level of microbial risk reduction. Estimation of the level of microbial inactivation through the application of the CT concept (product of disinfectant concentration and contact time) for a particular pH and temperature required for the more resistant microbial pathogens ensures that other more sensitive microbes are also effectively controlled.

The most commonly used disinfection process is chlorination. Ozone, ultraviolet irradiation, chloramination and chlorine dioxide are also used. These methods are very effective in killing bacteria and can be reasonably effective in inactivating viruses (depending on type) and many protozoa, including *Giardia*. *Cryptosporidium* is not inactivated by the concentrations of chlorine and chloramines that can be safely used in drinking-water, and the effectiveness of ozone and chlorine dioxide is limited. However, ultraviolet light is effective in inactivating *Cryptosporidium* and *Giardia* and combinations of disinfectants can enhance inactivation.

Storage of water after disinfection and before supply to consumers can improve disinfection by increasing contact times. This can be particularly important for more resistant microorganisms, such as *Giardia*.

6.1.3 Piped distribution systems

Water entering the distribution system must be microbially safe and, ideally, should also be biologically stable. The distribution system must provide a secure barrier to post-treatment contamination as the water is transported to the user. Residual disinfection will provide partial protection against microbial contamination, but may also mask the detection of contamination through conventional faecal indicator bacteria such as *E. coli*, particularly by resistant organisms. Thus, water distribution systems should be fully enclosed and storages should be securely roofed with external drainage to prevent contamination. Backflow prevention policies should be applied and monitored. There should be effective maintenance procedures to repair faults and burst mains in a manner that will prevent contamination. Positive pressure should be maintained as far as possible throughout the distribution system. Appropriate security needs to be put in place to prevent unauthorised access and/or interference. Example control measures are outlined in Box 6.3.

Box 6.3: Examples of distribution system control measures

Distribution systems

- Distribution system maintenance
- Availability of backup systems (power supply)
- Maintaining an adequate disinfectant residual
- Cross connection and backflow prevention devices implemented
- Fully enclosed distribution system and storages
- Maintenance of a disinfection residual
- Appropriate repair procedures including subsequent disinfection of water mains
- Maintaining adequate system pressure
- Maintaining security to prevent sabotage, illegal tapping and tampering

6.1.4 Non-piped, community and household systems

These are covered in Chapter 13 'Small systems'.

6.2 MELBOURNE WATER CASE STUDY – CONTROL MEASURES

Tables 6.1 and 6.2 detail the control measures identified for each of the hazards, and associated hazardous event, identified in Tables 5.5 and 5.6 respectively.

Table 6.1: Control measures relating to significant risks identified for chlorination of raw water at primary disinfection plants

Hazard	Hazardous event, source/cause	Control measures
Microbial	Inadequate disinfection method	Minimising ingress of contamination from humans and domestic animals to system (closed catchments) and long reservoir detention times. Source water specifications. Research programme underway to further quantify pathogen loads and disinfection method.
Chemical	Formation of disinfection by-products	Reducing water age through tanks downstream where possible in periods of low water demand. Upstream preventative measures and reservoir management to minimise disinfection by-product precursors (eg managing off takes to avoid higher coloured water) Levels of by-products researched and below guideline levels.
Microbial	Less effective disinfection due to elevated turbidity	None downstream of disinfection. Research programme underway to quantify effect of increased turbidity on disinfection effectiveness. Catchment research completed to show very low levels of bacterial pathogens in raw water.
Microbial*	Malfunction/failure of disinfection plant (i.e. no dosing)	Chlorination plants refitted for equipment and process reliability of 99.5%. On-line chlorine residual monitoring and alarms for low chlorine dosing. Procedures in place to invoke major incident response in any case where chlorination plant off-line. (Standard Operating Procedure Zero Disinfection Event). Contingency Plan (Emergency Disinfection; Disinfection Plant Prolonged Failure; Zero Disinfection Event). Water quality monitoring.
Microbial*	Reliability of disinfection plant less than target level	Defined band widths for chlorine dosing. Plants have stand-by equipment and power.

Hazard	Hazardous event, source/cause	Control measures
	of 99.5%	
Microbial*	Failure of UV disinfection plants	Alarms on power and globe outages. Plant shut down if globes not functioning. Globes replaced annually.
Microbial*	Low chlorine residual in distribution and reticulation systems	Set point designed to achieve microbial standards at consumer taps. Dose rate at plant set to maintain residual.
Microbial*	Power failure to disinfection plant	Dual power source Diesel generator Telemetry
Physical, Chemical, Microbial	Contamination of dosing chemicals or wrong chemical supplied and dosed	Fluorosilic acid has lab certificate from the supplier. On-line monitoring controls. Raw material specification contracts.
Chemical	Over or under dosing from fluoridation plants	Plants have alarms on high and low levels with dosing cut-offs on high levels.
Chemical, Physical	Over or under dosing of lime for pH correction	Plants have alarms on high and low pH with dosing cut-offs on high pH.

* Hazards followed up in Chapter 7

Table 6.2: Control measures relating to significant risks identified for protected water harvesting catchments and large storage reservoirs

Hazard	Hazardous event, source/cause	Control measures
Microbial	Animals in catchment (wild cattle, deer, wallabies, wombats, feral animals)	Long detention times in large reservoirs. Feral animal control programme – shooting, baiting patrol. Downstream detention, disinfection control. Research programme to determine types of pathogens present in native and feral animals.
Microbial Physical	Storms in catchments	Some creeks can be turned out during storm events (Procedure for Operation of Harvesting Sources During Catchment Rainfall Event). Downstream long storage detention.
Turbidity Colour	Bushfire in catchments	Fire management and protection procedures. Bushfire management policy. Fire towers in catchment and patrols. Fire Management Plan. Fire Impacts and Preparedness Plan. Fire Protection Plan. Fuel Reduction Burning Guidelines.
Microbial Chemical	Algal Bloom	Routine plankton monitoring for all reservoirs. Targeted programme for at-risk reservoirs.

Hazard	Hazardous event, source/cause	Control measures
		Emergency Response Plan for Blue/Green Algal blooms.
Microbial	Human access	Closed catchment status (Melbourne Water By-Law 1 prohibits human entry into water supply catchments). Signage. Regular catchment patrols (Catchment Security Manual) and patrols logged in database. Long detention times in reservoirs. Perimeter catch drains around catchment security fence.
Microbial	Reservoir short circuiting	Long detention times. Risk to be quantified through reservoir hydrodynamic modelling research programme.

6.3 KAMPALA WATER CASE STUDY – CONTROL MEASURES

Tables 6.3 and 6.4 detail the control measures identified for each of the hazards, and associated hazardous event, identified in Tables 5.9 and 5.10 respectively.

Table 6.3: Control measures relating to selected significant risks identified at treatment works in Kampala

Hazard	Hazardous event, source/cause	Control measures
Quantity (Gaba 1)	Shallow intake resulting in close contact with algae, plastic bottles, polythene bags and blockage of raw water screen	Ensure intake is set at an appropriate depth by changing depth setting (‘floating intake’). Regular cleaning of area close to intake.
Quantity (Gaba 2)	Tripping of raw water pumps and insufficient production due to clogging of screens	Regular cleaning of screens to reduce clogging and maintain pumping rate
Microbial	Poor performance of Mannesman filters as air scourers are not all operational causing uneven filter bed formation and breakthrough of protozoa	Maintain adequate air scouring rates and ensure all scourers function to maintain even bed formation
Chemical	Excessive algal formations in Patterson filters due to irregular back washing of filters <18 hour intervals	Ensure backwashing occurs based on head loss and flow rate and minimum of every 18 hours
Microbial	No chlorine dosing on high level water due to lack of booster pumps	Dosing rates at 3kg/hr in low water level and then mixed with incoming water
Microbial	Ineffective chlorination due to leaks in buried chlorine feeder line	Maintain minimum of 1 mg/l free chlorine residual at all times

Table 6.4: Control measures relating to selected significant risks identified in the distribution system in Kampala

Hazard	Hazardous event, source/cause	Control measures
Microbial	Birds faeces enter through vents because covers dislodged	Vent covers remain in place and regularly maintained
Microbial	Birds faeces enter through open inspection hatches	Inspection covers are maintained in place and locked to prevent unauthorised entry
Microbial	Ingress of contamination at inlet valve of service reservoir due to inundation of valve box and deteriorating valve packing	Valve box is kept in good condition with adequate external and internal drainage; the structural integrity of box remains effective and the valve packing is in good condition
Microbial	Microbial contamination at valve V 391/V796/V-390, Block Map 2023	Good external and internal drainage; structural integrity of box; valve packing in good condition
Microbial	Microbial contamination at valve -1766/V1765 Block Map 2713	Good external and internal drainage; structural integrity of box; valve packing in good condition
Microbial	Area surrounding tap and sanitary condition of tap allow entry of contaminated water	Community operators and owners trained to keep area close to tap clean and maintain integrity of tap and riser
Microbial	Contaminated water enters through damaged pipes at road crossings	Pipes buried at depth on roadside, collars reinforce joints; regular maintenance
Microbial	Contamination enters through exposed pipes in tertiary mains	Keep all mains buried to design depths; provide secure designs for over-ground pipes; recovering of pipes exposed due to erosion
Microbial	Poor hygiene in repair work allows microbial contamination to enter into the system	Hygiene code for work on distribution mains is distributed and followed by all maintenance staff
Microbial	Contamination of poorly maintained community tanks	Cleaning regime for tanks established for community operators