7

Limits and monitoring

An operational limit (often defined as alert limit or action limit) is a criterion that indicates whether the control measure is functioning as designed. Exceeding the operational limit implies that action is required to prevent the control measure moving out of compliance. The term critical limit is often in some water safety plans to single out operational limits linked directly to absolute acceptability in terms of water safety.

Monitoring is the act of conducting a planned series of observations or measurements of operational and/or critical limits to assess whether the components of the water supply are operating properly.

For each control measure it is important to first define the operational limits (range) which, as part of the overall process train, leads to the supply of water that meets the intended use (including the health targets). However, because it is rarely practical to measure the concentration of hazards directly, some other means of control measure performance needs to be identified and becomes the target of monitoring. Therefore, a relationship between control measure performance, as determined by measurable parameters, and hazard control performance needs to be established. This relationship can be established using theoretical and/or empirical studies (see Validation in Chapter 11). In general long-term performance data, design specifications and objective scientific and empirical analysis are likely to be combined.

Not all measurable properties of control measures are suitable for this type of monitoring. Only where the following criteria are satisfied it is possible to define operational limits for control measures:

- limits for operational acceptability can be defined;
- these limits can be monitored, either directly or indirectly (e.g., through surrogates);
- a pre-determined corrective action (response) can be enacted when deviations are detected by monitoring (see Chapter 8);
- the corrective action will protect water safety by bringing the control measure back into specification, by enhancing the barrier or by implementing additional control measures; and
- the process of detection of the deviation and completion of the corrective action can be completed in a timeframe adequate to maintain water safety.

7.1 MONITORING PARAMETERS

The parameters selected for operational monitoring should reflect the effectiveness of each control measure, provide a timely indication of performance, be readily measured and provide opportunity for an appropriate response. Some water quality characteristics can serve as surrogates (or indicators) for characteristics for which testing is more difficult or expensive. Conductivity, for example, is a widely used surrogate for total dissolved solids. Examples of operational parameters during treatment processes and water distribution are outlined in Table 7.1.

Table 7.1: Examples of water treatment and distribution operational parameters

	Treatment step/process					
Operational parameter	Raw water	Coagulation	Sedimentation	Filtration	Disinfection	Distribution system
pH		✓	✓		✓	✓
Turbidity (or particle count)	✓	✓	✓	✓	✓	✓
Dissolved oxygen	✓					
Stream/river flow	✓					
Rainfall	✓					
Colour	✓					
Conductivity (total dissolved solids)	✓					
Organic carbon	✓		✓			
Algae, algal toxins and metabolites	✓					✓
Chemical dosage		✓			✓	
Flow rate		✓	✓	✓	✓	
Net charge		✓				
Streaming current value		✓				
Headloss				✓		
CT					✓	
Disinfectant residual					✓	✓
Disinfection by-products					✓	✓
Hydraulic pressure						✓

CT = Concentration x time

7.2 OPERATIONAL LIMITS

The water safety plan team should define the operational (or critical) limits for each control measure, based on operational parameters such as chlorine residuals, pH and turbidity, or observable factors, such as the integrity of vermin-proof screens and as shown in Table 7.1. The limits need to be directly or indirectly measurable. Current knowledge and expertise, including industry standards and technical data, as well as locally derived historical data, can be used as a guide when determining the limits. Target or operational limits might be set for the system to run at optimal performance while the term critical limits might be applied when corrective actions are required to prevent or limit the impact of potential hazards on the safety and quality of the water.

Limits can be upper limits, lower limits, a range or an envelope of performance measures. They are usually indicators for which results can be readily interpreted at the time of monitoring and where action can be taken in response to a deviation in time to prevent unsafe water being supplied.

7.3 MONITORING

Monitoring relies on establishing the 'what', 'how', 'when' and 'who' principles. In most cases, routine monitoring will be based on simple surrogate observations or tests, such as turbidity or structural integrity, rather than complex microbial or chemical tests. The complex tests are generally applied as part of validation and verification activities (see Chapter 11) rather than in monitoring operational or critical limits.

Table 7.2 shows what could be monitored if bacterial contamination of source water is identified as a potential hazard and feral or pest animal control and disinfection are identified as control measures. It can be seen from these examples that the frequency of monitoring will depend upon what is being monitored and the likely speed of change.

Table 7.2: Monitoring examples

	Animal control	Disinfection control
What?	Wild pig densities in catchment must be below 0.5 per km^2	Chlorine, pH, temperature and flow must provide for a CT of at least 15 with a turbidity of <5.0 NTU
How?	Scat (animal faeces) surveys in spatially stratified transects across the catchment	Measured via telemetry and on-line probes with alarms
When?	Annually	Telemetry is downloaded automatically and continuously monitored
Who?	Catchment officer	Telemetry engineer

If monitoring shows that an operational or critical limit has been exceeded, then there is the potential for water to be, or to become, unsafe. The objective is to monitor control measures in a timely manner to prevent the supply of any potentially unsafe water. A monitoring plan should be prepared and a record of all monitoring should to be maintained.

7.3.1 Monitoring plan

The strategies and procedures for monitoring the various aspects of the water supply system should be documented. Monitoring plans should include the following information:

- parameters to be monitored;
- sampling location and frequency;
- sampling needs and equipment;
- schedules for sampling;
- methods for quality assurance and validation of the sampling results;
- requirements for checking and interpreting the results;
- responsibilities and necessary qualifications of staff;
- requirements for documentation and management of records, including how monitoring results will be recorded and stored (see also chapter 10); and
- requirements for reporting and communication of results.

7.4 MELBOURNE WATER CASE STUDY – CRITICAL LIMITS AND MONITORING

A number of microbiological hazards were highlighted (by means of an asterisk) in Table 6.1, the control measures for these hazards are summarised in Table 7.3, along with critical limits and monitoring information.

Table 7.3: Critical limits and monitoring related to microbial hazards potentially affecting primary disinfection

Process step	Potential hazard	Control measures	Critical limits	Monitoring
Primary disinfection	Microbial	Operating Procedures for operation of treatment plants Chlorine residual must not be outside bandwidth for >45 min (for process correction – not product safety) Duplicate facilities (e.g. chlorinators, service water pumps, dosing lines, PLC) Backup power generation	No zero dosing*. Chlorine concentration is not to record zero for > 10 minutes. This allows for plant control loop time. Chlorine residual must not be outside bandwidth for > 24 hours. Refer to the Melbourne Water SCADA system for real time access to chlorine set points and low level chlorine alarms. Bands (digital alarm settings) are set at the plants. (* no power or intensity outages for UV plants)	On-line, continuous flow and chlorine residual at the plant controls dosing at a constant set-point. Responsibility: Operations – duty operator responds to alarms on residual. (Digital alarms at plants set on high and low bands. Low level alarms set for very low dosing).

7.5 KAMPALA CASE STUDY – CRITICAL LIMITS AND MONITORING

A number of microbial hazards were highlighted in Table 6.3 and 6.4, the control measures for these hazards are summarised in Table 7.4, along with critical limits and monitoring information.

Table 7.4: Critical limits and monitoring related to microbial hazards potentially affecting water production

Hazardous event	Potential hazard	Control measures	Critical limits	Monitoring
Blockage of shallow intake	Microbial	Set intake at appropriate depth and keep intake area clean		Pumping rates
Tripping of raw water pumps due to clogging of screens	Microbial	Regular cleaning of screens and maintain pumping rate	3,500m^3/hr at 2 pumps (1 in standby)	Pumping rates
Poor performance of Mannesman filters	Microbial	Maintain air scouring rate and ensure all scourers functional	38.7m^3/hr at 0.9bar	Scour rates
Excessive algal formations in Patterson filters	Chemical	Backwashing based on head loss and flow rate (minimum every 18 hours)	<7.7m/hour filtration rate	Filtration rates; inspection
No chlorine dosing on high level water	Microbial	Dosing rates at 3kg/hr in low water level and then mixed with incoming water	3kg/l chlorine dose per dosing pump	Chlorine dosing
Ineffective chlorination due to leaks in buried chlorine feeder line	Microbial	Maintain minimum of 1 mg/l free chlorine residual at all times	0.2-0.5mg/l residual chlorine <1NTU pH of 6.5-7	Free chlorine residual, turbidity, pH

Table 7.5: Critical limits and monitoring related to microbial hazards potentially affecting water distribution

Hazardous event	Potential hazard	Control measures	Critical limits	Monitoring
Birds faeces enter through vents because covers dislodged	Microbial	Vent covers remain in place and regularly maintained	All vents covered; action once 50% of vent support struts are damaged	Sanitary inspection by maintenance teams (daily); sanitary inspection water quality control staff monthly
Birds faeces enter through open inspection hatches	Microbial	Inspection covers are maintained in place and locked to prevent unauthorised entry	Inspection covers locked in place when not in use; Excess loss of chlorine residual	Sanitary inspection by maintenance teams (daily); sanitary inspection water quality control staff monthly; chlorine residual
Ingress of contamination at inlet valve of service reservoir	Microbial	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	Tank structure sound with no cracks; drainage channels in good condition; action as soon as damaged noted	Sanitary inspection by maintenance teams (daily); sanitary inspection water quality control staff monthly; chlorine residual
Microbial contamination at valves	Microbial	Good external and internal drainage; structural integrity of box; valve packing in good condition	Valve boxes covered and do not have standing water or organic material in base; packing does not leak; no increase in turbidity; no loss of chlorine residual	Sanitary inspection (monthly) by operating staff; monthly to quarterly testing of turbidity and free chlorine by water quality control staff
Entry of contaminated water close to tap	Microbial	Community operators and owners trained to keep area close to tap clean and maintain integrity of tap and riser	No waste close to tap; tap and riser in good condition; no increase in turbidity, no loss of chlorine residual	Periodic sanitary inspection by community; periodic turbidity and free chlorine testing by water quality control staff

Hazardous event	Potential hazard	Control measures	Critical limits	Monitoring
Contaminated water enters at road crossings	Microbial	Pipes buried at depth on roadside, collars reinforce joints; regular maintenance	Pipes buried, no sign of leaks	Monthly to quarterly sanitary inspection by water quality control staff
Contamination enters through exposed pipes in tertiary mains	Microbial	Keep all mains buried to design depths; provide secure designs for over-ground pipes; recovering of pipes exposed due to erosion	All pipes buried or with secure protection; exposed pipes indicate action needed	Periodic sanitary inspection by water quality control staff; periodic inspection by community
Poor hygiene in repair work	Microbial	Hygiene code for work on distribution mains is distributed and followed by all maintenance staff	All workers have copy of hygiene code and follow requirements	Turbidity Chlorine residuals Site inspection
Contamination of poorly maintained community tanks	Microbial	Cleaning regime for tanks established for community operators	Tanks clean and in good condition; no increase in turbidity or change in appearance; no loss of chlorine residual; no community complaints	Periodic sanitary inspection by community and water quality control staff; turbidity and chlorine residual testing