Application of quality management systems for drinking water quality

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Abstract Over the past few years the water authorities in Australia have been applying the principles of quality management and risk management in their provision of drinking water of a safe and acceptable quality. These principles have been taken up by the regulatory authorities, and the Australian water industry is ensuring that drinking water guidelines, customer contracts, licences and auditing (both statutory and quality systems auditing), and appropriate quality management systems, are in place for drinking water quality management. A particular focus of this work has been the application of AS/NZS 4360 (Risk Management) and the principles of Hazard Analysis and Critical Control Points developed for the food industry. This paper discusses the important considerations in applying quality management systems to drinking water quality management within water authorities, and the key issues of how best to integrate these risk management systems with the business management systems of the water authority. A generally applicable model for drinking water quality management systems based on ISO 9002 and HACCP is described. The paper also discusses the process of how management systems already in place within a water authority can be assessed and improvements identified. The objective is that the management systems will be consistent with the authority's existing business management systems, ISO 9001, the principles of HACCP and AS4360, and the expected requirements of the revised Australian Drinking Water Guidelines.

Keywords Assurance; drinking water; hazard analysis and critical control points; management; quality; risk

Introduction

Over the last two years many of the major urban water authorities in Australia have been undertaking programmes to improve their management of the drinking water supply systems for which they are responsible (Nadebaum *et al*., 2000).

In this work, the water authorities are applying the principles of both AS/NZS 4360 (Risk Management) and Hazard Analysis and Critical Control Points developed for the food industry (HACCP), usually within the framework of an existing business management system (which is often based on ISO 9002 (Quality Management)). Some water authorities have implemented HACCP, and have achieved certification for HACCP (Nadebaum *et al*., 2001).

It is the purpose of this paper to outline the general approach being taken in Australia in the development of management systems for drinking water quality, and to suggest how the principles of HACCP can be integrated with a business management system such as ISO 9002. It is hoped that the approach outlined will provide a useful focus for authorities interested in applying these management principles, and will be a step in the journey of developing a uniform and appropriate approach to drinking water quality management.

The key elements of drinking water quality management

The requirements for drinking water quality management have been the subject of study by the CRC for Water Quality and Treatment. This work has resulted in the identification of a number of key elements which a good drinking water quality management system should include. These elements are summarised in Table 1.

Water Science and Technology: Water Supply **Vol 3 No 1–2 pp 359–364**

Table 1 Framework for drinking water quality management

Key elements	Description
1. Commitment to drinking water quality management	Drinking water quality policy Regulatory and formal requirements Engaging stakeholders
2. Assessment of the drinking water supply system	Water supply system analysis Assessment of water quality data Hazard identification and risk assessment
3. Preventive measures for drinking water quality management	Preventive measures and multiple barriers Critical control points
4. Implementation – operational procedures and process control	Operational procedures Operational monitoring Corrective action Equipment capability Materials and chemicals
5. Verification of drinking water quality	Drinking water quality monitoring Consumer satisfaction Short-term evaluation of results Corrective action
6. Incident and emergency management	Communication Incident and emergency response protocols
7. Employee awareness and training	Employee awareness and involvement Employee training
8. Community involvement and awareness	Community Consultation Communication
9. Research and development	Investigative studies and research monitoring Validation of processes Design of equipment
10. Documentation and reporting	Documentation and records management reporting
11. Evaluation and audit	Long-term evaluation of results Drinking water quality management audit
12. Review and continual improvement	Senior executive review Drinking water quality improvement plan

These elements are consistent with ISO 9002, AS/NZS 4360 and HACCP, and also other management systems such as ISO14001 (Environmental Management Systems).

While the framework summarised in Table 1 provides an excellent checklist of elements, the interconnection between the elements and staff responsibilities are critical for effective implementation, for review and for audit. These interconnections and responsibilities will be specific to each water authority, and need to be defined. The approach outlined in this paper is structured with this requirement in mind.

Key elements of a quality management system

The key elements of a quality management system consistent with ISO 9002 are summarised in Figure 1. They comprise:

- quality policy (statement of intent which sets the direction/vision);
- water quality manual (defines what needs to be done to manage water quality);
- procedures (defines how management needs to be done);
- work instructions (defines the detail of how management is done);
- records (documents what is done and performance achieved).

The sections of the quality management system with which the HACCP plan interfaces and provides inputs to are shown in Figure 1.

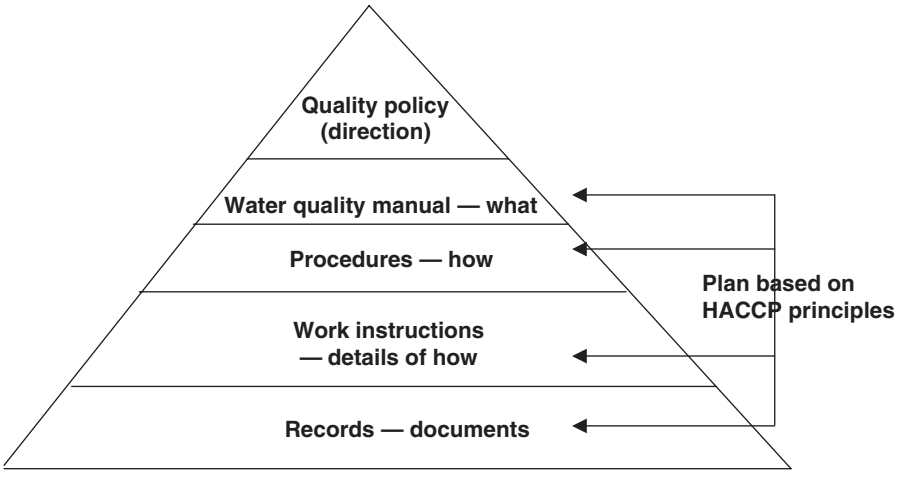

Figure 1 Quality management system and integration with HACCP principles

Developing a water quality management system

The practical steps and issues involved in developing a water quality management system integrated with the business management system are the following.

Stage 1: understanding the water supply system

The first step is to develop a good understanding of the water supply system. This should involve:

- confirmation of the water quality performance objectives;
- inspections of the key elements of the supply system (catchment to tap), interviews with operations staff to identify how each part of the system works;
- assembly of information on treatment processes and performance;
- discussions with operations, maintenance and management staff to identify gaps in the current management systems relating to water quality, using the framework for Drinking Water Quality Management as the reference checklist; this should also determine how water quality is controlled, which reference documents are available or in use, and what goes wrong.

This work should determine how the supply system and the management system operate in practice and what the shortcomings are in terms of:

- written procedures and work instructions;
- uncertainties in operation;
- known high risks;
- possible high risks;
- past failures or near misses.

Stage 2: identification and prioritisation of risks and requirements for control

The next step is to analyse the water supply system to identify:

- the highest risk issues with respect to water quality, for more detailed analysis and improvement of control;
- the issues for which control is critical, for more detailed analysis of control and inclusion in the HACCP plan.

Note that there are two different categories of risk items: one which is not fully under control and presents an unacceptable risk and improvement is required; and another

which are potentially significant and for which control is critical (these may be already be adequately controlled, and may therefore have a low risk).

This work requires a systematic approach to identify the sources of water problems, determine the "hazards" (water quality problems), existing controls (and procedures), the likelihood, severity of impact, significance of each risk, and the effectiveness of existing controls (e.g. water filtration processes, main cleaning programmes).

A hazard in this context would be, for example:

- a contaminated treatment chemical added to a filtration plant which could cause non-compliance or health impact at taps;
- a noticeable taste and odour event at customer taps;
- *Cryptosporidium* oocysts in water leaving a treatment plant.

The significance of a risk depends on how likely or frequently the hazard occurs, and the severity of effects when it does occur (e.g. health impacts, direct financial costs, public outrage, or non-compliance with drinking water guidelines). In the analysis it is important to consider different scenarios for each source of risk, such as a less likely more severe event, and a more likely, but less severe, event.

When determining risk and requirements for improvement, it is essential to consider the set of controls which apply, and their effectiveness. For example, water quality problems in a catchment may have a severe effect on water quality at the location where they occur, but may be fully controlled through a downstream reservoir and treatment plant and may therefore not present a significant risk to customers.

In this process, risks which should be managed by others will also be identified, and development of appropriate agreements or memoranda of understanding.

Finally, risks which are currently of low significance because they are well controlled will be identified and, importantly, the key control measures which need to continue to be exercised will be defined.

Stage 3: evaluation of controls for high risk water quality hazards

The next stage of work is to carry out a further assessment of the controls and their effectiveness, focusing on the issues which have the highest risk or where control is most important. This has two objectives:

- to identify the most important control points (including critical control points), and associated control limits for inclusion in the HACCP plan;
- to analyse the high risk water quality problems (i.e. those which are not fully under control) and to determine the improvement that should occur.

For each of the most important control points (the critical control points), monitoring requirements, corrective actions (e.g. incident response), verification actions (e.g. review of planned versus delivered maintenance) and validation (e.g. compliance at customer taps) should be identified, and water industry specific plans using the principles of HACCP should be prepared.

Stage 4: development of an overall management system

The first stages of work (particularly Stage 1) will indicate where there are gaps in the management system, and where improvement in the management system is required to assure water quality.

The DWQM system needs to include the following documentation:

- *Quality policy*. Statement of intent setting direction or vision for water quality management. This would be signed off by the board. An example of a typical policy is included in the DWQM framework.
- *Water quality manual*. A road map document which defines *what* needs to be done to

manage water quality. For each item in the framework, specific statements relevant to the water authority management practices and water supply system should be prepared. Responsibilities for implementation and review should also be described. Practically, this document can best be prepared using the DWQM framework as a checklist of issues for considering and defining what is to be done.

- *Procedures*. These define in broad terms *how* water quality management needs to be done. There may only be 7–11 of these covering subjects such as:
  - Process control (including reference to the contributions of operations and maintenance manuals and asset management activities to treatment process control)
  - Verification and validation of drinking water quality (includes monitoring of water quality)
  - Human relations management (includes training of WTP operators)
  - Document and data control (includes how documents are updated)
  - Records management (the records which demonstrate how due diligence is achieved)
  - Procurement (includes how chemicals and equipment spares are obtained and stored).

The procedures will reference other supporting documents, such as regulatory requirements (e.g. the 1996 Guidelines), and work instructions.

- *Plan based on HACCP principles*. This contains information relating to the control of control points within the water supply system. This plan will include sections on:
  - HACCP team
  - Product description and intended consumers
  - Raw water received from bulk suppliers
  - Water reaching customer's meters
  - Treatment chemicals
  - Supporting programmes
  - Process flow charts
  - Hazard identification
  - Risk assessment
  - Risk register
  - Alert and critical limits
  - Monitoring and corrective action procedures
  - Verification
  - Validation
  - Verification and validation records.

The relation between this plan and the other elements of the Quality Management System is shown in Figure 1. This plan provides documentation relevant to the sections of the Quality Management System shown in Figure 1. It provides detail of how water quality is managed by the treatment systems and who does what in a form suited to the catchment to tap responsibilities of water authorities. It also deals with supply problems unique to the water industry, such as no product recall. Information relating to control of water treatment systems (e.g. avoiding blue green algae, flocculation and filtration unit processes and repair of bursts in water mains) can be summarised and grouped, in this plan. The grouping should reflect the users of the Plan:

  - In the case of an operator of the critical unit processes, such as a filtration system, a summary table can group information on monitoring, corrective action, verification and validation requirements for critical control measures such as filter run time and rate of change of filter speed which prevent high filtered water turbidity.
  - In the case of a manager demonstrating control, and for an auditor, information may be grouped in terms of similar activities such as a register of verification activities.

- *Work instruction (WI)*. These define in detail how management of water quality is done (e.g. incident response plans).

- *Records*. Capture of what was done and performance achieved, e.g. annual report on water quality to board and the relevant regulatory authority.

Conclusions

All of the major urban water authorities in Australia have reviewed their practices for management of drinking water quality, and have been undertaking programmes for improving their management of drinking water quality. The management systems that are being adopted vary depending on the business management system that is in place. Generally, these systems are consistent with the principles of quality management (e.g. ISO 9002), NZS 4360 (risk management) and HACCP (Hazard Analysis and Critical Control Points developed for the food industry). However, there is considerable variation in the way in which these principles are being applied, and there is a need for a more uniform and industry-friendly approach.

The principles of HACCP can be integrated with a quality management system based on ISO 9002 principles, and this can form the basis for a good drinking water quality management system.

The Drinking Water Quality Management framework can be of considerable assistance in forming a checklist for the elements of a water quality manual: a key component of a water quality management system.

In assisting water authorities in the development of water quality management systems, and in reviewing management systems developed by others, we have found that the following issues are key to success:

- Clear definition of the water quality objectives and the allowable variations in water quality.
- Sufficient details of the cause and occurrence of each significant hazard.
- A good understanding of the existing management system, where the gaps are, and what is not working well.
- A good understanding of the control measures that are critical for maintaining control, and what needs to be monitored to ensure effective control.
- Involvement of operational and management staff through the process of development of the management system to ensure its relevance is understood by staff.
- The appropriate level of detail needed in the plans (based on HACCP principles) for system operators to find the plans useful.
- The way the plans are organised for use by organisations where there are operational responsibilities extending from catchment sources to point of consumption and there is little chance of effective product recall.
- Clear definition of the responsibilities and relationships between those who have management responsibility, those who have operational responsibility, and those who review and audit performance.

Acknowledgements

This work has had inputs from many people, including Samantha Rizak of the CRC Water Quality and Treatment, and from the water authorities, with whom the work outlined in this paper has been undertaken. Their contributions are gratefully acknowledged.

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