HAZARD ANALYSIS AND CRITICAL CONTROL POINTS FOR WATER SUPPLIES

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63rd Annual Water Industry Engineers and Operators' Conference
Civic Centre - Warrnambool
6 and 7 September, 2000

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ABSTRACT

Food safety plans have incorporated Hazard Analysis Critical Control Point (HACCP) principles for many years now to control the risks of contamination. The main thrust of HACCP systems is to understand the risks associated with the process and start focussing process control away from end-point testing and towards control of the critical operations earlier in the process. The result is production with higher quality assurance and greater opportunity to correct non-conforming product.

This paper describes how HACCP can be applied to public drinking water supplies and demonstrates the way in which Melbourne Water has developed HACCP. It outlines the approaches taken to risk assessment and identification of Critical Control Points and the integration of HACCP within water supply operations.

KEY WORDS

HACCP, water supply, risk assessment, hazard

1.0 INTRODUCTION

Hazard Analysis Critical Control Points (HACCP) is in its infancy for the water industry but has provided controls for the safety of foods for over three decades. Developed by the World Health Organisation and adopted internationally, it is the primary risk management system for the food industry.

Why might HACCP be necessary for our current drinking water systems, considering such sophisticated treatment technologies are available?

In recent years developed countries with conventional water treatment systems have still experienced water-borne disease outbreaks. The UK Department of Environment, Transport and the Regions (1998) reported on 25 known outbreaks of cryptosporidiosis associated with consumption of public drinking water supplies in the UK since 1988.

During 1998, pathogen monitoring in the Sydney distribution system detected some form of contamination. An industry-wide lack of knowledge was manifested about the significance of various pathogens and the lack of knowledge and control of modern water supply systems. The importance of relying on more than the treatment barrier to contamination was emphasised in the final report of the Sydney Water Inquiry by Peter McClellan QC (1998), in which it concluded: "*There is general agreement that the most effective approach to keeping Cryptosporidium and Giardia from a water supply is to adopt a multiple barrier approach.*"

Advances in pathogen testing have outpaced the understanding of their health significance leaving water authorities and health regulators in a quandary. On this issue McClellan (1998) stated, "*It is clear that the developing science has advanced beyond the capacity of the health authorities to provide an effective response*". Should there be assigned numerical limits for pathogens, mandatory testing or prescribed treatment systems?

Scientifically based, process oriented management systems such as HACCP are an alternative being investigated for inclusion as part of the rolling revision of the Australian Drinking Water Guidelines (NHMRC/ARMCANZ 1996).

The issues above have added to the demand for water authorities to give greater assurance to consumers and industries of water safety. This has put more emphasis on risk management, quality assurance and process control within the Australian water industry.

2.0 THE HACCP PRINCIPLES

The intention of a HACCP system is to focus on preventing or controlling hazards early in the process rather than relying mainly on end-point testing for quality control.

The HACCP Guidelines "Codex Alimentarius" (FAO/WHO 1996), meaning food code, detail 5 preliminary steps and seven principles for implementing HACCP. The preliminary steps are to assemble a HACCP team, describe the product, identify its intended use, construct a flow diagram and confirm the flow diagram on-site.

The seven principles are:

- *Conduct a hazard analysis.*
- *Determine the Critical Control Points (CCPs).*
- *Establish critical limits*
- *Establish a system to monitor control of the CCP.*
- *Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.*
- *Establish procedures for verification to confirm that the HACCP system is working effectively*
- *Establish documentation concerning all procedures and records appropriate to these principles and their application.*

A Critical Control Point is *"a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. The intent of the HACCP system is to focus control at CCPs*" (FAO/WHO 1996).

HACCP complements the principles of barriers to transmission of pathogens outlined in the Australian Drinking Water Guidelines (NHMRC/ARMCANZ 1996). The structured approach of HACCP to analysing hazards (to food safety) provides a means of assessing the existing barriers to contamination and improving upon their operation.

The application of HACCP within an organisation needs to be well supported by management and management systems (or "pre-requisite programs"). Management commitment and the principles of continuous improvement, incorporating auditing and management review, should support HACCP particularly because it is necessary that the HACCP system be continually updated whenever there are changes in the raw products, equipment design, operations or scientific knowledge on hazards. Consequently, quality management systems in accordance with the international standard ISO 9001 are important supports to HACCP.

3.0 CAN HACCP WORK FOR WATER?

3.1 Differences between the food and water industries

Although well established within the food industry there are some important differences in the water industry which need to be considered. The most obvious are:

- the diverse range of possible water-borne hazards, particularly from multi-use catchments
- the continuous nature of supply between raw water sources and consumption
- treatment facilities that are often monitored and operated remotely via telemetry, and
- the large, complex distribution networks

The HACCP Guidelines state: *"It is important when applying HACCP to be flexible where appropriate, given the context of the application taking into account the nature and the size of the operation."* (FAO/WHO 1996).

The diverse range of water-borne hazards can be assessed individually or in some cases groups of microorganisms, or chemicals can be assessed. For instance, groups of bacterial pathogens transmitted by birds such as Campylobacter and Salmonella spp. might be assessed together. As too might bacteria that are known to regrow in distribution systems. The protozoan hazards may be more specific in their prevalence in the catchment and unique in their resistance to disinfection, therefore warranting individual analysis. It is essential that the HACCP team includes representatives with the appropriate microbiological and chemical expertise to make these assessments.

The supply of water on a continuous basis from raw water (untreated) to tap results in the problematic management of any non-conforming product (ie. water deemed "unsafe"). The water is not precisely traced within the distribution system, although water quality models coupled with advanced flow monitoring systems are advancing rapidly. Therefore, much of the management of water that has been improperly treated or potentially contaminated relies on operational experience and cannot be described prescriptively for every circumstance. If water quality monitoring of treated water provides evidence of contamination the information, in some cases, is received too late for corrective action prior to significant amounts being consumed. This makes the need for preventive measures and corrective actions early in the process even more important for water supply systems.

Usually food manufacturing plants are completely contained in one factory location and it is relatively easy to validate the process flow. Site specific hazards and HACCP plans can be developed. However, for water systems multi-site HACCP plans are needed (particularly for large urban systems) and it is necessary to simplify the process description to an extent that does not compromise the identification of hazards. This is particularly so of the distribution system where generic process flow diagrams are inevitable.

Describing the critical control points may also benefit from some generic representation if there are many similar CCPs throughout the system. For example, at a disinfection CCP the critical limits, monitoring, corrective actions and verification systems might apply the same operational systems for many other disinfection plants controlled by the organisation. The systems and procedures for any remote operations via telemetry are crucial elements of the CCPs.

HACCP requires that *Prior to application of HACCP to any sector of the food chain, that sector should be operating according to the Codex General Principles of Food Hygiene, the appropriate Codex Codes of Practice, and appropriate food safety legislation"* (FAO/WHO 1996). When translated to water this means that HACCP should be applied to systems that already meet health-related regulatory requirements.

3.2 Developing Melbourne Water's HACCP Plan

The first step was to assemble a team with the appropriate expertise in water systems (catchments, water treatment etc.), microbiology, chemistry and local operations. This produced a mix of disciplines and organisational levels within the team. Representatives of the retail water companies (which manage the local distribution and reticulation systems) were included. The Melbourne Water team members all received formal training in HACCP prior to the workshops.

The workshops were conducted with the team to systematically proceed through the Codex Alimentarius HACCP principles and preliminary steps and to produce the necessary information for documenting the plan.

The team leader presented a draft product description, intended product use and process flow diagrams for the team members to discuss. The comments received from the team and informal consultation with the retail companies were then considered in finalising these details. Responsibility for confirming various components of the diagram in the field was given to individual team members belonging to field teams.

The Melbourne Water system was separated into four discrete major systems from catchment to retail company interface point. This allowed the unique water quality risks associated with each system to be examined but also allowed the grouping of common elements such as pipelines and tanks across the four systems.

The analysis of hazards by the team built upon the risk assessment work done previously by similar Melbourne Water teams under the direction of engineering consultants. At each process step the sources of risk to water quality (eg. native animals) and the associated hazards (eg. bacteria, viruses) were identified. Then the existing control measures were identified at that process step and the significance of the risk determined without consideration of the downstream controls. A simple matrix of likelihood and consequence with a range of 1 to 5 was used for assessing the risk.

The risks determined to be significant were evaluated further for Critical Control Points (CCPs) and other points of downstream control using the decision tree in Codex (see Figure 1 below). This is done starting at the upstream end of the process (the catchments) and working downstream.

The sub-teams then identified critical limits, monitoring systems and corrective actions for each CCP. Some critical limits could not be validated within the workshop setting and required technical investigation prior to implementing the plan.

Verification, validation, record keeping and documentation systems were addressed in part during the workshops. Most of these issues were developed further after the workshops during the documentation of the plan which was carried out by the team leader (Melbourne Water's HACCP representative).

3.3 Where are the Critical Control Points?

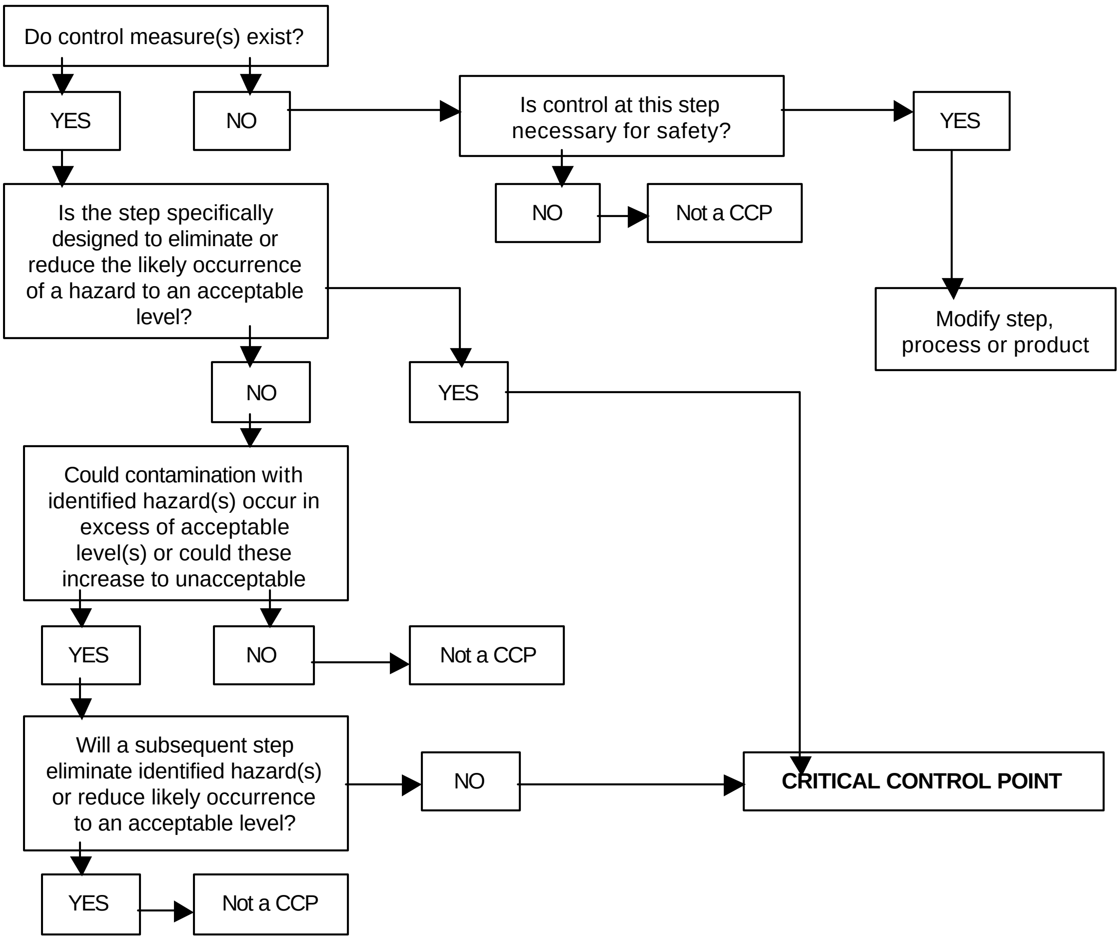
Possibly the most problematic of the HACCP planning steps is determining the Critical Control Points (CCPs). Codex provides a decision tree to assist with a logical procedure for this but the use of this decision tree is not mandatory.

Invariably it appears that those establishing a HACCP plan for the first time identify a large number of CCPs (ie. over 10). When developing the Melbourne Water plan there were initially 26 CCPs identified but it was soon realised that many of the controls being dubbed CCPs didn't practically work as CCPs. Therefore, some operations which were initially specified CCPs were not designated CCPs in cases where :

- The risks were adequately managed with standard procedural measures or "good manufacturing practice" which prevent or reduce the hazards entering the water (eg. catchment management procedures, reservoir security inspections, managing sediments and stagnant zones during operation the distribution system), or
- Adequate downstream controls exist.

The net result of this re-evaluation was that the CCPs for the Melbourne Water system are at the treatment plants. That is for Melbourne Water, at filtration, disinfection and pH correction. For comparison with the food industry, pasteurisation is a CCP for processing milk where temperature, time and mixing are monitored to ensure pathogen destruction.

Figure 1 : ***The Codex Decision Tree***



3.4 Critical Limits

CCPs must have critical limits which are scientifically validated wherever possible. The process must measure parameters to determine deviations beyond the critical limits at a rapid frequency that allows adjustments to maintain control within the limits and corrective actions before the product is consumed.

For water treatment plants it is important to establish critical limits that are practical for operating the plants. Therefore, some parameters used to validate the critical limits are not necessarily the same as those monitored at the Critical Control Point.

For example, in the case of disinfection with chlorine, these limits are validated by the scientific literature and guideline recommendations relating to the inactivation of microorganisms with specific Ct values and chlorine contact times. However, unless the control system is calculating Ct values on a continuous basis for operators to respond to it is not practical to set a Ct value as the critical limit because the limit must trigger a corrective action in time to manage the water downstream. In such a case, a specific chlorine residual level at the plant should be the practical limit which has been calculated (or "validated") to achieve the required Ct values.

3.5 The role of water quality monitoring

"HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing." (FAO/WHO 1996).

Water quality monitoring within the distribution system should be used primarily as a verification of the process control of hazards upstream. Of course this does not remove the need for response protocols and corrective actions where guideline values are not met. However, it does mean that monitoring programs should be designed to give an optimal performance assessment of the Critical Control Points.

For instance, the use of heterotrophic plate counts will give a more sensitive measure of disinfection performance than coliforms. Also, infrequent pathogen monitoring within the distribution system provides little value in verifying the effectiveness of upstream barriers. The information gained for understanding and managing risk is greater from monitoring high risk source waters for pathogens (and other indicators) and monitoring other treatment plant indicators (eg. turbidity and particles).

Through the identification of hazards, preventive measures, associated risk and Critical Control Points, HACCP can help optimise water quality monitoring programs.

4.0 APPLICATION WITHIN WATER SYSTEM OPERATIONS

There will be little sustained commitment from water authorities and individual employees to implement HACCP if there are not real improvements evident to operations. Some of the practical ways in which the initial implementation of HACCP within Melbourne Water is bringing improvement are:

- Correction to treatment plant alarm settings and improved awareness of alarm functions
- Clearer responsibilities for corrective actions
- Improved change control over treatment plant settings
- Control over important documents (particularly operating procedures and contingency plans)
- Key performance indicators at CCPs
- Documentation of procedures relating to significant water quality risks (eg. procedures for notifications during chemical spills in catchments and procedures for the isolation and draining of tanks).

One of the major benefits of developing the HACCP plan for Melbourne Water is the coordination of many systems related to process control into one management system.

This includes catchment protection plans, transfer system operation rules, treatment plant procedures, the incident management system, water quality research and future strategies, water quality monitoring programs, maintenance programs, training programs, supply contracts (particularly treatment chemicals) and customer feedback.

4.1 Operator training

Operators must be able to demonstrate their competence to fulfil the HACCP system requirements at Critical Control Points and for other operational preventive measures. This does not mean that operators need to understand all the theory of the HACCP principles, but they should at least have a general awareness of HACCP as a system for managing product safety. They must also understand of the significance to water quality of their role within the whole process.

They must also demonstrate that they carry out operating procedures, monitoring, corrective actions, documentation and record keeping in accordance with the HACCP plan. Again, this does not mean that operators need be well versed in the HACCP plan but the organisation must ensure that what takes place in the field is consistent with the plan. For the implementation of Melbourne Water's plan the existing systems at CCPs were already well established and the HACCP plan was able to provide a logical framework of process control by documenting or referencing these existing systems.

Work instructions and procedures should be documented and available at the places of operation. It is sometimes difficult to determine the level of detail required for written instructions and which procedures require documentation to support operator training. Basically, the combination of operator competence and work instructions should be able to adequately demonstrate operational control. HACCP by its nature helps focus attention to the significant risk areas and the CCPs, so at least documentation, at whatever level of detail, can be directed towards the priority areas.

4.2 Treatment plant monitoring controls

Where a treatment plant is a CCP, the monitoring must provide for a clear and immediate response to any breach of the critical limits. Therefore well managed control settings and alarm settings are crucial. Response protocols for alarms including clearly defined responsibilities should be incorporated in the HACCP plan and reference should be made to contingency plans for managing the inadequately treated water downstream of the plant.

The corrective action will take two forms: that required to bring the process back in control – ie. bringing the plant back into correct operation and that required to manage the water downstream of the plant. The former is practically the responsibility of a competent operator on duty but this operator is normally not in a position to manage the water downstream. Therefore others in the organisation are usually deployed for this latter issue, which will often need the coordination of other authorities, and in the worst cases the health department for managing the public if unsafe water is likely to reach consumers. The responsibilities, chain of command, notifications, resources etc. for these actions should be clearly identified.

4.3 Verification procedures

The frequency of verification is to be designed to allow determination of whether the HACCP system is working correctly. This involves routine operational checks, record reviews, internal auditing and performance reporting of finished water quality monitoring.
HACCP records must be checked including confirmation that CCPs are kept under control. At water treatment plants this means things like:

- Regular (eg. daily) review of plant performance and equipment status on SCADA or controllers
- Routine plant operation checklists
- Calibration checks on measuring equipment (eg. chlorine or turbidity analysers)
- Spot checks of water quality from treated water downstream of plant

Records of any critical limit deviations and corrective actions must also be reviewed. (Melbourne Water's pre-existing emergency response system covered these events and specifies responsibilities for log keeping, reporting and recording follow up actions).

Internal Auditing should be scheduled to cover all the CCP sites and pre-requisite programs (such as incident management, calibration etc.) over a reasonable period.

5.0 CONCLUSION

The experience of Melbourne Water's application of HACCP has demonstrated how water authorities can successfully adopt HACCP and overcome the aspects of water supply systems that differ from the food industry. HACCP can enhance the Multiple Barrier Approach to contamination through its systematic analysis of hazards and the points of control. It then ensures a rigorous control system at the Critical Control Points and this Critical Control Point concept applies well to water treatment plants.

HACCP, as a process control oriented management system, can therefore help water authorities to coordinate the functions of their various water quality management systems to provide assurance of a safe product.

6.0 REFERENCES

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