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Introduction: Why a new approach to "*Water Safety*"?

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Since pioneers such as John Snow and Robert Koch first established water as major route of disease transmission in the late 19th century, many countries have attained a high level of drinking-water safety. Nonetheless, these continue to struggle with some disease agents found in water, due to new pathogens evolving or being discovered, new chemicals being developed and found in water, and due to the development of our scientific understanding of both with respect to their health impact and their persistence in the water environment. Also, even the most developed countries are increasingly recognising their problems with surveillance and safety of small supplies. Furthermore, institutional and economical conditions for drinking-water provision are currently changing rapidly: ownership of water supplies is being re-organised between the public and private sector while at the same time many countries are reducing expenditures for public health surveillance. Concern is growing about an increasing lack of staff adequately qualified for conducting comprehensive supply system inspections, the crucial role of which was already advocated by the early public health and hygiene experts. Securing and improving our approaches to drinking-water safety thus is a continued challenge even for affluent countries with strong economies.

As pointed out by the World Health Organisation, although humans took the first leaps on the moon in 1969, the death rate of children due to easily preventable waterborne disease still amounts to 6000 per day in the year 2003, and one billion people do not have access to safe water. Mankind still needs to take a big leap to reduce this disease burden. While it does not even take high-tech "rocket science" to ensure the human right to safe water, it does require fundamental improvements in the way we approach drinking-water management.

Not only does drinking-water safety vary widely throughout the world – so do legislative and regulatory approaches to achieving and securing it. Some countries have detailed and centrally harmonized legislation in place since decades (e.g. the European Union and the USA). Many have passed legislation, often closely following the WHO Guidelines for Drinking-water Quality, but face substantial institutional and financial restrictions for enforcing it. These tend to have one approach in common: a strong focus on standards for finished drinking-water, and on compliance monitoring. Other countries historically had no nationally harmonized drinking-water regulatory framework and only recently began exploring possible approaches, using this opportunity for a focus on managing processes to ensure safety (e.g. Australia). Switzerland has recently fundamentally shifted its approach to regulating drinking-water safety towards such a system, using a tool widely and successfully applied in the food industry, i.e. "HACCP" (Hazard Analysis and Critical Control Points). A growing number of water utilities is also introducing formally structured quality management tools (e.g. the ISO 9000 series).

Worldwide, the drinking-water sector is increasingly aware of the limitations of end-product testing for ensuring safety. One limitation is the delayed availability of results in relation to the timing of interventions needed to maintain the safety of a supply: typically, by the time the results of microbiological and chemical analyses are available, water has already reached the consumer and interventions cannot prevent consumption. A further limitation is the steady increase of the number of potentially occurring pathogens and chemicals that need to be monitored, while at the same institutional and economic resources are limited. Ensuring the safety of a supply therefore requires monitoring not only of the finished drinking-water, but particularly of parameters which indicate whether the key control measures a given supply chain are working, i.e. process monitoring.

In recognition of these limitations as well as of the new developments in some countries, the revision of the WHO Guidelines for Drinking-water Quality (GDWQ) is proposing a more effective approach to safeguarding drinking-water in order to help focus available financial and institutional resources on the risks most relevant to public health in the specific setting. While the GDWQ have emphasised the multi-barrier principle, including the protection of sources, since their first edition in 1958, the current revision is developing the focus on processes of drinking-water provision a step further by introducing a management framework for safe water, i.e. "*Water Safety Plans*". These are a systematic approach to understanding the specific hazards relevant in a given water supply and to effective management of the processes most suitable for their control in the given system. The Water Safety Plan approach shifts attention from compliance monitoring in finished drinking-water towards establishing and managing safe processes.

In order to promote the understanding of currently available approaches to hazard assessment and risk management in drinking-water and in particular WHO's Water Safety Plan, an international conference was held Berlin from 28 – 30 April 2003. This conference was a forum for discussion of these concepts, of experiences with their implementation, and of this approach in relation to other quality management systems currently explored for securing drinking-water safety. It focused on introducing the concepts of HACCP and Water Safety Plans, the experience currently available from a range of countries with such approaches, their applicability to small systems and in developing countries, how they compare to other management frameworks used for drinking-water supply, how they work for chemicals in drinking-water and for distribution systems, and on their implications for regulation and surveillance.

The conference was organized by Federal Environmental Agency in collaboration with the World Health Organisation (WHO), the Federal Ministry of Health and Social Security, the German Technical and Scientific Association for Gas and Water (DVGW), and the International Water Association (IWA). Invited speakers presented an introduction into the Water Safety Plan approach and its background, the reasons for introducing it as a tool to improve drinking-water safety, as well as into specific aspects of recent experience with its implementation from the point of view of both water suppliers and public surveillance. Delegates discussed these concepts in more detail during afternoon workshop groups, the outcomes of which were compiled and reported back to the meeting. A concluding discussion of the conference collated open questions, further needs for information as well as suggestions for a way forward in further development and implementation of this new approach.

Conference discussions expressed a pronounced need for information on the Water Safety Plan approach – particularly on what it actually means and how it is performing in practice. A booklet of extended abstracts of the presentations was identified as one element towards meeting this demand. We are very grateful to the speakers for having provided these contributions in retrospect to the conference. This proved not feasible only for three contributions, for these, the presentations slides are printed in Annex A of this booklet.

The extended abstracts are arranged by sessions, in the order in which they were presented at the conference. These are followed by a report on the workshops as well as of the concluding discussion (Annex B), which are important because they highlighted open questions and information needs, and also outlined a way forward.

In the name of the Federal Environmental Agency, we sincerely thank all speakers for their contributions at the conference and in this volume, as well as all participants who contributed to the discussions. The latter were invaluable for an assessment of the current situation and of new approaches taken, as well as for identification of further needs for information and guidance. Particularly, we thank the sponsors for this event, who enabled invitation of the wide range of experts as well as some delegates from low-income countries: the German Federal Ministry of Health and Social Security, the German Technical and Scientific Association for Gas and Water (DVGW), the World Health Organisation (WHO), the International Water Association (IWA), and the United Nations Children's Fund (UNICEF).

Special thanks are also due to the Swiss Gas and Water Industry Association (SGWA) for mailing a booklet of their full papers and their guidance booklet "*Recommendations for a simple quality assurance system for water supplies*", translated into English on the occasion of this conference.

We also wish to gratefully acknowledge the smooth conference management organised by Michael Frobel and Johannes Wingler.

Drinking Water Quality – What and How?

Michael Rouse

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The paper takes a broad view of the requirements for water safety and quality, what regulatory and management ‘tools’ there are to meet the requirements, and how HACCP might fit into the regulatory framework. The presentation, made at the Workshop, had the objective of stimulating discussion on whether the elements of HACCP are more than just normal good operational practice, and did not pretend to be a definitive statement on drinking water safety.

The requirements

The drinking water quality requirements can be considered under the following headings

1. Protecting against the immediate threats to health, from pathogens or toxic concentrations of chemicals
2. Protecting against the short-term exposure effects of chemicals
3. Protecting against the lifetime consumption of low levels of contaminants
4. Achieving an aesthetically acceptable water at the tap
5. Protecting against contamination of water from plumbing fittings and from water ‘appliances’

Considering each of these in turn, the absolute priority must be protection against pathogens, including rapid reaction procedures which need to be in place if the ‘barriers’ appear to have failed to prevent contaminated water being delivered to consumers. The traditional approach has been to rely on disinfectants and to test for indicator organisms to check that the disinfectant is working effectively. The difficulty here is the time taken to collect and analyse samples, such that often water containing the indicators has gone into supply, and it is not known whether or not pathogens are present in the water. An advice to boil water may be issued, but it is likely that ‘it is closing the stable door after the horse has bolted’. Quicker methods of carrying out the microbiological analysis have been developed to offer a better chance of getting a result in time to take effective action.

Another rapid reaction planning requirement is in response to chemical spills affecting water resource intakes, to protect against the threat of highly toxic contaminants, or against harmless chemicals which nevertheless would cause consumers to lose confidence in the quality of tap water due to appearance, taste or smell. Generally, the concern is with river systems especially if the source is one of direct abstraction or there is limited bankside storage. Good river monitoring is required to give early warning of spills.

The next priority is to protect against chemicals which, although present in non-toxic concentrations, can result in short-term exposure effects. Examples of this are nitrate and methaemoglobinaemia (blue baby) and lead and the impact on the intellectual development of children. Obviously the effect of the former would be noticeable whereas with the latter, although proven, the effect is unlikely to be noticed in individual children. Another short-term exposure risk is skin effects from chemicals such as arsenic.

Regulating for the above is different from the general requirement in relation to chemicals, that of low level lifetime exposure. The most challenging requirement here is to protect against potential carcinogens where it may not be possible to establish no-effect thresholds.

An increasingly important requirement is to supply tap water which is pleasant to drink. This requirement can be in conflict with the critical requirement for safe water, due to the need to use disinfectants both in treatment and in distribution.

The requirements do not finish at the tap. Plumbing components and materials must be specified to avoid contamination from leaching. Also, it is now being recognised that regulatory attention needs to be given to the chemicals and materials used in water appliances such as kettles and filters.

The tools

In considering how these requirements might best be met there is a need to consider the range of tools and approaches available. The tools can be listed as follows

- Source risk assessment
- Specified treatment
- Indicator monitoring
- Numerical standards at the tap
- Treatment standards
- HACCP
- Quality Systems such as ISO 9002
- <u>Or any combination of the above</u>
- 'Beyond the tap' standards or controls

Consider now which tools are appropriate against each of the requirements. For protection against pathogens, numerical standards are not of much value because, as mentioned earlier, the sampling and analysis process is too slow. Risk assessment is essential to identify what pathogens are likely to be present so that appropriate barriers can be put in place. The barriers will include protection of the catchments, storage ahead of treatment, and treatment itself, generally disinfection, often preceded by particle removal, and organic removal to minimise the formation of disinfectant byproducts. Good management of the treatment processes is vital, with the need for close attention to key control points, such as disinfection controllers and alarms. Quality systems are an aid to continuous and consistent process operation. Monitoring needs to be by indicators, such as turbidity, which give early warning that 'breakthrough' has occurred. Rapid reaction procedures need to be in place, and to be rehearsed so that action to prevent unsafe water being consumed can be taken.

Protecting against a spill of chemicals is largely related to river water sources. Risk assessment is essential to assess the vulnerability of an intake, and to establish the need for river water quality monitoring and alarm systems, so that, if necessary, an intake can be shut-off. Indicator checks on both raw and treated water, for example using smell (the nose being a very sensitive instrument), are required to allow rapid reaction measures to be taken. Where activated carbon barriers are not in place as part of a continuous treatment requirement, say of removing pesticides, the facility of applying powdered activated carbon should be available for dealing with emergencies. Numerical standards are not feasible, as there are too many possible substances to monitor although, if chemicals do get into supply, it is necessary to know what they are and their concentrations to determine whether or not there is a risk to health from short-term exposure.

Dealing with low levels of chemical pollutants requires a different approach. There is no immediate risk to health, but it is necessary to know that consumers are being given a defined level of protection from a lifetime of exposure. Health risks have to be assessed and numerical standards established. Appropriate treatment needs to be in place to meet the standards, and monitoring carried out at a frequency dependent on the estimated variability in the source water. The analysis data is important to demonstrate that the standards are being met, and important for future health-based studies.

Consumers' confidence in tap water is related to how they perceive its quality, and their indicators are appearance, taste and smell. Achieving a pleasant drinking water is important in its own right, but it also reinforces the perception that it is safe to drink. As mentioned earlier, acceptable taste and smell can be in conflict with disinfection, and safety considerations must be paramount. However, much can be done to achieve both safe and good tasting water, by removing, in treatment, organics which react with disinfectants to affect taste, controlling biofilm formation in distribution systems and by controlling chlorine levels around distribution systems. The most common impact on appearance of water is corroded cast iron pipes, for which the solution is relining or replacement, but much can be done to prevent rusty water by careful operation of distribution systems. So the tools to be used for good aesthetic water are consistent effective treatment and good operational management.

Other considerations

Achieving the required drinking water quality in practice requires more than just standards or processes. Without some third party scrutiny of output measures, and the associated transparency in the reporting of water quality results, and without an external agency to require action when standards are not being met, there is no guarantee that the necessary investment will be made. Also, organisations perform better when their results are reported in comparisons with others. There is a strong argument for a drinking water regulator, whether the operation is private or public.

Approaches to be taken to achieve a good and safe water supply are dependent upon the affordability of expertise and laboratories, which in turn is dependent upon the size of the utility operation and the ability of consumers to pay for the service.

Scale of operation and professional capability

Taking first larger operations in developed countries, where expertise and good analytical services are available, it is to be expected that the full range of tools will be used. There is likely to be risk assessment of sources and appropriate source water monitoring.

Management systems are likely to be in place to achieve consistent good operation of multi-barrier treatment plant and distribution systems ‘all of the time’. Turbidity monitoring of treated water, with telemetered alarms, will allow rapid reaction to unusual results. Sampling and analysis will provide the necessary back-up, and give the ongoing reassurance that safe water is being supplied. Numerical standards will be in place for chemicals, with sampling and analysis, ideally with audited results. The results will be fully reported and comparisons will be made between comparable utilities.

With small operations, there are no economies of scale to be able to afford multi-barrier approaches or extensive monitoring. It is necessary to rely on easy to operate and maintain systems, with only occasional sampling and analysis to identify changes. Quality systems are likely to be limited to training of operators. Other than for the larger cities, the situation is similar in the developing world with limited professional resources available. Here, there is a need to identify the priorities to reduce the impact on health and apply affordable processes which can be produced locally. Training of operators is a priority and the key monitoring requirement is basic checks that the treatment is working.

The role of HACCP

The identification of hazards, and key control measures to deal with them, is something which is applied as part of normal good water supply practice. What is not applied generally is the discipline of the formal HACCP procedure. The question is to what extent can HACCP be applied as a regulatory measure, could and should it replace current approaches, or is it something which could and should be integrated with other regulatory measures. Clearly, we know that traditional numerical standard regulatory approaches are ineffective in monitoring for the presence of pathogens, and that water safety is dependent upon a combination of effective treatment and continuous indicator measurements such as turbidity. However, as shown in this paper, a range of tools are applied to meet the various requirements. Numerical standards have an important place for chemicals, and monitoring and analysis are needed to check that they are being met, to give consumer confidence and for future health studies. In my view HACCP adds value in providing a structured approach to risk assessment, and in focusing management and operatives’ attention on the key control measures, but that care needs to be taken to avoid the risk that ‘winning the badge’ will become more important than supplying safe water. The great value of HACCP today, based on its wide use in the food industry, is that it is stimulating a wide review of how we regulate to supply safe drinking water. The disciplined approach can only add to the provision of safe drinking water. The incorporation of HACCP at the heart of WHO Water Safety Plans is a significant step forward. I anticipate that it will become an integral part of regulation but will not stand alone as a regulatory tool.

Water for health

With all the emphasis on delivering safe water, too little attention is given to the benefits to health. The importance of full hydration to general health is being recognised. Generally in the developed world we have the benefit of good safe water. We should take some time to promote water supplies in a positive light.

Conclusions

Although protection from pathogens is the highest priority, there are the other requirements - protecting against chemical spills, protection against short-term exposure of chemicals, protecting against a lifetime of exposure to low levels of chemicals and providing water which is pleasant to drink.

Meeting all these requirements involves the use of various regulatory tools, but the approaches are limited by affordability and the availability of professional resources. Third party scrutiny, by an independent regulator, provides the incentive for high performance, transparency and achievement of standards, and gives reassurance to consumers.

HACCP is a valuable tool. Its incorporation in WHO’s Water Safety Plans provides the opportunity of a review of regulatory approaches.

Is there a Need for a Better Drinking-water Quality Management?

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Introduction

The basis of drinking water quality management was developed in the 19th century. Based on the criteria established at that time, drinking water quality in Germany has been developed to its present high standard. Thus, classical water-borne epidemic diseases such as cholera, typhoid fever, paratyphoid fever, shigella dysentery which threatened public health at that time were brought under nearly complete control, and particularly the high mortality rate for water-borne diarrhoeal illnesses in infants as a result of water-borne diarrhoel illnesses could be reduced drastically.

Quality management must, however, be checked regularly and adapted to changing current conditions for the following reasons:

- new findings about water-borne risks have emerged;
- new legal requirements and decrees are to be fulfilled; and
- risk characteristics of the population have changed due to demographic factors and medical conditions.

New findings particularly relating to health risks which can come from water are:

- newly occurring or identified pathogens;
- new chemical substances; and
- the increasingly recognised limitations of the indicator system.

New legal requirements are, e.g. the amended EU Drinking Water Directive and the German Drinking Water Ordinance, which is based on the former. This legislation has replaced the term “drinking water” with “water for human use”.

Similar to food hygiene, the total quality management (TQM) approach focuses on processes from the catchment area to the tap of the consumer rather than on the achievement of a certain water quality. Risk points are to be identified and are to be controlled by suitable mechanisms. Furthermore, the consumer will have an extended right of information: as consumers have no direct influence on the quality of drinking-water delivered to their tap, they must be able to rely on the hygienically perfect quality of the water made available to them.

In a population with a high level of medical treatment, susceptibility and thus risk changes through factors such as the increase in the share of older people, the increase in populations at a higher relative risk (i.e. immunocompromised) as well as changing individual consumption patterns.

The following explanations only refer to the conditions in the developed countries and do not deal with the partly clearly different problems in developing countries.

Historical aspects

As regards the drinking water-borne risks and their control at the beginning of the 19th century only empirical experiences were available. Through epidemiological investigations by *John Snow*, connections between contaminated well water and cholera outbreaks in London could be demonstrated. After the introduction of the central water supply in Munich *Pettenkofer* was able to show that there was a considerable decrease in the cholera and typhoid fever mortality or morbidity. The exact bacteriological diagnostic of typhoid fever was only established some decades later. 120 years ago *Robert Koch* published his reports about the detection methods of micro-organisms in water, soil and air, as a result of which quantitative bacteriological ascertainment of the bacterial concentration in the water became possible, and with this the efficiency of treatment could be verified. In 1884 Koch discovered the pathogen causing cholera in Calcutta which he was able to identify in a water tank used for the supply of water to persons which had fallen ill of this disease.

The hygienic microbiological quality tests of drinking water which were now possible were an important precondition to establish quality parameters. In 1892 there was a heavy cholera epidemic in Hamburg which was the trigger for the introduction of consistent legal rules for the catchment and treatment as well as distribution of water in Germany. By means of this it was possible to eliminate cholera, typhoid fever and paratyphoid fever as water-borne diseases almost completely. The knowledge and risk assessment, however, only related to a few water-borne diseases and risks, which *Gärtner* summarised in his monograph "Hygiene of Water" in 1915. At that time, cholera, typhoid fever, paratyphoid fever, shigellosis, leptospirosis, gastrointestinal infections and anthrax were among the most relevant water-borne infections. Intoxication caused by mercury, arsenic, barium, tin, zinc, copper, lead, and organic compounds were among the chemical risks. In the following years quality verification and the corresponding quality indicators aimed for the control of these infections, e.g. the level of the colony counts per millilitre, the occurrence or the absence of *E. coli* and coliforms, enterococcus and clostridia. With these basic quality assurance strategies it was possible to bring the very widespread water-borne diseases under control.

New findings on water-borne health risks with particular consideration of pathogens

Since the beginning of the 20th century a multitude of potentially water-borne pathogens could be identified. They are partly characterised by a very low infective dose. Some water-borne pathogens have an increased to a very high resistance against disinfectants such as chlorine. Moreover, these pathogens cannot be detected at all or they can only be detected insecurely with the classical indicators *E. coli*, Coliforms and Enterococci. In addition, water-borne pathogens of non-faecal origin have been detected which as pathogens are part of the natural aquatic microflora. Examples are Legionella and Pseudomonas which mainly multiply in biofilms in the water distribution network and particularly in plumbing systems. At the end of the 70s and the beginning of the 80s it became clear by means of the raster scan electron microscopy that facultative pathogenic micro-organisms as *Pseudomonas aeruginosa* and legionella can partly multiply in biofilms of water-leading systems in extremely high concentrations.

Some pathogens like EHEC, Campylobacter, Cryptosporidia and Giardia which have recently been discovered to be relevant have a very low infective dose. An important difference between chemical pollution and presence of pathogens is the fact that in most cases the former becomes health-relevant in drinking-water only through prolonged exposure, whereas the latter can cause water-borne epidemics even if present only very shortly. In contrast to the majority of chemical-physical noxes long-lasting pollution is not necessary to cause water-borne epidemics.

Besides the classical route of transmission through water ingestion, we now understand the importance of including other routes of infection such as inhalation or skin contact of pathogens in the risk assessment. Depending on their route of transmission water-borne pathogens must nowadays be subdivided into those that are transmitted via ingestion and those that are transmitted via inhalation or contact. An overview of transmission pathways is given in Figure 1.

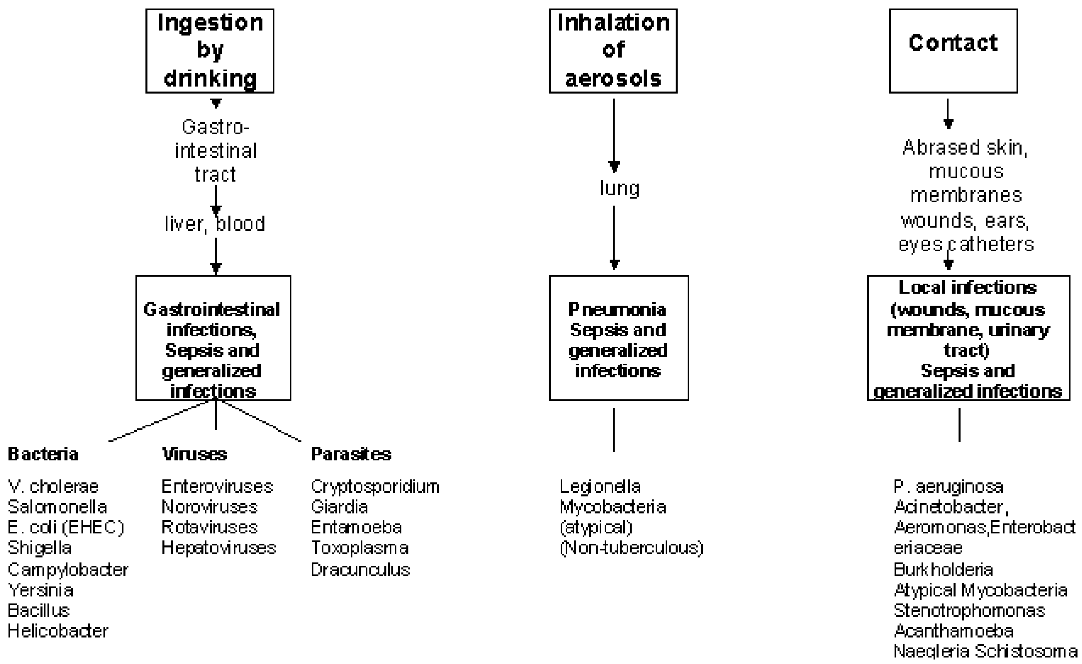

Figure 1. Transmission pathways for waterborne pathogens.

It is only a few years ago that new typing methods (as for example RAPD or PFGE) demonstrated that transmission of *Pseudomonas aeruginosa* to risk persons via contact (e.g. by cleaning) causes up to 40% of the pseudomonas infections occurring in intensive wards and up to 30% of *Pseudomonas aeruginosa* infections in normal wards. It has been assumed that 1400 death cases in the USA result from waterborne *Pseudomonas aeruginosa* pneumonia. (Anaissie *et al*., 2002).

The recent development of premises and requirements

In the WHO Guidelines, the European Drinking Water Directive as well as in national legislation on drinking water quality new premises and requirements are formulated. The following count among the most important:

- the principle of assessing and managing systems from the catchment area to the consumer;
- plumbing system and water tap are part of the water supply system;

- pathogens and chemical-physical hazards are not allowed to be in the water in concentrations which can harm health;
- the point where the quality criteria must be fulfilled is the consumer's water tap;
- water for human use should be safe also for domestic purposes including personal hygiene; and
- if limits for a given parameter are exceeded, a hazard analysis (risk analysis) must be carried out immediately.

The basic principle from "catchment area to the consumer" is a holistic approach. It means that risk points can be present from the catchment area throughout the water supply chain, in water treatment, in water distribution, in plumbing systems and at the water tap. They must be identified and brought under control. Up to now the corresponding risk analysis concentrated on treatment and analysis of treated water. The raw water and the water quality in the distribution network or at the final point of consumption were not a focus in this risk assessment. Drinking water control in public utilities is increasingly demonstrating contamination which originates either from the water distribution network or from the plumbing systems.

As a result of the explicit inclusion of plumbing systems and household installations up to the consumer's tap new problems have become manifest: the capability of micro-organisms growing and multiplying in biofilms to induce the release of hazardous substances such as copper and lead from plumbing systems.

A need for quantitative analyses of pathogens – i.e. their concentrations – as well as setting quantitative targets for their occurrence arises from two considerations: (i) recognition of the fact that a complete elimination of pathogens in the water is not realistic and (ii) that it is only a question of the volumes tested to possibly demonstrate their presence. Also, some pathogens such as cryptosporidia can already lead to water-borne outbreaks in concentrations which cannot be reliably detected or can only be analysed with considerable effort with the present analytical methods. Against this background the World Health Organization suggests to analyse their potential occurrence in raw water and from this to derive criteria for the treatment requirements to achieve removal down to safe levels. Such an analysis must also take the peak concentrations, for example after heavy rainfall, into account.

Water does not only have to be hygienically harmless for drinking water purposes (taken in per ingestion), but also for other purposes of use such as washing, showering, cleaning, food preparation. That means that certain quality criteria must also be observed for showering or personal hygiene.

In case of results exceeding limit values a hazard analysis (risk analysis) must be carried out immediately in order to ascertain whether or not the value exceeded constitutes a risk for the consumers. In doing so additional tests must be carried out for the specification of the risk.

These developments have considerable consequences for management and surveillance, and lead to a clear extension of the quality criteria in place until recently.

Demographic characteristics and increase in risk populations

In the developed countries the share of older people in the population increases. Persons above the age of 65 are regarded to be more vulnerable to infections, as due to their often existing multi-morbidity consequences of infectious diseases are more serious than in younger persons. Furthermore, there was an increase in further risk groups such as immunocompromised patients, patients with cancer, patients with invasive catheter systems. Due to attempts to reduce costs in health care the number of patients in home nursing has risen. The prevalence of risk persons in different European countries is depicted in Table 1. According to this it can be assumed that the ratio of risk persons (i.e. with an increased risk of infection) to the normal population is 1:6.

Table 1. Prevalence of „at risk“ persons in the domestic setting (note: a hyphen means that no data are available).

	UK	Germany	Holland
Total population	60 million	82 million	16 million
- over 65 year old	9 million	13 million	2 million
- living with cancer –significant proportion in the community, and undergoing chemotherapy	1 million	-	160,000
- under 1 year old	600,000	800,000	100,000
- discharged from hospital within previous 2 weeks	200,000	-	60,000
- hospital outpatients at home	-	1,270,000	-
AIDS cases	15,000		91
Total "at risk" persons	>1 in 6	>1 in 5.6	>1 in 6.3

These risk characteristics must also be taken into account in case of an assessment of the risk by drinking water.

Examples for water management problems

Most of the drinking water-borne outbreaks and events reported in the last few decades can be put down to an insufficient consideration of risk points which – knowing new risk potentials - could have been controlled in advance by systematic water safety policies. For a long time Germany was regarded as a country where water management problems and water-borne infections have not occurred. In the following, three characteristic examples are shown which have led to preventable problematic situations in Germany.

Case 1: Insufficient safeguarding of the water catchment

After a strong rainfall there was an occurrence of *E. coli* and coliforms in a well with a depth of 50 m. Disinfection could not be carried out. For this reason it was recommended to boil the water before use. The site inspection revealed that in the direct catchment at a distance of only 20 metres there was intensive pasturing with young animals and that there were two cattle watering tanks with heavy faecal soiling. According to the Water Safety Plan and the HACCP concept livestock and cattle watering tanks in the direct catchment area of a drinking water well would have been identified as risk points and should have been eliminated. This was done after that incident. Only after a worst-case situation – caused by heavy rainfall – unfavourable bacteriological results have been detected which under normal conditions would not have become noticeable.

Case 2: Water-borne Giardiasis

Water-borne giardiasis or cryptosporidiosis had not been reported from Germany. In 1999 an increased giardiasis gastroenteritis rate was detected among patients by a general practitioner who informed the health authorities. Besides carrying out an epidemiological investigation, water quality was also tested, and this detected low concentrations of Giardia. These were caused by a well situated on a pasture directly besides the course of a creek. The creek carried sewage. In case of strong rainfall the well water was influenced. The epidemiological clarification showed that the risk of giardiasis infection of the supplied population was 7 times higher compared to the control population (Kistemann *et al.*, 2003). This case could also have been prevented by a systematic water management and an identification of risk points.

Case 3: Hydrant contamination

In a routine examination a systemic contamination with *E. coli* at different places of the water distribution network of a water supply system was detected. It was recommended to boil the water before use, and a chlorination of the water supply system was carried out. However, a causal source could initially not be determined. By means of systematic investigation it was ascertained that in connection with the installation of a new hydrant into the distribution system the following stretches were contaminated with *E. coli*. *E. coli* could be detected by testing higher volumes of water samples taken from the hydrant which were compared by means of PFGE with the strains found in the network. The hydrant could be identified as a source of contamination by corresponding PFGE samples. Biofilms could be established in the hydrant. The exact cause of the contamination of the hydrant could not be ascertained. It is, however, not excluded that the hydrant was rinsed with contaminated water for testing purposes during production.

This case study points to the fact that interventions in the water distribution network have to be taken into consideration as potential points of risk in a water management system and that they can entail long-lasting contamination of the water supply system.

Consequences for a holistic approach to water hygiene

The consideration of the new knowledge about new pathogens and new harmful substances leads to a concept of a holistic water hygiene management (Table 2).

Table 2. The holistic water hygiene concept.

Water hygiene

Prevention		Health protection	Control	
Quality of structure and process	**verification validation**		**Surveillance**	**Incident and Outbreak Management**
• conservation of water resources • catchment areas • quality of raw water • water treatment • disinfection • distribution network • plumbing system • water outlet	• risk analysis (HACCP) • investigation of water quality • indicators of water quality • standard methods • responsibility • education • training • research • standards • legislation	by availability of water in quantity and quality with special regard to waterborne pathogens for the • public including • the ill and immuno - suppressed people • food preparation	• collection of data and analysis • early-warning systems • management of data • responsibility • education • training • legislation • information of the public	• contingency plans for response systems • capacity to re-spond and to investigate the causes • documentation and information system • lessons for the future (to prevent incidents and outbreaks)

The aim of a holistic water hygiene means health protection by guaranteeing water in sufficient quantity and hygienic quality particularly taking water-borne pathogens into account. Prevention measures include guaranteeing quality, structure and processes as well as verifying and validating these quality criteria.

Besides the systematic surveillance of water-borne diseases an efficient incident and outbreak management system is of great importance. In case of limit value exceedances as well as outbreaks of water-borne diseases its aim is to control these as efficiently as possible. Therefore, a changed quality assurance thinking and a changed quality management philosophy is necessary.

It is not sufficient to fulfil water quality criteria in treated drinking water. In food hygiene the single points of risk must be checked from farm to fork. Analogous, drinking water supply systems must be considered from the catchment area up to the tap of the consumer in the framework of a modern water management system.

Possible points of risk and hazard potentials must be defined taking the current scientific findings into account. It must be determined by which measures possible risk situations can be brought under control. The demands on the treatment are dependant on the raw water quality at worst-case conditions. For this reason a considerably higher importance must be attached to the raw water quality in future.

The whole system must be validated from a comprehensive point of view and the quality management system must be verified as regards its efficiency.

An incident and outbreak management must be planned proactively. Independent hygienic medical advice is indispensable.

The former drinking water quality management must be adapted to the current health requirements. For this reason, initiatives for the improvement of drinking water quality management by the World Health Organization and the endeavours for their evaluation in Germany are to be supported emphatically.

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HACCP: A Quality Management System Proven Successful in the Food Industry

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The Hazard Analysis Critical Control Point system (HACCP) as applied to food is considered to be a safety management system using the approach of controlling critical points in food handling to prevent food safety problems. It is a system which can be used to assure food safety at all levels of food handling and is an important element in the overall management of food quality and safety, more commonly referred to as Good Manufacturing Practices (GMP). The HACCP concept was developed in the late 1960s as a quality assurance system to enhance food safety. The basic principles underlying the concept were not new, but the introduction of HACCP signalled a shift in emphasis from resource-intensive end-product inspection and testing to preventive control of hazards at all stages of food production. The application of the HACCP system has been evolving and expanding to form a basis for official food control and for establishing food safety standards for the international food trade as well. HACCP is considered to be one of the most effective and efficient ways to enhance food safety.

Many interpretations of the HACCP concept were presented in the past. In general, HACCP aims at excluding influences that result in foodborne diseases in humans from the production, handling, treatment, transportation and storage of foods. For this reason, food establishments conduct in-house controls. As part of such in-house control systems, the HACCP concept serves to ward off health hazards through their systematic identification, evaluation, continuous recording and control.

An internationally valid explanation of the HACCP concept has been laid down by the FAO/WHO Codex Alimentarius Commission in an annex to its General Principles of Food Hygiene. According to this, the HACCP concept is a system for the identification, evaluation and control of significant health hazards from food. Thus, specific health hazards for the consumer (these may be hazards of chemical, physical and microbiological nature) should be identified (hazard identification) and the probability and significance of their occurrence assessed. Based on such analysis, the necessary preventive measures are to be defined which serve the purpose of preventing, eliminating or at least reducing hazards to an acceptable level. A system of this type can be applied in all establishments with established and permanently repeating operational processes. The HACCP-concept may be integrated into a quality management system according to the DIN EN ISO 9000 series (Untermann *et al.*, 1996; Untermann and Dura, 1996).

The framework of the HACCP concept consists of 7 principles. These are essential for a correct application of the concept. HACCP is often misunderstood due to wrong translation and interpretation of the terms, e.g. “hazard” in the sense of risk (rather than a potential danger which results in a risk only in some settings), “control” in the sense of random checking (rather than in the sense of steering a process) and “CCP” in the sense of an item on a checklist for which compliance is tested against hygienic requirements (rather than a specific point in the process which needs to be kept within operational limits). The term “CCP” as an abbreviation of the term “Critical Control Point” should not be translated into other languages since it has become an internationally recognized term similar to “HACCP”.

A great deal of national and international activity related to the utilization of HACCP-based systems in food safety assurance is already implemented or still under way. HACCP is increasingly being promoted throughout the world and, in some countries, food control agencies demand from the food industry, including food importers and exporters, to use HACCP based systems to assure food safety. In an environment of economic restraints, governments are under constant pressure to limit expenditures, and to look for more efficient and effective mechanisms to carry out their food control mandate. HACCP is being looked at as one of these mechanisms.

To successfully implement HACCP in the food production chain, producers and authorities responsible for food safety must first be aware of a need for a quality management system, and specifically of the advantages of using HACCP as such a system. Developing a HACCP plan for a given establishment requires a fair amount of commitment at every level, and this cannot be expected until the need for implementing HACCP is acknowledged. As a HACCP plan is part of the in-house control and quality management system, , the operator of such a food establishment will be responsible for its development and implementation. However, the development of a HACCP plan is required by law for food establishments in some countries, though in others HACCP-plans have been developed on a voluntary basis.

HACCP and general provisions of hygiene

There is a relationship between the HACCP concept and general measures of hygiene. However, it should be noted that the HACCP concept does not constitute a tool for the implementation of general measures of hygiene. It is rather based on an existing hygiene concept which comprises the hygienic requirements for working areas and technical equipment as well as for staff hygiene, cleansing and disinfection, pest control etc., most of which are required by law. The general prerequisites also include measures to separate operational steps and production lines (to prevent cross-contamination) and to control temperature and humidity in working and storage areas. Without this basis, no HACCP plan could work.

In many fields of food production, treatment and processing, it is virtually impossible to develop a complete HACCP plan because of the size or structure of an establishment or its wide range of products. This applies above all to the principles of documentation and verification (see below). Therefore, for example the European Community with its Council Directive 93/43/EEC has prescribed a flexible system for the development of structured and specific measures of health protection which does not require the implementation of a full HACCP plan but rather requires both in-house control based on individual principles of HACCP and general provisions on the hygiene of foodstuffs.

Application of HACCP

For the practical application of the HACCP concept according to Codex Alimentarius, certain rules have to be followed which are laid down in 7 main principles. The HACCP principles constitute the basis for the establishment of an HACCP plan.

- Principle 1: Perform a hazard analysis.
- Principle 2: Determine the Critical Control Points (CCPs).
- Principle 3: Establish one or several critical limit(s).
- Principle 4: Establish a CCP monitoring system.
- Principle 5: Establish corrective action to be taken if monitoring indicates that a specific CCP is no longer under control.
- Principle 6: Establish procedures of verification to confirm a successful working of the HACCP system.
- Principle 7: Introduce a documentation system taking into account all processes and records in accordance with the principles and their application.

In order to prevent misunderstanding it should be noted that a full HACCP-plan is always developed along all of the 7 principles. Hazard analysis should be done in a systematic manner, to prevent hazards from being overlooked. The information needed for hazard analysis comprises the agents that could be present in the food under study, the severity of their effects, and the likelihood of their occurrence, also the levels that could cause adverse health effects, and the conditions that could lead to unacceptable levels.

HACCP can and should be applied at all stages of food production and processing, i.e. from the primary producer to the final consumer to enhance food safety, enable a better use of resources and more timely response to problems. Within this framework, HACCP can aid official inspection and promote international trade by increasing confidence in food safety.

Practical implementation of the HACCP concept

The application of the HACCP concept encompasses a set of tasks requiring expertise in the fields of epidemiology, veterinary medicine, food chemistry, toxicology and food microbiology as well as quality management. If necessary, establishments need to rely on qualified and acknowledged external scientific expertise.

A detailed description of the approach has been given in the Codex document mentioned above. In a summarizing view, the seven principles listed above can be assigned to three steps that should be passed:

1. Hazard identification and evaluation (Principle 1).
2. Determination of the Critical Control Points and of measures for their control (Principles 2, 3, 4 and 5).
3. Verification and documentation of the system (Principles 6 and 7).

After a detailed description of the food and its typical production/manufacturing procedure (flow chart), hazards will be identified and evaluated. This stage comprises the identification of all hazards possibly associated with each single production step and the assessment of both probability of hazard occurrence and of its significance for the consumer's health. All potential hazards should be analysed individually. A detailed specification is necessary since methods used to monitor and control the problems may differ accordingly. Thus, it is not recommended to use general terms such as "pathogenic organisms" but pathogenic organisms possibly involved such as *Salmonella* or *Campylobacter* spp.. The same considerations apply to chemical contaminants as well as to "foreign matter" (i.e. glass, plastic material, metal etc.).

On the basis of an analysis of the entire process it has to be decided, if necessary with the help of a decision tree, whether the criteria for a CCP are met. A CCP must have all of the following four characteristics:

- It must specifically address the hazard identified initially.
- The measures to be carried out for control should eliminate, prevent or reduce the health hazard to an acceptable level as defined in the hazard analysis.
- Continuous checking whether a specific hazard has been eliminated (e.g. by means of a technological method) must be ensured by means of a suitable monitoring system using critical limits. With almost no exception, microbiological analyses are unsuitable as monitoring methods since their results are not available early enough to initiate in time corrective action in cases of deviations from normal values.
- At the same time, suitable and feasible corrective action must be available to be carried out if insufficient control of the CCP is reported by the monitoring system, i.e. if the defined critical limits have been exceeded. Corrective action may range from correcting a processing step to discarding an entire batch.

For a CCP, documentation is imperative. The functionality of a HACCP plan should be verified by means of laboratory analyses, inquiries or other measures (step "verification"). Of course, these must also be documented. If one of these characteristics is missing, the point in question is not a CCP.

Many questions have been raised concerning the application of the HACCP concept to control spoilage or product quality. The logical approach used for the establishment of a HACCP plan may also be applied to a targeted development of specific measures to prevent spoilage or to ensure product quality. In such cases, however, the term "CCP" should not be used. It will be left to the operator of the establishment involved to introduce other terms or names in the context of the in-house control system, e.g. "control point for measures of hygiene" or "control point for other measures of quality assurance". This is necessary to avoid the actual aims of the HACCP concept, i.e. the prevention of specific health hazards, to become masked and diluted. For such points, surveillance and corrective action as well as verification and traceability by means of documentation may be established by analogy to the CCP. If the concept is applied uncritically extensively, establishments may soon come up against the limits of their organizational possibilities, mainly concerning documentation. Eventually, this could severely compromise effective in-house control.

If a complete HACCP plan exists, the surveillance authority will mainly concentrate on the correct establishment of the CCPs for the control of possible health hazards, in addition to the general inspection of hygienic conditions. Its main focus will be on the documentation and verification of the system. If the HACCP concept is incorporated into a quality management system according to DIN EN ISO 9000, it is recommended that the operator of the establishment should keep separate, or mark accordingly, the parts relevant to official control in such a way as to ensure a consistent presentation and to avoid a time-consuming search in the documents during an inspection.

When reviewing an establishment's in-house control, which is structured according to specific principles of the HACCP concept under the Council Directive on the hygiene of foodstuffs, the food control authority will at first pay attention to a correct discrimination between the general measures of hygiene and the measures for specific hygienic control (on the basis of the HACCP plan). This will reveal whether the in-house measurements taken according to HACCP principles were analysed in compliance with the Directive and the establishment has taken these requirements as a guidance. Hence, it is the main subject of concern to check whether a structured hygienic concept has been applied. Concerning the implementation of measures, the records kept should provide for improved transparency and credibility for the food control authority.

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Water Safety Plans – Using Risk Management to Deliver Safe Water

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The management of risks and provision of safe drinking water is a core issue for water suppliers. Over the last two decades there has been a shift in the way that risk is perceived and managed in drinking water supplies. There has been an increasing focus on preventive risk management that accounts for a holistic approach from source to consumer and a move away from over reliance on engineered barriers and end point testing.

The use of preventive risk management guidance, such as Hazard Analysis and Critical Control Point (HACCP) is now included in the 3rd Edition of the World Health Organization Guidelines for Drinking-water Quality (GDWQ) and the Australian Drinking Water Guidelines. The WHO GDWQ give guidance on the use of Water Safety Plans (WSPs), based on the principles of HACCP. The use of WSPs is recommended by WHO for the management of drinking water safety.

HACCP is a preventive risk management tool that was developed in the 1960s by NASA and the Pillsbury food company in the USA to reduce the likelihood of food borne illness in astronauts. End-point testing had generally been relied upon for product safety assurance in the food industry. HACCP systems result in a focus on risk prevention and management through process control, which reduces the reliance on end-point testing. HACCP was adopted by the Codex Alimentarius Commission in the 1990s and is the risk management method of choice in many countries.

In 1994, Havelaar published an article in the journal *Food Safety*, which proposed that HACCP be used to manage risks in drinking water supply. This led to the development and implementation of HACCP certified drinking water supplies in Australia and the inclusion of HACCP principles in the Australian Drinking Water Guidelines. A number of individuals in Australia that participated in the adoption of HACCP were invited to assist WHO with developing HACCP guidance for the WHO GDWQ.

HACCP comprises 12 steps that include 5 preliminary steps and 7 principles. These 12 steps represent the basics of risk management and are used to support the development of a Water Safety Plan. The 12 steps of HACCP are shown in Figure 1.

In Plain English, HACCP asks three questions:

1. What is the hazard?
2. How is the hazard fixed?
3. How is it known that the hazard is fixed?

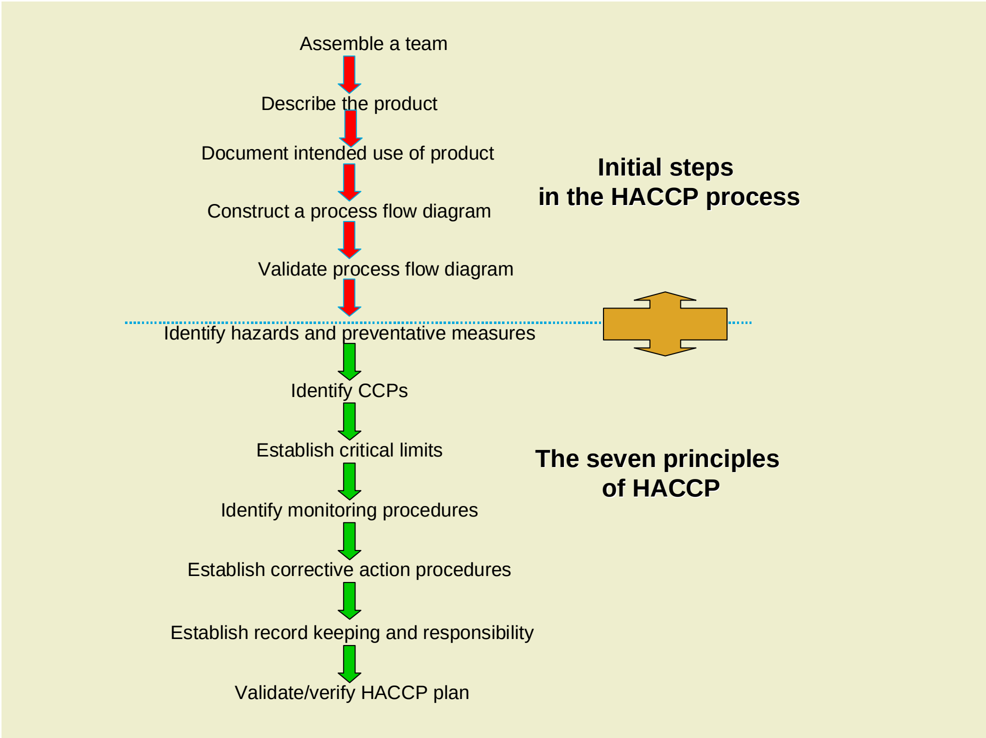

Figure 1. Steps and principles of HACCP.

The basics of risk management that are implicit in the HACCP process are as follows and described in the following paragraphs:

- Know your system
- Know what threatens it
- Know how to remove or reduce risks
- Control measures in place
- Monitor the control measures more than the water quality
- Verify the water quality at the end

Know your system

This includes information gained from sanitary survey and details of source water, treatment processes, storage and distribution. Information is also required on what the water is to be used for and which populations are going to use it.

Threats to the system

This includes knowledge of what hazards are present in a drinking water system. Threats such as pathogens from sewage and agriculture and chemicals from industry can impact drinking water quality. Understanding of events such as floods and fires is also used to assess risks in supplies. Risks that are identified need to be ranked and prioritised and significant risks identified.

What can remove or reduce risk?

One of the basics of risk management is an understanding of what measures can be out in place to reduce or eliminate risk. In some cases risks can be avoided by not allowing contamination to enter a drinking water system, for example through the protection of catchment areas or well protection zones. In other cases risks can be removed by treatment, such as conventional filtration, disinfection with chlorine or through UV inactivation. It is important to remember in drinking water systems that risk to consumer is minimised through incremental risk reduction by the use of multiple barriers. The more barriers to contamination in a supply, the more confidence can be gained for water safety.

Control measures in place

Control measures are activities that are designed to reduce or eliminate risk. Not all control measures are engineered barriers and many activities that are carried out in water systems are control measures such as standard operating procedures and water supply agreements.

Monitor the control measures more than the water quality

There are a number of reasons for monitoring in drinking water systems. The first is to support the risk assessment process and determine the threats to the system. This may involve research project results on pathogen monitoring or chemical analysis. Once risks have been identified barriers (control measures) in the system are monitored to ensure that the control measures are working effectively. This approach to monitoring ensures that effort is spent at points in the system where hazards are being controlled and not at the end of the system where it is too late to manage risk.

Verification of water quality (surveillance)

In a risk management approach such as HACCP the focus on water quality as it is delivered to consumers is reduced as control is effected earlier in the system. The role of end-point testing is to verify that the management plan is working and the results used as a long-term data-base. Risk cannot be managed by measuring and reacting to water quality once it has reached the consumer.

Water Safety Plans

The 3rd Edition of the WHO Guidelines for Drinking-water Quality contains guidance on risk management that incorporates HACCP and good manufacturing practice. The GDWQ states that the role of the supplier in ensuring the safety of water has three key components which are guided by health-based targets and overseen through public health surveillance:

Health based targets

Health based targets are water quality targets based on public health protection and disease prevention. They are a benchmark for water supplies and local circumstances need to be taken into account when setting the targets. The targets were developed by WHO using quantitative microbial risk assessment

System assessment (WSP component 1)

"*System Assessment to determine where the water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets identified targets. This also includes the assessment of design criteria for new systems*" (from WHO GDWQ).

The system assessment is a "reality check" before undertaking a Water Safety Plan. It determines the system capability to meet the health based targets.

Effective management – control measures (WSP component 2)

"*Monitoring of the control measures in the supply chain which are of particular importance in securing water safety*" (from WHO GDWQ).

This component involves the first steps of HACCP and ensures an understanding of the capabilities and limits of barriers. This component involves operational monitoring.

Management plans (WSP component 3)

"*Management plans documenting the system assessment and monitoring; and describing actions to be taken during normal operation and incident conditions, including upgrade and improvement and documentation and communication*" (from WHO GDWQ).

This component includes the development of a HACCP plan and supporting programmes. The management plan should include information like standard operating procedures, employee training and risk communication.

Public health surveillance

Public health surveillance is systematic independent surveillance that verifies that the elements of the Water Safety Plan are operating properly. The surveillance includes audit of the Water Safety Plan to show that the Plan is being adhered to. It also includes validation of control measures to determine if the Water Safety Plan is appropriate and that correct operational monitoring is being undertaken. The final component of surveillance is verification, which is end-product testing to show that the system as a whole is working properly.

The development and adoption of Water Safety Plans for large and small water supplies in developing and developed countries will result in a more systematic and rigorous approach to the management of drinking water safety. Through the implementation of plans with reference to a clearly defined health-based target, the risk to consumers of contaminated drinking water should be lessened.

HACCP at Melbourne Water – Implementation from Catchment to Tap

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The presentation, as described below, outlines the way in which Melbourne Water has developed HACCP for its water supply system. It summarises the approaches taken to risk assessment and identification of Critical Control Points and some of the benefits received from introducing the HACCP system.

Melbourne Water began preparing HACCP in 1999, at a time when HACCP was not known to have been applied to any water supply in the world. By June 2000 the system was established and certified by independent audits.

Introduction to the Melbourne Water supply system

Melbourne is a city of 3.5 million people situated in the south east of Australia. The city has a temperate climate. Melbourne Water is a Government owned Corporation that owns and operates the bulk water, sewerage and drainage systems. Drinking water is supplied to three Retail Water Companies who own and operate the reticulation systems. At the same time that Melbourne Water was preparing its HACCP plan, the retail companies were also preparing their own HACCP plans.

Because of Melbourne's dry summers and suburban lifestyle with large gardens, there is a relatively high consumption of water and therefore large reservoirs. (The total storage capacity is over 3 times the annual consumption.)

Multiple barriers

For many years the Australian water industry has had a strong emphasis on the principle of multiple barriers for the protection of water quality.

All of Melbourne's water comes from surface water. About 75% of Melbourne's water is supplied from indigenous forest catchments, protected from public access and development. The protected catchments and large water storages have produced water for Melbourne that is naturally clear, with a low level of pollutants and is aesthetically pleasing. As a result, the water from these protected catchments is not filtered and disinfection was only introduced in the 1970s.

Water sourced from multi-use catchments is filtered. All water supplied is disinfected, usually with chlorine, and the distribution system is a closed system of pipelines, tanks or covered storages.

The principle of multiple barriers is still strongly supported today. The addition of HACCP has improved the risk assessment and quality systems that are also necessary to ensure that the barriers are effective.

Important differences between food and water processes

When investigating HACCP Melbourne Water spoke to consultants in the food industry, attended short courses and looked at examples of HACCP plans for food manufacturing.

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

1. The diverse range of possible water-borne hazards, particularly from multi-use catchments;
2. The continuous nature of supply between raw water sources and consumption;
3. The large, complex distribution networks; and
4. Treatment facilities that are often monitored and operated remotely via telemetry.

The diverse range of water-borne hazards can be assessed individually or in some cases groups of micro-organisms, 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 a problematic management of any non-conforming product (i.e. 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. It is difficult to trace water as it flows through distribution systems, which makes it difficult to prescribe site-specific corrective actions.

Describing the critical control points (CCPs) 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 (many of which are automated) are crucial elements of the CCPs, but complex in nature and often not widely understood within an organisation.

Developing Melbourne Water's HACCP plan

The HACCP plan must assess risks to public health from the water source to the point to supply and specify the operational controls necessary to ensure safe water.

Therefore input is required from scientists, public health experts, engineers, operators and managers. A team-based approach worked well for Melbourne Water which brought people with these disciplines together in workshops. The plan was prepared by splitting the system into four supply areas.

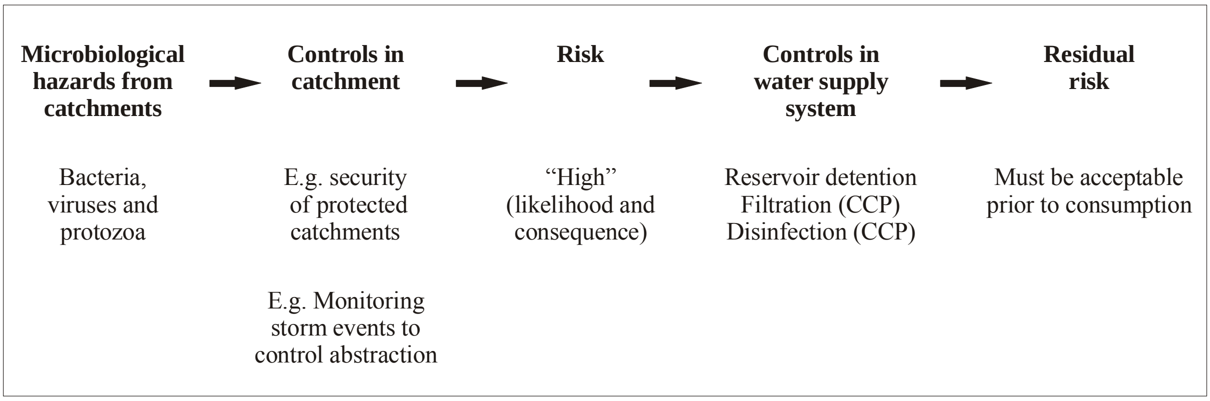
The Retail Companies were also involved in the Melbourne Water workshops and helped review the plan. The Health Department also commented on the plan. State Government legislation is being introduced that will soon make it mandatory for water companies in the state of Victoria to submit risk management plans as well as audit requirements.

The risk assessment is the key to the whole process - identifying risks, assessing their significance and the controls in the system that manage those risks in a systematic fashion – starting from the catchment and working down. This provides an improved understanding of the system and quickly highlights the gaps. The right people are essential.

Risk assessment

Melbourne Water's risk assessment was a semi-qualitative one and a simplified example is given below.

Flow diagrams of the system were drawn up. At each step in the process, the potential hazards to water quality were identified, as well as the controls to prevent the hazard entering the water – starting from the top end, the catchments (see Box below).



If the risk to water at any step in the process was considered significant then there MUST be controls in the system at that step or further downstream to reduce the hazard to an acceptable level before it reaches consumers.

A Critical Control Point is one which requires constant operational monitoring and control because if it fails the system cannot control the hazard thereafter. Therefore, there must also be specific corrective actions identified for when these points fail.

Identifying the Critical Control Points

Possibly the most problematic of the HACCP planning steps is determining the Critical Control Points (CCPs).

Invariably it appears that those establishing a HACCP plan for the first time identify a large number of CCPs (i.e. over 10). When developing the Melbourne Water plan there were initially 26 CCPs identified but it was soon realised that many of the controls at first designated as CCPs didn't practically work and did not have to be CCPs, in cases where:

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

The 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.

System improvements

Melbourne Water's systems and procedures were already reasonably well established and documented prior to introducing HACCP. There was no need to introduce new infrastructure (e.g. treatment), but rather, a number of procedural improvements. The HACCP document ended up being like a road map of all the systems that control drinking water quality, and because of the regular auditing introduced (internal and by external certification) it became a driving force for improving systems.

The process of preparing a HACCP plan resulted in a number of improvements. The ongoing auditing and reporting of the HACCP system continues to identify improvements. Examples include:

- The development of about 15 new operational procedures;
- Evaluation of the capacity of catchdrains around reservoirs (and subsequent improvement works);
- Adjustment of treatment plant alarm settings;
- Documentation of corrective action (and contingency) plans; and
- Training of operators on response levels to alarms at critical sites.

One significant gap in understanding of risk that came to light was the need for a sanitary survey of one of Melbourne's unprotected catchments. Although there are reservoir and treatment controls downstream of the catchment, Melbourne Water has begun a more detailed survey of the catchment in order to better understand the hazards and to better influence development in the catchment.

Performance reporting

Melbourne Water's HACCP system is integrated in an overall quality system to the international standard ISO 9001.

The two systems have proved to be compatible and result in meaningful audit, reporting and management review of the HACCP system.

Long term trending of performance indicators at critical control points provides a useful tool for providing assurance of water quality, in addition to the reporting of water quality monitoring, which samples only a small proportion of the water delivered at the end-point.

Melbourne Water has reduced the number of failures at its disinfection plants in recent years due to upgraded infrastructure as well as improved operator training. In addition, the HACCP system ensures that every failure of such a critical facility is responded to with the appropriate corrective action (it could range from simple spot dosing to providing alternative supplies and public notification, depending on the event).

Conclusion

Melbourne Water's implementation of HACCP is an example of how water suppliers can successfully adopt HACCP. HACCP can enhance the Multiple Barrier Approach through its systematic analysis of hazards and the points of control.

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

However, water suppliers should not overlook the fact that the best management systems in the world do not obviate the need for well trained people, committed to ensuring public health and able to respond to unexpected situations.

HACCP, Catchments and Environmental Management

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This abstract highlights the issues relating to the application of HACCP in catchments both in the narrower sense, to public health risk management, and, more broadly, to environmental risk management. In this abstract, the HACCP principles are considered one at a time with their application to catchments described. Then, the integration of HACCP risk management with environmental management is considered.

HACCP principles as applied to catchments

Assemble team

The core disciplines that need to be represented in any catchment HACCP team are hydrologists and hydrogeologists, to provide an understanding of water and pollution flows, and planners and regulators, to understand the control measures that can be applied to pollution control.

Beyond that, additional disciplines will be required for more complex catchments. For example, this may include field inspectors, agricultural scientists, environmental engineers, geographical information system support, social scientists, microbiologists, chemists, toxicologist and epidemiologists.

Describe product and intended use

In almost all cases catchments yield water for subsequent treatment, although not always. Therefore, there are several possibilities for defining the product and intended use for the catchment HACCP sub-plan of a water supply HACCP plan. These are:

- Consumption without treatment;
- Consumption after point-of-use treatment by the consumer; and
- Consumption after treatment by utility.

Consumption is highlighted to ensure that human receptors are considered the risk assessment end-point whilst the influence of treatment is explicitly considered to promote the consideration or risks within that context.

Construct and verify flow diagram

In constructing flow diagrams for catchments their spatial extent means that in general there are several levels of detail required and more than one flow diagram. Examples are given in Table 1.

Many conceptual level flow diagrams for catchments are available in books, journals and websites. These are useful references and can avoid the need to produce such diagrams from first principles. However, there are advantages in producing diagrams from first principles in terms of learning opportunities for HACCP teams. In the latter case the new diagrams can be cross-checked against published examples to reduce the risk of process steps being overlooked.

Table 1. Three levels of detail for flow diagrams for developing HACCP plans for catchments.

Level	What is it?	Form used	Who does it?
Process summary	Conceptual process overview	Flow diagram	Water supply or catchment management organisation
Spatially explicit	Spatial inventory of explicitly identified sources and controls	Map or Geographical Information System	Water supply or catchment management organisation
Site-specific	Detailed process conceptualisations of specific pollution sources and controls	Flow diagram or engineering process and instrumentation diagram	Polluters or their regulators

There will not be generic spatially explicit flow diagrams/maps available – these need to be generated for each catchment and sub-catchment. Explicitly inventorying the hazards and controls that exist is an important first step in risk management.

Hazard analysis

At this point the importance of considering downstream controls becomes evident. In assessing risk there is a need to consider both the raw risk, i.e. of water supply contamination if downstream controls are absent, and the residual risk, i.e. the risk assuming downstream controls are effective. Both are important to provide for a balanced assessment. If residual risk is considered alone, too much reliance is placed on downstream control measures, such as water treatment, and there will be inadequate attention to the additional control measures in the catchment. On the other hand, if raw risk is considered alone and downstream treatment control measures are not considered, there may be undue attention given to some hazards arising in the catchment, that are well controlled by downstream treatment, at the expense of other hazards that present a greater overall risk. A simple illustration is given in Table 2.

Table 2. Raw and residual risk assessment as part of hazard analysis in applying HACCP in catchments.

Hazard	Likelihood		Severity	Risk	
	Raw	Residual*		Raw	Residual*
Salmonella	5	1	5	25	5
Cryptosporidium	3	3	3	9	9

* Residual risk is the risk after downstream treatment - in this simplified, illustrative example, there is assumed to be a reliable chlorine disinfection system which would inactivate *Salmonella* vegetative cells but not *Cryptosporidium* oocysts.

Critical Control Points

Catchments are generally spatially extensive with many potential sources of hazards, and many potential control measures. This can cause some difficulty in efficiently identifying the critical control points (CCP) at the planning level. One solution is to consider a literal interpretation of the Codex (1997) definition of critical control points. Codex describes a CCP as:

> "*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 word "*step*" is the key here because a CCP is a step as identified on a process flow diagram. Therefore, the CCPs in a catchment HACCP plan are likely to be conceptually identified on the conceptual flow diagram. Once identified, the control measures that exist at CCPs can be identified, first conceptually and then the specific controls that exist in the catchment.

Critical limits

In catchments, the processes taking place in the natural part of the system, which forms the bulk of most water catchments, are highly variable, uncertain and poorly controlled. This makes the setting of scientifically based point-value critical limits difficult. Therefore, in catchment HACCP plans it is more likely that the critical limits will be *informed* by scientific understanding rather than directly determined in that way. Further, they are likely to represent best estimates informed by subjective human judgement, based on expertise and experience, as much as on objective scientific analysis and principles. Finally, it is likely that political and historical factors will lead to modification of the critical limits dispassionately identified by the HACCP team, even their elimination from the plan, before it is enacted.

Monitoring

Once again, the spatially extensive nature of catchments impacts on the type of monitoring that is feasible. In general, HACCP planning tends to lead to automated in-situ, on-line, real-time monitoring. However, there are probably no examples where such techniques provide the bulk of a catchment monitoring program, although their use is increasing and they do have an important role. Instead, monitoring in catchments would be largely observational, long-term and relatively infrequent. For example, inspection of fencing may only occur annually, be manual and involve only observation. Surveys of community attitudes, beliefs and behaviours are also important in catchment management and may only occur every five years and is somewhat subjective. Nonetheless, the same concepts apply to monitoring in catchments as at any other water supply stage, that is, the monitoring should focus on the critical limits associated with the control measures that are applied at critical control points. The monitoring should be of a nature, and frequent enough, to detect and trigger a response to deviations in good time to prevent unsafe water being supplied.

Corrective actions

The concept of corrective actions applies in catchments as to any other part of a water supply system. A key consideration, however, is that many of the control measures and monitoring activities are likely to be related to pollution sources that are not controlled by the water supplier or catchment management organisation. For example, if a sewage treatment system is malfunctioning, or a stock animal exclusion fence has been breached, it is likely to be a matter for the sewage treatment plant owner, or the landowner, respectively, to resolve. Therefore, downstream corrective actions may need to be considered in addition to actions at source. In many cases it may be impractical to apply a corrective action at source - the only available corrective actions to a pollution event may involve enhancing the operation of downstream controls.

Relationship between HACCP for public health protection and environmental management systems for environmental protection

The HACCP principles and steps are given descriptors, "jargon", that are not always familiar to environmental management professionals or, worse, that may mean different things to them. Further, there are many environmental risk assessment and management frameworks. This can cause communication difficulties in applying HACCP within catchments. However, in reality the differences are almost entirely semantic. A simple illustration is given in Table 3 to show how some examples of HACCP principles and steps match some examples of environmental risk assessment and management steps. Preparing such a table is a useful step in applying HACCP where the multidiscipline team includes professionals with environmental management but not HACCP experience.

Table 3. Comparison of a HACCP approach with examples of environmental risk assessment principles.

Some HACCP principles and steps	Examples of similar environmental risk assessment steps
Assemble team	Assemble team
Describe product and intended use	Define risk endpoints
Construct and verify flow diagram	Construct conceptual model
Hazard analysis	Inventory of pressures
Critical control points	Describe responses
Critical limits	Target setting
Monitoring	Measurement of response
Verification	Measurement of state

Despite the similarities between HACCP and environmental risk management paradigms, there are some differences. In practice this can lead to matters being considered important for public health, thus a core consideration of the HACCP plan, that are not relevant to environmental health, and *vice versa*. Some examples of conflicting paradigms are given in Table 4. The result of these different paradigms can be conflicts in priorities in catchment management between water supply and environmental risk endpoints. The specific conflicts will vary according to the nature of the catchment. For example, a catchment and reservoir system is generally able to ameliorate labile pollutants, such as pathogens, where these are derived from dry-weather flows and major storm events become the highest-risk causal event. However, the dry-weather pollution in that same catchment might represent the major environmental impact. In contrast, there are some risk endpoints in health and environment that, in terms of risk management responses, are related and do not present conflicts, such as eutrophication (environment) and cyanobacteria (health).

Table 4. Examples of risk assessment and management paradigms and their differences when health and environmental endpoints are considered.

Paradigm	Environment	Health
Timing	Chronic	Acute
Reporting	Continuous	Categorical
Monitoring	Populations and systems	Individuals and groups
Hazards	Cumulative	Specific
Endpoint	The broad natural system	Humans

Options to resolve these conflicts can be threefold:

- Just one or other endpoint can be considered in isolation and priorities set on that basis;
- One or other endpoint can be considered first, then the risk management plan can be reviewed from the perspective of the other endpoint; or
- A fully integrated water resources management plan can be developed that considers health and environmental endpoints.

A recent example of an integrated water cycle management plan that applies HACCP principles within the broader context of total catchment management is available in the public domain and has been developed by the NSW State Government in Australia. For further details and information this can be sourced from "Schneider, P., Davison, A.D., Langdon, A., Freeman, G., Essery, C., Beatty, R. and Toop, P. (2003) *Integrated Water Cycle Planning for NSW Towns*. Water Science & Technology 477-8, 87-94".

Lyonnaise des Eaux: Application of HACCP Principles in Drinking Water

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Lyonnaise des Eaux, France

The regulatory context

The Drinking Water Directive 98/83 adopted by the European Council on 3 November 1998 sets the European policy for drinking water.

Compared to the previous directive of 1980, the new directive emphasises water safety by :

- Stipulating in its first article that: "*The objective of the Directive shall be to protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean*."
- Stipulating in Article 4 that: "*Water shall be free from any substances constituting a potential danger to human health*."
- Moving sampling points from distribution network to the consumer's tap (Article 6)
- Differentiating microbiological and chemical parameters, which can be considered as health parameters set for water safety, from indicator parameters that should be used only for monitoring purposes (Article 5).

The European Directive was adopted by French law in December 2001 (French decree 2001-1220).

Like the directive, the French decree also enhances water safety. Moreover it sets a new framework based on risk assessment and risk management strategies allowing the optimisation of the monitoring programs.

As a matter of fact the new decree stipulates that part of the surveillance done by water suppliers can be integrated to the regulatory monitoring on the condition that risks have been analysed, critical control points and control measures identified.

Though the word HACCP does not clearly appear in the text of the decree, French health authorities are now explicitly supporting this approach. A working group is currently preparing a guidance document for health officers explaining what HACCP is and how it can be applied in the field of drinking water.

The SPDE approach

At the same time, French private water suppliers, associated in the SPDE (Syndicat professionnel des entreprises de services d'eau et d'assainissement), have taken into account client concerns on quality and particularly their wishes to be part of proactive risk management actions. This has lead SPDE to have a co-ordinated approach to experiment with the application of HACCP principles to the drinking water production and distribution process.

The HACCP method was implemented on 8 pilot sites from the smallest and simplest to more complex systems. At the end of the year 2000, an industry guide to “HACCP implementation in drinking water” was written based on the trials..

Since 2001, the SPDE is sharing its experiences with the health authorities’ working group.

Lyonnaise des Eaux’s HACCP trials

One of the pilot sites selected by Lyonnaise des Eaux to experiment with HACCP implementation was the Morsang sur Seine water treatment plant which is a large multi-barrier treatment plant, situated 30 km to the south of Paris.

The 7 key principles of the HACCP method have been applied to Morsang sur Seine water treatment plant.

Identifying hazards

Hazards have been identified from source to tap being as exhaustive as possible.

At source there is possible microbiological, chemical and even radioactive contamination of the Seine river since there are a lot of factories and even a nuclear power plant upstream of the water intake.

During treatment over- or underfeeding of chemicals can occur as well as saturation of activated carbon leading to potential desorption of retained compounds, and by-products can be formed during oxidation.

Identified hazards during storage are break-ins and contamination during cleaning operations.

Throughout the distribution network there is a risk of microbiological revival or a possible contamination from an interconnection, a broken pipe or a backflow from domestic or industrial network.

Prioritising hazards

Hazards have been prioritised using matrixes crossing the severity and the likelihood for each identified risk.

Risks have been classified according to their seriousness from 1 to 3, 1 being the least serious.

Likelihood has been classified in the same way from 1 for a probability of once in ten years to 3 for a risk occurring once every quarter. An additional level 0 for events with an occurrence inferior to once every 100 years has been set.

The priority rate is the result of the likelihood of the event multiplied by the seriousness of the consequence.

Identifying control measures

At source, an observation centre, situated upstream from water intake, triggers off an alarm if a high level of contamination is detected. In that case water can be drawn from the Essonne river, which is a tributary to the Seine, into the treatment plant activating an emergency interconnection. There is also the possibility to stop the plant in case of emergency and of course database records of previous measurements can help us to be aware of any unusual fluctuation of a parameter.

During treatment and storage, there are a lot of on-line sensors with remote monitoring to a control room working 24 hours a day, 7 days a week, and all the operations are described in the procedures of our Quality Management System.

The control measures on the distribution network are the procedures for maintenance and repair, the sampling and monitoring program, and maps we draw with the results of these analyses.

Determining Critical Control Points

At that stage of our experimentation, only hazards with a priority rate superior to 3 have been considered.

Going through the decision tree of the method, the following Critical Control Points on Morsang sur Seine treatment plant have been determined:

- Aluminium contamination due to coagulant overfeeding;
- Microbiological contamination due to chlorine underfeeding; and
- Microbiological contamination due to chlorination dysfunction.

Setting critical limits

Critical limits have been set according to Lyonnaise des Eaux internal standards, operating procedures and performance targets of the Quality Management System.

For aluminium, a critical limit of 0,1 mg/l of residual aluminium has been set to be met after the first filtration stage.

For chlorine, the critical limit has been set at a value of 0,15 mg/l to be met at the production outlet. Chlorine concentration at the production outlet should not be inferior to this limit.

Establishing monitoring

A wide range of parameters are monitored with on-line sensors upstream and on site to detect any unusual concentration that could lead to aluminium contamination or chlorine underfeeding.

A sampling and laboratory analyses program has been established for these parameters at different stages of the process.

Establishing corrective actions, verification procedures, documentation and record keeping

The final three steps are already described in the Quality Management System which is ISO certified.

Conclusion

This first trials have demonstrated the applicability of HACCP in the drinking water treatment field. It has shown that HACCP is a very accurate system to guarantee water safety in addition to the quality management system approach of the ISO 9000 series.

Moreover, in the French regulatory context, HACCP implementation should help water suppliers meet the requirements of Article 18 of the French decree thus allowing an optimisation of monitoring programs. The French Health authorities explicitly endorse this approach and are preparing a guidance document for health officers explaining what HACCP is and how it can be applied in the field of drinking water. The SPDE is sharing its experiences of HACCP implementation with the health authorities .

Lyonnaise des Eaux is now implementing HACCP principles to a large number of its water treatment plants of different sizes to assess practical aspects of its application and its cost-effectiveness.

Vivendi Water: Application of HACCP Principles in Drinking Water

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Introduction

In order to ensure quality and safety of drinking water, European legislation (98/83/EC Drinking Water Directive) is still based on compliance monitoring of distributed water (parametric values and minimum frequencies for water monitoring).

However the mechanisms based on compliance monitoring for controlling the safety and the quality of the drinking water have shown their limitations. Indeed, an increase in documented waterborne infectious intestinal illness is recorded in industrialised countries. Several acute gastro-intestinal disease outbreaks were recently recorded in France. They were related to either accidental degradation of the resource used for producing drinking water (Sète), failure in the water disinfection process (Gourdon, Fécamp), post contamination of the water supply network after breaks or repairs of mains (Strasbourg, Le Havre), or backflow recontamination of the drinking water supply system by wastewater (Dracy le Fort).

Additionally compliance monitoring deals with a reactive management. Hence, a more preventive approach to insure sanitary quality of water is needed. A new comprehensive management system including risk assessment and risk management approaches is a new trend endorsed by World Health Organisation. Such management systems have to be implemented from catchment to consumer's tap.

HACCP (Hazard Analysis Critical Control Points) is part of this new approach. HACCP is a systematic method for identification, evaluation and control of food safety hazards. This risk assessment method is already known and used in the food industry (defined by the Codex Alimentarius 97/13A and recommended by the 93/43 Hygiene Directive). It is also tightly connected to the Quality Management System (ISO 9001 certification, laboratories accreditation). HACCP provides a structure in order to list and to rank risks in a rigorous and systematic way and to implement control measures to assure consumer health.

Moreover, this new approach has been introduced in French legislation, in Decree 2001-1220 (French transcription of the EC Directive). Indeed Article 18 indicates that in order to ensure water quality, the operator must continuously examine assets (plants, networks, etc.), monitor where risk have been identified, keep and record all relevant information. While at least 50 % of water quality surveillance is performed by health authorities, additional water quality monitoring done by operator can be taken into account if risk analysis identifying critical control point has been done, control is realised and operating instructions are followed, and analyses are performed by skilled laboratories (laboratories with accreditation and certification).

Therefore French water suppliers have implemented the method on different water distribution systems.

HACCP implementation in Vivendi Water – Generale des Eaux

Vivendi Water has now more than 2 years experience in developing and establishing water safety management plans using HACCP in France.

- *March 2000 – June 2001 (pilot phase)*: HACCP was first implemented in a multi-barrier treatment plant in Annet sur Marne (near Paris) producing 100,000 m3/day from the Marne River and delivering 700,000 inhabitants. The method was evaluated by AFAQ (the main French certification body) in June 2001. AFAQ had by then validated the system conformity to the HACCP Codex rules.
- *End 2002*: HACCP has been conducted on 25 different water production-distribution systems. Such systems include groundwater and/or surface water (rivers, reservoirs) resources, different size water systems, most of them from catchment to consumer, representing different treatment lines (disinfected-only and multi-barrier treatment plants and/or water supply networks). Most of the systems have been evaluated by AFAQ. This represents today 2.8 millions inhabitants. The implementation is expected to reach about 7 millions at the end of 2003.

HACCP implementation in the water domain

HACCP is a systematic method for identification, evaluation and control of food safety hazards. It is implemented according to 12 steps (5 preliminary tasks and 7 principles), described by Codex Alimentarius 97/13A.

The 5 preliminary tasks are:

- Task 1: Assemble HACCP team
- Task 2: Describe product
- Task 3: Identify intended use
- Task 4: Construct flow diagram
- Task 5: On-site confirmation of flow diagram

The analysis is conducted locally by a multidisciplinary team (production manager, supply manager, and quality manager – referring to quality management system and/or water quality). This team can be assisted by specialists at the regional level, with competencies in drinking water treatment technologies, analyses, quality management, consumer services.

The final product (tap water - elaborated from raw water, chemical reagents, etc.) and its use (e.g. consumption for drinking, food, sanitary use, industry) are precisely identified. The complete process is described and checked on site: resource, treatment plant, storage, public and private network.

The 7 HACCP principles are:

- Principle 1: Hazard analysis and control measures determination
- Principle 2: Determine Critical Control Points (CCP)
- Principle 3: Establish critical limits for each CCP
- Principle 4: Establish a monitoring system for each CCP

- Principle 5: Establish corrective actions
- Principle 6: Establish verification procedures
- Principle 7: Establish documentation and record keeping

Application of the 7 principles to the distribution network

The water supply process has several specificities compared to the food industry. First, the production and distribution process is continuous. Moreover, the network itself is wide and open, and the knowledge about it is usually incomplete (e.g. network constitution, pipe materials, events on the network, hydraulic regimes). Consequently, different tools are developed in order to have a better knowledge about the network (e.g. monitoring information tools (GIS), hydraulic models, water quality testing). The presence of different operators on the network (suppliers, subcontractors, firemen, road maintenance, specific customers as potential polluters, and individual consumers) may be another difficulty.

An example of implementation of the 7 principles for the water distribution network is developed below.

<u>Hazard analysis</u>

First, hazards have to be analysed and control measures have to be identified (Principle 1). Hazards are parameters (microbiological or physical-chemical) which may be present at the consumer's tap because they are introduced into the water distribution system, and which may have an impact on the consumer's health. Examples of potential hazards introduced to the water distribution network are:

- *Microbial hazards*: free living amoeba; environmental bacterial strains (e.g. coliforms, *Citrobacter*, *Enterobacter*, *Klebsiella*, Mycobacterium) may colonise biofilms in cold waters; legionella in hot domestic plumbing systems; all enteric pathogens (protozoa: *Giardia*, *Cryptosporidium*; viruses; bacteria) in case of post-contamination (e.g. back-siphonage, cross-connections).
- *Chemical hazards*: nitrates, pesticides (inefficiency of treatment); THM (treatment by-products); metals (e.g. lead), PAH (from pipe materials); other chemical hazards (from solders/jointing compounds, chemicals used in cleaning and disinfection).

The causes of introduction of these hazards on the network are:

- *Accidental, uncontrolled events*: pipe bursts and leaks; cross-connections and proximity to sewers; infiltration and ingress of contamination from cross-connections and backflow; vandalism, sabotage, and natural disasters.
- *Operational practices*: inadequate repair and maintenance; inadequate maintenance of disinfectant residual; failure of alarms and monitoring equipment; inadequate disinfection after construction and repairs; biofilm, sloughing, re-suspension and regrowth; build-up of sediments and slimes; corrosion of pipes and reservoirs.
- *Network structure and third party activities*: age and nature of pipes materials; flow variability and inadequate pressures; short circuiting and stagnation zones; illegal connections.

Control measures identification

As a next step, the team will prioritise the risks and identify the control measures to be implemented (e.g. in pollution prevention, treatment).

The method allows the team to identify Critical Control Points (CCP) with the decision tree (Principle 2). CCPs are steps where a supervision needs to be done and is essential to prevent or reduce the hazard's presence to an acceptable level. Each CCP is subjected to supervision: critical limits, monitoring system, and corrective actions have to be defined. (Principles 3, 4, 5).

Two examples of CCPs for microbiological parameters on the network are given below:

- On service reservoirs, bacteriological contamination may be due to vandalism or sabotage (hazard cause). Control measures which may be developed in order to prevent this contamination are: installation of fences, locked doors, screened windows. The critical limits which can be set are alarms given by the warning system or after inspection (e.g. at gates, doors, screens). Monitoring is mainly based on warning systems against intrusion, periodic inspections, traceability of keys for access. Corrective actions can be specific actions according to QMS documented procedures such as contact with authorities, advice for limited water uses, distribution of bottled water, an additional monitoring programme.
- On main pipes, bacteriological contamination may be due to back-siphonage. The following control measures may be developed: check valve disconnectors, list of consumers who may cause specific risks. The critical limits are compliance with parametric or indicator values (e.g. bacteria, turbidity), odour, or taste. Monitoring is mainly based on check monitoring and consumer complaints. Corrective actions deal with specific actions defined in QMS documented procedures (e.g. emergency situations, flushing operations, check valves installation).

The HACCP system is integrated to the quality management system (Principle 7) and is then checked regularly (Principle 6).

Results and assessment of HACCP

Pilot sites on which HACCP has been implemented have enabled a validation of HACCP as a suitable quality management system to ensure sanitary safety of supplied water.

Hazard knowledge

With this method, Vivendi Water anticipates problems of sanitary safety. Indeed, hazards are identified at three levels:

- Hazards that have been identified at a national level have to be analysed at a local level. For this purpose a check-list is constituted. Therefore, a HACCP plan at least needs to cover the parameters of French regulations.
- At a local level, the HACCP team analyses the risks due to every hazard identified through hazard analysis.
- Moreover, Vivendi Water has a specific entity called "Expert Committee" which is in charge of identifying new parameters with potential health impacts, proposing

appropriate actions, and defining needs for research and development. This assures that every hazard is taken into account, and it goes beyond the Codex Alimentarius requirements.

Risk analysis and control

From the identified hazards, the analysis allows to check the adequacy of the production plant and –the distribution system in relation to the target of supplying safe water. A risk ranking allows to give priority to control measures within the supply chain from the source to the consumer.

Water quality monitoring

The water supplier monitors supplied water quality by monitoring programs that are specifically designed to control the risks which have been identified and ranked.. They are adapted to the local situation (conditions of the resource, at the treatment plant, and in the distribution network). They assure the sanitary monitoring of water, control of critical points in respect with the economical constraints defined by the main shareholders.

Where this rigorous and systematic method for the determination of monitoring programs is implemented, the sanitary authorities can – in part – rely on the results and reduce their own, independent surveillance. (Article 18, D 2001-1220): best monitoring for best sanitary control.

Communication

Control of some critical points is sometimes beyond the scope of Vivendi Water responsibilities. Water catchments have to be protected in order to avoid the introduction of substances with health impacts, and private networks have to be maintained in order to avoid a degradation of water quality. HACCP places consumer health at the top of its priorities. It leads the different shareholders to communicate on water quality.

Quality management system

The implementation of HACCP in the different water treatment plants in Vivendi Water is a lot easier thanks to the existence of the quality management system. HACCP is integrated into it. Almost all the documents referred in the HACCP system had been already created through the ISO 9001 system. HACCP gives a sanitary vision of the system and allows some revisions.

Conclusions

The implementation of HACCP in water distribution system is part of the integrated approach of Vivendi Water concerning the water quality management which consists of the following elements: recording of data, traceability, reporting of data, risk management and monitoring based on risk assessment, quality control/quality assurance for results of analyses, water quality evaluation, information on water quality and heath risks.

HACCP becomes naturally integrated into the quality management system. This systematic and rigorous method drives the continuous improvement of sanitary safety of water distributed to the consumer. It gives a framework to the monitoring of the emerging parameters and allows to anticipate sanitary crises. It provides a ranking of risks and gives a global vision of water quality. It allows an optimisation of monitoring plans related to risks. It provides a discussion frame with sanitary authorities.

The different players of the water area are involved in this approach: national or regional authorities (in resource management, water quality monitoring), local authorities (owner of the public installations), water suppliers (management of public production-distribution installations), users (owners of private installations and final consumers). Future legislation seem to take more and more these kind of approaches into account in order to ensure water quality and sanitary safety.

Adoption of HACCP Principles for Water Safety with Particular Reference to Cryptosporidium

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Introduction

United Utilities supplies in the region of 2000 Ml of drinking water a day to nearly 7 Million people in the north west of England. Surface water sources account for 90 % of the water supplied by its 150 water treatment works. - Historically the incidence of cryptosporidiosis in the region is twice the average for England and Wales as a whole (21 and 10.5/100,000 respectively). In both 1999 and 2000 there were outbreaks of cryptosporidiosis which, on epidemiological investigation, were found to be statistically associated with the consumption of unheated tap water from an unfiltered surface water source.

The paper describes the steps taken to reduce the risks of waterborne cryptosporidiosis until new treatment plants are commissioned in 2004. In the absence of treatment effective at removing cryptosporidium oocysts, reliance was placed on measures to protect source water quality, both on catchment and during bulk transfer along 100 km of aqueduct prone to ingress of surface water. The risk management process adopted was based on HACCP principles.

Hazard analysis

Thirlmere reservoir is located in the English Lake District near Keswick. The reservoir was formed by the construction of a dam which was completed in 1894. Water flows by gravity southward for 100 km through a series of parallel tunnels to supply Manchester and surrounding areas. Sections of the aqueduct were tunnelled through rock, whilst others are pressurised pipelines. The remaining sections were constructed using a process known as "cut and cover". This entailed excavating a rectangular channel over which was placed rock slabs and a covering of soil. In order to equalise internal and external pressure, the latter caused by groundwater, pressure relief valves were installed in the floor of these sections. The valves permit water to flow in or out of the aqueduct, the direction of flow being into the aqueduct when the water table is high.

Treatment at source (Dunmail Raise water treatment works) consists of microstraining (pore size 90 µm), disinfection and pH correction. The maximum daily output is 225 Ml. At points along the passage of the aqueduct water is abstracted, rechlorinated and used to supply surrounding areas. The aqueduct terminates at Lostock (Nr Bolton) where the water enters the Manchester ring main (Figure 1).

The catchment area of the reservoir covers 41 km^2 and ranges from 190 – 950 m above sea level (asl). Land use within the catchment consists of forestry and livestock production, almost exclusively sheep. Stocking densities are low because of the generally unproductive nature of the land, much of it being above 500 m (asl). The area is also populated by Red Deer (*Cervus elaphus*) and Roe Deer (*Capreolus capreolus*). For much of its length the Thirlmere Aqueduct (TA) passes through land used for agriculture, including livestock production and arable farming that may employ landspreading of animal manures or slurries.

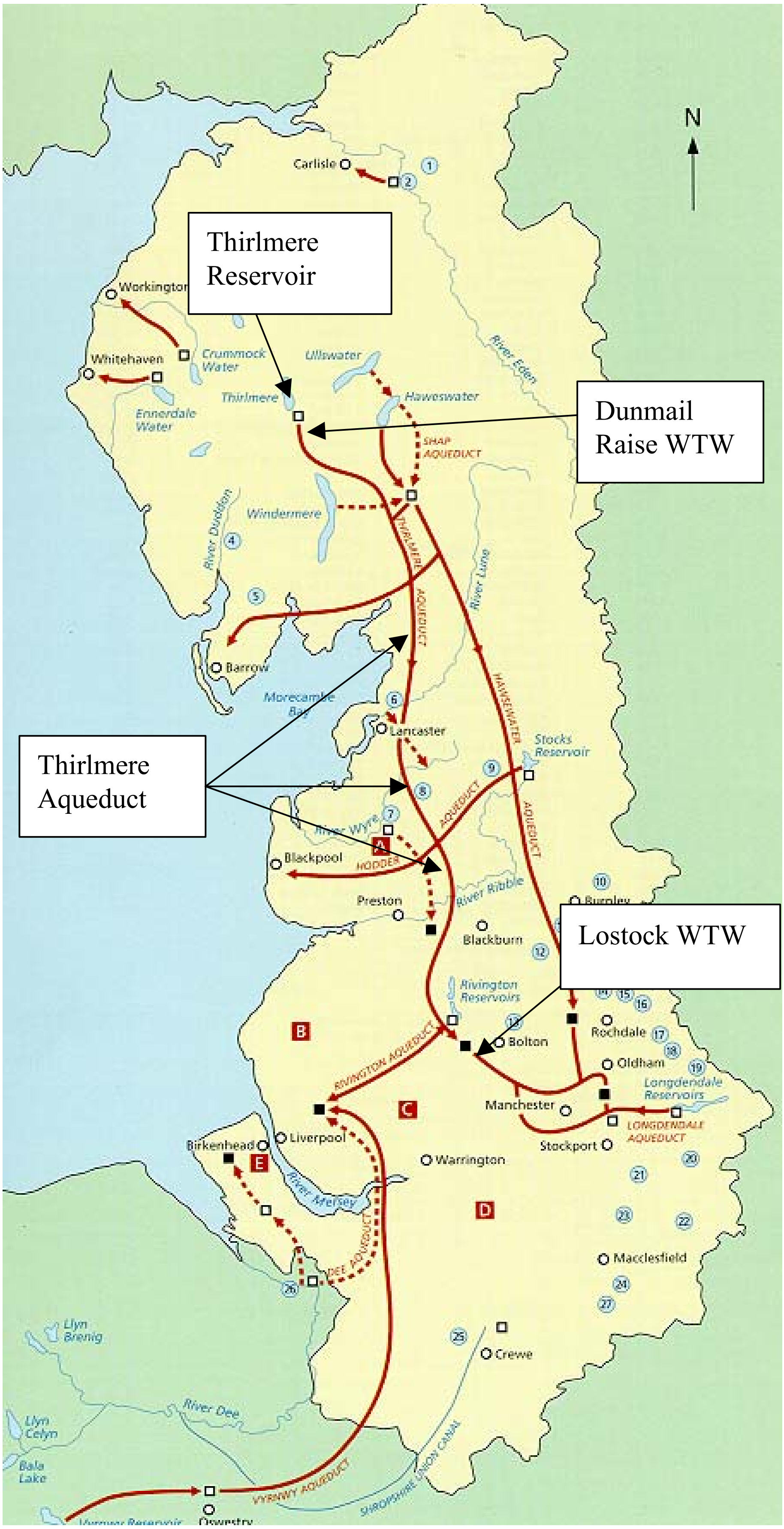

Figure 1. Location of Thirlmere reservoir and treatment works.

A hazard analysis was carried out to identify the risks associated with the Thirlmere supply. This scope was not restricted to the catchment and treatment process but incorporated also the 100 km of treated water aqueduct. Long term water quality monitoring data showed consistently low levels of faecal indicator bacteria. Weekly reservoir sampling for cryptosporidium and giardia commenced in 1994. These were 10l grab samples. In January 2000, continuous large volume sampling at Dunmail Raise WTW commenced using the methods specified in the UK Cryptosporidium Regulations (http://www.dwi.gov.uk/regs/crypto/legalindex.htm). Levels of cryptosporidium are generally low but do show intermittent larger numbers of oocysts, often immediately following intense rainfall (Figure 4).

The hazard analysis exercise indicated clearly that cryptosporidium was the principal hazard associated with the supply, contamination potentially affecting the reservoir and/or the treated water aqueduct.

Control measures

In the absence of a treatment barrier effective at removing cryptosporidium oocysts, control measures were identified that would have the effect of eliminating or minimising the entry of oocysts into both the reservoir and the treated water aqueduct.

Reservoir

The reservoir receives flows from a large number of feeder streams. Many of these contribute only a small proportion of the total inflow to the reservoir. Two streams, Mill Gill and Wyth Burn between them contribute over 40 % of the flow. A hydrodynamic model of the reservoir was constructed using computational fluid dynamics (CFD). The model outputs demonstrated that, under certain conditions, water entering from Mill Gill would not mix effectively with the body of the reservoir and could produce a surface flow reaching the abstraction point within one hour. The reservoir is fitted with two "bubble mixers" (perforated pipes across the bed of the reservoir through which air is pumped to produce a curtain of bubbles which assist mixing). Originally installed as a means of preventing stratification, the mixers were operated earlier in the year during the spring period when the risk of cryptosporidium contamination was at its greatest. Running the CFD model with the mixers operating showed that the inflow from Mill Gill was incorporated into the mass of the reservoir, thereby diluting the levels of oocysts in the incoming water.

Feeder streams

The two principal feeder streams (Mill Gill and Wyth Burn) flow across land in the bottom of the valley. Over time much of this land has been improved and is used during the spring to hold sheep during the short lambing period. Inevitably the animals housed on this land congregated along the sides of the streams for access to drinking water but also because it afforded some shelter during inclement weather. The presence of large numbers of animals in close proximity to the streams increased the likelihood of cryptosporidium oocysts entering the water and being carried into the reservoir. The control measure instigated was to fence off the streams and provide alternative supplies of drinking water for livestock. Animals tend to congregate close to water and by locating drinking troughs well away from the streams, creating a buffer strip between the stream and the areas most likely to be contaminated with animal faeces.

Catchment

United Utilities is fortunate in owning much of the land that forms the catchment of Thirlmere reservoir. This enables to company to restrict, by means of tenancy agreements, agricultural activity. By working with tenant farmers it is possible to sustain agriculture whilst minimising any adverse effects on water quality. In 2000, the company arranged at its own expense to move some 1000 pregnant ewes off the catchment to alternative grazing land until such time as lambing was completed and the young animals were capable of inhabiting the higher land well away from the valley floor.

Treated water aqueduct

The treated water aqueduct is prone to ingress from surface water or shallow groundwater. In order to minimise the risk of ingress by water containing cryptosporidium several measures were instigated. Firstly, the aqueduct was run at full flow during the high risk spring period. When running full the internal water pressure reduces the potential for ingress and also serves to dilute what ingress does occur. Secondly, the line of the aqueduct was treated as a raw water catchment for those sections passing through agricultural land. Farmers were contacted requesting their assistance in reducing contamination for example by not applying animal manures within the route of the aqueduct. The line of the aqueduct is regularly inspected for evidence of contamination or practices that could give rise to contamination.

Monitoring

Monitoring the effectiveness of the control measures was instigated. This included:

- Examination of Mill Gill and Wyth Burn for cryptosporidium oocysts (Figures 2 and 3);
- Continuous monitoring for cryptosporidium at Dunmail Raise WTW and two points along the length of the treated water aqueduct (Hoghton and Lostock) (Figures 4 and 5);
- Regular visual inspection of the Thirlmere catchment and the line of the aqueduct;
- Rainfall, including weather radar to provide advance warning of intense events; and Reservoir levels (large increases in water levels may be associated with increasing numbers of oocysts entering the reservoir).

Action limits for cryptosporidium in aqueduct samples were set at 10 %, 40 % and 100 % of "UK Treatment Standard" (< 1 oocyst per 10 litres). Contingency plans were established to define responses to results in excess of the action limits, including immediate catchment/ aqueduct inspection, additional water monitoring and discussion with local health agencies.

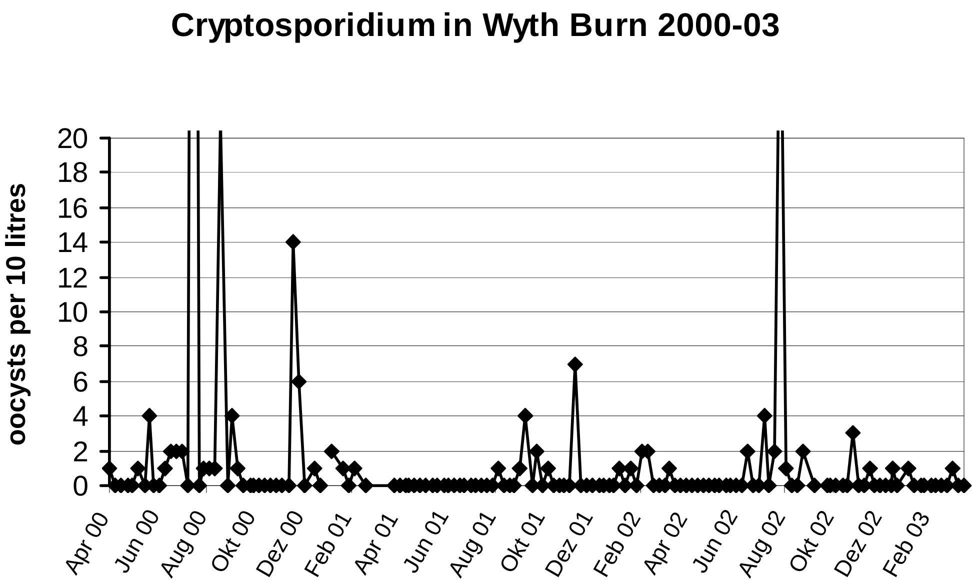

Figure 2. Cryptosporidium in Wyth Burn (10 l grab samples).

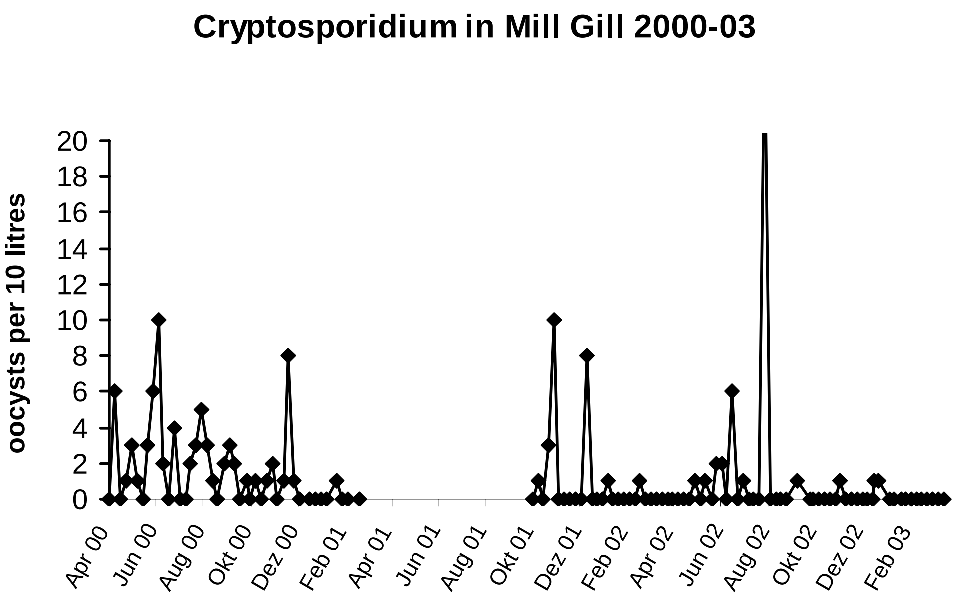

Figure 3. Cryptosporidium in Mill Gill (10 l grab samples).

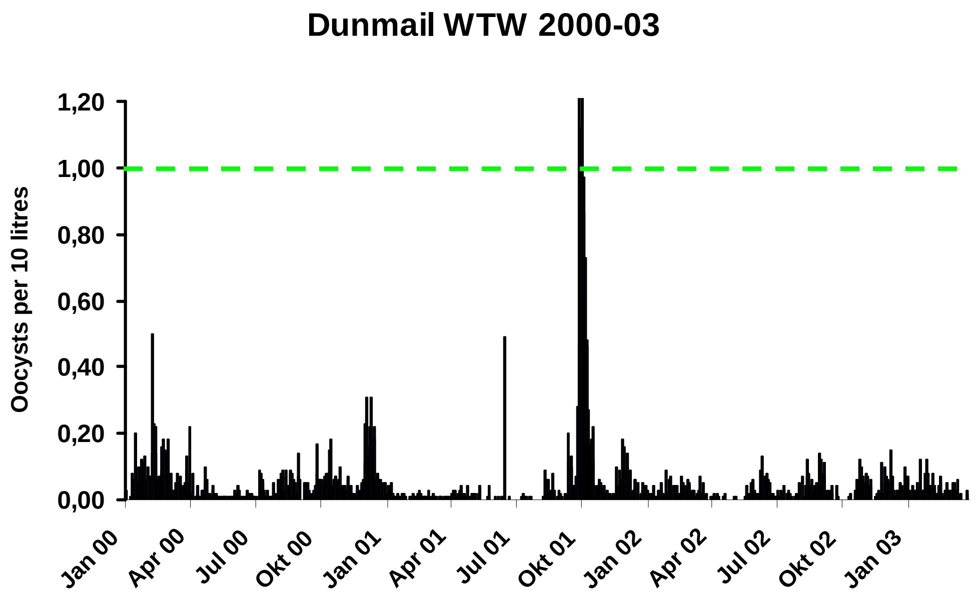

Figure 4. Results of continuous monitoring for cryptosporidium at Dunmail WTW (broken line denotes UK "Treatment Standard").

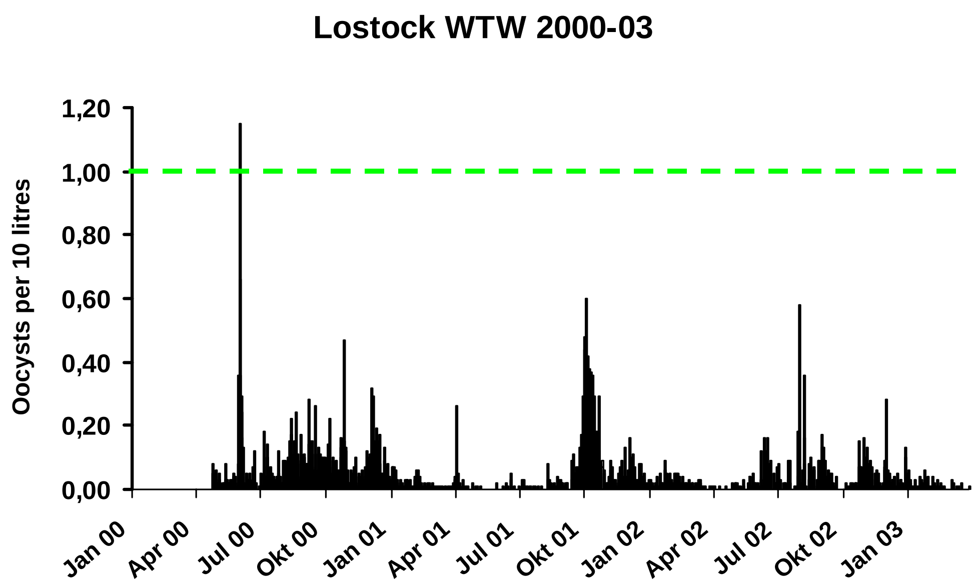

Figure 5. Results of continuous monitoring for cryptosporidium at Lostock WTW (broken line denotes UK "Treatment Standard").

Effectiveness of control measures

The effectiveness of control measures may be assessed from a number of criteria. Firstly, there have been no outbreaks of waterborne cryptosporidiosis detected in the areas served by the Thirlmere supply since 2000. An indirect measure may be obtained from the incidence of cryptosporidiosis within the region (Figure 6). Great caution must be exercised when using this measure to assess the effectiveness of the controls. Firstly, the data on human cryptosporidiosis are not restricted to the area supplied by this source of drinking water. Secondly, in non-outbreak conditions the source of infection cannot be determined for the majority of cases, a proportion of which are associated with foreign travel. Finally, there is no evidence that in non-outbreak conditions that any of the cases of sporadic cryptosporidiosis are associated with drinking water. Indeed a recent study in north west England and north Wales failed to demonstrate any association between the source of drinking water and the incidence of cryptosporidiosis (in press). However, it is apparent that the incidence of cryptosporidiosis in the north west of England declined in 2001, a trend that has continued (Figure 6). The reasons for this are unclear. Over the same period there has been a decline in cases nationally (England and Wales). What is clear however, is the absence of a “Spring peak” which was a observed consistently in the years up to and including 2000.

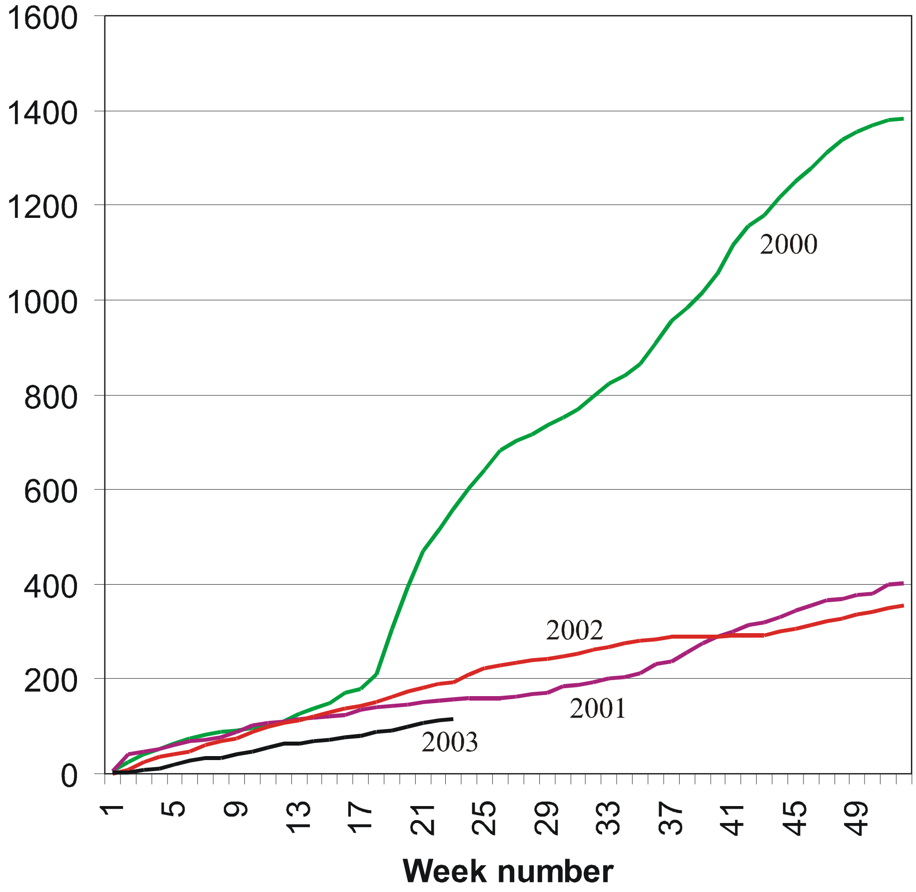

Figure 6. Cumulative number of cases of human cryptosporidiosis in NW England 2000 – 2003 (source CDSC NW).

Future control measures

Since 2001, the company has been working to implement a major capital scheme that will introduce additional measures to reduce further the risk of cryptosporidiosis. This entails the construction of a new water treatment works at Lostock capable of treating 160 Ml/day by a process incorporating coagulation and filtration (direct filtration). Water abstracted from the aqueduct further north will be piped to an expanded existing treatment works where it will be treated by conventional coagulation, clarification and filtration. The areas supplied by the smaller offtakes, primarily to the northern end of the Thirlmere aqueduct, will be supplied from alternative sources. These schemes are due to be completed in Spring 2004 at which point the aqueduct effectively becomes a raw water pipeline.

Acknowledgements

The authors wishes to thank colleagues in United Utilities for information and data used in the preparation of this abstract. To Dr Eoin Casey, Dr Steve Hearn, PFD, Dublin for the CFD modelling; CDSC NW for data on human cryptosporidiosis. Finally, I would like to thank the organisers of the Water Safety Conference for permitting me to present this work. The views expressed are those of the author and do not necessarily reflect those of United Utilities plc or any other organisation referred to.

Safeguarding the Drinking Water Quality: Using the Example of the Industriellen Werke Basle

Richard Wülser and Hans Trachsel

Industrielle Werke Basel, Switzerland

Introduction

The Industrielle Werke Basel (IWB) supplies the city of Basle and the surrounding municipalities with electricity, district heating, gas and water. As the producer and supplier of drinking water for more than 200,000 people, the IWB is one of the most important foodstuff companies of North-west Switzerland. In former times, water, as the most important element for the support of life, was also the largest carrier of sickness and epidemic diseases. Even today, water-caused infection diseases are not to be underestimated (Meylan and Jordi, 2001; Maurer and Stürchler, 2000). Continuous monitoring of the water quality and all installations is therefore a prerequisite for a safe water supply. A comprehensive management system should thereby serve to reduce the existing risk of a serious failure to a minimum and to guarantee the foodstuff quality at all times.

Initial situation

In recent years, the IWB has experienced a continuous change in the framework conditions of the water supply. New, increased requirements from both internal and external bodies have led to a continuous further development of the quality policy within the company. The original quality control served primarily to check the product specifications and to measure deviations in the product quality, in order to be able to initiate measures to correct the fault where necessary. With the demand for a comprehensive and customer-oriented quality policy, new quality assurance and management systems have arisen. A possible rewriting of the term "quality" could thereby read: The best quality is that that supplies the customers with high quality drinking water with the lowest costs and environmental impact.

New legal requirements (Tremp, 2000)

Up to the renewal of the 1992 foodstuff law (LMG, 1992), the cantonal laboratories played a dominating role in the quality assurance of water supply companies in Switzerland. The predominant part of the quality assurance tasks, which today belong to the area of responsibility of the drinking water producers, was carried out by the foodstuff/drinking water inspectorates. In fact, therefore, the responsibility for the drinking water quality lay with the cantonal chemists and not with the responsible managers in the water supply company.

This situation, which often led to conflicts, has been largely clarified with the coming into force of the new foodstuff law, which expressly prescribes self-checking. The stipulations that are valid today (foodstuff ordinance (LMV, 1995), hygiene ordinance (HyV, 1995), impurity and ingredient ordinance (FIV, 1995)) require from the drinking water producers a systematic quality assurance according to a defined and clear concept. In addition, the liability in cases of damage has been regulated for producers and suppliers with the introduction of the product liability 1993 (PrHG, 1993).

Increased quality requirements

It is not only the new legal requirements that have caused a re-alignment of the quality concepts. The consumers of drinking water and the consumer organisations also increasingly expect further quality improvements in drinking water. Examples of the corresponding quality demands are:

- The drinking water should be fresh and have a neutral taste. A taste of chlorine is regarded as irritating. The water should also be of such a good quality that disinfectants only have to be used in small concentrations, or not at all.
- In general, customers would like drinking water that is left as natural as possible, and that contains no additives.
- The appearance of rust water or water that leaves easily deposits of lime are regarded as unpleasant.

Customer orientation

Despite the existing monopoly, a re-alignment and continuous development are demanded from the water supply companies. In many discussions, queries and contacts with customers, it is noted again and again that there is only a little knowledge regarding the relationships in the water supply and regarding the water quality. The confidence in the quality of the most important foodstuff - drinking water - does not arise on its own, however. The precondition for this is a quality policy that is lived, and in which customer satisfaction and openness in consultation form the basis when dealing with the consumers of drinking water. Complaints and questions regarding the water quality should be accepted, be assessed, and be answered in an understandable way. The provision of brochures and quality data is also very helpful in this. Here also, the quality management plays a role, in that the expected customer relationships are described and are measurably put into practice.

The water supply of Basle City (IWB, 2001)

The water supply of the canton of Basle City relies on IWB's own groundwater plant in the Lange Erlen and the Hard groundwater plant of Hardwasser AG, in which the canton of Basle City holds a 50 % shareholding. The population in a area of 40 km^2 is supplied with the drinking water from these two plants (Figure 1). The most important characteristics are listed in Box 1.

Box 1. 2002 characteristics of the IWB water supply.

Water supply:	26 Mio. m3 per year
Purchases (from Hardwasser AG):	11.5 Mio. m3
Per capita consumption (incl. small businesses):	225 litres per day
Delivery to neighbouring municipalities:	2.75 Mio. m3
Length of pipe network:	465 km
Number of reservoirs:	13
Pressure levels (2 high areas):	5
Water price (incl. VAT.)	Fr. 1.30 per m3

The groundwater enrichment plant Lange Erlen (Figure 2) stretches from the edge of the city of Basle in a north-easterly direction along the river "Wiese" up to the national frontier at Lörrach. With a withdrawal of 30,000 – 70,000 m^3 per day, Lange Erlen covers around 60 % of the drinking water consumption of the city of Basle. In order to make the large withdrawals possible, the natural groundwater is artificially enriched by means of pre-filtered Rhine water in forest areas (Rüetschi *et al*., 2001).

Balanced groundwater levels are achieved when the infiltrated raw water volume corresponds approximately to the pumped groundwater volume.

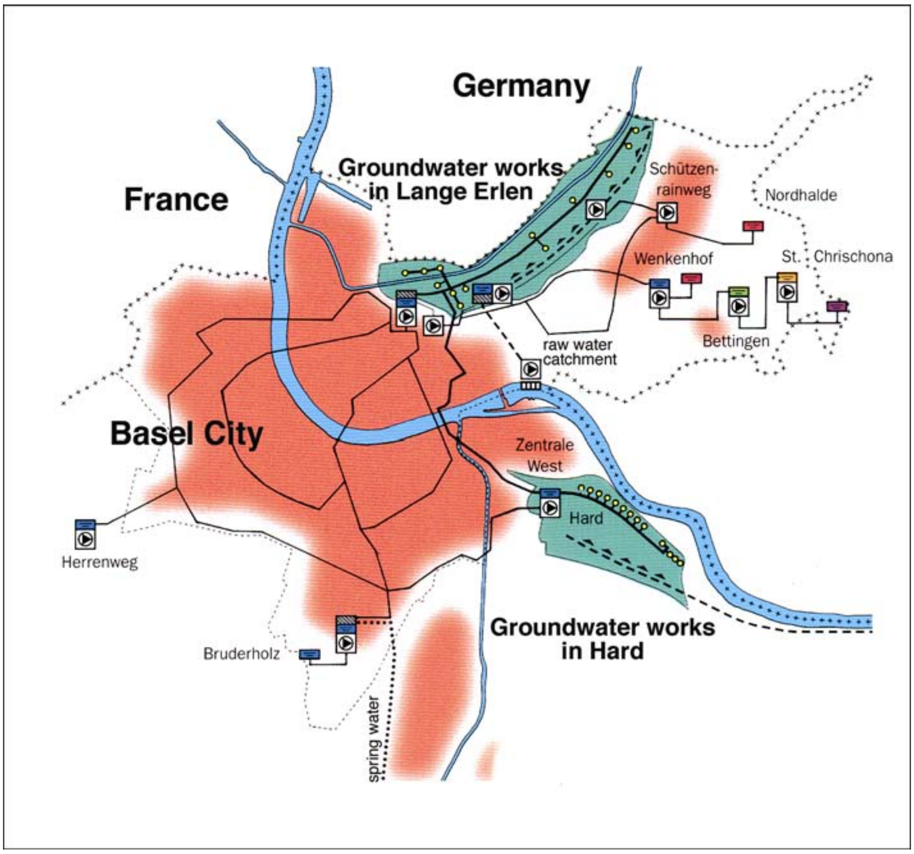

Figure 1. Survey of water supply of the IWB.

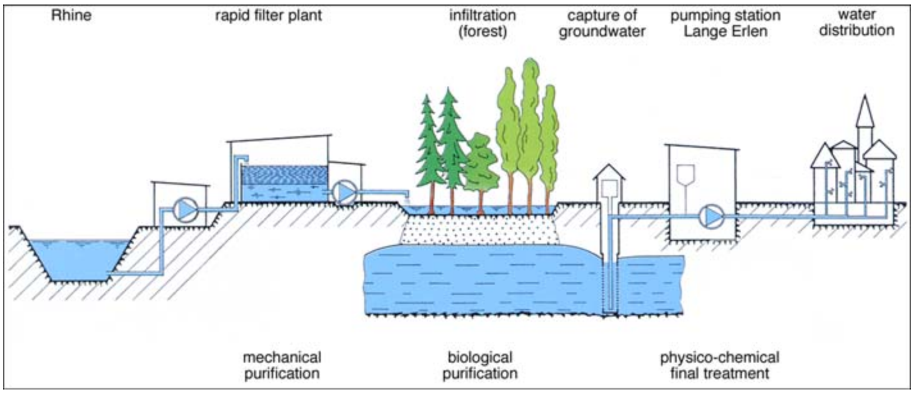

Figure 2. Flow diagram of the ground water plant “Lange Erlen”.

Systems for safeguarding the drinking water quality

The old foodstuff law basically limited the self-checking of the water supply companies to analytical investigations. With the latest revision of the hygiene ordinance of 1995, a system according to the HACCP concept is now expressly demanded in Article 11 (Kantonales Laboratorium St. Gallen, 1995). The implementation of the requirements for a corresponding quality standard and the consistent application of "good manufacturing practice" (Box 2) have been completed for the water supply of the IWB over 3 phases in the last few years:

- Development of a risk analysis and fixing of plans for measures (1996–1997).
- Development and introduction of a quality management systems (EN 45001 and EN 45004) in the department quality assurance water/laboratory (1998–1999).
- Introduction of a process-oriented management system according to ISO 9001–2000 (2002).

Box 2. Terms regarding "quality assurance".

Self-checking (Foodstuff Law 1992)
"Whosoever manufactures, treats, supplies, imports or exports foodstuffs, food additives and articles of daily use shall as part of his or her normal duties ensure that the goods comply with the legal requirements. He or she shall analyse them, or have them analysed, in accordance with good manufacturing practice."

Good manufacturing practice (GMP)
One does not only judge by the laboratory tests. A prerequisite for a good manufacturing practice is a comprehensive, critical control on all stages of the water treatment, distribution grid and the service pipes as well as a regular assessment of the situation and improvement of the processes.

Limit value
Legal requirement: If a limit value is exceeded, the drinking water is judged as unsuitable for use.

Tolerance value
Legal requirement: If a tolerance value is exceeded, the drinking water is judged as contaminated or in the value decreased.

Target value
Requirement of IWB water laboratory: If a target value is exceeded, there is a deviation to experience of drinking water checks. Measures must be met.

With these developments, the IWB now has the required instruments at its disposal in the product area Water, in order to completely fulfil the new, increased requirements. The consistent implementation and application of these systems also led to a higher level of technical competence among the employees. The accreditation and the certification were achieved almost as a side effect. The individual elements will be explained in more detail in the following.

<u>The risk analysis (Pierson and Corlett, 1993)</u>

The possible hazards and weak points of the water supply with effects on the water quality were surveyed in 1996 in an internal workgroup. The production, quality assurance, networks and installation control departments were involved. The existing and potential hazards from the catchment of the raw water through the processing, transport and storage of the drinking water up to and including the delivery to the consumers were jointly registered, noted and evaluated.

The consideration of the weak points according to HACCP (Box 3) thereby took place according to the following criteria:

- the influence on the quality at the drinking water resources;
- the production volumes;
- the processing procedures;
- the condition of the means of production; and
- the distribution system (drinking water network and reservoirs).
- the available plans for measures for faults and emergency situations

Box 3. Terms regarding "risk analysis".

Hazard
Every biological, chemical or physical characteristic that could bring about an unacceptable health risk for the consumer.

Risk
The assessment of the possible occurrence of a danger or hazard.

HACCP System = Hazard Analysis and Critical Control Points
Recognised international standard for a comprehensive type of quality control. The basis for this control system is a risk analysis of all production and distribution installations.

CCP = Critical Control Point
A critical control point is defined as every point or every process in the entire water supply system at which loss of control could cause an unacceptable health risk.

The potential faults or hazards with a higher rate of probability and an unacceptable effect on the drinking water quality were listed in a hazard catalogue (Figure 3).

In places, where the risk of a health-endangering quality impairment of the drinking water was particularly large, the necessary measures and critical control points (CCPs) were defined. Influences with a higher risk are, for example: damage with an effect on the raw water catchment, leaking waste water lines in the groundwater protected zone, germ-filled or contaminated supply lines, flooding situations in the catchment area of the groundwater wells, etc.

The results of the risk analysis served to redefine the control points in the testing and inspection programmes of the laboratory and to introduce the required control measures. The overview diagram (Figure 4) shows the control points of the water supply. In a further step, particularly critical operating plants were immediately renovated, or were put out of operation in the sense of weak point elimination.

Hazard analysis: Influence on the quality of the drinking water - from catchment to consumer

The probability of occurring of a fault and the possible effects on the drinking water quality must be evaluated:

1 = low / acceptable	Quality targets can't be met for a short time. Tolerance values and limit values are kept to.
2 = middle	Tolerance values for drinking water are exceeded. A health risk for the consumer does not exist however.
3 = large / unacceptable	The contaminated water can lead to a health endangerment of the consumers (limit values are exceeded)

1. - 3. Production of drinking water

Pos.	*Hazard/Fault*	*Probability of occurring / Frequency of fault*			*Effect on drinking water quality*			*Measures to eliminate or reduce the hazard*
		1	2	3	1	2	3	
1	**Raw water catchment and treatment**							
1.1	**Pollution of raw water (Rhine and Wiese)**							
1.1.1	Pollution of Rhine water due to oil accident		X		X			Alarm plan switch off the pumping station
1.1.2	Pollution of Rhine water due to chemical accident	X			X		X	Switch off the pumping station
1.1.3	Pollution of Wiese water		X			X		Switch off of local ground water well

Figure 3. Extract from the hazard catalogue.

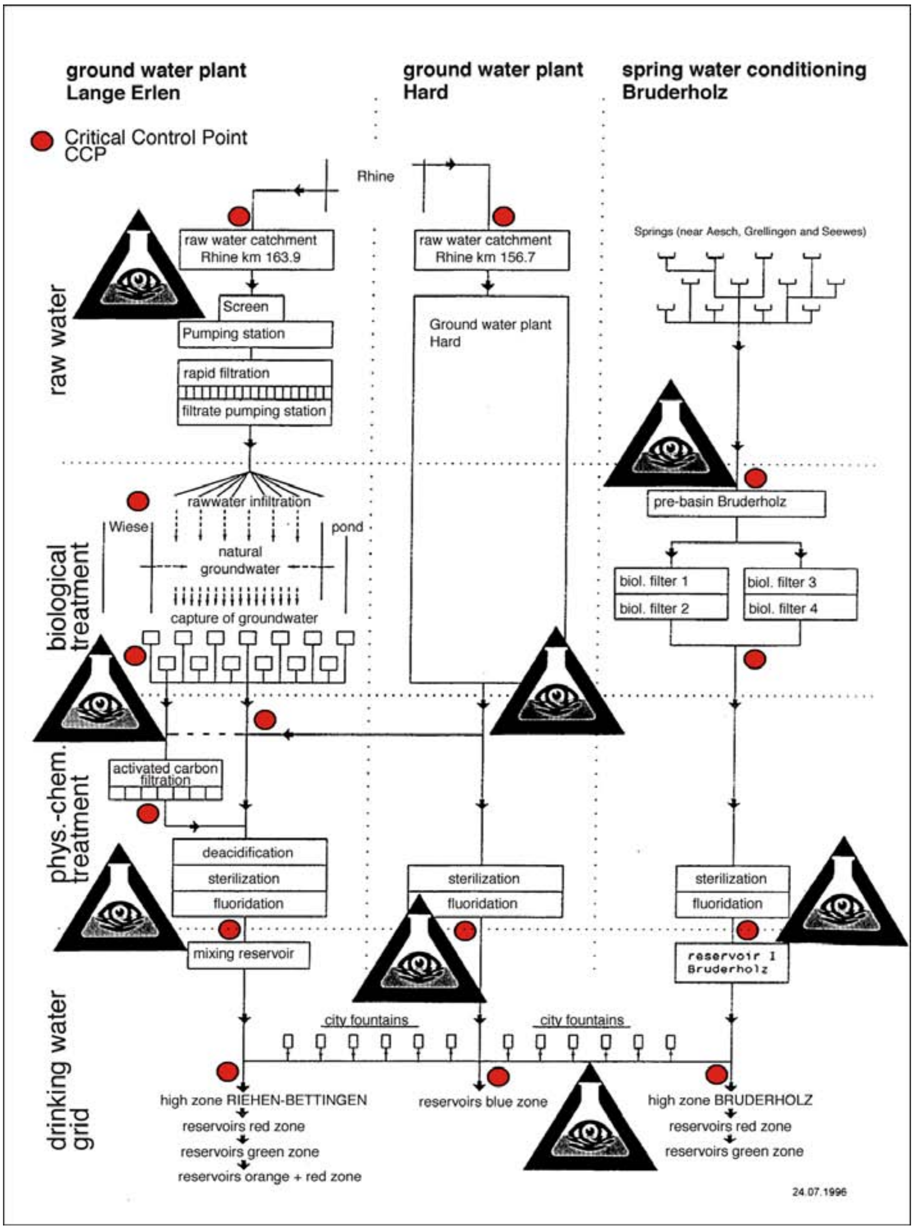

Figure 4. Diagram of water supply plants including critical control points.

QMS introduction in the water quality assurance department

The responsibility for the definition and co-ordination of the quality assurance measures in the procurement, processing, distribution and storage of drinking water in the supply area of the IWB is incumbent on the water quality assurance department (IWB Water Laboratory). With the 1999 accreditation by the Swiss Accreditation Service, the Quality Assurance Water department received the "accredited" label for both the testing laboratory and for the inspection body according to EN 45004.

The precondition for the attainment of the accreditation was not only the description of all processes and procedures. An additional requirement was to bring the personnel to a higher specialist level through internal and external further training. The scope of action and the responsibility of the employees could thereby be significantly expanded.

The accredited inspection body. With the additional accreditation of the water laboratory as an inspection body, the following goals were pursued:

- quality controls and operational controls by technically competent, independent employees (inspectors);
- exactly defined inspection and sample-taking programmes;
- traceability through unambiguous and secured recordings; and
- continuous evaluation and interpretation of the quality and operational data.

As the basis for the inspection activity within the involved areas of the water supply, the risk analysis described above is used. The inspection body of the IWB differentiates between three kinds of inspection, which arise from their triggers:

- routine inspection for the constant monitoring of CCPs;
- inspection following extensive maintenance / cleaning work; and
- inspection following a fault or an impairment of the quality.

In the routine inspections, the critical control points of objects are monitored according to a pre-defined inspection programme (Figure 5). The results of the taking of samples and the quality controls will be included in the inspection.

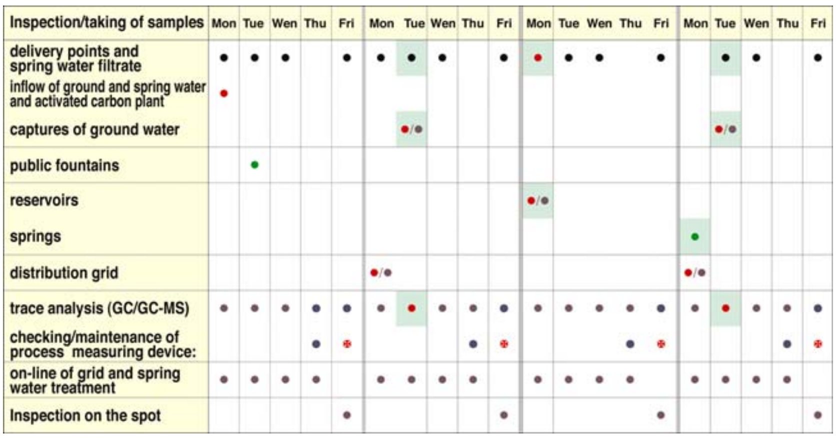

Figure 5. Extract of programme for inspections and taking samples.

The inspections following extensive maintenance and cleaning work are used to detect and avoid at an early stage any undesirable effects on the efficiency of the processing or any impairment of the water quality following modifications to the installations. Examples of inspection triggers:

- renewal and commissioning of water supply lines;
- cleaning of reservoirs;
- re-commissioning of installations after long interruptions of their operation; and
- renovation work on dosing systems (disinfection, deacidification, etc.).

Following an operational fault with effects on the water quality, or if target, tolerance and limit values are found to have been exceeded, an inspection will be immediately carried out and the necessary measures will be immediately initiated. The repetition of inspections (= post-check) on the basis of serious findings from the inspection also falls into this category of inspections.

Introduction of a management system according to ISO 9001:2000

The certification of various departments of the IWB is a development that has been underway for several years and has not yet been completed. The following goals were in the foreground at the introduction of a management system:

- optimisation and control of the work processes;
- alignment to the needs of the customers;
- increase of the technical competence and efficiency;
- handbook to secure the know-how and as a management instrument;
- attainment of the ISO certificate; and
- reinforcement of the positive image as a public company that is aware of its responsibilities.

Process-oriented management system. The requirements on the drinking water supply company (DVGW, 1999) such as quality, security of supply, efficiency, documentation, etc. place high demands on the involved employees and installations. The control and optimisation of the work processes forms an important precondition for the fulfilment of this requirement.

Process-orientation means that a process owner is nominated for an overall process or a sub-process, who is then responsible for the complete process cycle, regardless of who is involved in the process or carries out the activities. He is responsible for the fulfilment of the defined requirements and introduces corrective measures in case of deviations. The consistent process orientation and the analysis of the process requirements help to disentangle processes and to clearly define interfaces.

Drawing up the processes. The processes that exist in the water supply had to be recorded and be presented in a clear manner. Initial considerations regarding relationships and interfaces were recorded. On the basis of the process structure, the determination of the individual processes and sub-processes took place (Figure 6). For the description of the processes, a special method was applied. The basic idea of the method is that you first define the requirements for every process, and then determine how the process result should be checked or measured in a second step. Only then does the description of the implementation take place. Improvements are introduced at a later stage using a planned-actual comparison. Figure 7 shows the process cycle pattern used.

Process groups	Processes	Subprocesses	Forms
Management	– company – corporate identity – principles / policies – management system – document administration		associated – flow diagrams – forms – tables – listings
Resources	– personnel – training – know-how management – safety at work – investments		
Customer relations	– marketing – sales – contract processing – customer service and maintenance – customer property		
Realisation	– planning / development – procurement – production – service – traceability – testing – disposition of nonconformity – handling, stocking, delivery	– ordering – incoming goods – production of d.w. – disposition of d.w. – fault management – maintenance – repair	
Support	– measurement of performance – testing equipment – audits – data analysis – continuos improvement – IT – accounting		

Figure 6. Process structure in the IWB management system.

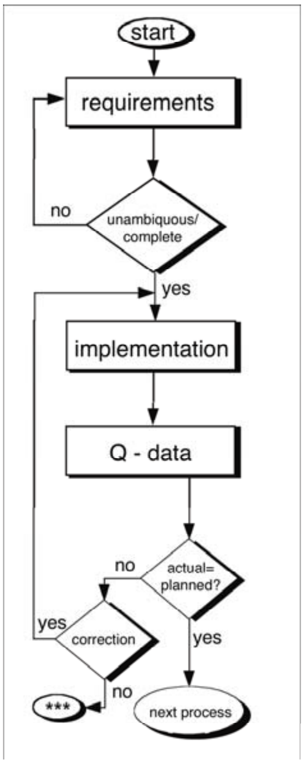

Figure 7. Process cycle pattern.

Continuous improvement process (CIP). In a work process (e.g., as the result of new business and departmental goals, suggestions for improvements, customer complaints, etc.), the CIP permits deviations to be detected and the necessary corrections to be initiated through suitable measures. A continuous improvement of the business and production processes is initialised and safeguarded with the CIP, but also with the periodic management reviews and audits. Figure 8 visualises the continuous improvement process in the annual cycle.

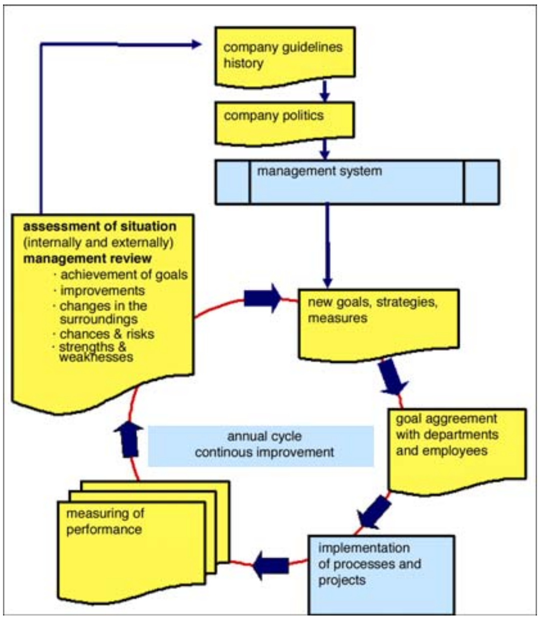

Figure 8. Continuous improvement process.

Focal points for a secure operation. Without a competent operational management, an effective and integrated maintenance and optimally trained employees, a water supply cannot be operated in a reliable and future-oriented manner.

The required high quality standard can only be assured if the production plants, the process controls, the measurement devices, the buildings and the equipment are continually adapted to the state-of-the-art – and the management systems are lived by all employees. The risk analysis presented above with the description of the status of all installations and safety precautions must be periodically revised, supplemented and updated.

Practical application of HACCP (case example)

An example out of the risk analysis within the water supply of IWB will concretise this procedure with the use of HACCP.

The river "Wiese" flows by the groundwater use area "Lange Erlen". At normal water flow rate (approx. 10 m^3/s) the wells are not influenced by the river regarding quality. The ground water wells are protected under normal conditions by sufficient large separated areas and affluent zones (protected zones S1, S2, S3).

Only at water flow rates above approx. 25 m3/s the banks of the river "Wiese" are overflooded (Figure 9), and an intensified infiltration of the river water can lead to an impairment of the water quality. The situation could be described more accurately after hydrogeological investigations and event-related water analyses in the affluent zones to the "Wiese" groundwater wells (Figure 10). As a result appropriate monitoring measures could be specified.

Figure 9. The river Wiese overflowing the banks.

The water quality in the groundwater well No. 12 is represented in the diagram in Figure 11. The higher the flow-rate of the "Wiese", the higher is also the germinating tendency in the groundwater well 12. Besides the water quality of the "Wiese" plays a substantial role for the germinating of the wells. The time and the extent of the germinating depend thus also on the hygienic-microbiological load of the river water.

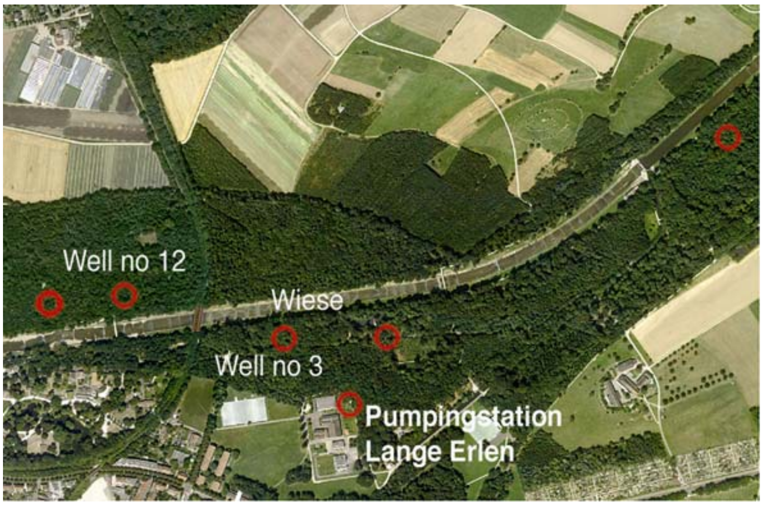

Figure 10. Sampling points at groundwater wells and at the river Wiese.

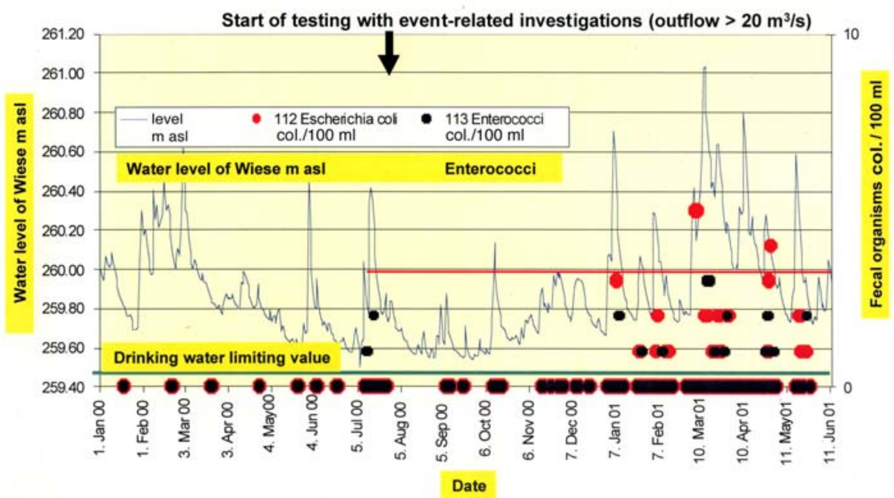

Figure 11. Faecal bacteria in groundwater well No. 12 at high water.

Evaluation of the risk

With flood situations a contamination of the groundwater from the well No. 12 is possible. *E. coli* and Enterococcus serve as indicator bacteria. They indicate that also pathogens such as salmonella, typhoid fever, cryptosporidia, etc. can occur in this water. This water represents thus a danger for the health of the consumers, since only a small amount of chlorine dioxide is added as disinfectant. It results thus a microbiological risk.

Monitoring measures

The groundwater well No. 12 is defined as CCP. According to the existing risk suitable monitoring measures must be specified. In addition to the periodic sample investigations the following continuous measurements were furnished:

- water level (first monitoring value); and
- continuous particle counting in the well (second monitoring value).

In the range up to the first alarm value one does not have to count on an impairment. Only above it and with particle numbers over 30 counts/mL (1-20µm) the probability of a germinating of the well rises clearly.

<u>Measures and responsibilities</u>

The necessary measures and responsibilities are fixed in appropriate work instructions and checklists:

- Alarms and messages are generated automatically by the process control system. The well is monitored by the dispatcher.
- In case of a fault (e.g. exceeding a limit value):
  - immediate shut-down of the well
  - additional inspections and laboratory analyses
- With particle numbers > 50 counts/mL the well is taken out of operation as a precaution.
- The independent inspection body decides on the re-start-up of the well.

The completeness and traceability of the recordings as well as the data analysis are fixed with the existing quality management systems. Accordingly they are regularly examined on the occasion of internal and external audits. Beyond these own controls surveillance by the foodstuff authorities takes place periodically.

Conclusion

The step-by-step development and introduction of the described systems (risk analysis, accreditation of inspection body and test laboratory, QM system according to ISO 9001) has allowed the IWB to fulfil considerably better the requirements on a water supply company mentioned at the beginning. On the basis of the risk analysis and the systematic operational controls, the foodstuff safety has improved in particular. It can be seen from the internal audits that the guidelines and contents of the management systems are being lived by the employees. Furthermore, the regular evaluations of the process results (review, Q-data) confirm that the continuous improvement process can be applied profitably.

Thanks to accreditation and certification, IWB has recently succeeded in gaining several municipal water supplies and various customers from very different branches for regular water investigations, inspections and maintenance services.

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Hazard Analysis and Critical Control Points at the Zurich Water Supply

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Introduction

One of the most important tasks of any water supply company is safeguarding the quality of drinking water. In order to be able to achieve the quality goals on the basis of legal requirements, the water supply companies already carry out comprehensive quality checks today. As a rule, this involves periodic checks of samples, which are supplemented by various on-line measurements. Investigations of the water quality can increase safety, but they cannot provide a guarantee for the consumers, as, in most cases, the water has already been drunk before all the results of the analysis are available. Preventative measures have therefore become very important. A process-technical control of possible risks and the monitoring of critical points offers a solution for preventing the occurrence of quality defects. A procedure of this kind for the determination of hazards and for their avoidance is presented by the HACCP method (Hazard Analysis and Critical Control Points). In principle, it involves the control of the processes and not the control of the products (ICMSF, 1988). The basis of this method is the determination of potential risks. The significance of this method can be seen from the fact that it was declared to be the binding directive for foodstuff production in the USA in November 1989 by the National Advisory Committee on Microbiological Criteria of Foods (Pierson and Corlett, 1993).

The HACCP method is a systematic method of guaranteeing the quality of foodstuffs. It consists of seven general principles regarding microbiological quality in the manufacture of foodstuff products. Fortunately, the method has now also found acceptance in the drinking water branch. This is manifested in the resolution of the WHO to supplement product controls with a hazard analysis of the production process. This principle, which approximates very closely to the HACCP fundamentals should be taken into account in the "Water Safety Plan" and be embodied in the third edition of the "Guidelines for Drinking Water Quality", which should appear in the year 2003. This decision should not fail to have an influence on national legislation. In Australia, the HACCP approach was already embodied in the "Drinking Water Framework" in May 2001 (Deere and Davison, 1998). In Switzerland also, Art. 276 of the foodstuff ordinance (LMV) requires that installations, equipment and procedures may only be used if the treated drinking water always corresponds to the requirements of Article 275 of the LMV (1995). This initial position persuaded the Swiss Gas and Water Industry Association (SGWA) to revise the "Directives for the monitoring of the drinking water supplies with regard to hygiene" and the "Recommendations for a simple quality assurance system for water supplies" (SGWA, 1997; 2003).

The Swiss Hygiene Ordinance (HyV) makes in its Article 11 the LMV more precise; it explicitly demands the use of the HACCP method without, however, actually using this term (HyV, 1995). It requires that "*anyone who produces, handles, stores, transports or delivers foodstuff […] must ensure that the latter will not be impaired by micro-organisms.*" This should take place according to the following principles:

- identification and evaluation of the possible health risks of products that could arise during the production of the food. The following must be taken into account: production materials, storage and sale, as well as the foreseen use of the end product (hazard analysis);
- determination of points, work processes or procedural steps in the production process at which a health risk can be reduced or be eliminated (Critical Control Points, CCPs);
- determination of standard values and tolerance ranges (CCP conditions) that are to be maintained and that are binding in the CCP monitoring;
- the setting up of a monitoring system with which the compliance with the pre-defined CCP conditions can be checked;
- the determination of measures to be taken if a deviation from the CCP conditions is determined by the monitoring;
- the determination of procedures for the verification of the functionality of the control system;
- documentation of the above-mentioned measures

In addition to the foodstuff requirements, those of the product liability law must also be observed, according to which the producer is liable for the damage if a faulty product leads to the death or injury of a person (Bundesgesetz über die Produktehaftpflicht, 1993). Illnesses as a result of water deliveries that do not comply with the regulations of the foodstuff ordinance are thereby considered to be injuries, whereby the water supply company can be held liable. The risk of a product liability of this kind can be kept low with the correct application of the HACCP principles.

For the Zurich Water Supply (WVZ), the attainment of a high quality standard is a component of the company policy. All legal quality requirements must be able to be maintained. The consumer should receive hygienically flawless drinking water with a constant composition (hardness, etc.), which is clearly below the legally prescribed tolerance and limit values at all times. Only in this way, it was possible to do without addition of a network protection agent in spite of a proportion of 70 % surface water.

The following presentation will indicate how the Zurich Water Supply has implemented the HACCP principles and how these have been integrated into their management system.

Expressions and standards

It is well known that a large number of laws, standards, directives and concepts exist. This flood of ordinances does not often contribute to the simplification of our daily lives. The HACCP method is fast included in this viewpoint. In the same way as for the ISO 9000 certification standards or Total Quality Management, the purpose is often not recognised, and is merely regarded as additional outlay (Bosshart and Maier, 1997). That often has to do with the fact that even the expressions are not clearly clarified. In the following, an attempt will therefore be made to briefly explain the various expressions used in this report and their meaning:

- HACCP is a method. It is focussed on safeguarding of the product quality. The goal of the method is to be able to control the production of the foodstuff by means of a hazard analysis and the determination of critical control points (CCP) in such a way that the quality can be guaranteed, documented and traced.
- Validation means that it must be scientifically proven that drinking water is being produced – within the limits of practical possibility and at all times – that corresponds to the legal requirements, from the raw water, through every stage of processing, distribution and storage and up to the consumers.
- The ISO 9001:2000 is a process-oriented international standard that can be used in all companies and industries. "*It determines the requirements on a quality management system if an organisation has to prove its ability for the continuous provision of the products […] and then endeavours to increase customer satisfaction through the effective application of the system […]*"(SNV, 2000).

Validation and HACCP at the Zurich Water Supply

The basis for quality assurance is the exact knowledge of a production process, so that a perfect product can be produced with certainty and in accordance with the specifications. Not only are the individual processes important, but, in the long run, the actions of the entire company must be seen as a series of interconnected processes. The validation as carried out at the WVZ, covers all raw materials (raw water, additives), installations and equipment (air-relief valves, flaps, reservoirs, etc.) and treatment or process stages (ozonation, filtration etc.). In the case of chemical processing stages (chlorination, ozonation, flocculation, etc.) the formation of by-products and waste products must be included in the hazard analyses. For the assessment of processing procedures, goal fixing and hazard analyses must be carried out for all stages that are necessary for the achievement of the overall goal.

The "quality monitoring" process instruction in the management system of the WVZ describes the procedure for the validation, which integrates the hazard analysis. In order that the quality assurance measures can be recognised and be checked at all times, a representation in the form of flow diagrams is practical. The assessment at the water works can be systematised if a sub-division of the drinking water catchment and distribution (Figure 1) takes place – into the four steps "raw water", "processing", "storage, distribution" and "domestic installation", insofar as the responsibility of the water supply company only ends at the tap.

The validation of the drinking water production in the flow diagram from raw water to drinking water (Figure 1) has been divided into four sub-aspects at the Zurich Water Supply, namely "man", "materials", "machines" (installations) and "methods" (procedures):

- Risks often not only lie in faulty methods and/or procedures. Also the personnel must possess the corresponding know-how and capabilities for the tasks that are entrusted to them. Continuous training and further education are essential for this. The guaranteeing of these requirements is carried out at WVZ through the "personnel process" of the management system.
- Under "materials" there are protected zones, raw water, additives and auxiliary materials. The assessment of the raw water quality and the protected zones is a significant component of the validation. Limit values for impurities are defined for

additives and auxiliary materials, which must be complied with by suppliers. Details are regulated in the procurement process and in the product specifications at WVZ. Companies are checked by random sampling. All incoming goods are subjected to a receiving inspection according to their specification.

- Machines, installations and materials that come into direct contact with the water must not affect the water quality negatively (Verordnung über Gebrauchsgegenstände, 1995; Verordnung über Materialien und Gegenstände aus Kunststoff, 1995). The KTW directives (KTW, 1977) and the DVGW directive W270 (DVGW, 1990) can be applied for the assessment of materials. Processing plants must be designed in such a way that the safeguarding of the water quality is guaranteed, and buildings and reservoirs are constructed so that no pollution can enter the water from outside.
- The method includes the procedure for the catchment, production and distribution of the drinking water.

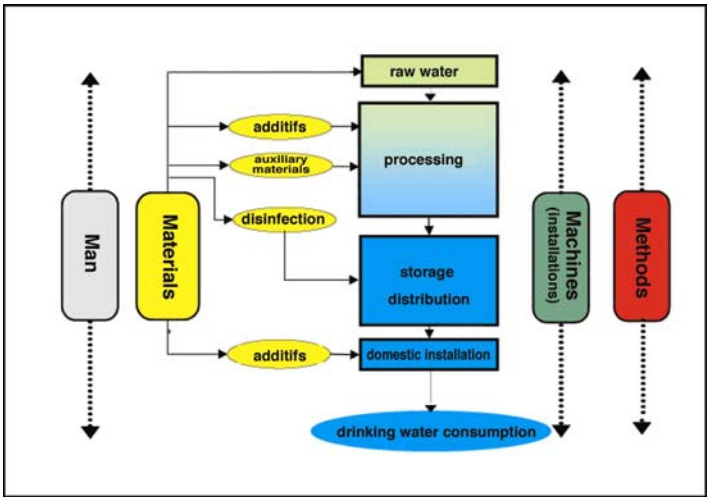

Figure 1. Flow diagram from raw water to drinking water at WVZ and aspects of validation of the production process.

An important component of every validation is the clear definition of the requirements on the product. The drinking water quality must satisfy the Hygiene Ordinance and the Impurity and Content Ordinance (Verordnung über die Fremd- und Inhaltsstoffe in Lebensmitteln, 1995) at all times. Depending on the quality of the raw water, a treatment has to perform more or less in order to fulfil the requirements. For the validation, each processing plant with raw water and the transport and distribution network with storage has been assessed together. The large data record of water quality data measured in the laboratory and online made it possible to define target areas for the critical control points (CCP) and to determine warning and alarm values. Exceeding of any warning values will cause the personnel to move to a higher level of watchfulness. Alarm values indicate that a plant or a process is outside its defined characteristics. If alarm values are exceeded, the quality of the drinking water can no longer be guaranteed and the defined measures must be applied.

Assessment of the protected zones and the raw water

Protected zones. The goal of exclusion of protected zones is the long-term, qualitative and quantitative preservation of the drinking water. Protected zone exclusions and the pre-defined measures within the protected zone regulation have a preventative and preservative function. In order to guarantee qualitatively flawless ground water or spring water, and in addition to the measurements, great attention must be paid to the visual inspection of compliance with the protected zone regulations.

These regulations represent a list of restrictions. The individual survey reports (Figure 2) for the protected zone areas of the individual springs are based on the protected zone regulations and the hazard analysis. A work instruction regulates the inspection tours and the implementation of the prescribed measures. Important or sensitive protected zones at critical control points are periodically measured or continuously monitored.

5.6 Valleys A, B, C			
Situation	**Deficiency**		**Details**
	yes	**no**	
General survey in the protected zone			
syncline, sink, course of a brook, open ditch			
animal holes			
windfallen trees			
Specific inspection in the protected zone	**Objections**		
Known conflicts:	**yes**	**no**	**if yes, what?**
Valley A2: 3 occupied animal holes in Z1			
Valley B: field track through Z2			
Valley C: duck pond in Z2b			
Sewer pipe in Z3, built 2001 First testing of tightness on 14.5.02 Further inspections according to environmental authorities as of 11.7.01			
~~Valley A + B: storm damage "Lothar" in Z1 + Z2~~			Forest has recovered (inspection 3.6.02)
~~Valley A: farming in Z2a~~			No more agriculture in Z2 (inspection 4.9.01)
~~Valley B: cattle feedlot in Z2b~~			New cattle feedlot in Z2 (inspection 4.9.01)

	+ allowed - forbidden					known conflicts		Deficiencies and new conflicts
	Z1	Z2	2a	2b	Z3	yes	no	
Waste water installations								
lines for domestic and industrial waste water, tight construction	-	-[3]	-	-	+		x	
[3)] allowed with official permission								
soaking pits for all waste waters like meteoric, domestic, industrial, cooling, etc.	-	-	-	-	-	x		
Storage of hazardous liquids								
stocks with small volumes, trans-shipment stations, etc.	-	-	-	-	+		x	
Storage of solids, dumps								
garbage, sewage sludge, water-soluble matter	-	-	-	-	-	x		
Mining/Backfilling								
gravel pits, sand pits, clay pits	-	-	-	-	+[5]		x	
[5)] backfill with inert matter needs an official approval								
Agricultural land use								
cultivation of grass	+	+	+	+	+		x	
pasture, fruit-culture and farming	-	+	+[1]	+	+		x	
[1)] farming undesirable								

Figure 2. Form for inspection tours of the protected zone in valley A, B, C.

Surface water. For the chemical and biological assessment of lake-water, the raw water data measured by WVZ have been checked for its extreme values. For the characterisation of the hazard potential in case of incidents (worst cases), the chemical risk land register of the Canton of Zurich (Verordnung über den Schutz vor Störfällen, 1991) provides valuable information. Scenarios for the effects of pollutants allow limit values to be defined, and weak points to be pointed out.

Assessment of the processing plants

In a first step, the quality-relevant process stages have been determined on the basis of the overall goals and of the quality status of the raw waters under consideration of the worst cases. Following the "Surface Water Treatment Rule" of the US EPA (1989), a deactivation and/or removal of 99.99 % for the pathogenic bacteria and viruses, of 99.9 % for giardia and of 99 % for cryptosporidia was defined as the overall goal for surface water. The sub-goals for the individual processing stages could be derived from this (Figure 3).

In validation reports of the individual processing plants, the process stages have been assessed and evaluated on the basis of internal reports, scientific publications and in-house quality and production data. Any weak points determined were immediately corrected or were recorded in a priority list. The critical control points were determined. Wherever possible, monitoring takes place using online measurement devices. For further critical and non-critical control points, the periodicity and the parameters to be measured have been defined in the analysis plans. The warning and alarm values, together with the measures to be taken if the alarm values are exceeded, have been documented in work instructions. The long-term quality planning has been derived from the assessment of the measured data (Figure 4).

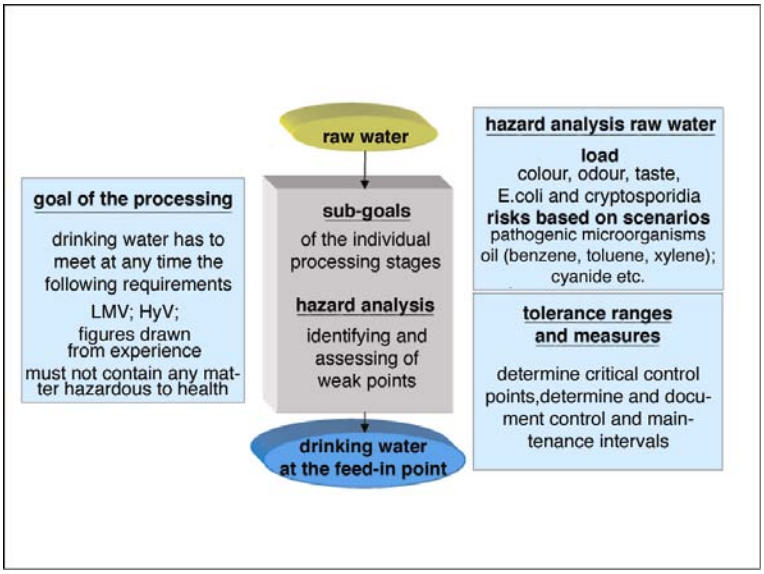

Figure 3. Determination of the goals for the processing and hazard analysis.

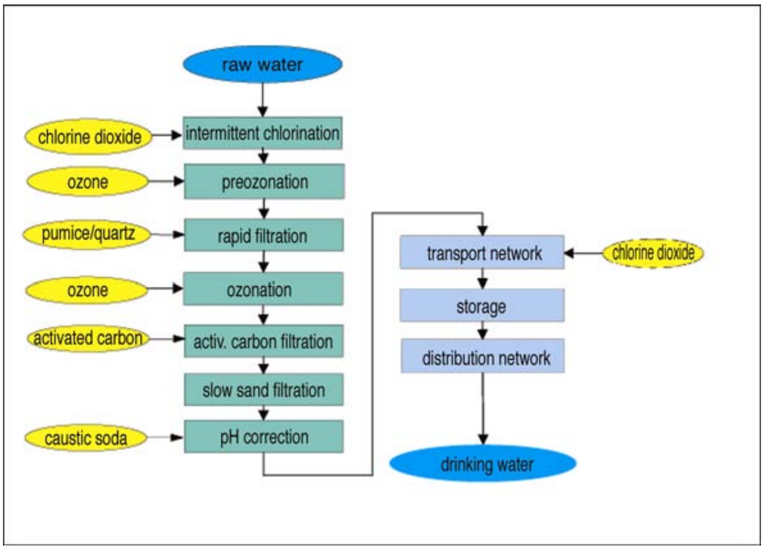

Figure 4. Flow diagram of the lake-water plant Lengg including additives and auxiliary materials.

Validation of the lake-water plant Lengg. Using the example of the lake-water plant Lengg, we will show how a physical, chemical and micro-biological validation can be carried out. The validation answers the questions that arise from the objective for the processing the raw water to drinking water:

- Which process conditions fulfil the microbiological requirements on the drinking water and/or the objectives of the process stages?
- Will chemicals that are present in the lake-water be broken down in such a way that the tolerance and limit values for drinking water will be maintained at all times?
- Will chemicals that could find their way into the lake-water as a result of accidents be broken down to such an extent that the tolerance and limit values for drinking water will be maintained at all times?
- Will the natural organic contents of the water be oxidised in such a way that they can be optimally broken down in the subsequent biological stages (activated carbon filter, slow sand filter)?

In Figure 5, it will be shown on the basis of the two protozoa *Cryptosporidium parvum* and *Giardia lamblia*, of the polio virus and of the chemicals benzene, xylene and atrazine how the de-activation or the decomposition was assessed during the processing. A clear inactivation of the micro organisms and the oxidation of the benzene, xylene and atrazine through the ozonation are noticeable. Further investigations (Kaiser *et al*., 2000) have shown that the de-activation level in the pre-ozonation of the lake-water plant Lengg for *Cryptosporidium parvum* reaches approx. 0.5 log-units, for *Giardia lamblia* 4 log-units and for Enteroviruses 6 log-units. During the filtration of cryptosporidia and giardia, the de-activation level seen conservatively was one log-unit in the fast filtration, and 2 log-units in the slow sand filtration. Information regarding the filtration of the polio virus and the above-mentioned chemicals is not known, and is therefore not taken into account. The activated carbon is used in the processing stages of WVZ as carrier material for microorganisms and has been used for much longer than ten years. Atrazine and benzene will therefore only be insignificantly adsorbed at existing concentrations. Exact knowledge regarding the breakthrough behaviour of the pre-loaded activated carbon is not available. It is known that on shock loading an adsorption occurs followed by a subsequent delayed desorption. These processes were observed with own measurements, but were not quantified.

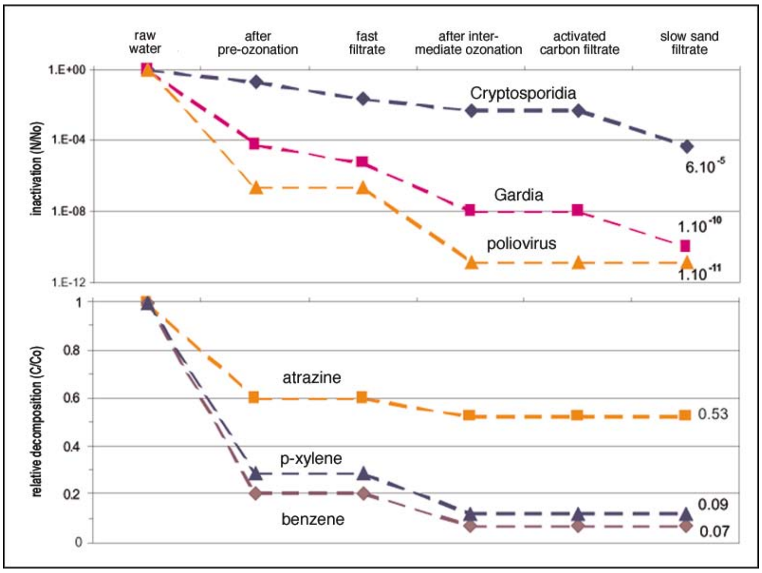

Figure 5. Inactivation of selected microorganisms and viruses and chemicals in the lake-water plant Lengg.

The assessment of the processing stages shows that the microbiological objective is clearly exceeded. Atrazine is broken down to approx 50 %, and the tolerance value at a concentration of 200 ng/l can still be maintained. The concentration in Lake Zurich is currently approx. 10 ng/l. Benzene and p-xylene are broken down by approx. 70 % to 90 % during the ozonation. The activated carbon can serve as a further short-term safety barrier in case of increasing concentrations.

From this data, and taking the biological characteristics into account, an optimal ozone dosage for normal operation could be derived. The efficiency of the ozonation could be estimated with model investigations for the whole processed water volume (Kaiser *et al*., 2000). In order to guarantee the desired efficiency at all times, the ozone exposition, that means the product of the ozone concentration multiplied by the time (ct-value), is kept constant. Depending on the water quality or the ozone consumption, the ozone dosage is adapted, which is guaranteed through the continuous measurement of the residual ozone content with control of the ozone dosage. The residual ozone measurement is defined as a critical control point. It guarantees that tested and assessed components will be sufficiently oxidised as long as the component concentrations and the produced water and ozone quantities remain within the predefined ranges. If the residual ozone content falls below the alarm value, the efficiency of the ozonation will no longer be guaranteed, and immediate measures will be initiated.

Operation of the processing plants. In the Zurich Water Supply, the defined measures will be implemented following violations of the alarm values. The warning and alarm values for the online measurements are integrated into the operational control system. If the alarm values are exceeded, this will be indicated both visually and acoustically. Figure 6 shows the representation in the operational control system. The measures that are to be initiated are also stored in the control system and can be called up immediately. All warning and alarm values from laboratory measurements will be logged in the laboratory information system. An automatic output of the warning and alarm value violations takes place daily.

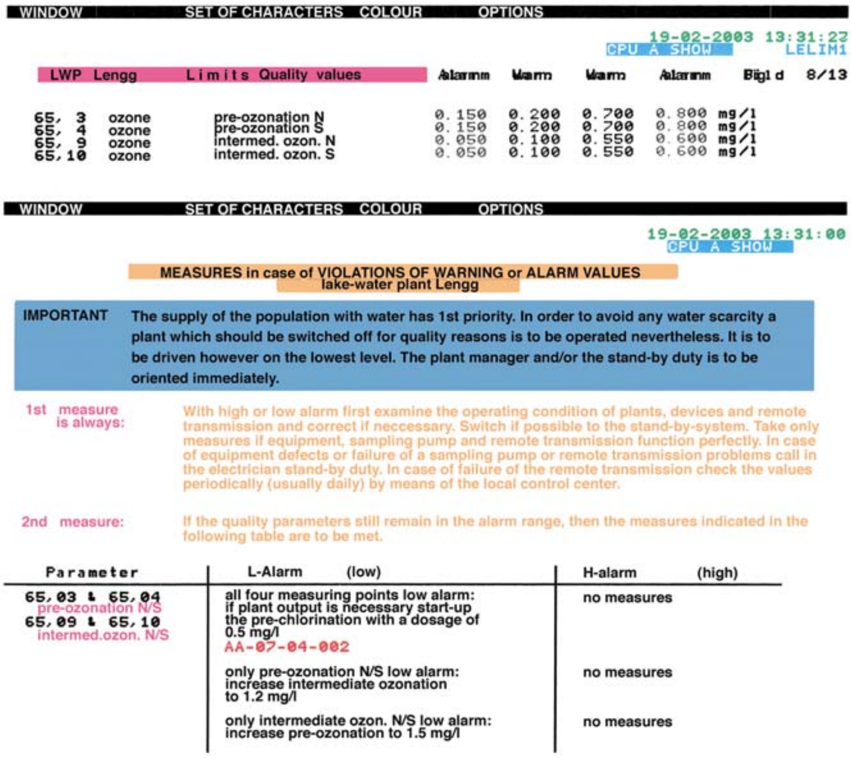

Figure 6. Example of alarm and warning values and of measures to be taken in the lake-water plant Lengg.

<u>Validation of the pipe network and the storage</u>

The pipe network delivers drinking water to the consumers with sufficient constant pressure, and, thanks to the reservoirs, this can be maintained over a specific period regardless of the drinking water production. The following goals are primarily achieved through the microbiological hygienic quality checks in the distribution network:

- general evaluation of the quality in the distribution network on the basis of the microbiological characteristics;
- early recognition of quality changes;
- bases for release decisions; and
- the precautionary assessment of operationally-necessary interventions or incidents in the distribution network and in the reservoirs (cleaning, maintenance, repairs).

The hazard analysis indicates that the following possibilities exist for the impairment of the quality of the drinking water during transport, in main and distribution pipelines and in the reservoirs (Figure 7):

- the absorption of problematic chemical substances, nutrients or other organic substances from the pipe materials (possibly also leading to an impairment of the taste of the water);
- the transformation of chemically harmless water contents into problematic or toxic compounds as a result of the addition of disinfecting agents;

- increase in germs in an existing substrate, sufficient residence time and favourable growth conditions;
- oxygen consumption;
- pick-up of nutrients by biofilms (quality improvement) or germ or material discharge from biofilms (quality reduction);
- entry of germs, nutrients or chemically problematic matter through leakages in the line, pipe ruptures or as a result of work on the line at construction sites; and
- deliberate anthropogenous contamination of the water.

The determined hazards were subjected to an assessment with regard to the probability of their occurrence and the consequence of an event. In doing this, internal reports and scientific publications were included and the largely microbiological data of the distribution network and the reservoir samples taken over more than 15 years were evaluated. The weak points found were partly corrected immediately, or were listed in a priority list for correction.

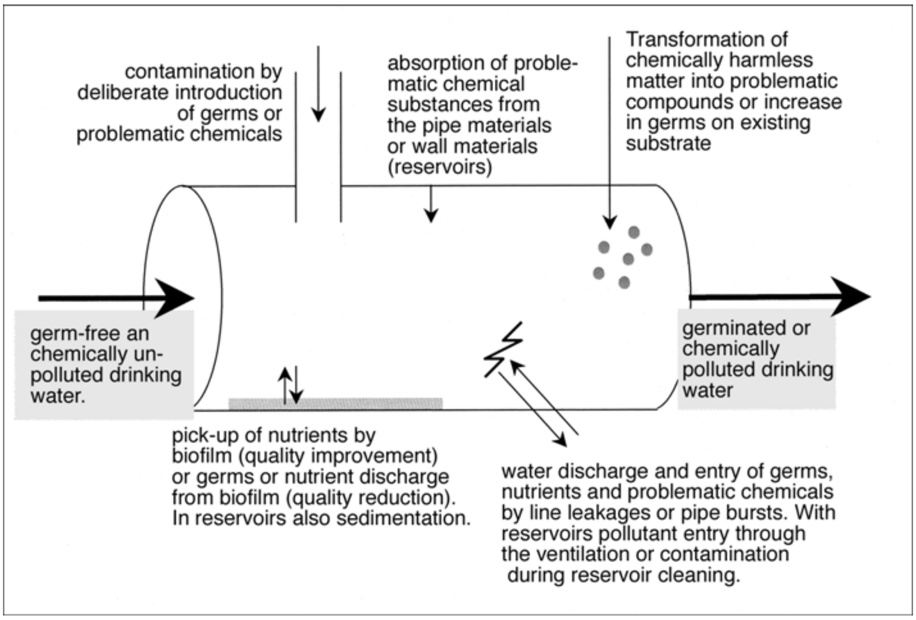

Figure 7. Hazard analysis in the pipe network and storage system at WVZ.

Operation of the pipe network. For the quality control, the feed-in points of the drinking water into the transport network and an exact monitoring of the treatment processes are the most important control points. The assessment also revealed that the critical control points in the network would have to be increasingly defined according to hazard potentials, for example, in the case of reservoirs (high impact). The distribution network as a whole was assessed as being less critical, and the number of CCPs could be reduced. Special microbiological questions (the influence of biofilms, the influence of changes in flow-rate, residence time of the drinking water in the network, start-up of lines, etc.) will have to be investigated in more depth. The corresponding projects for this have been planned. The goal of these investigations is to improve the detection of causes and the understanding of microbiological mechanisms. In the future, locations that show increased risks over limited periods (e.g. during construction work, special operational conditions, standing water in final branches, etc.) will be increasingly checked. Alarm values for microbiological analyses have been defined in work instructions for the feed-in points, reservoir outlets into the distribution network and in the distribution network.

Linking of the HACCP into the management system of WVZ

In contrast to many other water supply companies, the responsibility for the quality monitoring is separated from production in the WVZ. The quality monitoring (Figure 8) is responsible for the implementation of the statutory stipulations of the foodstuff law, for the investigation of the drinking water, for the quality planning, for the service and maintenance of the continuous quality control devices, for the taking of samples and for the tests in the laboratory. The quality department must make available the instruments for the implementation of the quality stipulations to the production department. In particular, quality criteria and measures must be consistently defined. The production department is responsible for the production of the required amount of drinking water with the stipulated quality. Quality-induced decisions regarding the production are taken jointly.

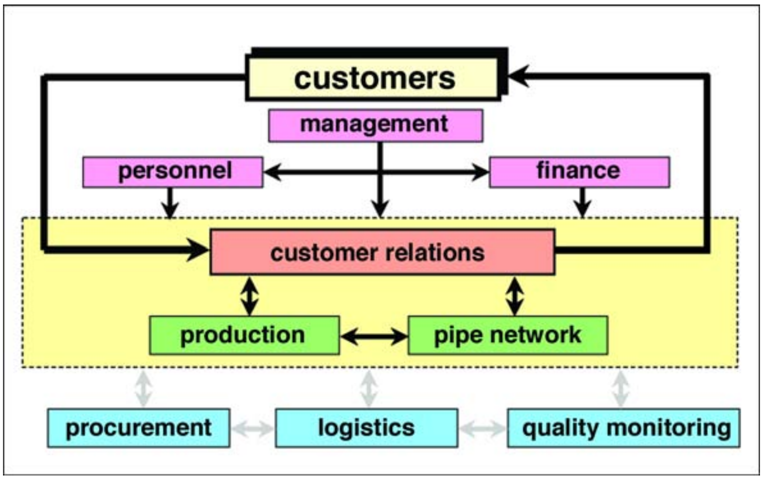

Figure 8. The process network of Zurich Water Supply according to ISO 9001:2000.

<u>Process-oriented management system of WVZ</u>

In order that quality goals can be reached and the quality-supporting methods established, a smooth interaction of all company processes is required. With the certification according to the ISO standard 9001:2000, the Zurich Water Supply has a system that includes all processes and procedures and is described in nine business processes (Figure 8). The laboratory is integrated into the “quality monitoring” business process, and is accredited to ISO 17025. The responsibility for the processes is transferred to the highest company level. As a result, the support of the management is guaranteed.

The process owner of the quality monitoring is responsible for the correct implementation of the HACCP principles. The “quality monitoring” process describes the procedure of the validation and, additionally, all further tasks of the quality monitoring (sample taking, online and laboratory analysis, technology development, etc.).

As a result of the process-oriented management system, weak points determined in the validation and variables affecting the drinking water quality can be assigned to the responsible processes. This ensures that the quality-affecting measures can be implemented efficiently. Interfaces arose mainly between the "quality monitoring" process and the "production" and "pipe network" business processes. Further interfaces with the "personnel", "procurement" and "management" process instructions were determined during auditing.

Evaluation

The step-by-step procedure of WVZ:

1. The introduction of a management system and the accreditation of the laboratory.
2. The implementation of the validation and the HACCP principles thereafter has proved itself.

First, all the somewhat complex interfaces and responsibilities in the management system were clarified. In this way, existing work instructions could be referred to for the handling of documents, for the safety aspects, for the personnel training and development and for the auditing. The process-oriented management system thereby significantly facilitated the implementation of the HACCP principles.

The procedure described indicates an efficient way for large water supply companies. The separation of quality monitoring and production into different processes permits a simple implementation of the validation and the HACCP principles in the «quality monitoring» process, and clear interfaces to the other processes. The consistent implementation of the HACCP principles allowed WVZ to eliminate many weak points within a short time. The security for an impeccable quality of the drinking water could be increased with the validation and the HACCP method.

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Development of Water Safety Plans for Urban Utility Water Supplies in Uganda

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Introduction

This extended abstract presents the findings of a programme to improve risk assessment and management in utility piped water supplies in Uganda through the establishment of Water Safety Plans (WSPs). The paper outlines the stages followed in developing WSPs and in particular with reference to the WSP developed for the Kampala water supply.

Uganda is a small country in East Africa with a population of roughly 22 million people. Kampala is the capital and largest city of Uganda, with a population of approximately 1.2 million. It is experiencing rapid in-migration and urban poverty is a significant problem in many parts of the city. Uganda is a poor country, although the 1990s has seen increasing and sustained economic growth. The water sector suffered significantly during the upheavals of the 1970s and 1980s, but during the 1990s has developed rapidly. In larger urban areas including Kampala, piped supplies are provided by the utility National Water and Sewerage Corporation (NWSC) and in smaller town by Town Councils. In many towns, including Kampala, there are also a large number of alternative water supplies, such as protected springs and boreholes with handpumps.

In the Global Assessment of Water Supply and Sanitation 2000 Report, it was estimated that 50% of the total Uganda population and 72% of the urban population had access to an improved water supply within 1 kilometre of their home (WHO and UNICEF, 2000). The number of people in urban areas with access to piped water is lower than this figure. Howard and Luyma (1999) estimated that in 1999, only 20% of the population of Kampala had access to at least a single tap at the house, although at a Parish level, this varied between 2.5% to 100% of households. This figure has risen and currently it is estimated that nearer 40% of households have at least a single tap.

The remaining population relies on a range of public taps and protected point sources for their domestic water needs. Howard *et al.* (2002) showed that multiple source use is common among the population without their own tap, but estimated that just under 70% of the population using communal sources used piped water for part of their needs.

The Kampala water supply

The Kampala water supply is operated under a management contract. NWSC are responsible for the production of water at the treatment works, for overall asset management and monitoring of water quality. Operation of the distribution system is by Ondeo Services Uganda Limited (OSUL). Using estimates by Howard *et al.*(2002), the Kampala water supply serves about one million people through household connections and public taps.

NWSC have been operating a water quality monitoring system for many years and additional monitoring of the piped water was undertaken by environmental health staff from the City

Council during a pilot surveillance project between 1997 and 2000. It is not known to what extent this continues to date, although some testing is known to occur. Although the supply is generally well run, the results of water quality testing show occasional contamination and also sanitary inspection in the past has revealed operational weaknesses.

In recognition of the importance of water safety, NWSC in collaboration with WEDC and Makerere University have been investigating means of improving risk assessment and management within their supply. The development of WSPs was initiated in 2001, with funding from the knowledge and research programme of the Department for International Development (UK). The aim of the project is to develop and test approaches to developing WSPs and to evaluate the feasibility of using assessments of vulnerability of the supply to contamination as a means of directing activities into priority areas.

Organisational issues and establishing the team

The first stage in the development of the Water Safety Plan was a presentation to Managing Director and senior management of NWSC and representatives of OSUL. This presentation was designed to present a coherent case for the development of risk management approaches to water safety. The presentation drew heavily on the development of the materials on WSPs within the WHO Guidelines and emphasised the benefits of proactive quality assurance over quality control. In addition, the value of WSPs in promoting good asset management was also highlighted as a key selling point to the senior managers. This presentation and subsequent discussion proved essential in obtaining management buy-in to the process. Without such high-level support, developing the subsequent activities would have been more problematic given existing staff commitments.

Once agreement had been reached with the senior management, a rapid organisational review identified key internal stakeholders within NWSC who needed to be involved in the development of the WSP. This allowed a multi-disciplinary team to be established to guide the system assessment, Water Safety Plan development and field verification exercise. The members of the team represented the water quality control department (WQCD), operations department, production engineers and planning engineers. In addition, representatives from Makerere University (MAK) were also included to provide additional guidance and support. The head of the water quality control department was nominated as the overall risk manager. An activity-responsibility matrix was developed to guide the activities, an extract of which is shown in Table 1 below.

Table 1. Activity/responsibility matrix (where R = responsibility; I = involved; A = aware).

Activity/Responsibility	Name Responsible	NWSC				
		WQCD	HQ	OSUL	MAK	WEDC
1. System assessment						
Identification and printing of maps	Senior Engineer	I	A	R	I	A
Field work	Engineers	I	A	I	R	A
Reporting and data analysis	Engineers	I	A	I	R	I
Transport arrangements	Principal Analyst	R	A	A	A	I
Management of logistics	Principal Analyst	R	A	A	A	I
Co-ordination	Principal Analyst	R	A	I	I	I
2. Water quality assessment						
Laboratory analysis	Principal Analyst	R	A	A	I	I
Sampling	Principal Analyst	R	A	A	I	I
Transport	Principal Analyst	R	A	A	A	A
Co-ordination	Principal Analyst	R	A	I	I	I
Report and data analysis	Principal Analyst/ Quality Control Manager	R	A	I	I	I
Logistics	Principal Analyst	R	A	A	I	I
Training for water quality analysis	Consultant	I	A	A	I	R
Water quality assessment preparation	Consultant	I	A	I	I	R

System description and analysis

The first stage was to develop a full system description and analysis on which to base the WSP. There was a significant amount of information available on the Kampala water supply, including details on pipe materials, age and size. The first stage of the exercise was to describe the water treatment system and to produce a detailed map of the water supply with supply zones demarcated. This detailed description is illustrated in Figure 1 below.

Following the desk-based exercise, a field assessment was undertaken to provide some field ‘truthing’ of the system. In particular this exercise was designed to assess the status and condition of major infrastructure as a means of understanding whether the system was likely to be able to deliver safe drinking water. Furthermore, the field exercise provided the team with an opportunity to asses what hazard events could occur within the distribution system, to consider how these could be controlled and to pilot some simple monitoring tools for data collection. This exercise proved to be invaluable to terms of developing a fuller understanding of the water supply and what threats it was exposed to.

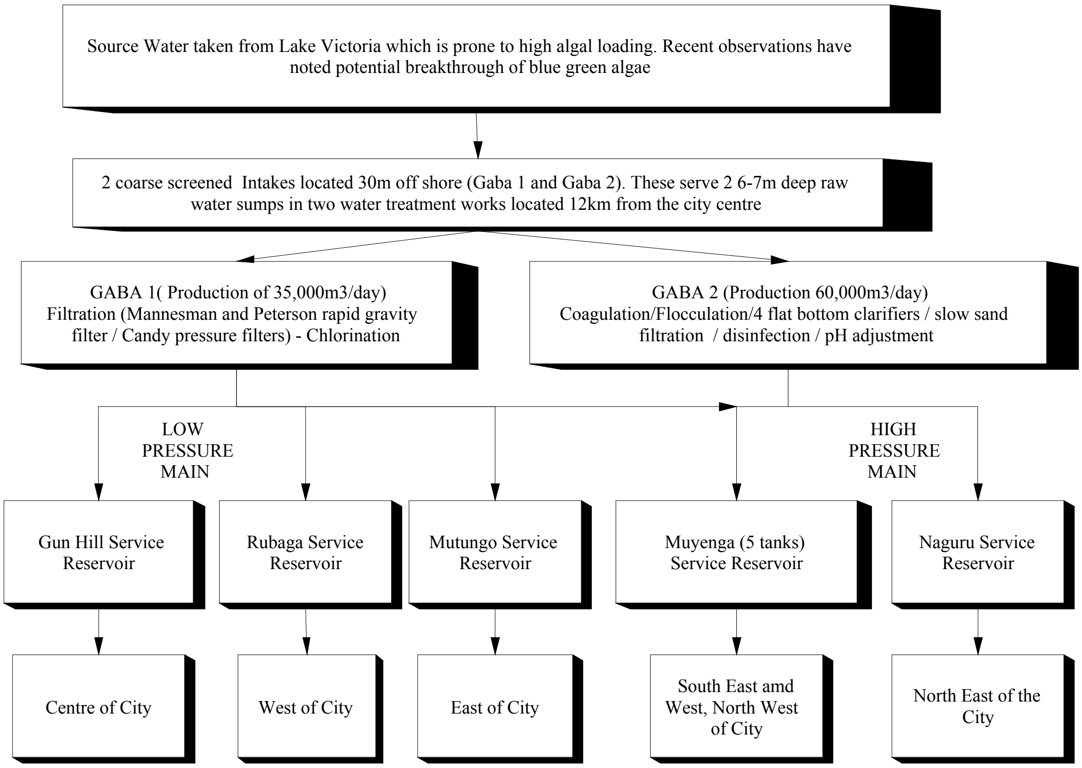

Figure 1. System description and analysis: Kampala.

Risk ranking, developing the WSP and verification

A list of potential hazard events was developed for the Kampala supply based on the information obtained from the system description and analysis, the field assessment and a review of recorded incidents within the literature. A risk ranking exercise was undertaken for the identified hazard events based on qualitative estimates of the likelihood of an event occurring and the severity of the impact. The system described by Deere *et al.* (2001) was used to define risks and is shown in Table 2 below.

Table 2. Risk ranking (after Deere *et al.*, 2001).

Likelihood	**Definition**
Almost certain	Once a day
Likely	Once per week
Moderate	Once per month
Unlikely	Once per year
Rare	Once every 5 years
Impact	**Definition**
Catastrophic	Potentially lethal to large population
Major	Potentially lethal to small population
Moderate	Potentially harmful to large population
Minor	Potentially harmful to small population
Insignificant	No impact or not detectable

A draft Water Safety Plan was developed, which identified priority points (service reservoirs and major valves) where control was particularly required. This WSP provided a detailed management plan for the entire system, with simple process monitoring tools and identified means of verification for the whole supply.

The WSP was verified through an intensive water quality assessment of the system that tracked water from the source, through the treatment works and into the distribution system. As the principal hazard events identified were microbial in nature, the assessment focused on testing of parameters relevant to pathogen control. Three indicator organisms were used in this assessment. *E. coli* and faecal streptococci were analysed throughout the system and were designed to provide an indication of the risk posed by bacterial pathogens. *Clostridium perfringens* was analysed in source water and through the treatment works as a surrogate for protozoa removal performance. The verification exercise indicated that the WSP was well formulated and that although the supply functioned reasonably well, problems remained in a number of areas, notably distribution management. After the verification exercise, the WSP was finalised.

A second exercise is currently underway to provide further information regarding the risk posed by the Kampala supply. This is effectively a form of validation and is using two pathogens (*E. coli* O157 and *Salmonella*) to assess removal within the treatment works. In addition, analysis of coliphage is also being undertaken as a surrogate for viral movement. This data and data from the previous assessment of *Clostridia perfringens* will be used in a quantitative risk assessment to define the likely health burden derived from the water supply.

Prioritising areas for control

In order to enhance the ability of the utility to implement effective water safety management, a methodology for defining priority areas within the distribution system using AutoCAD. A matrix has been developed to take into account hazardous environments (areas where there is an increased risk of hazard presence), vulnerability of the pipe (a set of characteristics of the system materials and design) and variable vulnerability (as described by sanitary inspection). This is combined to allow important points of similar nature within the system to be ranked in terms of the likelihood of a hazard event occurring. The maps developed are dynamic and can be regularly updated in relation to changing conditions brought about by investment or deterioration within the system. In the future water quality models are being developed to further enhance these risk management tools.

The approach to risk management has also incorporated measures of socio-economic status as a measure of the susceptibility of the population to water-related disease. This is based on the well-established links between poverty and health. The use of socio-economic variables enhances the ability of the utility to identify priority areas and to determine appropriate interventions, including collaboration with communities in improving management in the tertiary infrastructure.

Conclusions

The project in Uganda shows that water safety plans can be developed and implemented in developing countries. A WSP for a second town has been drafted and is undergoing the first verification exercise. In addition to the development of understanding of the system and how risks may occur, it is important to understand varying susceptibility of communities to disease. Furthermore, as well as scientific and technical inputs, resolving internal and external institutional issues is crucial in the overall success of water safety management.

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Thailand's "Safe Tap Water Certification Program"

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The importance of a good water supply, and an effective sanitation system has been recognised in Thailand since King Rama V first foresaw the link with the prevention of disease in the early 19th century. Since then the country has achieved good progress in the provision of safe drinking water for its people.

Early methods of excreta disposal were not successful in preventing and controlling disease, and often resulted in contamination of water supplies, but the situation began to improve in the early twentieth century when a water works operated for the first time in Bangkok, and rules were issued prohibiting defecation directly into rivers and canals.

Improvements have continued, and water supply and sanitation has featured prominently in National Plans since the first in 1960. The government also assigned the period 1981 to 1990 as the "Decade of Water Supply and Sanitation in Thailand" in line with the World Health Organization declaration. This decade provided the impetus for remarkable growth in access to piped water supplies with coverage levels rising from a low of just over 10 percent in the early Seventies to nearly universal coverage by the late Nineties.

Despite these levels of coverage, there are still many water quality problems, particularly microbiological, and increasingly chemical, due to the contamination of both ground and surface water sources. This deterioration, particularly in the quality of rural water has been compounded by the lack of any co-ordinated protection of water sources, and from poor water supply management and maintenance that has resulted in the quality of piped water in some areas being below accepted standards.

To address this situation a program to certify the safety of drinking water has been implemented. This program, by ensuring that tap water quality meets the required standards, and by certifying that the water is safe to drink, will increase public confidence in their piped drinking water. This confidence and the adoption of tap water as the normal drinking water supply will contribute greatly to a general improvement in the health of all Thai people. It will also reduce their reliance on expensive bottled drinking water bringing added economic and environmental benefits. As an example, 1000 litres of treated piped water can be supplied for the same price as 1 litre of bottled drinking water.

To achieve this, health authorities and water suppliers have joined hands in a drive to make safe tap water available to all, and in 1998 the Thai Ministry of Health entered into a memorandum of understanding with the Provincial Water Authority (PWA) to launch the "Safe Tap Water Certification Program".

The process began with the assessment of the risk factors, and degree of contamination of the water sources by examination of the entire process from source to the consumer conducted using hazard analysis principles and the identification of critical control points (the HACCP approach). Preliminary work in this process has already been carried out during the field trials of the WHO protocol "Assessing Priorities for Risk Management" which allows for the prioritisation of the chemicals of greatest health significance, and considering how these might be controlled or eliminated.

Under the program, water supply agencies are encouraged to use appropriate technologies to improve their performance levels to reach the requirements for safe water certification and to put into place a regime of water quality monitoring to ensure that the supply consistently meets standards.

Effective management, and encouragement of local investment in community water supply systems ensure that water treatment is standardised. Indeed, the whole process requires the active involvement of the community in protection, conservation, rehabilitation and maintenance of their water sources and supply systems.

Both the water supply and health agencies encourage the consumption of piped drinking water by ensuring there is an adequate and continuous supply of good quality water that is affordable by the local community.

Rigorous water quality monitoring is used to both enable certification of safe water systems and in ongoing surveillance of the supply. Public relations campaigns are used after the supply system has been certified as being safe; to inform the public of the health benefits, and to help develop positive attitudes towards drinking tap water.

Water supply agencies are responsible for selecting and surveying suitable supplies for inclusion in the program and for the certified distribution system. They are required to perform sufficient surveillance of the supplied water quality to ensure that it meets standards at all times. These agencies are also required to make sure that facilities meet all the required standards regarding management processes, infrastructure, maintenance, that are necessary to sustain satisfactory water quality. Together with health agencies they inform the community on water quality issues and encourage community participation in the program.

The Department of Health is responsible for ensuring that the water supply systems deliver safe tap water continuously. It reports regularly on water quality surveillance, and in collaboration with the supply agencies, surveys and reports on community attitudes to piped drinking water. It conducts surveys on tap water usage, recommends follow-up actions, and gives awards to outstanding water supply systems. The Department is responsible for the certification of safe tap water, and the organization of certification ceremonies involving community participation.

Both water supply and health agencies provide ongoing education and promotion of the health benefits of safe and reliable drinking water, and its proper protection, handling and use. To encourage the adoption of piped water as the primary source of drinking water, behavioural change programs are necessary. These programs inform the community and encourage them to become actively involved in the protection of their water supplies, and to participate in all functions of the process, including planning, design, implementation, and evaluation to raise confidence in the drinking of tap water.

Since its inception, the program has expanded and now incorporates over four hundred rural, and eighteen urban water supply systems. This represents over a quarter of a million rural, and 1.25 million urban dwellers who are now consuming low cost certified tap water.

To quantify success, studies are planned to document the health impacts of the program. In particular, one of the initiatives related to the program, and in parallel with this year's World

Health Day theme of "Healthy Environments for Children", is to study the effects of water, sanitation, and hygiene on the health of Thai school children. The information derived from these studies will be used for policy development. Future work plans include ongoing promotional activities, and the encouragement of water supply agencies to continually improve their management practices, to ensure that quality consistently meets safe water criteria. It is also intended that the program will expand to cover more areas, particularly those where adverse health effects from water-borne diseases are evident.

The beneficial outcomes of the project are that by achieving a greater understanding of the drinking water situation, water quality will meets standards over the longer term. With the greater reliability of piped water systems, public confidence will increase, and drinking water directly from the tap will become the norm. This will have the economic benefit of reduced impacts from water borne disease a reduced reliance on expensive bottled water, with the associated reduction in plastic waste from bottles.

What is clear is that consumers participating in the program are already enjoying safe drinking water, conveniently on tap, at a far lower cost compared to bottled water.

HACCP – Hazard Analysis and Critical Control Points in Modern Management Systems of Water Suppliers

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What is a modern management system for water supply companies?

A survey carried out by the SGWA (Swiss Gas and Water Industry Association) among water supply companies in Switzerland indicated that, even today, leading managers nominate product quality as the most important criterion, although accompanied by additional economic, ecological and social criteria. The comprehensive control of the drinking water quality still stands at the centre of the daily routine of water supply companies.

According to Figure 1, however, almost every-one within a water supply company has a different understanding of quality and also a different reference basis. In general, the idea of quality has developed very strongly in the last few decades. For a long time, the focus was largely concentrated on the product itself, mostly monitored by more or less frequent checks of the end product. From the viewpoint of the water supply company, this means, for example, the physical, chemical and bacteriological analysis of the drinking water from the distribution network.

Who	Understanding	Basis
Chemist	– components within allowed limits	foodstuff law
Works manager	– no pollution – sufficient quantities and pressure – no supply interruptions	efficient + problemless operation
Director	– satisfied customers + authorities – no complaints – excellent employees – sufficient budget	mission
Politician	– low water price – sustainable use of resources – targeted performance	public interest
Quality manager	– fulfilment of requirements – implementation of improvements	company targets

Figure 1. Different definitions of quality in water supplies.

Even in the past, however, this was not enough for the water supply companies, and they also considered the production of the water and the corresponding installations – in other words, the complete technical area (Figure 2). The branch federations have contributed to the corresponding requirements with a very specific and, in some points, a very detailed set of technical rules and have described the so-called good manufacturing practice. The goal of this set of rules is the preventative control of the generally known hazards to quality that exist in specific parts of the installation of a water supply. This set of industrial rules could equally well be described as a technical and operational quality assurance system with validity from the inflow area of the raw water to the point of delivery to the customers.

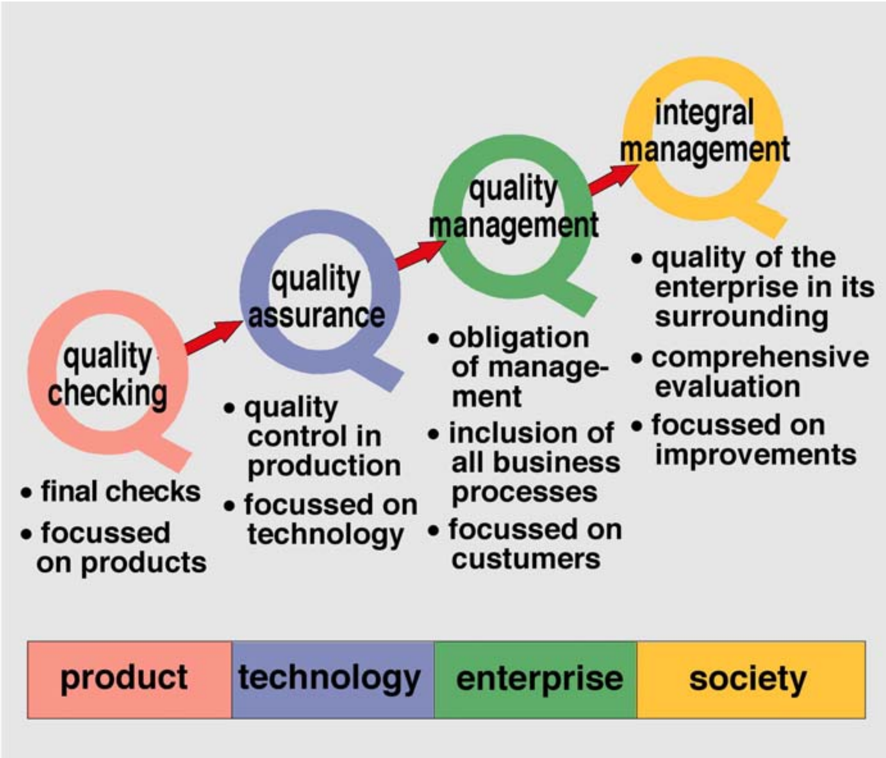

Figure 2. Development of the quality understanding.

The expression "quality management", which has been used in public for more than ten years as virtually a synonym for the ISO-9000 quality standard, appears even more modern and comprehensive. At this level, the entire water supply company is considered, and all the business processes. In this way, the product quality is only one of several criteria, as can be seen in Figure 1. Characterised by the ISO-9001 standard on which the certification is based, the activities in the company are represented as processes and are managed with corresponding process variables. From the viewpoint of HACCP and from the viewpoint of the industry, one should be warned against a too rigid application of the standard. There is the danger that processes of little relevance for quality are processed with an outlay that is (too) high. Here, the use of a risk management, for example, HACCP, makes a meaningful limitation to the most important points possible. From the viewpoint of the industry, the danger of limitation to the operative processes of the water supply company is even worse, whereby external influences and critical conditions in the environment of the water supply could be easily overseen. A branch-adapted risk management (in the form of HACCP or of the branch quality management BQM) is clearly of advantage here. For water supply companies, the importance of "conditions" can hardly be overemphasised (Figure 3). Obvious examples are the bacterial aftergrowth in drinking water that has been standing for a long time before seasonally-occupied holiday homes, or the entry of pollution through unprotected reservoir ventilation, or even any illegal dumping or animal cadavers in protected zones or immersed water feeds with the possibility of sucking back in industrial galvanisation plants.

In recent years, the development of the basic quality theory has gone even further, in that the attempt is made to obtain a complete consideration of the entire company in its social environment. The characteristic of this level is that, in integral management systems of this kind, many other criteria, such as economy, safety at work, environment, relationships with public and so on, will be handled as being of equal importance as the quality of products and services. These criteria should cover the demands of all internal and external lobbies.

Quality assurance in water supplies

= mastery of conditions, events and processes

Figure 3. Main aspects of QA in water supplies.

Because different standards and benchmarks come up against each other here, there is the danger of clash of beliefs between the management systems, similar to that shown in Figure 4. At this level, where it is the own wish of the company for improvements, and no longer legal or local authority specifications that are decisive, certification according to a standard becomes optional. It is of much greater importance to extract the relevant benefits from the different management systems and to make use of them in a single, but genuinely integral management system. To do this, one only needs to correctly apply the well-meaning forces and to limit the outlay using an integrated HACCP, as shown in Figure 5.

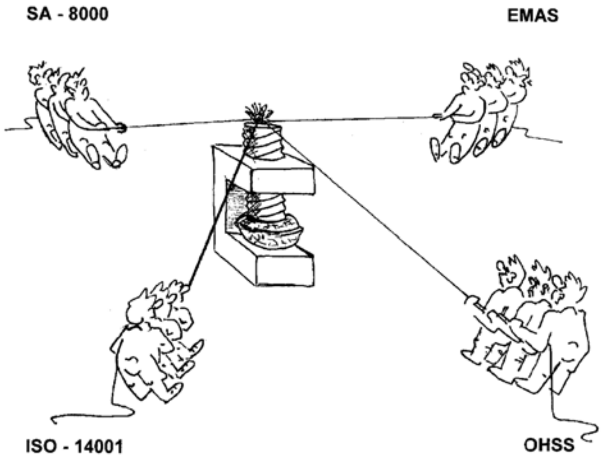

Figure 4. Clash of management systems.

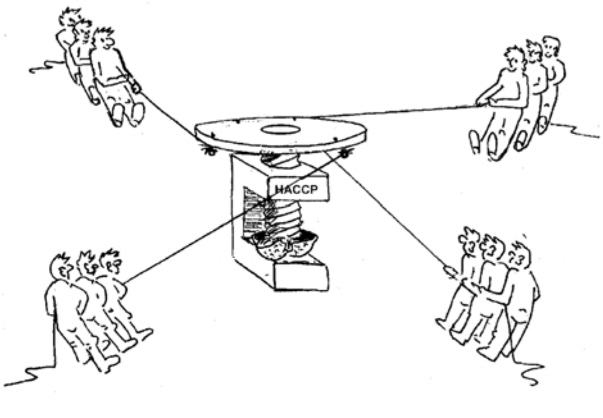

Figure 5. HACCP-based integral risk management.

At this highest level of management systems, the prior application or integration of a genuine risk management is of decisive importance for the integral benefits of this integral management system. Unfortunately, we do not yet know of any water supply company that has already reached this total quality management level.

From the point of view of a modern risk management, it may, however, be stated with satisfaction that a standard risk management in the sense of the HACCP is already available for the water supply companies with the branch-specific quality assurance on the second level of Figure 2. For the most important risks, the corresponding preventative measures are already described as regulations or recommendations in the technical rules of the branch associations – at least in Switzerland, Germany and in several neighbouring countries. Or, to put it another way: Many critical points have already been mastered with the application of the branch-specific rules of technology.

Where and how does HACCP apply in the water supply company?

In many small water supply companies, the periodic analysis of the distributed drinking water was and is the most important control point. Even when certain other maintenance and control measures are practised in addition, it would be unthinkable to exclude physical, chemical and bacteriological analyses. In Switzerland, they are required to various extents by all foodstuff authorities and by the directives of the SGWA.

The quality assurance philosophy of the Swiss water industry, however, goes well beyond the assessment of the product water itself. In addition, the water plants (from the inflow area, through the catchment, treatment, storage and distribution, and up to the delivery of the water), the processes used in the construction and operation (from the sealing procedures up to the periodic hydrant flushing), the personnel (from know-how up to responsibility) and the organisation of the water supply company (from structure up to process organisation) are used as a multi-level system for safeguarding the product quality. In order to make this concept better understood by the users and by the responsible authorities, the SGWA has represented this graphically as “the big Q for water supply” (Figure 6). This is a five-shell Q, which indicates the most important control areas, and which helps to control present and potential hazards as a quasi “multi-barrier-system”. The control areas are as follows: Product/Installation/Process/Personnel/Organisation, which result in the English abbreviation PIPPO.

In all these control areas weak points or direct and indirect hazards to the water quality could be present. These can possibly result in critical points within the meaning of a modern HACCP. As a result, "HACCP thinking" acquires the same company-wide significance as the "risk management" expression that is more commonly known in the company world.

The area of application of a comprehensive product quality HACCP thereby goes far beyond the technical area of a water supply company (compare here the WQS, BQM and TSM systems of the branch federations SGWA and DVGW). Or to express it more concisely: Although the quality of the drinking water is produced in the technical division, it is only safeguarded over the complete organisation.

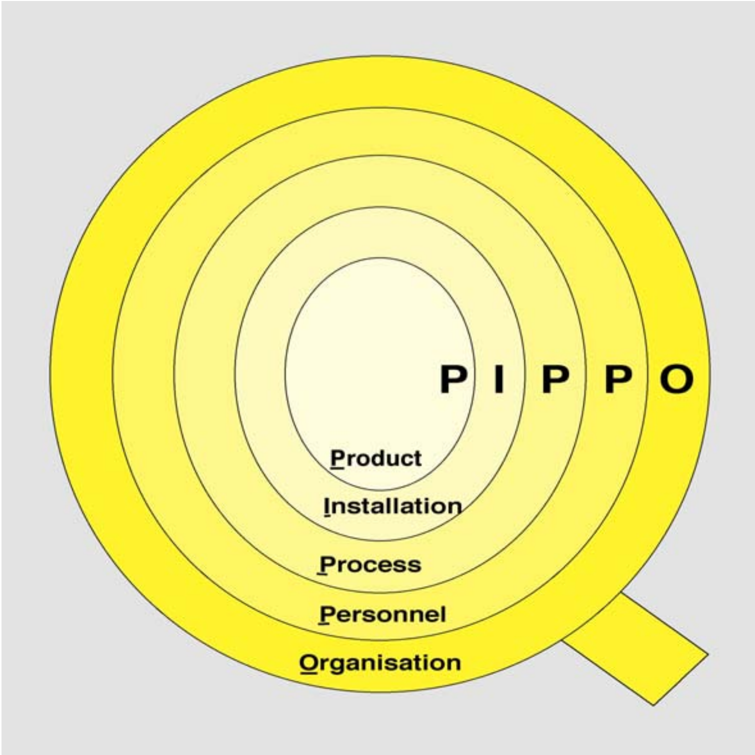

Figure 6. The big Q for water supply.

How do you adapt the HACCP to the different water supply companies?

The experience of the SGWA in the bandwidth from very small supplies for less than 100 people without any treatment up to complex sea-water plants with seven treatment stages for 1 million inhabitants clearly shows that a single quality assurance system is not suitable for all complexities and sizes. Only a few of the basic requirements on a quality assurance system for water supply companies are common (Figure 7).

A suitable QA-system for water supplies has ...:

- to take into account the peculiarities of the branch
- to be based on existing rules of technology
- to orientate on the hazard analysis
- to adapt to the complexity of the water supply
- to be simple and understandable
- to bring use in the every day life

Figure 7. Requirement profile to water-QA-system.

Seven years ago, in order to cover the wide range of requirements of the different water supply companies, the SGWA drew up a branch-specific management concept for supply companies. The goal was a self-compatible system of different complex management systems based on the laws and technical rules, which would be open for expansions in the direction of ISO standards and Total-Quality-Management (Figure 8). In doing this, the integration of the HACCP concept was an obvious factor, because, as early as 1995, Swiss legislation had placed the precondition of a suitable quality assurance system in the Hygiene Ordinance and had explicitly required the “self-control” and “HACCP method”. While most water supply companies did not know what to do at first, the branch federation (SGWA) and the respective supervisory authorities (the cantonal chemists) started to develop practical systems that, above all, would also be usable by the more then one thousand small water supply companies in Switzerland.

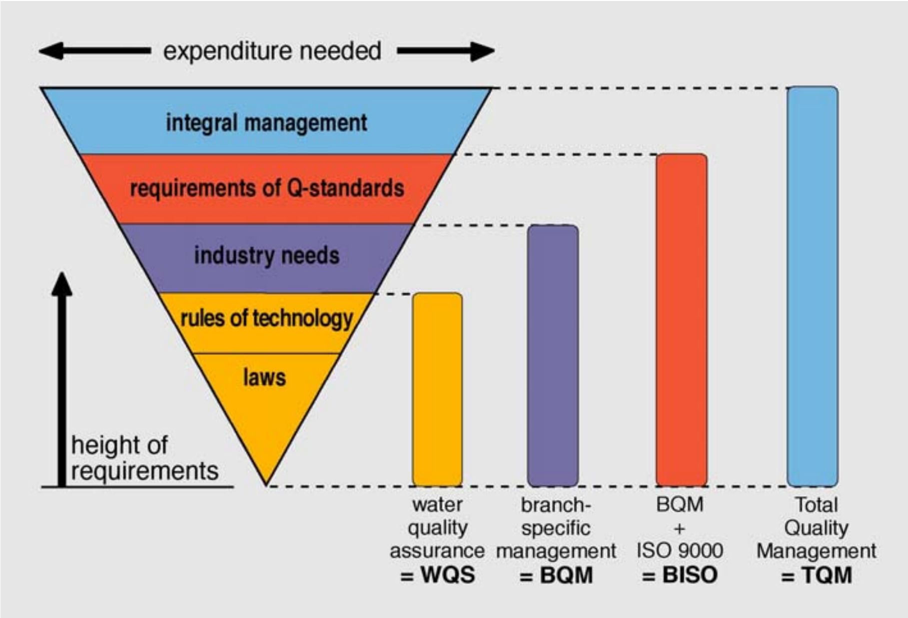

Figure 8. Main aspects of QA in water supplies.

Two fundamental realisations for the management concept of the SGWA arose from the pilot phase of the first applications, and were confirmed in the subsequent wider application:

- Small or simple water supply companies need a QA system that is similar to a recipe book, which, on the one hand, supports the hazard identification with check lists and keeps the assessment of hazards very simple, while guaranteeing, by means of additional aids in the shape of forms, that the detected hazards and critical points will also be mastered with suitable measures on the other.
    - As a result of this realisation, the SGWA drew up “Instructions for a simple quality assurance system for water supplies”, the so-called WQS system. Several hundred examples were sold in the first year alone.
- For the more complex or larger water supply companies, the QA system has to be more open with regard to the identification of hazards, and – as part of an integral management system for the water supply company – must also allow criteria other then the product quality.
    - From this, the “Guidelines for a branch-specific quality management for supply companies according to SGWA/SEV“ arose, the so-called BQM system, which is also applicable to gas and electricity supply (Girsberger, 1999; 2001).

How do branch management systems directly implement the HACCP principle?

General experience with modern management systems and the specific assessment of the HACCP method indicate that a clear and well guiding system already makes the half of the success possible. But only one half, because the other half of the success can only be achieved with the corresponding technical know-how. This perception is a clear limitation of universal management systems (such as the ISO-9000) or universal methods (such as the HACCP). Only after a branch adaptation has been carried out these systems are understandable for the users in the branch and sufficient for a comprehensive hazard assessment.

The advantage of branch management systems now lies in the fact that they already contain the branch adaptation in their fundamentals and aids, and do not have to be expressed or interpreted in universal terms or procedures. Furthermore, the branch management systems of the branch federations (WQS and BQM of the SGWA or TSM of the DVGW) have the additional advantage that they will be checked by genuine experts from the branch in a system and specialist audit.

In the simple WQS quality assurance system of the SGWA, the above-mentioned branch adaptation, the methodical procedure according to HACCP and the assessment by branch specialists can be clearly seen (Figure 9).

	Step	Content	Help tools or "forms"
Inventory	1	Describe the water supply organisation as well as the duties and technical expertise of the employees	"Organisation of the WS" and "Job description" SGWA directive W11
	2	Update or draw up the survey of the complete water supply	"Basic data"
Setting up the system	3	Look for possible hazards, evaluate them and list the critical points	"Hazards list" "Evaluation of hazards" SGWA directives W1 to W10
	4	Carry-out one-off measures for the elimination or reduction of hazards	"Elimination of hazards" "Planned measures"
	5	Update or draw up the maintenance instructions	"Maintenance instructions"
	6	Draw up instructions for the checking of critical points	"Control point instructions"
Practical system	7	Follow instructions in daily work and record and assess the results	Example report
	8	Draw up an annual evaluation regarding water, installations, processes and organisation, and propose and implement improvements	"Water supply" self-check
Confir-mation	9	Have the fulfilment of the self-check-system confirmed by specialist third party assessment	SGWA audit SGWA certificate

Figure 9. Nine working steps of WQS.

The nine working steps of the WQS are arranged in the following four stages:

- Inventory of current status, in which the quality-relevant elements of the organisation (responsibilities), the personnel (know-how), the installations (plans) and the processes (procedures) will be registered.
- Setting up the system, in which the HACCP method is implemented with hazard identification, hazard assessment and hazard control (elimination, maintenance, checks).
- System practice, in which compliance with the maintenance and control point instructions is ensured and the adaptation of the QA system to the changed conditions and processes will be implemented.
- Confirmation, in which the correct registration, assessment and control of the hazards is certified with third-party specialist assessment.

In the WQS system, the control of the critical points takes on its central significance, based on branch experience and the existing technical rules. In addition to the fundamental idea of the HACCP, which places the emphasis on the critical control points, the WQS system also takes once-only elimination and periodic maintenance into account as preventative measures for the control of critical points (Figure 10).

Mastery
of critical points by:

a) one-off elimination
b) periodic maintenance
c) current control

Figure 10. Different ways of mastering critical points.

Since the first issue of the “Instructions for a simple quality assurance system for water supplies”, the SGWA has supported and assessed many projects of this kind. In doing this, three factors for success quickly became very clear for the WQS system:

a) The instructions must provide clear guidelines for the normal well master or water manager and the corresponding tools/aids must be available as ready-for-use.
    - Therefore, the WQS instructions provide for each working step a task, an illustrated example and an implementation form in the appendix that can be copied. A trivial, but nevertheless instructive example of a maintenance instruction can be seen in Figure 11.

b) The probability of implementation of the WQS system can be increased with the provision of flanking services.
    - Regionally, the SGWA has carried out several one-day instruction courses for well masters and their (often political) superiors. The resonance from the participants was very good.

c) The basing of the WQS system on the accepted technical rules is warmly welcomed by the system implementers and the regional supervision authorities.

- The branch regulations give to the system users – in addition to guidelines for the operation of the water installations – also help in their construction and maintenance. And, from the viewpoint of HACCP for water supply companies, many potential critical points for the water quality can thereby even be avoided.

Sample form 5

Maintenance Instruction	No. 1.4.10

Critical point:	BACKWATER IN THE BROOK "WILDENSTEIN"
Maintenance area: (Which area is to be maintained?)	THE WHOLE BACKWATER GATE INSTALLATION IN THE BROOK WILDENSTEIN
Time: (When and how often?)	a) EVERY MONTH b) AFTER EVERY HEAVY RAINFALL
Work instruction: (What is to be done?) 1. Judgement of situation 2. Execution of work	1. JUDGEMENT ▪ IS THE BACKWATER GATE FREE OF FLOATING MATTER AND SEDIMENT TRANSPORTED? ▪ IS THE BACKWATER GATE DAMAGED? ▪ DOES THE BACKWATER GATE WORK WITHOUT LARGE RESISTANCE? 2. EXECUTION OF WORK ▪ CLEAN THE WHOLE OUTLET INSTALLATION ▪ GREASE THE FLAP IF NECESSARY ▪ OPEN AND SHUT THE FLAP TWICE
Confirmation of realisation (Who did it when?)	

Created on: .... by: ....

Figure 11. Example of a maintenance instruction.

Because of the success with the WQS system, and also due to ongoing pressure of authorities on comprehensive implementation of quality assurance at simple water supply companies, the SGWA has decided to revise the instructions. The improved "Recommendations for a simple quality assurance system for water supplies" were published in March 2003– as it were, as a Swiss contribution to the Year of Drinking Water. Significant improvements have been carried out in the hazard lists and in the explanatory examples. In cooperation with the cantonal chemists (the regional supervisory authorities), a standard checklist has been added for the self-check step.

The supervision authorities welcome the WQS system because it is simple, and nevertheless, in the sense of the „big Q for water supply“, contains –in addition to the water itself – also the quality assurance elements of installation, process, personnel and organisation (Figure 6).

Where can HACCP thinking lead?

For complex water supply companies with multi-stage chemical treatment plant (and normally with specialists with higher levels of education) the more sophisticated branch quality management system BQM is the right solution (Girsberger, 1999; 2001). The BQM uses the same procedures as the WQS, but makes the HACCP stage more intensive in that the hazard identification is designed to be freer and wider and the hazard assessment takes place as a quantified risk assessment. In principle, generally valid hazards are handled by the branch regulations; beyond that the BQM guarantees that the locally additional hazards will also be registered. Both the branch regulations and the company-specific BQM must be continually developed further with regard to new hazards, requirements and knowledge.

The BQM level pushes itself forward if HACCP should be implemented in a single management system for water supply and for other utilities (such as gas, electricity, signals) or for other criteria (such as reliability against failure, safety at work, environmental protection, economy, etc.). HACCP will then become the basic idea of a genuinely integral management system that should control all hazards for the entire company.

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Principles of the German Drinking Water Sector

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The importance of high-quality drinking water and of ensuring supply security

The development of the German water supply was characterised by the fight against the transmission of diseases. This refers not only to the drinking water quality, but to a great degree also to the availability of adequate water for everyone, in other words to supply security. And this fight was not won in a matter of years, it ultimately took over half a century until people in Germany could feel safe against epidemics resulting from a poor drinking water supply.

This experience has resulted in a code of values within the German water supply sector that are as follows:

- Drinking water is the most important substance for sustaining life. Therefore, drinking water is essential for the public supply of daily needs;
- Water is a common good;
- The supply of water must be seen in the overall context of the hydrological cycle; and
- All aspects of supplying drinking water are accordingly committed to sustainability.

Using a code of values of this kind, we have successfully supplied water in Germany for many decades.

The draft WHO Guidelines rightly point out that it is not sufficient to merely monitor the quality of drinking water supplied and to take corrective action only if the water does not meet the required standards. Rather, securing safe drinking water must incorporate all areas of water supply, from resource management, water acquisition, water treatment and water distribution right up to domestic installations. This is completely in harmony with the principles of German water supply.

Moreover, the principles of German water supply set even greater emphasis on preventive measures.

Drinking water quality - a continuous process of optimisation

The German drinking water sector has defined the basic requirements according to which the orientation for drinking water quality is the characteristics of groundwater of ideal quality obtained from a sufficient depth by passing through sufficient layers of filtration, which is taken from the natural hydrological cycle and is not in any way contaminated.

These requirements are a voluntary commitment by the water supply sector. Thus they go much further than the statutory requirements for drinking water quality. In fact, this formulation clearly illustrates the three features, which the water supply sector demands for the quality of drinking water:

- Drinking water should be abstracted from water sources which are protected as well as possible;
- Drinking water should, as far as possible, be of natural origin; and
- Drinking water contamination must be kept as low as possible, but well below the specified limit values (principle of minimization).

The principle of minimisation has established itself for good reasons:

- This basic requirement for drinking water prevents any tendencies of accumulation of substances right up to the limit values;
- In many cases, limit values are a compromise between what is required for hygienic reasons and what is technically/economically feasible; and
- It is also a question of image of (the) drinking water (sector).

Furthermore, implementation of the minimisation principle also means that the water supply sector in Germany acts in the interests of great safety.

Securing "drinking water quality at the highest level" extends into all areas of the water supply sector, for example:

- Up to the exit point of the waterworks the drinking water quality must be guaranteed by a multi-barrier-system.
- The risk of contamination of the drinking water due to deficits in the distribution systems (e.g. leaks) must be minimised as far as possible.
- Domestic installation must be planned and operated in such a way that drinking water taken from the tap is still of good quality. No harm to the water quality in the public drinking water network is allowed.
- Comprehensive controls within the catchment area, water acquisition, raw water, treatment, mains network and domestic installation are necessary. These controls should not be limited only to the drinking water quality; they must also entail the fault-free and safe functioning of the water supply facilities.
- Water supply facilities must be adequately protected against malicious or negligent damage to the water supply.
- Water supply companies have to fulfil basic requirements for the qualification of their employees and organisation.

Multi-barrier system and comprehensive controls - the prerequisites for ensuring required drinking water quality

The German water supply industry attaches great importance to the multi-barrier system. This can be seen in the finding

- that no single barrier can adequately rule out all risks for drinking water quality, quantity and supply pressure;

- that a safety analysis must always check the entire supply system ("from the water resource to the water meter") in order to be able to adequately avert all of the risks to the water; and
- that the barriers must be effective with regard to the drinking water quality, as well as to the functional integrity and control of the facilities.

The first barrier is the catchment area of the water intake. In principle, there is societal consensus in Germany

- that water resources protection has to cover the entire water cycle; and
- that the principle of "zero immissions" applies to groundwater reserves (well over half of the drinking water in Germany comes from groundwater reserves).

In spite of these far-reaching targets for waterbody protection, "residual risks" to the waterbodies can obviously not be ruled out. To minimise these residual risks as far as possible within the catchment area of drinking water intakes, the catchment area of drinking water acquisition facilities is additionally protected by water conservation areas, where certain dangerous actions are prohibited and there is certain mandatory action.

Special importance is also attached to monitoring the water catchment and water conservation area. The water supply companies are very actively involved in the state monitoring measures and supplement them greatly.

Comprehensive technical standards on water acquisition (well construction, groundwater monitoring, etc., by DVGW Technical Standard W 110 to W 135) ensures that, for example, contamination during water acquisition can be ruled out with adequate reliability.

The second barrier is any water treatment that may be needed. For this purpose there is a comprehensive range of DVGW technical standards that lays down the foundations for the construction, operation and control of these facilities (DVGW Technical Standards W 200 to W 296). As well as a guarantee of the safe functioning of the treatment facility, these rules also contain the minimisation of quality changes to the drinking water resulting from the treatment and the ongoing control of water treatment.

The risks to drinking water treatment for drinking water quality that can arise from malfunctions, for example are identified in these Technical Standards and measures to minimise them are laid down.

It is a generally recognised rule of technology that water treatment should, where possible, possess several "internal barriers", so that a contaminant in water treatment would once again have to overcome several obstacles until it could reach the drinking water.

The third barrier is - if necessary - effective and safely functioning disinfection. To minimise the risks the DVGW Technical Standards and the Drinking Water Ordinance describe in great detail the disinfection procedures, the measures to monitor the facilities and to ensure perfect functioning.

Obviously, this multi-barrier system can ensure effective protection of the drinking water only if secondary contamination of the drinking water by the facilities for water transport and water distribution and by domestic installation is prevented. The majority of the DVGW Technical Standards deal in great detail with all questions relating to safe mains operation.

Water protection and sustainability - in the long term the most efficient method of quality assurance

The German water supply sector attaches central importance to securing a fault-free water supply. The aim is to ensure a perfect water supply, where possible without or at least with only natural and semi-natural treatment methods. There are a number of good reasons for this:

- Water protection is a part of the first barrier in the multi-barrier-system for ensuring good drinking water quality just mentioned.
- Not all raw water can be treated into drinking water. There are impurities in raw water for which no highly developed treatment technology is available yet. Furthermore, any technical change to the water properties resulting from treatment can entail "side effects" as well as the desired effect.
- The safety of water treatment is heavily dependent on the quality of the raw water.
- As far as possible, drinking water should remain a natural product and be recognised as such by the consumer.
- From a cost point of view, it is also much more efficient to prevent water pollution from occurring in the first place.

In principle, managing and protecting water bodies is an original task of the state. But for selfish reasons alone the water suppliers are intensively involved in measures to protect and monitor water bodies.

It is precisely this self-perception by the water supply companies as being dependent on a natural resource that has to be protected and managed according to the principles of sustainability, that makes it a matter of course for the water supply industry to feel highly committed to sustainability.

Highly qualified staff - the basis for ensuring water quality and a safe water supply

The German water supply sector attaches great importance to its staff. A high level of staff qualification is much more important that any risk management system, no matter how sophisticated, which bears the risk of suggesting apparent safety. By contrast, a critical employee, who understands both the impact and the consequences of his action and the reaction mechanisms of the operational processes, is in a position to recognise unforeseen critical situations that are not included in a risk management system and to take appropriate counter measures.

In Germany, the water supply industry has therefore developed a comprehensive systems of basic and further training. For example, the DVGW conducts well over a thousand professional training events per year with approx. 20,000 participants. They comprise the entire spectrum of water supply and reach all areas of staff.

The German water supply industry also pays great attention to the specification of minimum qualifications for employees, which must be in place for the water supply tasks to be performed correctly. For example, the minimum requirements for the responsible employees of a water supply company are laid down in detail in DVGW Technical Standard W 1000. But the qualification of companies who work on behalf of the water supply companies are also specified precisely. For example, there are DVGW Technical Standards that refer directly to the qualification of experts (e.g. DVGW Technical Standards W 100 and W 201). And staff qualification also plays a central role in the Technical Standards that also deal with the qualification of sub-contracted companies (e.g. DVGW Technical Standards W 120, W 200 and GW 301).

Technical self-regulation and technical safety management - high-quality supply on a cost-orientated basis

The high levels of safety with a concomitant high level of efficiency in the German water supply industry is not least due to the fact that the German water supply industry has built up over 125 years of self-regulation with a comprehensive set of technical regulations. The government has long been aware of the value of this technical self-regulation, for example by making repeated reference in the Drinking Water Ordinance to the generally recognised rules of technology. The reasons for this success in technical self-regulation of water supply are obvious:

- The technical rules are drafted jointly by specialists from water supply companies, universities and regulatory authorities. This ensures broad consensus when they are adopted.
- The strong practical orientation ensures that risks to drinking water quality and supply safety in the various technical facilities are identified and measures to minimise these risks are specified.
- Furthermore, the strong practical orientation ensures that the measures to be implemented can be carried out appropriately, i.e. effectively at a reasonable cost.

The Technical Standards have been included to a great extent in the DVGW Technical Standards W 1000, W 1010, W 1020 and W 1050, where special reference is made to the measures of company organisation.

The principles of water supply in Germany - the Hazard Analysis and Critical Control Point (HACCP) concept in practice

The HACCP concept is thus completely formed by the principles of the German water supply industry. In particular, the principle of establishing the safeguarding of drinking water quality not only by controlling drinking water quality, i.e. by product quality, but also and in particular by controlling the processes is enshrined in the principles of the German water supply industry. This will be shown below on the basis of a few points of the HACCP concept:

- *Overall understanding of the system*: Even when planning water supply facilities, which are also the basis for regulatory permits, it is necessary to gather, prepare and summarise in suitable form all information, for example relating to the catchment area, supply area, water quality, geological, climatic and topological conditions, water demand and water distribution network.
- *Hazard analysis and risk assessment*: These points have played a central role in the planning and operation of water supply facilities for many years. For example, this is the case for the catchment area or for a water conservation area. The risks in this respect and the associated consequences for actions in water conservation areas are

described in detail in the DVGW Technical Standards W 101 to W 112. The same applies to drinking water treatment, disinfection, operating a water supply network and to the facilities in domestic installation, for which the risks are identified and the safety measures laid down in the DVGW rules.

- *Specifying control points; specifying standard values and tolerance values; establishing monitoring systems*: For many years the German water supply industry has not limited itself merely to controlling the quality of the drinking water that is piped to the customers. Much rather, the control system in the water supply companies comprises many different control points. Carrying out these controls, the key measuring points and strategies and specifying the CCP conditions are based on the specifications in the Drinking Water Ordinance, the contents of the DVGW Technical Standards and experience in every company.
- *Specifying measures*: The subject of "Action Plans" is currently being discussed intensively in Germany in connection with the amended Drinking Water Ordinance. According to this, every water supplier is obliged to draw up an Action Plan in case there is a deviation from the statutory requirements of drinking water quality.

In summary it can be said that the principles of the HACCP concept in the German Drinking Water Ordinance have long been implemented. But we should critically examine the approach of forcing all of these principles in a formalised Water Safety Plan. Is it not more sensible to motivate the employees to think independently and constant critical questioning than to use their energies and motivation for filling in forms?

DVGW Technical Safety Management System as a Quality Management Tool for the Drinking-Water Supply in Germany

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Principles and objectives of the Technical Safety Management system

With the publication of the technical directive “Requirements to be met by drinking-water supply utilities“ (DVGW-W 1000), the DVGW (German Technical and Scientific Association for Gas and Water) laid the foundations for a technical safety management system. On the basis of this technical directive, further technical regulations, guidelines and other information have been evolved in recent years. These include:

- guidelines for internal inspection of the organizational and operational structure and of the technical safety, the so-called checklist;
- guidelines for the compilation of an operations manual;
- principles and organization of the standby and fault clearing service;
- recommendations and suggestions in the event of limiting values being exceeded and of deviations from the requirements of the German Drinking Water Ordinance; and
- provision planning for emergencies in the public drinking-water supply.

The sequence of a Technical Safety Management (TSM) system inspection is as follows:

First, a self-rating is to be performed by the water supply company on the basis of the above-stated checklist. As a supplement to the internal inspection by the company itself, the DVGW offers an inspection by independent experts. If the inspection has a positive outcome, a certificate is issued, certifying that the requirements are met by the water supply company on the basis of the above-stated technical directives and of the checklist. The arrangements found as well as any recorded need for action to improve the arrangements are documented.

The TSM inspection has a 5-year validity period and is subject throughout this period to the retention of the fundamental organizational structure and of the technical executive manager.

Like the WHO Water Safety Plan (WSP) and thus the HACCP concept, the TSM is designed as a preventive concept. The aim is to ensure and record that not only the product quality (product safety) of drinking-water as a consumable but also the reliability, the sustainability and the economic efficiency of the water supply is guaranteed through appropriate qualification and organization. In this context, the TSM is not confined to hazard analysis and to the identification of critical control points in the production and distribution processes. Through corresponding requirements to be met by all divisions of the water supply company for the entire drinking-water supply process, it also represents a comprehensive, branch-oriented quality assurance system. The terms “control point“ and “critical control point“ should be applied not only formally to the water purification or catchment processes but to all operations relating to the drinking-water supply, e.g. to staff training, to the repair of damaged pipes, or to the maintenance of a water sampling faucet.

With this external inspection of the Technical Safety Management system, the correct execution and observance of all relevant operations and/or processes in the drinking-water supply in accordance with the WHO Water Safety Plans are confirmed, i.e. verified.

Requirements deriving from the Technical Safety Management system to be met by drinking-water supply utilities

General

The concrete requirements deriving from the TSM to be met by water supply utilities relate essentially to the following areas:

- Requirements relating to personnel, including the technical executive manager or specialists;
- Organizational and operational structure;
- Stipulation of the tasks and fields of activity to be expertly performed; and
- Technical equipment.

Personnel qualifications

The personnel qualifications are of crucial importance in the context of a preventive water safety plan. The drinking-water supply process has to be headed by the "technical executive manager", who is responsible for planning, construction, operation and maintenance. This technical executive manager can be a member of the company management or can have a lower rank. He must have the necessary expertise and the necessary specialized experience as well as the necessary decision-making responsibility to perform the tasks assigned to him. These include in particular the authorization and the obligation to act on his/her own responsibility in matters of relevance to safety. This implies three decisive characteristics:

- Technical competence;
- Decision-making competence; and
- Responsibility-oriented competence.

The level of the demands made on the technical executive manager varies, depending on the size of the water supply company and the scope of its tasks. Whereas a qualified engineer with a scientific-technical education and training is needed at large companies and at waterworks with advanced treatment, a skilled worker qualified in supply technology or mechanical systems is often adequate for small plants without purification facilities and for utilities selling only small quantities of water.

The other technical specialists, from the skilled worker to the engineer, must also have a qualification meeting the requirements of the specialized tasks. The "technical executive manager" has to take care that only specialists with the necessary qualification are employed and that further education and training measures are available to ensure that those specialists have the necessary know-how relevant to the generally recognized state of the art (DVGW regulations, standard specifications, official regulations). This ensures that the requirements of drinking-water supply legislation are met and that the technical personnel are capable of assessing and executing the tasks assigned to them and of recognizing potential risks.

In other words, it is ensured in accordance with the WHO Guidelines that, in planning, in operations and in risk analysis, both determination of the critical control points and process inspection and control are in the hands of purpose-trained specialists. In addition, staff motivation is enhanced by the further education and training measures required.

The above stated requirements apply too, of course, to the personnel of subcontractors and service providers and – if the company management is sourced out – to the personnel working in this field. In other words, when selecting service companies, the water supply utility has to ensure that the personnel are suitably qualified to meet the general technical rules and the special requirements of the water supply company. Within the framework of the technical regulations, the DVGW also undertakes the inspection and certification of service providers. If, then, the water supply company subcontracts only to such companies, the requirements of the WHO Guidelines are met in this field too.

Organizational and operational structure

In addition to the personnel qualification, the requirements to be met by the organizational and work flow structures form the second mainstay in the Technical Safety Management system for water supply utilities. A proper organizational structure is subject to explicit, clear-cut rulings of the tasks and activities in terms of discipline and of expertise. The primary functions have to be stated in writing, with overlapping responsibilities being ruled out. Within the framework of the operational structure, the main work flow sequences have to be stated and to be recognizable to all those involved. The interfaces between the individual departments or divisions within the water supply company as well as those interfaces resulting from calling in subcontractors have to be regulated with consistency. In this context, those relationships not described in the organizational structure are to be outlined. In practice, this can be done by formulating organizational instructions or work flow instructions. The functions and responsibilities of the technical executive manager must also be clearly recognizable from the organizational and operational structure.

One focal point of the inspection of the Technical Safety Management system is therefore an inspection of the organizational charts and of the internal guideline or instruction system.

A consistent organizational structure ensures that

- in addition to the technical precondition for risk analysis, the personnel and organizational responsibilities for the inspection and control of processes and work flow sequences and for the necessary control procedures are also stated; and
- the crucial work flow sequences and/or processes involved in the water supply are subject to ongoing efficiency controls and appropriate adaptation to the requirements.

Task definitions and spheres of activity

The requirements to be met by water supply utilities also define the spheres of activity for which responsibility is assumed by the water supply company and which are essential to the proper performance of planning, construction, operation and maintenance. Reference is also made to the procurement tasks including materials management as well as to contingency planning and the standby service for failure logging and fault clearing. If these tasks are properly performed too, the foundations are laid for eliminating or defusing risks from the very outset or for taking measures to ensure that the processes and operational sequences of the drinking-water supply are adequately organized with respect to product and supply safety.

Technical equipment

Wwater supply companies, including the smaller ones, have to maintain a minimum standard of technical equipment. The presence of appropriate planning schedules and records are of crucial importance, as they provide the preconditions for determination of the main production-specific limiting values (pressure, flow, energy input, quality parameters). Appropriately (documented) gauged or calibrated measuring instruments and equipment that has undergone practical testing form the precondition for checking that limiting values are observed and for controlling processes and operational sequences or correcting them if necessary.

Ongoing optimization of the TSM

Practical application of the TSM in the utilities and review by the external inspectors provides an ongoing process of optimization of the Technical Safety Management system and of the technical management of the individual operational sequence and processes involved in the drinking-water supply. Exemplary arrangements by a company are noted by the inspectors and are recommended to other utilities that are subject to inspection for optimization of their procedures, organization or qualification.

The 280 questions in the checklist for inspection of the organization and of the technical safety system are also continuously updated on the basis of the experiences gained by the water supply company. Know-how and experience undergo constant expansion in the course of the inspections of the water supply company. In addition, there are ongoing training courses and interchange of experience for the inspectors.

As many inspectors are involved in developing technical DVGW and DIN specifications within the framework of the technical self-administration of the German water supply industry, registered deficits as well as exemplary arrangements with respect both to the drinking-water supply and to organization, qualification and technology can be taken directly into account in the development of such specifications or can be used to set special priorities in them.

The authorities responsible for the water supply in each of the federal states of Germany have also recognized the advantages of the Technical Safety Management system, with respect both to ensuring the reliability of the supply and to safeguarding the utilities concerned. The federal states of Saxony, Bavaria and Lower Saxony have proposed to the water supply utilities in their region that inspections should be undertaken on the basis of the TSM.

Conclusions

The Technical Safety Management system of the German water supply industry is already implementing the WHO Guidelines and forms the basis for the outstanding quality of the water supply in Germany.

The HACCP concept has long been a fact of life in Germany. As a result of the TSM of the DVGW, it has also undergone systematic hazard analysis and documentation by internal and external specialists during the past two years.

A formalistic or rigid application of the principles of the HACCP concept to the drinking-water supply in Germany is not necessary.

The Technical Safety Management system offers the water supply utilities an integrated, comprehensive management system that highlights the non-technical aspects too on account of its comprehensive approach and goes beyond the requirements of the HACCP concept.

Towards Public Health Risk Management Plan Implementation in New Zealand

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Introduction

The New Zealand Ministry of Health (the Ministry) is taking steps to shift the basis for managing the country's water supplies from one of product monitoring to the preventive approach of risk management. Key to this process is the proposed introduction of new legislation. Two major provisions of the legislation will be the requirement for water suppliers to prepare and implement water safety plans – termed, *Public Health Risk Management Plans*[1] (PHRMPs); and the requirement for water suppliers to take all practicable measures to comply with the *Drinking-Water Standards for New Zealand (DWSNZ).*

In anticipation of the enactment of the proposed legislation, the Ministry has developed a risk management framework and a set of "tools" to assist water suppliers in their preparation and use of PHRMPs. Small suppliers, particularly those for who water supply is not their primary responsibility (e.g. rural schools, Maori communities) suffer from limitations of finance and expertise. For these suppliers, the task of preparing PHRMPs will be most difficult, yet it is these supplies for which the operation of a water safety plan may bring the greatest benefits. Despite small supplies serving a small fraction of the population (5%), designing a framework and "tools" that can be readily used by small supplies has been a major consideration in the Ministry's strategy for implementing the new approach to water supply management.

New Zealand's framework for Water Safety Plans

Water quality targets

The establishment of water quality targets, to define what a community considers to be a safe water, is a necessary preliminary step in the development and implementation of water safety plans. In New Zealand, compliance with the *DWSNZ* defines a safe drinking water, hence compliance provides the water quality target for water suppliers. At present, there is no legal requirement for water supplies to comply with the *DWSNZ*; the Ministry encourages water supply improvement and compliance through the use of a number of non-regulatory measures that ensure the public is informed about the quality of their drinking water. The proposed legislation will give the *DWSNZ* a statutory mandate, and is expected to lead to improved levels of compliance.

Introduction to PHRMPs

PHRMPs are intended to map out the way in which the water supplier is to proceed in reducing the risk to the quality of their water, and consequently to the health of their

[1] These risk management plans for water supplies are termed "Public Health Risk Management Plans" to distinguish them from other forms of risk that need to be managed such as financial, legal etc.

consumers. To establish a course of action, needed improvements must first be identified by comparing the measures that should be in place, with those that are in place. In most situations resource limitations do not allow these improvements to be made immediately, consequently they need to be prioritised, taking account of their relative importance for water quality, and the availability of resources. The New Zealand framework acknowledges that the implementation of preventive measures takes time, and that there should be, for water suppliers and regulators, a yardstick against which progress towards minimising public health risk can be assessed.

To provide a yardstick, PHRMPs are required to contain a schedule that identifies needed improvements to a supply, names those with responsibility for making the improvements, and sets out a timetable for making the improvements. In this way, while implementation of the full set of preventive measures may not be immediately achievable, the water supplier is able to show continuing progress towards reducing public health risk by the stepwise achievement of each milestone in the schedule.

Framework development

The foremost consideration in developing the framework has been to produce a system that would best suit the New Zealand circumstances. As a result, to create the framework we have borrowed from other approaches, rather than strictly following any existing model. The system from which most was obtained was the Hazard Analysis and Critical Control Point (HACCP) framework[2], but ideas were also taken from other sources.

Fundamental to the development of the New Zealand framework was the decision to focus on *events*. These are defined as incidents or situations that may lead to hazards being introduced into, or not being removed from, the water, i.e. things that may go wrong in the supply. This is a departure from the principles of the HACCP system which starts with the identification of possible hazards, assessment of the risk they present, and determination of the steps needed to reduce or eliminate the hazards. The New Zealand framework initially sets aside the need to identify hazards, and assumes that hazards in the water can be adequately controlled by the presence, and proper operation, of four barriers:

- Prevention of contaminants entering the raw water of the supply;
- Removal of particles from the water;
- Inactivation of micro-organisms in the water; and
- Maintenance of the quality of the water during distribution.

By ensuring that these barriers are present, and minimising the likelihood of their failure (i.e. events occurring), public health risks are reduced.

This difference in focus between the two approaches was adopted for the following reasons:

- It is easier for small water suppliers who are unfamiliar with water quality issues, to understand that they need to stop a particular event happening in part of their supply, than to put in place controls for a specific hazard they know little or nothing about.

[2] Codex Alimentarius Commission – "Hazards Analysis and Critical Control Point (HACCP) System and Guidelines for its application" Annex to CAC/RCP 1-1969, Rev. 3 (1997).

- The approach provides a logical path that can be easily followed by a water supplier trying to identify what they must do to minimise risk to the quality of their water.
- A focus on hazards limits the ability of a water safety plan to protect against hazards not presently thought to present a risk to health.

The second fundamental feature of HACCP that is not used in the New Zealand framework is the concept of critical control points (CCPs). The following are the reasons for this:

- The idea of control points lends itself best to control measures that are part of the treatment process. Other measures may be required, however, that are not associated with physical locations at the treatment plant. We have preferred to consider all measures that contribute to risk reduction together, and refer to them as preventive measures.
- The multiple barrier model works well in water supply protection because it provides for mutual backup against the failure of one barrier. We have a concern that the identification of CCPs may encourage water suppliers to focus on these alone at the expense of other preventive measures that are also important in reducing risk.
- The level at which preventive measures are identified affects the appropriateness of identifying CCPs. At the level of detail required to make a water safety plan useful, a number of preventive measures, which act together in parallel, are usually identified for each event. The likelihood of the event occurring is minimised by having as many of these preventive measures in place as possible.
- The identification of CCPs in the Ministry's generic "tools" (see below) could provide misleading advice. The circumstances of each individual supply will influence the relative importance of preventive measures in risk reduction.

Implementation of the framework

In the implementation of the framework, the provision of generic risk information in the Ministry's set of "tools" is a primary step in making PHRMP preparation as easy as possible for suppliers, both large and small. The "tools" have simple structures and use simple language wherever possible. They provide information at a practical level to avoid water suppliers having to try to produce their PHRMP from a generalised, high-level discussion of water safety plan preparation. By providing this type of help it is hoped that costs can be reduced (as suppliers will be able to prepare their own plans), suppliers will gain a better understanding of the risks associated with their supply, and the new approach to water supply management will be more readily accepted.

The first of the Ministry's tools is a set of 39 PHRMP *Guides* that provide risk information for use as the basis for preparing full PHRMPs. A modular approach has been taken to do this by regarding water supplies as being composed of *supply elements* (or *elements*), and providing generic risk information about each of these components. Elements are the physical and operational components of a water supply that act together to determine the quantity and quality of water received by the consumer. By identifying which elements/sub-elements their water supply contains, a water supplier can select the appropriate *Guides*[3] for developing the PHRMP for their supply.

By themselves, the *Guides* do not instruct a water supplier in how a PHRMP should be prepared. Step-by-step guidance in doing this is available in the Ministry's second tool: an overview document entitled "*How to prepare and develop public health risk management plans for drinking-water supplies*"[4], which also sets out how to use the Plan once it has been prepared.

In addition to the *Guides* and the overview booklet, two other tools are available to water suppliers:

- Two worked examples for small supplies: a rainwater-sourced supply using treatment by cartridge filtration and UV disinfection, and a groundwater-fed supply treating by chlorination only. The examples show the form simple PHRMPs may take if the approach described in the overview booklet is followed.
- A video, which introduces small suppliers to the ideas of risk management. This was produced to help communities where there may be difficulties in understanding a written discussion of PHRMP preparation.

The PHRMP Guides

Each *Guide* has five sections:

1. *Introduction*: This section states which aspects of the water supply are covered by the *Guide*, the events that can be associated with the particular supply element, their possible consequences for public health, and how this element may influence, or be influenced, by other supply elements. This last item provides an understanding of the way risks associated with the element can be modified by other elements in the supply.
2. *Risk Summary*: The purpose of this section is to identify the events (linked to this element) that would represent the greatest public health risk if they were to occur, and the preventive measures expected to be most effective in reducing the likelihood of their occurring.
3. *Risk Information Table*: This table contains the key information in each *Guide*. It identifies possible events, the hazards that might enter the supply, or not be removed, should an event occur, and provides an indication of the typical level of risk associated with each event. For each event the following information is then provided:
   - possible causes of the event;
   - preventive measures that can be taken to reduce the likelihood of the event arising from that particular cause;
   - *checks* that can be made to determine whether the preventive measures are working;

[3] These documents are available on the Ministry's website: www.moh.govt.nz/water and select "publications".
[4] Available as a booklet and available on the Ministry's website: www.moh.govt.nz/water and select "publications".

- signs that show when preventive measures have failed and further action needs to be taken; and
- corrective actions that need to be taken if an event occurs (despite the preventive measures in place).

4. *Contingency Plans*: This section provides guidance for preparing plans to deal with events resulting in serious microbial contamination of the water, or substantial chemical contamination that will have acute consequences.
5. *PHRMP Performance Assessment*: The final section lists checks, for the element in question, that can be used to establish how well a PHRMP is working, and suggests the frequency at which the checks should be made. Based on the checks, changes to the Plan to address any weaknesses can be made.

The necessary checks identified in the Performance Assessment section are, where possible, the monitoring requirements of the *DWSNZ*. This link to the *Standards* shows that water quality monitoring, which has been traditionally used in water supply management, is still part of the broader and more effective approach of managing risk by risk management principles.

Preparation and use of PHRMPs

The overview document "*How to prepare and develop public health risk management plans for drinking-water supplies"* serves a number of functions by:

- Setting out which Guides are available;
- Explaining in general what they contain, and the terminology used;
- Offering direction in the use of the Guides in preparing PHRMPs; and
- Offering direction for the use of the PHRMPs once they have been prepared.

PHRMP preparation

A diagram in the overview outlines a series of steps that could be taken in preparing PHRMPs, provides some detail as to how to carry out each step, and indicates how each step contributes to the PHRMP. These steps are:

- *Step 1*: Produce an overview of the supply and decide which PHRMP Guides are needed.
- *Step 2*: Identify the barriers to contamination.
- *Step 3*: Use the *Guides* to identify events that may introduce hazards into the water.
- *Step 4*: Use the *Guides* to identify causes, preventive measures, checks, corrective actions.
- *Step 5*: Decide where improvements should be made in the supply to better protect public health.
- *Step 6*: Decide on the order in which improvements need to be made.
- *Step 7*: Draw up a timetable for making the improvements.

- *Step 8*: Identify links to other quality systems.
- *Step 9*: Prepare contingency plans.
- *Step 10*: Prepare instructions for performance assessment of the plan.
- *Step 11*: Decide on communication policy and needs.

PHRMP implementation

For a prepared PHRMP to be of value, it has to be used. The overview document therefore outlines a series of steps to guide suppliers in the implementation of their PHRMPs.

- *Step 1*: Refer to the Improvement Schedule and follow the timetable in the schedule for making improvements.
- *Step 2*: Review information gathered by monitoring and maintenance programmes.
- *Step 3*: Refer to and use the Contingency Plans if necessary.
- *Step 4*: Review the operation and performance of the PHRMP making changes if necessary.
- *Step 5*: Return to Step 1.

Conclusion

Based on our experience we would suggest that while HACCP offers a good basis for the development of a risk management framework, some flexibility in its translation to water supplies, making modifications where it seems appropriate, will be helpful in designing a system that best suits the needs of a particular situation. This is especially important when aiming to assist small water supplies in their preparation of water safety plans.

Integration of Quantitative Microbial Risk Assessment (QMRA) and Risk Management in Water Safety Plans - Report of a Workshop

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Risk assessment as part of the Water Safety Plans

Providing water that is safe to drink is the primary objective of water supply and water supply regulation. Absence of indicators of faecal pollution has been in use for over a century as a tool to demonstrate microbial safety of drinking water. This concept has significantly improved drinking water quality and the overall health status of EU-countries. It does have shortcomings: outbreaks of disease have occurred even in the absence of *E. coli* and the system of end-product testing is always too late; at the time contamination events are detected, the contamination has already reached the consumers. The WHO is preparing a revision of its *Guidelines for Drinking Water Quality* where the indicator-concept will be complemented by a preventive, integral (catchment-to-consumer) framework for assessing and managing the safety of drinking water. The elements of this framework are quantitative microbial risk assessment (QMRA), and Water Safety Plans (WSP), based on Hazard Analysis and Critical Control Points (HACCP) for the management of microbial risks. This new approach is in line with developments in other areas of consumer safety. It is not completely new, but encompasses many elements that are already in place, but it is a systematic and science-based approach to warrant safe drinking water and efficient safety management.

Integration of QMRA and WSP

The EU is co-funding a research project (Microrisk) on risk assessment as scientific basis for management of the microbial safety of drinking water. The first step of this project was to use the available documents and frameworks of risk assessment and Water Safety Plans for drinking water safety (e.g. WHO), in order to highlight the links between quantitative microbial risk assessment (QMRA) and HACCP in the Water Safety Plan. A document was prepared identifying and describing both individual systems and the links between them and what help these links provide for the risk manager, particularly at the water supply level. The links between HACCP and QMRA are described below. Figure 1 is a graphical representation of the links.

<u>Link 1: Health targets</u>

Setting of health targets: This link is already represented in the overall framework (Figure 1). The risk assessment is used to determine the risk related to drinking water. The risk estimate and the level of risk that is considered tolerable in relation to drinking water are translated into health targets. The health target set for drinking water is the starting point for risk management. The system should be designed, operated, controlled and maintained to ensure that the health target is met at all times.

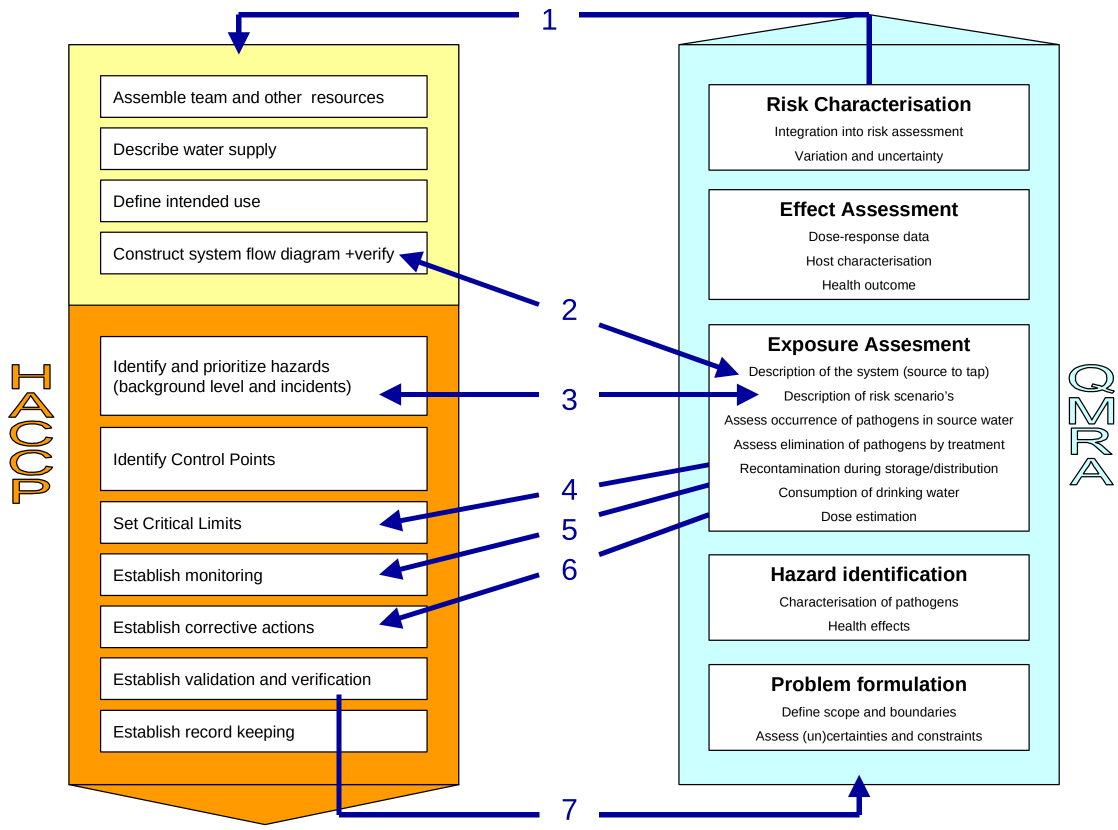

Figure 1. The links between HACCP (Water Safety Plan) and QMRA.

Complying with health targets: At the water utility level, a QMRA can be conducted to answer the question: "Do we meet the health target?". It is up to the water utilities to meet the health-based targets and to demonstrate to the regulators and the public that these targets are met. During the HACCP process the risks are approached in a qualitative manner (high, medium, low etc.) and are therefore subject to personal interpretation. Hence, the HACCP fails to answer the question whether the water supply system is in keeping with the health based targets. A QMRA of a drinking water system can demonstrate that the health-based targets are met. A QMRA would therefore be a logical first step when health risks of a water supply system are under consideration. For a first indication of risk, general (literature) data on pathogen occurrence, treatment efficacy and contamination risks during storage and distribution can be used to avoid costly data collection. The outcome of this assessment will be the basis for further development. If the outcome indicates that the drinking water is safe, the QMRA can be further refined and a WSP can be prepared to guarantee this safety under all conditions.

If the outcome of the assessment indicates that the drinking water could be unsafe under some conditions, the water supply system (management) needs to be adapted. The effect of different solutions can be investigated by using the QMRA as a scenario-study tool. Feeding the alternatives into the QMRA will help to identify the most economical, sufficiently effective measure to bring the risk within the health-based targets. These measures can be either physical (covering clean water reservoirs, new treatment processes), operational (new critical limits) or management measures (reducing human or domestic animal activities in catchments). These measures can then be implemented in the WSP.

Link 2: System description

To perform QMRA and HACCP at the level of a water utility (or type of water utilities), both systems need a description of the system from source to tap, including all steps that are significant in determining and controlling the health risk.

Link 3: Hazardous events are risk events

HACCP to guide QMRA to risk events: In the HACCP-system, hazardous situations are identified and prioritised. These hazardous situations are significant information for risk assessment, as they may comprise most of the health risk. Bartram *et al*. (2001) already identified that QMRA should not only be directed at the nominal performance of treatment systems, but also at the moments of poor source water quality and treatment performance. Knowledge about hazardous situations and their probability of occurrence can be used in QMRA as risk scenarios.

QMRA to guide HACCP to risk events: Similarly, during exposure assessment information is collected about occurrence of pathogens in source waters, treatment efficiency and distribution system integrity. This may yield information about peak events in source water, moments or periods of suboptimal treatment performance and distribution integrity breaches, and thus about hazardous events. This can be used in the Water Safety Plan in the process of hazard identification and prioritisation.

Objective risk priorities with QMRA: In HACCP, fault trees and risk factor matrices are used to prioritise hazards in a semi-quantitative way. The estimation of occurrence and effects is subjective to personal knowledge and experience of the WSP-team members. Therefore hazards that have already occurred are likely to be weighted more heavily than yet unknown hazards. This could lead to high unnecessary investments or overseeing relevant risks. Using QMRA to prioritise hazards will result in an objective, quantitative prioritisation of the hazards.

Link 4: Health targets can be translated into critical limits

The risk management is focussed on the question "Do we meet the health target?". In the HACCP approach, critical control points are identified that are crucial for the safety of the drinking water. It is stated that failure of any of the control points could result in unsafe drinking water. To identify failure, critical limits are set. These limits can be applied to process operation (e.g. ozone dose, filtration rate) or to monitoring parameters (e.g. residual ozone, filtrate turbidity). To set critical limits for these parameters, the relationship between the barrier efficacy and the parameter for which a limit is set must be known (e.g. the relation between Ct and decimal elimination capacity for ozone disinfection).

One also needs to determine what the required contribution of the barrier to the total safety of the water supply needs to be. The required contribution can vary due to changes in source water quality. As many water supply systems are set up as multiple barrier systems, the required contribution of one barrier depends upon the efficacy of the other barriers. The setting of critical limits is further complicated by the unwanted side effects that may occur when some barriers are increased (e.g. disinfection by-product formation will increase with high doses of chlorine). This means that the barriers cannot be set at a ‘highest level of security’ all the time.

To reach appropriate critical limits for each control point of the system, QMRA can be applied to ensure that the resulting water quality will always comply with the health-based targets.

Exposure assessment for QMRA provides information about the contribution of individual steps of the multiple barrier system to the overall exposure. In other words, the exposure assessment provides information about the relative contribution of control points to the overall risk estimate. With the health (risk) target as reference, the required contribution of all individual control points to produce and deliver drinking water that meets the health target can be assessed. This can be translated into critical limits for each individual control point.

Link 5: Designing monitoring and verification

Monitoring and verification will determine the period for which a possible failure of the water supply system may remain unnoticed. It is obvious that a longer exposure time will result in an increased risk. However monitoring and verification will require resources and funds, and cannot be applied limitless. QMRA can provide validation of the monitoring plan, by determining the risk when the maximum period of (unnoticed) exposure is reached. Thus funds and resources can be divided in such a way that maximum safety for the consumers is reached.

Link 6: Selecting corrective actions

Corrective actions: When critical limits are exceeded, corrective actions are needed to bring the control point back to the required level in order to prevent non-compliance with the health target and hence an increased health risk. Different corrective actions may be undertaken. These could be restricted to the control point that is out of bounds, but also to other control points that may be enhanced or even already working to a relatively high efficiency. QMRA can be used to determine to what extend exceeding the limits of the individual control point is actually resulting in non-compliance of the system as a whole. If that is the case, QMRA can also be used to select the most appropriate corrective actions under the given conditions, as it looks at the system as a whole, rather than at individual control points.

Treatment design - comparing alternatives: During the design of a water treatment plant, or when changes to a treatment plant are required, one needs to choose between different solutions. Each (combination of) solutions needs to comply with the health based targets. A QMRA can help identifying the most economical alternative. Thus unnecessary investments can be avoided. The QMRA is in fact used as a design tool.

Link 7: Validation

The risk management actions in the Water Safety Plan are put into place to ensure that the water system meets the health target set by the regulator. The validation phase in the Water Safety Plan is to ensure the correctness of the information underlying the risk management plan. The aim of the initial risk assessment was to determine if the drinking water meets the health target. QMRA can be used again to re-determine the answer to the question "Do we meet the target?" with the risk management actions that were put into place.

The main conclusions of the document were:

- QMRA provides a scientific, transparent, quantitative and objective basis for efficient risk management;
- Risk assessment and risk management are two related steps in an iterative cycle;
- QMRA can answer the question: "Is my water supply system able to meet the health or water quality targets?"; and
- QMRA can help the Water Safety Plan by providing a science base for prioritising risks, setting critical limits for performance monitoring and developing appropriate corrective actions when a control measure exceeds its critical limits of operation.

Workshop

Within the Microrisk project, a workshop was organised. The objective of this workshop is to explore the interactions between assessment and management of the microbiological risks to drinking water safety. A framework document addressing the interactions QMRA and Water Safety Plans was presented and discussed.

Different stakeholders in the risk management of drinking water (drinking water utility manager, drinking water legislator/inspector, public health official) were invited to participate, review the framework document and present their review comments to all participants. The implication of the most significant topics that emerged out of these review comments were discussed in working groups.

<u>Workshop conclusions</u>

The main conclusions of the workshop about the document were:

- The framework is closely related to the revision of the WHO *Guidelines for Drinking Water Quality* and the recommendations of the Bonn workshop in 2001 (organised by drinking water regulators and suppliers) on assuring drinking water quality in the 21st century;
- QMRA provides a framework for dealing with microbial risks in much the same way as chemical risks are dealt with;
- QMRA closely matches with the Multiple Barrier Approach. The current draft document is focussed on water treatment as primary and quantifiable barrier. However, the barriers in the catchment, distribution system and in-house installations are maybe less quantifiable but are still equally important;
- QMRA requires a point of reference (what is the tolerable level of risk?). WHO has been developing such a point of reference for infectious disease from drinking water (0,001 DALY per person per year)1;
- The recognition that the microbial risk of drinking water is not zero, but low, requires risk communication to explain drinking water safety to the consumer;
- QMRA is better in assessing the level of safety than in assessing the health risk;

[1] DALY = disability adjusted life years, a unit to measure the burden of a disease to a population, allowing the comparison of the health burden of different types of disease.

- The implementation of this risk-based approach will eventually shift inspection of water supply towards an audit process. An important issue is to determine how much verification of the new approach is needed, before it can be (and when it is) adopted in new (EU) drinking water regulation. Replacement of the current indicator concept is not the goal, but rather a gradual improvement of current practice and health protection;
- QMRA requires quantitative data on all major aspects of the water supply system. Given the current state-of-the-art, QMRA has to rely partly on assumptions and estimations;
- Variability in source water quality (contamination spikes) and in treatment efficacy (poor performance of a treatment process) needs to (and can) be incorporated in QMRA; and
- Implementation of the HACCP concept in Water Safety Plans will shift the demonstration of system performance towards operational monitoring parameters (on-line assessment of adequate system performance).

The comments of the workshop participants will be incorporated in the framework document. This document will be send out for peer review and form the backbone for the Microrisk research project. At the end of the project a follow-up workshop will be organised to present what the Microrisk project has provided and discussion on how this facilitates the management of safe drinking water at a water supply.

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Assuring the Microbial Safety of Drinking Water

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This paper provides an overview of a number of research areas, and shows how advances in pathogen detection methods and risk assessment techniques can be used to implement effective treatment barriers within the HACCP program to assure the microbial safety of potable water supplies.

Introduction

The historical approach for microbial protection has been embodied in the multiple barrier concept (Figure 1), process control (turbidity, disinfection, etc.) and monitoring. The information for assessing this approach has been principally based on bacterial indicators. The assurance of the microbial safety of water in the 21^{st} century is moving to incorporate data obtained by the direct detection of pathogen (typically using molecular methods), targeting pathogens that are hard to treat (viruses and protozoa), and application of microbial risk assessment techniques that push even lower the acceptable levels of potable water risk.

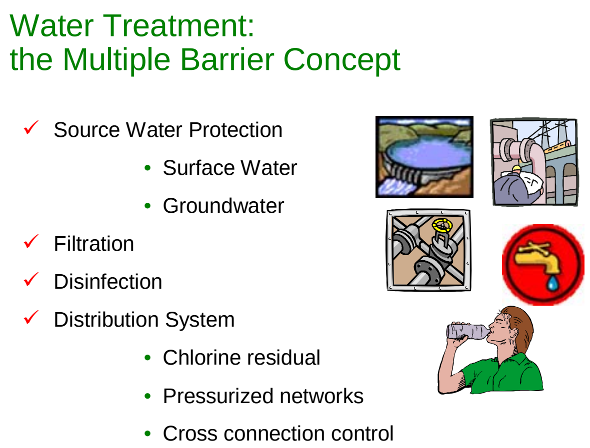

Figure 1. Multiple barrier concepts.

Advances in pathogen detection

Application of sensitive molecular methods for microbial detection is changing the assessment of potable water safety. For example, virus detection using reverse transcriptase polymerase chain reaction (RT-PCR) enables the detection of human enteric viruses in samples where culturable viruses cannot be recovered (Abbaszadegan *et al*., 1998). Although the public health significance of a PCR result is unclear, the presence of virus RNA illustrates that routes of fecal contamination exist in many groundwater supplies. Development and application of cell culture-PCR methods permit the detection and tracking of infectious *Cryptosporidium* oocysts in watersheds (DiGiovanni *et al*., 1999, LeChevallier *et al*., 2003a). Similarly, molecular methods for hard to isolate organisms like *Mycobacterium avium*, are demonstrating the presence of this opportunistic pathogen in biofilms (Falkinham *et al*., 2001). Recently methods have been reported for identifying toxin gene in cyanobacteria, permitting the application of control measures even before the algal toxins reach detectable levels. Some of the advances are not in microbiological methods. Electronic pressure recorders have detected negative pressure transients in distribution systems (LeChevallier *et al*., 2003b).

Target pathogens of concern

Despite the myriad of microbial threats that may be possible, for most systems there is a "controlling microbe" on which treatment processes can be based. For example, in true ground waters, viruses are the major concern because of their small size and mobility in porous media (Abbaszadegan *et al*., 1997). A study using monthly sampling of 20 groundwater systems for a large array of microbial indicators demonstrated that, over time, eventually all the wells showed some indication of fecal contamination (Figure 2). For surface water supplies the controlling microbe is *Cryptosporidium*. A recent study of 82 filtered drinking water plants showed the presence of low levels of infectious *Cryptosporidium* in 26% of the systems (Aboytes and LeChevallier, 2003). For distribution systems, the target organisms are bacteria that can regrow in pipeline biofilms. A study of the occurrence of *Mycobacterium avium* complex in drinking water biofilms showed significant correlations to AOC and BDOC levels (Falkinham *et al*., 2001).

12-Month Monitoring of 20 Groundwater Supplies, 2003

Well ID	Enteric viruses (cell culture /RT-PCR)	Coliphage Method 1602	E. coli	Total Coliforms
CAHOHW	N	+	-	-
INRI10	R	+	-	+
MOPC04	E, R	-	-	+
NHHA09	N	+	-	-
PAPH03	R, A	-	-	+
CARU04	R	+	-	+
ILPER4	R, N	+	+	+
INKO18	-	+	-	+
INMU01	cell culture + (2)	-	-	+
NJEH12	E	+	-	-
OHTI21	N	+	+	+
MAFMF3	-	-	+	+
MAHM02	cell culture + (1)	-	+	+
NHHA10	R	+	-	+
NJSHK5	E, N	-	+	+
NMCL10	R, N	+	-	-
ILPK01	E, R	+	-	+
MOPC06	-	+	-	+
PAFR02	N	+	+	+
PAPH02	E, R, N	-	+	+
Total +	17	13	7	16
Missed	-	6	11	4

Enterovirus, Rotavirus, Hepatitis A, Norwalk, Adenovirus

Figure 2. Monthly monitoring of 20 groundwater systems.

Microbial risk assessment

Development of microbial risk assessment techniques provide a framework for evaluating the effectiveness of current control measures and justification for additional treatment barriers. Because of the large uncertainties with risk assessments, these results should not be used as proof of disease. The USEPA has set an acceptable risk of 1/10,000 annual risk of microbial infection. For *Cryptosporidium*, this goal translates to one infectious oocyst in 290,000 liters of filtered water, based on an average 40% recovery. For enteric viruses, the equivalent risk goal equates to one infectious unit in 4 $x10^6$ liters of drinking water. Current monitoring data suggests that many treatment processes do not meet these risk goals (Aboytes and LeChevallier, 2003). Data for other microbial agents are lacking or are inappropriate, but risk estimates continue to extrapolate beyond measured levels.

Improvement in treatment barriers

The value of the advanced monitoring and risk analyses is in the ability to assess the adequacy of current treatment processes and the cost of future modifications. Data for ground water supplies support the cost-benefit of disinfection of ground water. Surface water systems will benefit from the installation of UV for treatment of *Cryptosporidium* and reduction of disinfection by-products. Moreover, the design of UV systems is being informed using Failure Analysis and microbial risk analysis (adenovirus) to determine the level of redundant safeguards (Cotton *et al*., 2003). Research is also providing the basis for supporting a cost-benefit for biological treatment for control of biofilm growth, and surge control to consistently maintain positive distribution system pressures (LeChevallier *et al*., 2003a). Still to be determined is the value of source water control and reservoir maintenance practices for algae control. These data support the assertion that effective water quality management through the HACCP process is dependent upon obtaining and analyzing accurate data to implement effective treatment barriers to assure the microbial safety of potable water supplies.

Acknowledgements

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Quality Assurance Strategies for Distribution System Protection

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Introduction

Protection of water quality in the distribution system forms the final barrier in the multi-barrier approach to providing safe drinking water. This distribution system barrier is known to fail as evidenced by reported waterborne disease outbreaks linked to distribution system practices. Several pathways exist for contaminants to enter the distribution system including storage facilities, cross connections, water main repair sites and intrusion through points of leakage due to pressure transients. When system operations and maintenance practices are substandard, contaminants may enter the system through one or more of these pathways. Quality assurance strategies focus on three main goals: (1) Minimizing intrusion potential; (2) Maintaining water quality; and (3) Keeping the distribution system clean.

Minimizing intrusion potential

Contamination can be caused by chemical, physical or biological hazards. The main concern is typically biological hazards, specifically waterborne pathogens. For contamination to occur, three conditions are needed: (1) waterborne pathogens need to be present in the local environment; (2) a pathway must be available to these pathogens, i.e. a leak, faulty seal or other opening in a pipe or storage facility; and (3) a mechanism must be present which allows the pathogen to travel via the pathway into the water system, i.e. a pressure transient, cross connection, or a water main break. As an example, bird droppings containing *Salmonella* are present on a finished water storage facility roof (Condition 1). The roof hatch does not have a watertight seal (Condition 2). Rain or wind could potentially transport the bird droppings into the tank via the roof hatch's faulty seal (Condition 3).

Pressure transients can travel throughout a distribution system and cause significant pressure fluctuations in some portions of the system. Many of the causes of pressure transients are a part of regular water distribution system operations, and therefore, pressure transients may occur frequently in certain water distribution systems. Pressure transients can result in contamination when the pressure of water surrounding the water main exceeds the internal pressure. Under these conditions, water external to the main may flow into the main through leakage points, submerged air-vacuum valves, cross connections, and faulty seals or joints.

Contamination associated with transient pressure surges was investigated as part of AwwaRF Project 436 - *Pathogen Intrusion Into the Distribution System* (Kirmeyer *et al*., 2001). Project investigations included water quality/soil monitoring, surge modelling and pressure monitoring. Undisturbed soil and water samples were collected immediately adjacent to distribution system mains and analysed for various microbial parameters. Many of these samples contained evidence of faecal pollution and enteric viruses, confirming the potential for pathogen contamination given an available pathway and favourable pressure conditions.

Further research on pressure transients and pathogen intrusion was conducted for AwwaRF 2686 - *Field Testing of Surge Modelling Predictions to Verify Occurrence of Distribution*

System Occurrence (Friedman *et al*., 2003). Pilot-testing experiments indicate that significant volumes of water can enter distribution system piping through small leaks during transient pressure events. Pressure monitoring activities confirmed that transient negative pressures could occur in distribution systems, as negative pressures were observed in three of the seven distribution systems studied. The negative pressure events lasted as long as 40 to 50 seconds, and went as low as negative 10 psi. In 12 of the 13 events where a negative pressure was observed, the cause was a sudden shutdown, either unintentional (e.g. power outages) or intentional (e.g. pump stoppage/startup tests), of all pumps at a treatment plant or pump station. The results of these research efforts have shed light on several fundamental issues:

- Low and negative pressures do occur within distribution system networks (not just within transmission piping).
- Mechanical pen and chart recorders may capture transient events, but may not respond quickly enough to accurately measure transient magnitude. These monitors are not capable of providing detailed information on transient duration.
- Intrusion can occur during a pressure transient when there is a pathway and an external head.
- Intruded water is not merely re-extruded out of the pipe. A portion stays within the pipe and is carried downstream.

Key measures to minimizing intrusion potential include the development and implementation of training, inspection and cross connection control programs. Training programs should emphasize sanitary practices for water main repair and installation, and operational practices that minimize pressure surges and pathogen intrusion (i.e. pressure maintenance, proper methods for opening/closing valves and hydrants). Inspection programs are critical to assuring the integrity of finished water storage facilities and for supervising water main installation and repair activities. Cross connection control programs should include regular inspection and testing of devices, record keeping and customer education. Leak detection and repair will reduce pathogen intrusion through this pathway. Surge mitigation measures may be needed to minimize the occurrence of pressure surges.

Maintaining water quality

Finished water entering the distribution system is ideally non-corrosive, biochemically stable, non-scaling and free of pathogenic organisms. Water quality conditions in the distribution system should be characterized by analysing related water quality information from source to tap, including water quality data, operating data, customer complaint records, inspection and maintenance records, hydraulic model output, and as-built records. Data integration may be used to simultaneously evaluate numerous information sources. A baseline water quality database should be established so that if aberrant values are detected, they can quickly be identified and addressed. Additional water quality monitoring may be needed to further characterize a particular water quality event. The utility should establish specific water quality goals and performance standards for accomplishing these goals. Written standard operating procedures should be developed for routine operations and maintenance practices. Written action plans should be prepared for addressing specific water quality issues (i.e. nitrification event, internal corrosion, contamination, etc.).

Water age should be minimized as both the bulk water decay characteristics and the interactions between the pipe walls and the bulk water help to deteriorate water quality. Within storage facilities, water age may be reduced by increasing the daily water turnover rate, fluctuating the water levels widely, and/or improving tank inlet and outlet piping orientation to increase the water's momentum.

Within the piping network, water age is controlled primarily by system design and demand conditions but it may be further reduced by modifying pressure zone boundaries or pressure set points at pumping stations; inspecting valve position to avoid artificial dead ends; and by flushing to remove stagnant water at dead ends. System operators need to understand how to balance water quality goals with other system goals for maintaining pressure and storage reserves for emergency needs.

Keeping the distribution system clean

Key strategies used to keep the distribution system clean include biofilm control, pipeline rehabilitation and replacement programs, flushing programs, and tank cleaning programs. The choice of biofilm control strategies is a site-specific decision that often requires the use of several tools (i.e. nutrient control, disinfectant residual maintenance, contamination control, etc.) rather than a single best tool. The utility needs to evaluate rehabilitation versus pipe replacement considering the costs, the pipe's structural condition, disruption to customers, plus other factors. In establishing a flushing program, the utility should identify specific objectives to be accomplished by flushing, and should then select a flushing method and frequency that can meet these objectives. Finished water storage facilities need to be cleaned periodically to remove silt, sediment, biofilms and other accumulated material. It is recommended that covered storage facilities be cleaned every 3 to 5 years while open reservoirs should be cleaned 1 to 2 times per year. Newer tank cleaning techniques employing divers or remotely operated vehicles offer significant benefits by reducing the time that the facility is out of service. Utility staff or contractors employed to perform maintenance need to use sanitary techniques to avoid introducing contaminants into the distribution system.

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Quality Assurance in Berlin's Unchlorinated Distribution System

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The basic elements for a hygienically impeccable drinking-water supply are uncompromised resource protection, a high standard for treatment, storage and distribution, as well as a quality management system which also includes defined processes and organisational structures.

Currently, Berlin's drinking-water is supplied from 8 waterworks within the city and one north of it, which exclusively use wells with a depth ranging from 26 to 170 m. Treatment includes aeration and the removal of iron and manganese in rapid filters. Chlorination was applied until 1978 by order of the allied forces, although the excellent microbiological results indicated no need for disinfection. The decision to do without became possible on the basis of long time series of microbiological data of raw and treated water as well as extensive public communication. Currently, areas of the distribution network are chlorinated only occasionally in the context of maintenance measures. The option for chlorination is kept in place, and in order to ensure that it can be put into action rapidly and smoothly when needed in case of any incident or indication, these systems are tested once a week in all waterworks. This maintains both their technical standard and the staff's know-how.

Up to the early 1990's, the waterworks Friedrichshagen treated surface water (400,000 m³ per day) from Lake Müggelsee to supply most of the East-Berlin area. This could gradually be reduced and abandoned only after shifting the supply to groundwater and bank filtrate. Since 1994 this waterworks also follows the regime of weekly testing the function of the chlorination system and no longer chlorinates on a regular basis. Thus, the total chlorine consumption of the *Berliner Wasser-Betriebe* (BWB) was reduced from 157,250 kg in 1989 to 2,457 kg in 1998.

A crucial aspect of guaranteeing high quality and safety of Berlin's drinking-water during transportation is therefore ensuring a very high level of operational safety for the distribution network.

Network maintenance is therefore a comprehensive term. It includes careful surveillance, both during construction and repair of mains and pipes, and when they are brought into service. Systematic and continuous upkeep involves:

- inspection;
- maintenance;
- repair; and
- documentation.

Within the BWB, specific units are responsible for these tasks, i.e. for their coordination, for their implementation, and for surveillance of sub-contractors. One of their core responsibilities is implementation of immediate interventions if damage to the distribution system occurs or there is any indication of hazards.

A sufficiently substantiated assessment of the quality of the water at the point where it is delivered to the consumer requires regular microbiological and chemical analyses of a defined number of samples. Terminal pipes with less through-flow are intensively included in the monitoring cycle. Drinking-water is monitored microbiologically and chemically according the frequencies determined in §§ 5, 6, 7 and 8 and according to the annex “monitoring“ of the German Drinking Water Ordinance. Since its implementation on 1 January 2003, samples are taken at monthly intervals at 180 points in Berlin’s distribution system at the meters where water is delivered to the buildings. Additional monitoring is performed in response to specific circumstances, i.e.

- in the context of commissioning of new installations;
- if limits of the Drinking Water Ordinance are exceeded;
- if changes in colour, turbidity, odour or taste are reported;
- if backflow of water which does not have drinking-water quality into the mains is suspected, e.g. in consequence of pressure losses or other disturbances, or if ingress of substances is suspected, e.g. through repairs;
- if unauthorised access or tinkering with the system has occurred or is suspected;
- if cross-connections to non-drinking-water installations is suspected (i.e. household supplies that do not meet drinking-water standards, see DIN 1988); and
- if there is indication of water having been taken from hydrants by unqualified third parties (see DVGW worksheet W 345).

In contrast to the mains and larger distribution pipes, terminal pipes are successively flushed as precautionary measure to ensure that drinking-water quality is maintained.

After construction of drinking-water pipes as well as after measures for repair or maintenance performed on open systems, these may be reconnected and put into operation only after microbiological testing has demonstrated them to meet all requirements. Where continuous disinfection is not performed because microbial contamination is neither present in the raw water nor in the distribution system, construction and maintenance works on the distribution system are performed in such a way, that contamination with pathogens is largely excluded. Practical experience of the BWB with operating 7,800 km of network without continuous disinfection has shown the following procedure to be effective:

- camera monitoring of pipes;
- cleaning with high-pressure flushing;
- flushing after testing pressure and re-connection; and
- microbiological testing and opening of the network segment if results meet requirements; otherwise disinfection with repeated flushing and microbiological testing.

If routine microbiological controls of the network show an increase of colony-forming units (at 22°C and at 36°C) in a segment of the network, precautionary chlorination is performed in this segment in order to counteract this abnormal change. Further, investigations of the cause are initiated. Specific analyses of assimilatable organic carbon (AOC) allow an assessment of the potential for bacterial proliferation.

An issue not to be underestimated for maintenance and repair of drinking-water pipes is the occurrence of those coated with "tar" instead of bitumen. Cleaning them mechanically involves the risk of release of high concentrations of polynuclear aromatic hydrocarbons (PAHs), sometimes above the drinking-water standard and even after repeated flushing. The consequence is that mechanical cleaning of pipes known to be coated with tar or bitumen should always be accompanied by laboratory analyses in order to detect the potential occurrence of PAHs and to initiate measures if necessary. The following procedure has proven effective for the BWB:

Mechanical cleaning is followed by high-pressure flushing (40-60 l/min at a pressure of approximately 400 bar). The water used for flushing collected and analysed for PAHs. Attention needs to be given to discharging this water if it contains high concentrations. The pipe is then coated with cement. This step is followed by flushing and microbiological as well as chemical analyses (pH, PAHs) and quality control.

A basic change has occurred particularly for documentation. Distribution network plans, formerly elaborately hand-drawn, have been replaced by digital plans, and lists of fittings by a data base. Information systems are increasingly being used.

In summary, the target of distribution network maintenance is:

- ensuring drinking-water quality;
- maintaining safety through early recognition of disturbances and responses to prevent damage or hazard; and
- avoiding water losses.

Can HACCP Principles be Applied to Chemicals in Drinking Water?

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HACCP principles have been successfully applied to the protection of food and water against contamination by pathogens. That such initiatives have concentrated on microbial contaminants is appropriate but the same principles can be very valuable in considering chemical contaminants in drinking water. One initiative was an international workshop held in Bonn in October 2001 with drinking water practitioners, regulators and experts in a variety of topics and sponsored by the drinking water supply associations in the USA, Europe and Australia. The Bonn workshop was to develop a framework for assuring drinking water quality in the 21st century and had the overall goal for the framework 'to provide good safe drinking water that has the trust of consumers'. This means drinking water that is safe both for microbiology and chemistry, is acceptable in taste, odour and appearance and is reliable in quality and quantity in order to achieve the trust of consumers. UKWIR (United Kingdom Water Industry Research) commissioned a project to develop a framework for introducing the principles, based on HACCP, developed at the international workshop held in Bonn in October 2001. This project covers both microbial and chemical contaminants from source to tap.

The differences between microbial pathogens and chemicals are broadly that pathogens are usually an acute problem while chemicals are a chronic problem. This means that for chemicals average exposure is important and that monitoring for chemicals requires the identification of specific chemicals and measurement of the concentration rather than the presence/absence monitoring using an indicator, as is the case with pathogens. However, there are many parts of the approach used in HACCP that will apply to chemicals and in some cases there are clear parallels with microbial pathogens. The overall approach of identifying the hazard, assessing the risk, identifying steps to minimise the risk are as important for chemicals as for pathogens. There are, however, differences in the way in which risks are determined, since chemicals are usually judged on the basis of a safe concentration, i.e. the presence of a chemical does not necessarily present an unacceptable risk to health. The water quality targets are standards or guidelines that usually incorporate a significant margin of safety, so in many developed countries the risk is that of exceeding the standards and so undermining consumer confidence. In addition, the risk may relate to an impact on the acceptability of the final product to the consumer and in this case the judgement of unacceptable may, at least in part, be subjective. Another consideration is chemicals and materials that are an important part of the process of ensuring the safety of the water supply. In this case the risk must be considered in a slightly different way, in terms of balancing risks, costs and benefits. An example of such a case would be the addition of chlorine as a disinfectant balance against the production of unwanted disinfection by-products. Analysis for chemicals is often difficult and/or expensive and chemicals may require specific treatment so that generic barriers are not always applicable.

Assessing the hazards and risks from chemicals from catchment to tap is a key feature of the application of HACCP, as is the assessment of risks indicated above. However, there are significant differences between water supply, which is continuous and effectively direct to the consumer, and batch processes that are usually the case in the food industry. The influences on risk are concentration in the water, the source of the contaminant (before or after treatment) and the frequency of its presence in water (some are intermittent and others continuous), amelioration in the environment (the chemical may break down or adsorb to soil and rock) and whether the chemical is removed by existing/conventional treatment. The identification of critical control points is also similar but, in some cases, the critical control points will be outside the control of the water supplier, e.g. spills or leaching into raw water or lead plumbing, and will require close co-operation with a wide range of stakeholders. In many cases monitoring of controls will require specific chemical analysis of the chemical of interest and is therefore little different to the current system of output controls. However, in the case of chemicals used in treatment or those that deposit in distribution systems, causing problems with sediment, there are operational controls that can be monitored using simple operational control criteria such as turbidity and pH. In addition, there are some raw water contaminants that have a common chemical characteristic in that they are relatively hydrophobic. Such contaminants have been shown to be removed by particle removal and adsorption processes in drinking water treatment and operational criteria can be determined that will ensure, and demonstrate, their removal in treatment without the need for difficult chemical analysis. In these cases multiple barriers will also apply in a very similar way to pathogens.

Raw water contaminants can arise from natural sources, e.g. arsenic or fluoride in groundwater where the need is for source screening, or from naturally occurring organisms such as cyanobacteria (blue-green algae) where the control relates to prevention of blooms since there is considerable uncertainty as to which toxins will be present. Agriculture can give rise to pesticides, nitrate and the nutrients that can exacerbate cyanobacterial blooms. In such circumstances changes in the amounts applied, the timing of application and the types of products applied can make a major impact. Industry and human settlements are potential sources of a number of chemical contaminants, which can be dealt with by involving the stakeholders in the process and encouraging appropriate practices. In the UK, the river Dee, which frequently suffered from polluting spills, was designated a water protection zone with the cooperation of industry.

It is, therefore, clear that HACCP principles can be applied to chemicals in drinking water, albeit with some modification. The advantages of the HACCP type of approach are:

- Proper risk assessment;
- Proactive assessments;
- Concentration on prevention;
- Less need for check monitoring and increasingly long lists of standards;
- Less reliance on check monitoring, except for verification; and
- Already widely used, although it is not frequently formalised in national water supply practice.

The conclusions are, therefore, that there are significant benefits in applying the Bonn principles/water safety plan approach to the assurance of water safety from chemical contaminants.

There is a requirement for a more integrated and diverse approach than is normally the practice for water suppliers at present.

However, there are significant overlaps with assuring safety from pathogens and the integration of the whole will lead to a more streamlined and effective process for assuring the safety of drinking water.

Not only can HACCP principles be applied but, modified and adapted for water supply, they should be applied.

Chemical Safety of Drinking Water: Assessing Priorities for Risk Management

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Comprehensive management of water quality, from catchment to consumer, rather than relying primarily on treatment to comply with numerical targets, is the most valuable preventive approach in the provision of safe drinking water. Key elements of an effective risk management strategy for chemicals in drinking water may include standard setting and monitoring to ensure that chemicals of concern are being adequately controlled. In order to ensure that resources for monitoring and control are optimally allocated, it is necessary to identify those chemicals that may be of greatest priority for risk management purposes.

The WHO *Guidelines for Drinking-water Quality* (3^{rd} Edition) will list over 100 chemicals for which guideline values (GVs) have been set. The GVs recommended for individual chemicals are not mandatory limits, but may be used by national authorities in the development of risk management strategies, which can include setting national drinking water quality standards and implementing monitoring programmes.

A number of chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking-water. However, this is only a very small proportion of the chemicals that may reach drinking-water from various sources. For developing countries and other settings where resources are limited, it makes sense to use a protocol to prioritise chemical contaminants for monitoring and remedial action.

The *Guidelines for Drinking-water Quality* (GDWQ) therefore recommend that users prioritise chemicals for the purpose of adopting risk management strategies. WHO in an additional publication will provide guidance as to how to prioritise. This paper describes the rationale for the need for prioritisation of chemicals to be monitored, especially for use in developing countries or other settings where resources are limited, and provides guidance for action. Some case examples from around Asia are referred to as well.

The full text of the relevant documentation on GDWQ and the documentation on assessing priorities for risk management can be found on www.who.int/water_sanitation_health/en .

Chemical hazards in drinking water addressed by the WHO GDWQ

The WHO *Guidelines for Drinking-water Quality* cover microbiological, chemical and radiological contaminants. They describe in detail the scientific approaches used in deriving the Guidelines Values. In this way they provide a sound framework for ensuring an appropriate level of safety and potability of drinking water.

This is, however, a framework only. For example, it would rarely be appropriate to simply incorporate the whole set of guideline values into national standards without proper consideration of the specific problems and cultural and economic environment of the particular country. The guidelines reinforce that it is necessary for each country to take into account a variety of geographical, socio-economic, dietary and other conditions affecting potential exposure. This may lead to national standards that differ appreciably from the guideline values put forward by WHO.

This is particularly applicable to chemical contaminants, for which there is a long list, and setting standards for, or including, all of them in national standards or monitoring programmes is neither feasible nor desirable.

It is important that chemical contaminants are prioritised so that the most important are considered for inclusion in national standards or monitoring programmes.

The scientific basis for guideline values has been made as transparent and as clear as possible in the *Guidelines for Drinking-water Quality*. This is particularly important in helping to modify guideline values to suit national requirements or in assessing the significance for health of concentrations of a contaminant that are greater than the guideline value.

Chemical contaminants in drinking-water may be categorised in various ways, however, the most appropriate is to consider the primary source of the contaminant (Table 1). This aids in the development of approaches that are designed to prevent or minimise contamination, rather than those that rely solely on the measurement of contaminant levels in final waters.

Table 1. Categorisation of source of chemical constituents.

Source of chemical constituents	**Examples of sources**
Naturally occurring	Rocks, soils and the effects of the geological setting and climate
Industry and human settlements	Mining (extractive industries), manufacturing and processing industries, sewage, solid wastes, urban runoff, fuel leakages
Agricultural activities	Manures, fertilisers, intensive animal practices and pesticides
Water treatment and distribution systems	Coagulants, disinfection by-products, and piping materials
Larvicides used in water for public health	Larvaecides used in the control of insect vectors
Cyanotoxins	Cyanobacterial mass developments in eutrophic water-bodies

Some contaminants may fall into more than one category but the primary category is the one under which the guideline summary evaluation is listed. In addition the categories are not always clear cut. The group of naturally occurring contaminants includes many of the inorganic chemicals that are found in drinking-water as a consequence of release from rocks and soils by rainfall. However, some of these substances may become problematical only under specific circumstances in which man has caused environmental disturbance such as in mining areas.

The criteria for including specific chemical constituents in the *Guidelines* are that:

1. The chemical is of significant international concern,
2. There is credible evidence of (relatively frequent) occurrence in drinking water, and
3. There is evidence of actual toxicity together with evidence of occurrence at or near concentration of health concern.

On this basis, Arsenic and Fluoride are clearly chemicals of priority health concern, with Selenium and Nitrate following. Several other naturally occurring chemicals, heavy metals, pesticides and industrial compounds are listed as well and may cause present or future concern in a locality. In terms of health and economic concern, especially in developing countries, exposures to fluorides and arsenic in drinking water require most attention.

Assessing priorities

Each country must decide how it can be confident that adopted standards or guidelines are being met. The introduction of standards for which there can be no monitoring can be misleading and may cause the general public to believe that water is safe when this may not be the case. The most important technique for ensuring that drinking water does not contain contaminants at concentrations of concern for health is monitoring.

However, monitoring is costly and the resources required for monitoring need to be taken into account. In developing national risk management strategies, each country should ensure that resources are not unnecessarily diverted towards substances of relatively minor importance from a health perspective or to substances which may not even be present within a particular setting.

Many of the chemicals with guideline values in the *Guidelines* may not occur in significant concentrations in a given water system. Nor may they occur with significant frequency in every country. In a particular setting, they may not occur at all.

Many countries, however, lack the necessary resources, data bases and experience needed to determine which of the many chemicals should be considered as priorities for risk management in the national or local context. WHO has therefore drafted a simplified, rapid assessment process to assist these countries in prioritising chemicals for further attention. This publication will guide a country or agency to:

- Determine priority chemicals;
- Develop risk management strategies;
- Set standards; and
- Define monitoring strategies.

The way to start off the process in a country or locality is to form an inter-agency committee, representing those sectors and competencies that are needed to assess the issues. Apart from regulatory agencies in water, health and environment, users and producers such as agriculture, mining, trade and industry should be included in the committee. Scientific and specialized institutes such as universities (engineering, geology, regional/urban planning) and representatives of civil society (consumers association, environment think tank) may need to be included to ensure adequate networking for current information gathering and to ensure ownership for eventual actions proposed.

Obviously priority should be given to known problems: e.g. arsenic in Bangladesh or fluoride in Tanzania, however care should be taken not to dismiss other concerns as less relevant until so proven. Many countries, and many water systems within countries, already have identified a number of drinking water quality problems, especially if these are causing obvious health effects or aesthetic problems. Logically, countries often assign first priority for risk management to such problems.

The committee should review international norms and risk assessment information and methods such as those published by WHO or USEPA to arrive at an initial shortlist of chemicals of concern in its situation. Feasibility of monitoring and proposed control measures will then become important in the light of available resources.

To determine the exposure risks to various chemicals, there are three prerequisites:

There must be a SOURCE of contamination, there must be a CONSUMER (or receptor) and there must be a PATHWAY from the source to the consumer.

In addition, an assessment will also need to be made of the processes that may ATTENUATE the contaminants.

Interestingly, few developing countries have developed risk management strategies on the basis of national or local epidemiological evidence, mainly due to lack of technical capacity to develop such evidence. Cuba is a notable exception.

Keep in mind that often information is available on chemicals in water in the country or locality. It may not be with the ‘water’ people, though. It may be that a University research project collected data, or an agricultural development programme, or the Geological Survey. It is often worth asking around and think ‘out of the box’ to see whether information is available locally, nationally or –even- internationally.

Testing the protocol

Drafts of the WHO publication on chemical safety of drinking water have been tested in four countries – Thailand, Indonesia, Nepal and Bangladesh. The overall objective of the review was to make a judgement about how effective the WHO publication is likely to be at meeting its objective. At the time (2001) the working title was “Chemical safety in drinking water: identifying priorities using limited information”. This reflected well the focus of the fieldwork.

The method used in Thailand in testing the draft is shown in Figure 1 below, illustrating the approach discussed earlier.

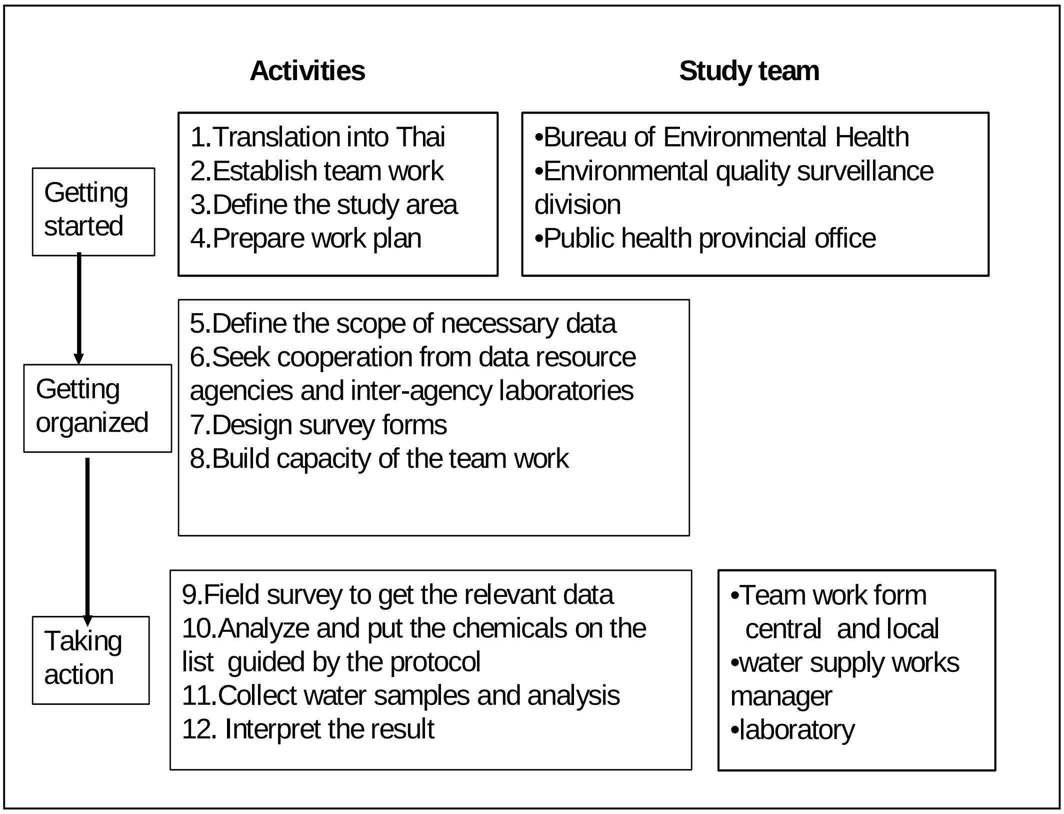

Figure 1. Test method used in Thailand.

In Indonesia, the process quickly established a shortlist of chemicals of concern. The chemicals on the short list were: arsenic (As), boron (B), cadmium (Cd), copper (Cu), fluoride (F), lead (Pb), manganese (Mn), iron (Fe), nitrate, nitrite, selenium (Se), chlorine. Some pesticides were also included. Field confirmatory testing was subsequently carried out. The team enthusiastically and professionally approached the process. The education levels of the team members were high and the workshops conducted resulted in excellent understanding of the process and issues.

In Bangladesh an approach was chosen to test the protocol in three divisional capitals through a workshop that brought together local representatives of water, health, environment, local government and NGOs, and some national level resource persons from the Geology Department and Department of Public Health Engineering. Although the average level of education of the participants was lower than in Indonesia, with many having secondary school certificate and some professional (diploma) education, the response to the approach was very good:

- Concepts and publication's principles were generally well understood;
- The checklist system worked well overall, and for a very rapid approach appears quite successful. It is noteworthy that a geology reference in the Guide led to a selection of potential hazardous chemicals (in the Barind Tract) that could instantaneously be confirmed from a recently published water quality survey report;
- The approach 'whom to ask for what information" was found to be very helpful but networking with the right people is critical for good success; and

- The field trip to demonstrate pollution pathways was found a thought-provoking exercise for the participants in the identification of polluting chemicals.

It may be noted here that water professionals in Bangladesh are alert to the issue of water quality as arsenic in ground water is quite widespread.

In the meantime the Government of Bangladesh through the Department of Public Health Engineering has adopted a *Water Quality Surveillance Protocol for Rural Water Supply Options in Bangladesh (April 2003).* This protocol lists the various bacteriological and chemical parameters that need to be tested at the time of installation and during subsequent monitoring, and at what interval. Currently an even more extensive protocol exclusively dealing with arsenic is drafted by a high-level inter-ministerial task-force.

The testing of the Guide has shown that it is indeed possible in widely varying circumstances to make an assessment of the risk-chemicals and do so at reasonable cost. In several countries national or regional rapid assessments have been done or can be done at reasonable cost that can help to determine the shortlist of chemicals to be screened for now, on a regular basis, as well as those that one should include as chemicals to keep a check on with a longer time-horizon (e.g. certain natural or agricultural chemicals). These assessments are excellent starting points that will help save money and unnecessary long term outlays for laboratories and staff. - An example of such an informative and cost-efficient national assessment is given in Box 1 below.

Box 1. National water quality assessment in Cambodia.

During 2000, the Royal Government of Cambodia, with support from the WHO, completed a survey of drinking water quality from sources located throughout a large portion of the country. The survey focused exclusively on testing the chemical quality of urban and rural water supplies in densely populated areas. As qualified laboratories were not available in Cambodia, samples were transported to Australia for testing. The potential for naturally-occurring toxic chemicals to appear in groundwater was among the main concerns guiding the survey design.

Groundwater used for urban and rural supplies was generally of good chemical quality, and did not have any detectable levels of pesticides. However, as would be expected, groundwaters had higher levels of dissolved solids than local surface waters. Iron, manganese, sodium, chloride, and other naturally-occurring elements are common constituents of groundwater, particularly in tropical environments such as Cambodia's. The most significant finding of the survey is that groundwaters from certain areas in Cambodia contain levels of chemicals that could pose concerns for human health. Most of these chemicals are naturally occurring, although a few may result from human activity. The most important of these chemicals is arsenic.

Other chemicals of potential human health significance detected in the survey include barium, chromium, fluoride, lead, manganese, molybdenum, nitrate, nitrite, and selenium. Of these, the most significant are nitrate and nitrite, as they were detected at elevated levels in several locations in the study area. By contrast, the barium, chromium, lead, molybdenum, and selenium exceeding occurred in only one or two locations each, and appeared to be exceptions to the general trend. Fluoride levels were generally lower than would have been anticipated, based on previous tests conducted by other organizations using portable test kits.

Conclusion

In combination with the third edition of WHO *Guidelines for Drinking-water Quality*, with its emphasis on Water Safety Plans and comprehensive management of water quality, from catchment to consumer, the how-to WHO guide on *Chemicals in Drinking-water: Assessing Priorities for Risk Management* offers a helpful and affordable approach to controlling hazardous chemicals in drinking water. National authorities are invited, through the third edition of the Guidelines, to review and update their national standards and the Guide on *Chemicals in Drinking water* then can assist in determining relatively quickly for which chemicals priority monitoring and remediation is required.

Arsenic and Fluoride in Groundwater: The New Menace in Asia

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The excess of naturally occurring harmful inorganics like arsenic and fluoride in groundwater is a major health concern in a number of Asian countries like India, Bangladesh, China, Taiwan, Thailand, Myanmar, Nepal, Vietnam, etc. Drinking arsenic-rich water over a long period is unsafe, as arsenic is a documented carcinogen. Almost 50 million people in Bangladesh are at the risk of drinking water with arsenic concentrations above 50 microgram per litre. The same figure for West Bengal in India would be between 5-10 million. The most commonly reported symptoms of chronic Arsenic poisoning include hyperpigmentation, dypigmentation and keratosis. Skin cancer and internal cancer can also occur. It is estimated that 0.29% of the population (or 375,000 people) in Bangladesh are at risk of excess lifetime skin cancer at the present arsenic contamination level). A scientific epidemiological assessment of the extent and magnitude of the problem in India and Bangladesh has not yet been made. High concentrations of arsenic in community water sources do not necessarily co-relate with high levels of arsenicosis symptoms in the community.

The problem of arsenic contamination of groundwater came to light during the early 1980s but the use of arsenic contaminated water by the people might have started much earlier, possibly during the 1950s/1960s. Arsenic is a cumulative position in the human system and depending on the level of contamination it could take 5 to 20 years for a person to show the symptoms of sickness. Over the years the number of affected people has increased though the total number of people who have reported to the hospitals for treatment has not crossed more than a few thousands, and the recorded mortality is less than a few hundred. Unofficial sources, however, put the number of affected people to be many times higher. Accruing to Dr. Dipankar Chakravarty of Jadavpur University, Kolkata, 6 million people in West Bengal consume drinking water with arsenic concentrations >50 microgram per cubic metre. And of 86,000 persons screened by them, 9.8% did have arsenic skin manifestations. The question is whether we have already crossed the peak or it is only the tip of the ice-berg. However, the long term risk element of arsenic contamination of groundwater should not be judged only by the number of people affected so far.

Though there have been localized causes of arsenic contamination due to anthropogenic factors like dumping of industrial waste containing high amount of arsenic, the present crisis in the Indian sub-continent is due to geo-morphological reasons. Although arsenic occurs in alluvial sediments the ultimate origin of the arsenic must be in the outcrops of hard rocks higher up the catchment of the rivers like the Ganges, Brahmaputra, Mekong, etc., as those were eroded in the recent geological past and then re-deposited in the delta.

The critical concerns for governments and other sector partners in the affected countries are:

- Restrict the people from drinking arsenic-contaminated water.
- Provide alternative sources of arsenic-free safe drinking water.
- Inform the people about the health risk associated with drinking arsenic-contaminated water.

- Provide medical relief, by way of training medical practitioners in government systems as well as outside the same.

The technological options for safe water supply in the arsenic affected areas include the following:

- Tapping groundwater from alternate arsenic-free aquifers at a higher depth and proper sealing-off of the arsenic bearing aquifer from the same.
- Largescale piped water supply for the rural communities by drawing water from the rivers and treating them for removal of pathogenic microbes.
- Conservation and quality upgrading of traditional surface water sources like ponds, dug-wells, etc., in the villages. These sources are generally free from arsenic but grossly contaminated with faecal pollution.
- Removing arsenic from the ground water, by using technologies like absorption (activated aluminium), co-precipitation (oxidation, coagulation and filtration) or ion exchange. These technologies could be applied in community plants attached to hand pump tube-wells or large tube-wells. Domestic filters could also be developed on the basis of these technologies.
- In-situ remediation of arsenic contaminated aquifers.

Unfortunately, however, efforts so far have been less than adequate. The approach has been *ad hoc*, piece meal and fragmented. Informing people about the risk and the status of their drinking water sources is a fundamental responsibility of all sector partners. The absence of proper infrastructure, lack of laboratory facilities, etc., have posed a challenge for the government to develop a comprehensive water quality surveillance system and a village-specific database. Unshakable faith created over the last 50 years in the purity of tube well water has created a crisis of confidence and lack of faith in other sources like protected ponds, dug-wells or rain water harvesting.

Though the WHO Guideline value for arsenic in drinking water is 10 microgram per cubic metre, many Asian countries like India, China, Bangladesh, Indonesia, Nepal are still adhering to the standard of 50 microgram per cubic metre. While setting standards for chemicals like arsenic in drinking water along with the health concerns, one needs also to take into account cost of implementing the same. Table 1 depicts the costs of implementing WHO Guideline Values as well as the present national standard in Bangladesh.

Table 1. Costs of implementing WHO Guideline Values for arsenic contaminated tube wells in Bangladesh (source: Prof. F. Ahmed, BUET, Bangladesh).

	Arsenic level in drinking water		
	Present	**< 50 μg/L**	**< 10 μg/L**
Population Total risk of skin cancer	377,000	55,000	15,000
Percent of population	0.290	0.042	0.012
Number of tube wells s to be abandoned	-	2.0 million	3.5 million
Cost for abandoning tube wells (Taka)	-	9.1 billion	15.5 billion
Cost of alternative water supply (Taka)	-	12 billion	24 billion
Cost of monitoring remaining safe tube wells (Taka/year)		170 million	800 million

Note: Assumptions: Number of shallow tube wells = 75 million; cost of a shallow tube well = 45,000 Takas.

The problem of fluoride in groundwater has been reported from large number of countries all over the world. 30 million people suffer from flurosis in China. In India 20 out of 35 states are affected by a high level of fluoride in groundwater and 66 million people are at risk of flurosis. 6 million children below the age of 14 are suffering from skeletal flurosis. Fluoride problems have also been reported from countries like Thailand, Bangladesh, Japan, Pakistan, Iran, Turkey, and others. Like arsenic in case of fluoride the most important control measure is also to provide alternate safe sources of water, or fluoride contaminated water must be treated for its removal. Domestic filters as well as community installations, based on adsorption principles (activated aluminium technology) are being used in the villages of India and other countries.

The preceding discussions about the health burden from microbiological and chemical contamination of water would make one realise the enormity of the task of prevention and control.

With a significant proportion of the population in the developing countries like India and Bangladesh being in extreme social and economic deprivation, competing environmental health risks exist in the society. Without diluting the gravity of the situation it must be emphasized that we need to be objective and realistic in making political and economic decisions in relation to the current problems of arsenic and fluoride contamination in groundwater in the context of the huge health burden from microbiological contamination of drinking water and other environmental health hazards.

Basis for the Quality Management Recommendations from the Walkerton Inquiry[1]

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The central theme of this conference is drinking water safety. The importance of returning "*safety*" to our regulatory vocabulary should not be underestimated because the public has a notion of what safety means and they are justified in expecting the safety of something as pervasive as drinking water is to our quality of life. We know how to achieve safe drinking water; the challenge is to commit the appropriate attention and necessary resources to ensuring that we do what needs to be done.

This paper outlines the rationale for a Total Quality Management approach to drinking water safety that emerged from the public inquiry into the Walkerton tragedy. This public health disaster claimed seven lives, infected 27 (median age of 4) with the serious kidney ailment hemolytic uremic syndrome, hospitalized 65 and made over 2000 severely ill in a prosperous rural community of 5000 in Ontario, Canada in May of 2000 (O'Connor, 2002a).

Introduction

There has been a trend over the past 25 years to recognize that managing public health issues like preventing disease transmission via drinking water inevitably requires risk management. Adopting a risk management approach is useful, to the extent that risk is accurately characterized as being the likelihood that specific hazards (recognizing that hazards are only the potential to cause harm) will truly cause harm in specific scenarios with specific consequences (Kaplan and Garrick, 1981). Unfortunately, the adoption of risk management has led many public agencies to purge safety from their discourse about public health; viewing safety as a target that risk management cannot achieve because we know that risk management cannot achieve zero risk. Of course, that is flawed logic because a pragmatic notion of safety does not demand zero risk (Hrudey and Krewski, 1995). Rather, safety can be viewed as a risk that is simply too small for a sensible person to worry about. Accordingly, Justice O'Connor, Commissioner of the Walkerton Inquiry, concluded with regard to developing his strategy for safe drinking water for Ontario in the wake of the Walkerton tragedy (O'Connor, 2002b, p. 74):

"*The goal of any drinking water system should be to deliver water with a level of risk that is so negligible that a reasonable and informed person would feel safe drinking it. This goal must inform all decisions that affect the safety of drinking water and should provide the objective against which risk assessment and management decisions are to be made. The goal as I have set it out above implies that there will always be some risk. That said, I base my approach to this issue on the premise that in regard to safety of drinking water, the reasonable and informed person will not feel safe with anything other than the most imperceptible level of risk, a level that is simply not practical to remove.*"

[1] The views expressed here are those of the author and they do not represent the Walkerton Inquiry except where the Inquiry Reports are quoted verbatim.

This notion of the goal for safety clearly recognizes that even when safety is achieved, a negligible level of residual risk will remain that would inevitably attract diminishing returns to reduce further. The challenge for achieving safety by means of risk management is being able to recognize that point where the pursuit of additional precaution, beyond the precaution inherent to a reasonable standard for safety, becomes self-defeating (Hrudey and Leiss, 2003).

Total quality management for drinking water safety

Because of the range and scope of institutional failures that were revealed by the Walkerton Inquiry, Justice O'Connor recommended that Ontario introduce mandatory operational planning and accreditation for all systems providing drinking water to the public. That standard, to be based on the best practices across Ontario, Canada and the world is to be developed by the Ontario regulator (Ontario Ministry of Environment, MOE) in concert with the industry and other knowledgeable parties. In recommending this approach, Justice O'Connor took note of the emerging Total Quality Management framework that was being developed by a working party of the Australian National Health and Medical Research Council (Rizak *et al*., 2003; Rizak and Sinclair, 2001) that has now been incorporated into the latest draft edition of the Australian Drinking Water Guidelines (NHMRC, 2003). Romain *et al*. (2002) outlined details for application of this approach to Ontario for the Walkerton Inquiry.

The Walkerton Inquiry Part 2 recommended that a Total Quality Management system for Ontario should be based on the following features (O'Connor, 2002b, p. 336):

1. "*the adoption of best practices and continuous improvement;*
2. *'real time' process control (e.g. continuous monitoring of turbidity, chlorine residual, and disinfectant contact time) wherever feasible;*
3. *the effective operation of robust multiple barriers to protect public health;*
4. *preventive rather than strictly reactive strategies to identify and manage risks to public health; and*
5. *effective leadership*."

The basis for these requirements followed directly from the public inquiry into the multiple failures at individual and institutional levels that caused the Walkerton disaster.

<u>Best practices and continuous improvement</u>

The Walkerton Public Utilities Commission (PUC) as the utility responsible for producing the drinking water supply for Walkerton was remote from any notion of a commitment to best practices. Rather, they engaged in numerous deficient, poor and dangerous practices including:

- *Inadequate source protection* – the shallow well (well #5) that was contaminated to cause the outbreak was producing water from only 5-8 m depth and was located less than 100m from the manure contamination source on a nearby family farm.
- *Inadequate disinfection* – system operators consistently applied inadequate chlorine dosage and the system was incapable of dosing the chlorine level required to produce the required chlorine residual even in the absence of any chlorine demand.

- *Process monitoring* – the required chlorine residuals were not measured, data log entries for chlorine residuals were falsified.
- *System knowledge* - operators had no knowledge of serious threats to the system or even of the need for treatment to protect the health of consumers; the operators who committed all of the errors and misdeeds that occurred continued to drink the water during the outbreak.
- *Operator training* – there was no commitment by the PUC to any training programs to allow operators to learn about the many needed improvements.
- *Management* – there were no incentives from the PUC to encourage any personal initiative or improvement; there was also no accountability for poor practice.

The primary provincial regulator for drinking water was the MOE. The local health unit (HU) also had responsibilities but the respective roles and responsibilities were blurred. These agencies failed to achieve effective regulatory practices in several ways including:

- The MOE failed to implement a 1994 policy requiring continuous chlorine residual monitoring for groundwater sources under direct surface water influence, i.e. Walkerton well #5.
- MOE failed to act on deficiencies identified at Walkerton from the time that the offending well was brought into service in 1978 throughout the 1990s.
- MOE failed to do regular or thorough inspections.
- MOE privatised the laboratory systems without implementing a reporting regulation that would oblige laboratories to report adverse results to the MOE or HU.
- HU officials showed little or no interest in repeated adverse microbial monitoring results; HU officials chose to rely totally on MOE.

<u>Real time process control</u>

A key element of the HACCP principles that provide valuable guidance for drinking water risk management is that once that critical control points are identified for managing the risks posed by identified hazards, monitoring systems that are effective for verifying that critical limits are achieved must be continuously maintained at that control point. In the Walkerton situation, the applicable requirement was to maintain a chlorine residual (with the majority present as free chlorine) of 0.5 mg/L for 15 minutes contact time. The MOE policy since 1994 had been that a well such as well #5 that was known to be subject to surface contamination should have had a continuous chlorine residual monitor.

When the MOE introduced this policy in 1994, they failed to implement any plan to identify those water supplies that should be required to follow the new policy. Instead, the Walkerton Public Utilities Commission (PUC) was expected to measure their chlorine residual only once per day. Generally they PUC operators did not measure chlorine residual at all and often recorded falsified data. As events unfolded, well #5 was contaminated by runoff from cattle manure at a nearby family farm during an intense series of rainstorms, but no evidence of the contamination emerged until 5 days later when microbial monitoring results revealed the contamination. At that time, the epidemiologic curve was already near its peak. Because the PUC General Manager concealed these adverse monitoring results from the MOE and the

HU, issuance of a boil water advisory was delayed a full 9 days after the contamination occurred. Justice O'Connor concluded (O'Connor, 2002a, p. 15): "*the outbreak would have been prevented by the use of continuous chlorine residual and turbidity monitors at Well 5*."

Effective operation of robust multiple barriers.

The Walkerton Inquiry adopted a description of appropriate multiple barriers for securing drinking water safety as (O'Connor, 2002b, p. 73):

- "***Source protection*** *keeps the raw water as clean as possible to lower the risk that contaminants will get through to overwhelm the treatment system.*
- ***Treatment*** *often uses more than one approach to removing or inactivating contaminants (e.g. filtration may be followed by chlorination, ozonation, or ultraviolet radiation).*
- *Securing the* **distribution system** *against intrusion of contaminants and ensuring an appropriate chlorine residual throughout is highly likely to deliver safe water, even when some earlier part of the system breaks down.*
- ***Monitoring programs****, including equipment fitted with warning or automatic control devices, are critical in detecting contaminants that exist in concentrations beyond acceptable limits and returning systems to normal operation.*
- *Well-thought-out, thorough, and practiced* **responses to adverse conditions***, including specific responses for emergencies, are required when other processes fail or there are indicators of deteriorating water quality*."

Walkerton was clearly deficient among all these barriers, because they had:

- inadequate source protection considering the vulnerability of well #5;
- inadequate and occasionally no treatment given the inadequate chlorine dosage and occasional operation without chlorination;
- chlorine residuals were not maintained for the distribution system and that system was also found to have many cross connections and other vulnerabilities;
- monitoring was inadequate to non-existent including falsification of results;
- responses to adverse results or identified deficiencies were woefully inadequate at all levels from the operators through management to all of the regulators.

This pattern of failures across several barriers was also evident in a review of previous outbreaks that was performed for the Inquiry (Hrudey *et al*., 2002).

Preventive rather to identify and manage public health risks

The epidemic curve for Walkerton clearly demonstrated that reliance on microbiological monitoring would not have prevented the outbreak, even if done properly. The actions of the PUC General Manager in concealing adverse microbial monitoring results was identified as serious misconduct that is now the subject of several criminal charges. However, Justice O'Connor concluded that had the PUC General Manager revealed these results when questioned by the HU (O'Connor, 2002a, p. 4): "*the health unit would have issued a boil water* *advisory on May 19, and 300 to 400 illnesses would have been avoided*." This pattern of microbial monitoring results or confirmation of illness in the community lagging seriously behind the occurrence of the contamination episode is common to many waterborne outbreaks, even where the serious personal misconduct of Walkerton is absent (Hrudey *et al*., 2002).

Effective leadership

Implementation of any effective Total Quality Management system will not succeed if the program has weak or non-existent leadership or lack of support of management at all levels up to the very top. In Walkerton, there was virtually a total lack of leadership, including:

- the PUC Board and town council had no knowledge of water safety;
- the PUC Board ignored explicit 1998 MOE warnings about water system deficiencies;
- PUC operators were certified retroactively by the MOE without training or any assessment of competence; and
- when disaster hit in May of 2000, Walkerton community leaders failed to respond or immediately investigate the water system even after the boil water advisory had been issued.

The rampant deficiencies that were revealed for Walkerton led Justice O'Connor to recommend in the Part 2 report (O'Connor, 2002b, p. 296):

"*Given that the safety of drinking water is essential for public health, those who discharge oversight responsibilities of the municipality should be held to a statutory standard of care*."

Overall, there was an evident need for a culture change to replace to the complacency that was rampant in Walkerton and other drinking water disease outbreaks (Hrudey and Hrudey, 2002; Hrudey *et al*., 2002;). Factors necessary to reverse the complacency include recognition that:

- drinking water safety relies on applying quality science and technology;
- water authorities must enhance and promote a knowledge-based culture; they cannot focus strictly on business values or political expediency;
- drinking water safety cannot be assured by treating drinking water like any other municipal service such as street sweeping or garbage collection.

Conclusions

1. A multiplicity of failures contributed to the Walkerton and other waterborne disease outbreaks, far too many failures for a single, simple fix.
2. The most serious elements of failure involve inadequate system knowledge, training and competence among operators, managers, regulators and health officials.
3. HACCP principles are essential as part of these measures, but they must be implemented "wisely" to promote effective, thorough and adaptive system knowledge and understanding within a Total Quality Management framework.
4. A Total Quality Management approach is needed in Canada to ensure that industry best practices are universally expected and applied for anyone providing drinking water for public consumption.

5. There is as great a need to create and foster competence among regulators as with operators; hence the need for accreditation and true third party audits to make all parties accountable for their role in the system.
6. Complacency has become the common enemy of drinking water safety in Canada.**Acknowledgements**

I am indebted to Justice Dennis O'Connor for documenting so thoroughly what happened in Walkerton and to Dr. Harry Swain for guiding the Research Advisory Panel. I acknowledge the role of the Canadian Water Network – Réseau canadian de l'eau in facilitating my involvement in the Water and Public Health theme of the network.

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Safety of Drinking Water Supplies in Switzerland: Evaluation by the Health Authorities

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Introduction

In Switzerland, drinking water suppliers must comply with federal food regulations just like other food distributors. The control authorities are the 20 so-called “cantonal chemists”.

In the Nineties, two important legal stipulations came into force:

- Self-check-system: Everyone who manufactures, handles or delivers food products must ensure that the product complies with the legal food requirements.
- Food safety according to the HACCP rules.

Following early discussion on risk principles in 1996, the cantonal chemists came to the conclusion that the hazard analysis and the control of the critical control points by means of suitable measures and their written documentation promote food safety. They defined the minimum requirements in a specific document (see website [1]).

The professional organisations have drawn up quality assurance manuals for their members. The SGWA (Swiss Gas and Water Industry Association) provided the guidelines for the drinking water suppliers.

If the foodstuff companies are expected to guarantee safety of its products, it is also right to expect that the control authorities are able to assess the safety level of a food processing company. The cantonal chemists accepted this challenge, and decided to establish a concept for the assessment of the foodstuff safety of the foodstuff companies based on an inspection.

This paper presents the concept as applied to the supply of drinking water. The concept for all foodstuff companies has been published in German and French (see website [2]).

Concept

The safety level of a food processing company should be determined on the basis of an inspection which lasts between two hours and one day, depending on the size of the company.

The following requirements were set in order to establish the evaluation concept (Table 1):

- “*Understandable for all parties involved*” means simple language. A scientific theory which is not understood is useless. If the controlled persons do not understand what it is about, everything is done in vain.
- “*Practice-oriented*” means that the evaluation should be carried out on the basis of a practical inspection. Evaluating the safety of a drinking water supply presupposes domain-specific knowledge. Theoretical knowledge of any risk manager is not sufficient.

- "*Easy to use*" means that the safety evaluation can be made in three to five minutes following the inspection.
- "*Transparent*" means that the evaluation is carried out on the basis of fixed criteria and that water distributors, consumers and politicians can understand the results.

Table 1. Requirements on the evaluation of water supplies.

1	Understandable for all parties involved
2	Practice-oriented
3	Easy to use
4	Transparent

Evaluations should take place throughout all Switzerland according to the same criteria, so that the results can be compared. The results should also serve the planning of any future work. The highest possible efficiency should be obtained with the limited human resources available. Inspections should be more frequent for companies where safety deficits have been previously determined.

Following an inspection the data are assigned to one of the four following evaluation domains (Table 2) (see also website [3]):

A. Keywords to the self-check system: critical control points are identified and suitable measures are prescribed and documented. The documentation can cover a few pages up to several hundred pages. The documentation size is adapted to the size of the enterprise. The evaluation of this domain has been recently introduced and is now part of an inspection.

B. Analysis of the water as a final step in its control is not as meaningful as it used to be. It remains however essential to follow the evolution of the water quality and to check if the prescribed measures have been realized.

C. Evaluation of the processes and activities is a crucial innovation. It examines whether the decided measures are effective to control the hazards. As an example we could mention the continuous monitoring of both turbidity and UV disinfection. The control of processes is a guarantee and in the long term a preventive measure. Further staff training is assigned to the "activities" domain.

D. The fourth domain – buildings, equipment and devices – is a classical point of inspection and can be assessed according to the technical rules.

Table 2. Domains of inspections of the authorities.

A	Self-check system
B	Water quality
C	Processes and activities
D	Buildings, equipment and devices

The safety of each of the four examined domains is weighted, judged and given a mark according to one of the four following safety levels given in Table 3.

Table 3. Safety levels for food safety evaluation.

Safety levels	State	Safety
4	bad	not guaranteed
3	poor	compromised
2	fair	reduced
1	good	guaranteed

The result is registered into the following data sheet (Table 4) which helps to determine the global safety level of the assessed company. The data sheet shows the specific evaluation domains where problems have been determined. These problems are individually specified in the inspection report with corrective measures ordered for each problem.

Table 4. Data sheet for results of safety assessment.

Safety level / State		Self-check system	Water quality	Processes and activities	Buildings, equipment and devices
4	not guaranteed				
3	compromised				
2	reduced				
1	guaranteed				
global safety of the water supply company / : ……					

The training of the cantonal chemists regarding this concept lasted one full day and the training of inspectors lasted two days: this was a necessary condition. The application of the concept was practiced using examples. Evaluation results obtained in training sessions were compared with case examples. The comparison showed an astonishing homogeneity.

Results 2002

Evaluation of the state of safety in food processing companies in Switzerland for 2002 is shown Figure 1. In this graph the companies are classified according to safety levels. In red (in the back) the results represent approximately 40000 food processing companies, in blue (in the front) the results represent approximately 1500 drinking water suppliers.

The parallel between all food suppliers and the drinking water suppliers is noticeable. 95% of the companies can be assigned to the safety levels 1 and 2, approx. 5% to level 3 and less than 1% to level 4. Each canton (district) can compare its results with the average values for Switzerland. Significant deviations are very important starting points for the examination of the effective situation or the manufacturing practice.

With these statistics the safety of the Swiss food suppliers and the drinking water suppliers is documented according to defined criteria for the first time.

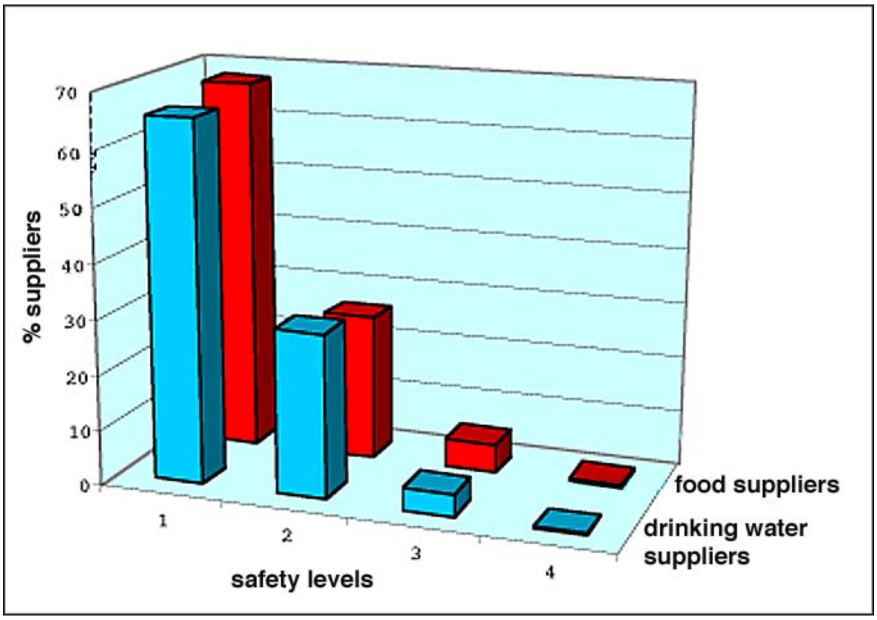

Figure 1. Results of inspection of 1500 water suppliers and comparison with other food suppliers.

Benefits

The evaluation concept may be useful in different ways for all parties: for politicians (very short and understandable statements about the safety of the food processing companies), for the control authorities (as a planning instrument), for the companies (as an independent external investigation) and for the consumers (as an understandable tool for evaluation and for building confidence).

Epilogue

Starting in 2004 drinking water distributors have to inform the consumers annually about the quality of the drinking water. In a help manual (see website [4]) the cantonal chemists have specified the minimum information that water suppliers should give to their customers.

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Application of the Australian Risk Management Framework: A Public Health Authorities' Perspective

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Background

A number of factors came together in Australia in the late 1990s that demonstrated the need for a multi-agency risk management approach to be applied to drinking water supplies to improve assurance of safety. The factors included:

- growing concern about over-reliance on a number driven approach with management and health decisions being based on compliance testing and adherence to guideline values (under this approach 0 *E. coli* per 100 mL meant the water was microbiologically safe);
- lack of a coordinated approach involving all appropriate agencies (health, water suppliers, catchment managers, planners, etc.) to assurance of drinking water quality (as evidenced by the 1998 Sydney water incident);
- a disparity in standards/attention applied to rural and remote supplies compared to capital cities; and
- a major revision of food legislation confirming that drinking water is regarded as a food and hence that quality assurance programs consistent with the HACCP system were required.

The 1998 Sydney Incident provided a clear example of management based on end-product monitoring and the lack of a co-ordinated approach to dealing with water quality. The incident received widespread media coverage and while “bad press” is often dismissed as inaccurate and sensationalist sometimes it can reflect real problems.

In July-August 1998 following the reported detection of *Giardia* and *Cryptosporidium* in drinking water samples “boil water” advice was issued to the public on three separate occasions over the period of a few weeks. There was intense media coverage with headline stories suggesting that the response to the incident was poorly organised with no evidence of an established emergency protocol and that at least initially there was a lack of a co-ordinated response from the health and water agencies. There were stories about arguments between the two agencies. The reports also indicated that there was a lack of understanding about the source of the organisms and the cause of the incident.

There was a loss of public confidence in the management and quality of Sydney drinking water supplies and the Chief Executive of Sydney Water and the Chairman of the Sydney Water Board both resigned because of the incident. Importantly although newspaper headlines included statements such as “Do panic!” and “Safe water: the big lie” epidemiological investigations found no evidence of illness. This was despite the fact that many people ignored the “boil water” advice, particularly on the second and third occasion.

The Sydney Incident was a "wake-up call" that could have occurred elsewhere in Australia. In September 1998, Adelaide newspapers ran front page stories about the detection of *Giardia* in a reservoir. While the incident did not represent a health risk the media reports indicated that there was poor communication between Government ministers on a water issue.

The response

The need for the development of a preventive risk management approach was identified as a high priority by the Co-ordinating Committee for the ongoing review of the Australian Drinking Water Guidelines (ADWG). The Committee includes representatives from peak health and water agencies.

As a result the *Framework for Drinking Water Quality Management* was developed over a 3-4 year period by health and water agencies for inclusion in the ADWG. Development included workshops, pilot trials and extensive agency and public consultation.

The *Framework* is consistent with the WHO Water Safety Plans, includes the HACCP principles and is also consistent with ISO 9001 and 14001. Like the Water Safety Plans the *Framework* is a purpose-designed system to meet the particular requirements related to supply of drinking water.

Structure of the Australian Framework

The *Framework* includes 12 elements divided into 4 areas:

- commitment to drinking water quality management;
- system analysis and management;
- supporting requirements; and
- review.

Many of the 12 elements such as system assessment (hazard identification and risk assessment), identification of preventive measures, process control, verification, incident and emergency management, documentation and reporting, and evaluation and audit are common components of risk management systems.

Health authority requirements

Protection of public health requires implementation of a preventive risk management approach to provide a measurable assurance that safe drinking water is supplied 24 hours a day. From a regulatory perspective confirmation that drinking water is recognised as a food under Australian legislation reinforced the requirement for this type of approach.

It is also important that management is cost effective. One of the standard responses to incidents such as those that occurred in Sydney and Adelaide is a call for installation of very expensive water treatment systems without a detailed risk assessment to determine whether such systems are necessary to protect public health. Supply of safe drinking water is a vital health requirement but it is just one component of providing community health services. Implementation of risk management systems provides a sound basis for cost-benefit analyses of suggested improvement programs.

Other health authority requirements include:

- a systematic catchment to consumer approach;
- identification of major hazards and appropriate control/preventive measures;
- identification of operating limits for control measures with a particular emphasis on identifying critical limits for critical control points;
- operational monitoring that detects faults prior to supply of water (wherever possible) so that corrective actions can be implemented before unsafe water reaches consumers. In some cases this monitoring will be continuous e.g. free chlorine residuals and turbidity in water produced at treatment plants;
- an agreed incident and emergency protocol between the water and health agencies;
- regular reporting of results;
- documentation; and
- a system that can be externally audited.

Role of health authorities in the implementation of the Framework

An important feature of the *Framework* is that implementation requires multi-agency involvement. While the lead should be taken by the water agency, health authorities should provide assistance in the identification of hazards and risk assessment and contribute to the identification of appropriate control measures, critical control points and critical limits. The development of incident and emergency protocols should be a joint responsibility. Health authorities should provide an assessment of the effectiveness of the management system.

Health authorities should also provide support to the water agency, where necessary, in communicating with the public and with other agencies, particularly those involved with catchment management and urban and rural planning. Wherever possible the aim should be to protect public health by preventing contamination from entering the water supply.

Advantages to health authorities

The implementation of risk management systems by drinking water suppliers provides a broad range of benefits to health authorities. Importantly it provides greater confidence in the continuous management of drinking water quality. In addition, participation of the health authority in the implementation process will lead to a better understanding about operational aspects of supplying drinking water, potential health risks and what can go wrong. This will support more informed decision-making by health authorities as regulators of drinking water quality as well as informing assessment of priorities as part of developing overall health policies.

Implementation should also lead to greater co-operation between health and water agencies including improved communication, better preplanning for incidents, fewer surprises and unexpected disasters and more measured responses when needed. A co-operative approach between agencies enhances public confidence and penalties prescribed in legislation should only be used as a last resort.

Yorke Peninsula Incident

Advantages provided by implementation of *Framework* elements were demonstrated by an incident on the Yorke Peninsula of South Australia in April 2000.

The cyanobacterium *Phormidium* was detected in an open storage reservoir at the head of a water distribution network. Although *Phormidium* was previously believed to be harmless, mouse bioassays suggested that it was toxic. The interagency incident protocol developed after the 1998 events was activated immediately and advice was issued to the public that mainswater should not be consumed. All nursing homes, hospitals, hotels, motels, etc., were contacted individually.

Over the next 7 days DHS (the health authority) and South Australian (SA) Water communicated progress through joint press conferences and media releases. DHS provided health information while SA Water reported on operational issues. During the 7 days, toxicity was found to be sensitive to heat and chlorine. As a result the advice not to consume the drinking water was changed to a "boil water" notice. SA Water provided bottled water for individual use and larger volumes of carted water for businesses such as bakeries. The boil water notice was rescinded after 7 days when the entire distribution system had been flushed with chlorinated water.

Although the incident occurred 3 days before Easter in a local tourist area there was no evidence of a downturn in tourism. Media coverage was balanced and a survey conducted after the event found that confidence in SA Water had increased. This reflected the level of co-operation between the two agencies and the co-ordinated and organised manner in which the incident was handled. The public perception was that the agencies had acted responsibly and that they knew what they were doing.

Application of the Framework in Australia

State capital cities are implementing or have implemented risk management systems. This has been undertaken in a variety of ways, which is consistent with the flexibility built into the *Framework*. Some authorities have adopted the *Framework* as written while others have followed a classical HACCP or ISO approach to achieve a common outcome.

Implementation has also commenced in other urban centres and rural areas. In South Australia work has commenced on application of the *Framework* to remote indigenous supplies (supplying as few as 50 people). The *Framework* will also be adapted to alternative water supplies commencing with domestic rainwater tanks (relatively common in rural Australia).

In one State (Victoria) implementation of a risk management plan will be required by legislation.

Summary – Advantages of the Framework

The *Framework* provides a structure for development of system specific management plans that can be applied to all water supplies irrespective of size. For larger supplies it formalises and organises existing procedures into a systematic and accessible package that can be easily communicated both inside agencies and externally. In some cases it identifies gaps and the need for improvement.

For smaller supplies that are often “overlooked”, application provides a basic assessment of needs and an organisational structure. Analysis of almost 2000 rural and remote supplies in Australia identified lack of management as a bigger threat to drinking water quality than inadequate monitoring, poor source water quality or poor treatment.

Reference

The Australian Drinking Water Guidelines and the Framework for Management of Drinking Water Quality are available at: www.health.gov.au/nhmrc/publications/

Drinking Water Inspection in Ghana

N. O. Kotei

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Major water sector reforms started in 1993 to enable various sectors to play significant roles in the delivery of the service. For efficiency and public accountability it was necessary to separate regulatory from systems and service provision functions.

A generic flow chart that shows the main players in Ghana's drinking water sector is given in Figure 1. The Ministry of Works and Housing (MWH), Ghana Water Company Ltd. (GWCL) and the Community Water and Sanitation Agency (CWSA) are the main stakeholders in the delivery of drinking water. The main regulatory bodies include the Public Utilities Regulatory Commission (PURC), Water Resources Commission (WRC), Environmental Protection Agency (EPA), and the Ministry of Health (MoH).

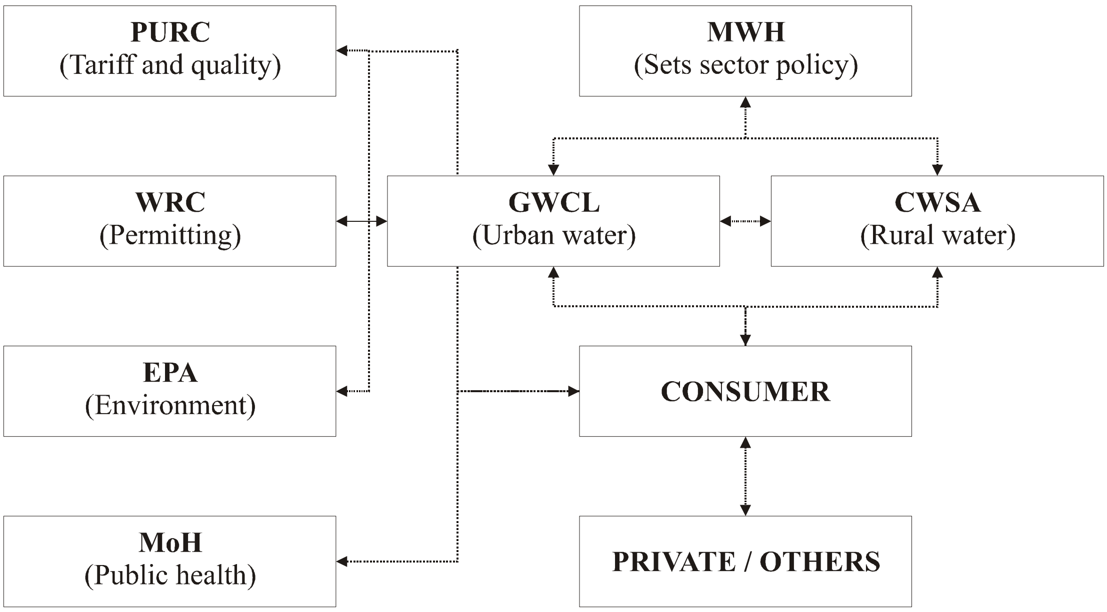

Figure 1. Generic flow chart for drinking water production oversight and monitoring in Ghana.

The Public Utilities Regulatory Commission (PURC) was established in October 1997, as an independent regulator of tariffs and water supply operational performance. The Water Inspectorate was then set-up in the last quarter of 2000 under Section 44 of the PURC Act 538, 1997, to give special attention to the provision of drinking water taking into account public health concerns of consumers.

Given the many other priorities in the water sector and the resource constraints in the country as a whole the approach to drinking water regulation for compliance in Ghana is the audit approach where the burden of proof of compliance is shifted onto the water supplier who has a legal responsibility to carry out sampling and analysis of water quality. PURC requires the following types of information from the water utility to facilitate the Commissions regulatory activities:

- *Performance Report:* Report at the end of each year. Reasons given for any variance, plans and activities to rectify these variances if negative.
- *Water Quality Report:* Results of laboratory tests of water samples delivered by the system. Details of failures to satisfy the water standards and reasons for those failures as well as details of plans to meet the required standards.

An independent laboratory network had been identified. This is to act as independent agent in assessing drinking water quality. It is to build independence and confidence in the testing procedures adopted. An accreditation system for these laboratories that can apply testing and verification of drinking water to strict guidelines is being developed.

Water quality is utmost importance to the health of consumers. The Commission is therefore pursuing the setting of basic water quality targets for the water utility for the improvement in the quality of service to consumers. These targets would always be linked to the tariff regulation to ensure that consumers get value for money and expected supply.

Consumers have a right to information on health related issues of water supplied to them. Public education by all stakeholders on the rights and responsibilities of consumers is being intensified. With the awareness being created on water quality and health, the Inspectorate would sustain active monitoring of response to consumer complaints.

Protection of water quality could be enhanced with increase in the accessibility to water delivery as currently a high percentage of consumers depend on water from intermediaries such as tankers and other small scale water producers. The Ghana Government had identified the importance of the role of such small-scale water producers in recent times. A project to identify and test constraints, opportunities and strategies for enabling such small-scale water producers to deliver an acceptable water service to consumers is under way.

Assessment of the Suggested Risk Management Strategies

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Introduction

In the German state of Baden-Württemberg, approximately 700 billion m³ of water are withdrawn each year for public water supply. Some 1,200 community supplies account for approximately 50% of the water requirements, 186 regional water supplies account for about 20% and 4 supra-regional suppliers for some 30%. In addition, there are around 3,000 private water supplies with abstraction volumes of less than 1,000 m³/a. In total, there are some 5,000 water extraction facilities in Baden-Württemberg.

This decentralised structure is in keeping with the principles of the Federal Water Resources Act (Wasserhaushaltsgesetz) and the Water Act of the State of Baden-Württemberg, under which the security of continuous water supply in the State is safeguarded by:

- giving highest priority to the community based or regional supplies;
- acknowledging that community based or regional supplies can obtain water from supra-regional supplies in limited periods of local or regional water shortage due to weather conditions or peak consumptions;
- supra-regional water supplies in regions with insufficient natural water resources.

With regard to the combination of community based or regional supplies and supra-regional supplies, it should be noted that supra-regional supplies also safeguard water supply to the population in the event of a water shortage or a deterioration of water quality as a result of weather events. These measures ensure consumer's health protection.

Water abstraction facilities are protected by water conservation area ordinances. At present, some 2,500 water conservation areas have been classified for public water supplies. Near-surface sources, such as those in the Black Forest, the "Karstbrunnen" in the Schwäbisch Alb mountain range and regions with shallow sedimentary cover such as the Rhine, Oberland and Hohenlohe regions, require special protection as regards microbiological contamination and the effects of nitrate and pesticides. For this reason, over 20% of the area of Baden-Württemberg has been classified for water conservation purposes.

Pursuant to the 2001 German Drinking Water Ordinance (Trinkwasserverordnung), water supply facilities are monitored by the local health authorities, while the four supra-regional suppliers are monitored by the Baden-Württemberg Health Authority (Landesgesundheitsamt, LGA).

Is there a necessity for implementation of HACCP in Germany?

The question arises as to whether the implementation of a HACCP concept for water supplies in Germany is in fact necessary.

In Germany, the multi-barrier concept is applied to drinking water supplies. This concept focuses on the following areas:

- Resource protection (1st barrier);
- Treatment (2nd barrier);
- Product control when the water leaves the water works (3rd barrier); these checks comprise:
  - a) continuous control (chemical/physical); and
  - b) intermittent control (microbiological and chemical);
- Distribution system maintenance and delivery point control (4th barrier).

In Germany, a risk analysis such as envisaged by the HACCP concept already begins prior to water abstraction with the comprehensive protection of water bodies, the protection of groundwater and surface water and the classification of drinking water conservation areas (i.e. resource protection). As a result, raw water quality is already optimised by the first barrier. If this protection is adequate as far as groundwater is concerned, the water does not require any further treatment and is ready for immediate use as drinking water. If the first barrier is not adequate, then a second barrier, namely the reliable treatment of water, must be added before the water leaves the water works and is fed into the distribution system for consumption. The distribution system itself is a further critical point for safeguarding the quality of the water supplied to consumers. This system must be monitored and maintained round the clock.

It is important to remember that, as far as water supplies are concerned, there is no generally valid risk analysis or generally applicable HACCP concept, since a process analysis must always be adapted to local realities. For example, a risk analysis for drinking water obtained from surface water will differ from a risk analysis for water originating from bank filtrate or groundwater. The water enterprise is responsible for conducting a risk assessment and risk analysis and for establishing process optimisation as well as setting priorities for water treatment measures. In many instances, German water companies have already done their homework.

Example 1: supra-national water supplier

To illustrate the successful implementation of a HACCP concept, we have selected a supra-regional water supplier producing drinking water from surface water. Optimum treatment of the water from this origin is required, and treatment consists of the following steps:

- micro filtration;
- ozonation for oxidation and/or disinfection purposes;
- flocculation;
- sand filtration; and
- chlorine disinfection, if required, i.e. chlorinated transport.

The water supplier monitors water quality for critical parameters and at critical control points during the treatment process. Under treatment process monitoring, several chemical/physical parameters are subject to continuous monitoring, while intermittent microbiological and chemical checks are also performed. Continuous monitoring includes raw water flow, turbidity, temperature and ozone concentration.

The following finished water parameters are also subjected to continuous monitoring: temperature, pH, conductivity, turbidity, particles, spectral absorption coefficient at 254 nm, colour intensity at 460 nm, red-ox potential, residual chlorine, iron concentration (iron is added for flocculation) and ammonium concentration (because the drinking water is produced from surface water). Other microbiological and chemical parameters are monitored intermittently.

Data from the continuous monitoring checks are transmitted to the control room, thus ensuring on-line monitoring with round-the-clock surveillance.

In this particular case, critical control points are as follows:

- the catchment area;
- the raw water source;
- after filtration;
- after flocculation;
- after sand filtration;
- control of the finished water; and
- control at delivery points (= distribution system control).

The monitoring results are regularly sent to the LGA for inspection and archiving. Furthermore, the supra-regional supplier and the LGA co-operate closely on several technical issues.

Example 2: spring water sources

There are some 1,400 spring water sources in Baden-Württemberg where, in the past, occurrences of raw water microbial contamination with no significant increase in turbidity have been successfully disinfected solely by chlorination or UV radiation with no further treatment. Under the new Drinking Water Ordinance of 21 May 2001, these spring water sources must (with effect from 1 January 2003) be treated using state-of-the-art technology and methods in all cases where microbial contamination of the raw water with the risk of a transmittable disease has been established. Cryptosporidia and Giardia in particular cannot be eliminated by general disinfection, but require further specific treatment. From an economic point of view, it is not possible to retrofit all spring water sources simultaneously with adequate treatment facilities. The Ministry of the Environment and Transport of Baden-Württemberg therefore commissioned the DVGW Water Technology Centre (WTC) in Karlsruhe to conduct a study to establish raw water quality (situation analysis) and to develop criteria for setting priorities based on the microbial contamination of the raw water (classification).

WTC drew up a catalogue based on quantitative evidence of *E. coli* and other microbiological parameters in raw water (see Table 1 below) and set priorities for action on the basis of the values measured. These criteria differ from those developed by the Federal Environmental

Agency (FEA). The FEA bases its criteria on the number of positive coliform bacteria samples, while WTC bases its criteria on quantitative microbial contamination of the water.

Table 1. Microbiological criteria for classification (bacterial content/100 ml).

Test organism	Low priority	Medium priority	High priority
E. coli	< 1	1-10	> 10
Coliform bacteria	< 10	10-100	> 100
Enterococci	< 1	1-10	> 10
Clostridium perfringens	< 1	?	?

On the basis of the FEA criteria, under which 50% of the samples tested positive for coliform bacteria, 85% of the sources tested would classify as high priority. Based on the WTC criteria, however, 25% of the sources would be high priority, 33% medium priority and 42% low priority. The WTC recommendations allow a degree of flexibility as regards the introduction of treatment measures over several years, thus ensuring consumer health protection while taking the risks into account.

Conclusion

To conclude, this study constitutes a risk analysis and represents a feasible approach for managing current risks under present economic conditions, thus strongly resembling a HACCP concept.

EU Council Directives on the Quality of Water Intended for Human Consumption: The Past, the Present and the Future

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Abstract

The current Drinking Water Directive (DWD) 98/83/EC is compared with the previous DWD 80/778/EEC and where possible some first thoughts and ideas are presented on future legislation on water intended for human consumption. The current DWD came into force in 1998 and replaced the DWD after nearly twenty years. However, the revision of the "new" DWD is already foreseen and this process will start in autumn of 2003. The revision of the DWD is the first opportunity to make changes to the Directive. The comparison between the previous Directive, the current Directive and future drinking water legislation will address a number of basic issues.

In the past drinking water legislation made little reference to other Community legislation, this has changed significantly since. There is increasingly more harmonisation and interaction between European Union legislation, especially since much water related Directives are included in the Water Framework Directive. This process might well continue in the future, where reporting on the state and trend of the aquatic environment will be addressed in a different way, combining data and information exchange on different pieces of legislation.

The current DWD is more transparent than in the past and principles of the Directive are clearly identified in the legal text. More so than this was the case in the past. A number of principles of the new Directive are discussed.

The WHO Guideline Values for drinking water are in principle the basis for EU legislation on drinking water. Even though sometimes a different approach is used and deviations are possible on the advice of the Commission's Scientific Advisory Committee (CSTEE). There is a link between WHO initiatives (such as discussions on an HACCP-based approach) and future developments of Community legislation.

Finally, some aspects of the revision of the DWD 98/83/EC are highlighted like: the relationship between the DWD and the European Acceptance Scheme for materials in contact with drinking water (EAS), new analytical techniques, new emerging threats to drinking water and, last but not least, the protection level offered by the DWD. In principle the protection level offered by the DWD is based on average adults exposure (except of course for some parameters such as lead). More and more questions are raised about vulnerable groups in society and the need to better protect e.g. infants, older people and people under medical treatment.

EU water legislation

Water is one of the most comprehensively regulated areas of EU environmental legislation. Early European water policy began in the 1970s with the adoption of political programmes as well as legally binding legislation. As regards programmes, the First Environmental Action Programme covered the period 1973-76. Parallel to political programmes a first wave of legislation was adopted, starting with the 1975 Surface Water Directive and culminating in the 1980 Drinking Water Directive 80/778/EEC. The previous DWD 80/778/EEC was based on scientific and technical state of the art of tens of years ago. Since then both scientific and technological knowledge and the approach to EU legislation has changed. It was therefore necessary to adapt the original Directive to bring it in line with scientific and technical progress, but also to bring it into accordance with the principle of subsidarity by reducing the number of parameters for which Member States had objectives and by focusing on compliance with essential quality and health parameters.

The Drinking Water Directive's revision process

In 1993 the Commission organised a European drinking water conference in Brussels to consult all stakeholders in the supply of drinking water in the revision of the DWD then in force. This resulted in 1998 in the adoption and entry into force of the current DWD 98/83/EC (OJ L 330, 5.12.98). The 1998 DWD had to be transposed into national legislation two years after entry into force which is at the end of the year 2000 and has to be complied with by the end of 2003 (with some exceptions for critical parameters such as lead and disinfection by-products).

In the mean time the Commission has started preparations for the revision of the new DWD five years after it has come into force. This revision process is foreseen in the DWD. Exactly ten years after the consultation of European stakeholders, the Commission again organises a seminar to consult stakeholders on the need for revision of DWD 98/83/EC. This time 25 countries will be involved, the current Member States and the ten countries that will join the European Union in 2004, an ambitious project that will take place on the 27th and 28th of October 2003 in Brussels (see dedicated website: www.drinkingwaterseminar.org).

Main aspects of the Drinking Water Directive

Related Community legislation

The first generation of EU water legislation were more or less isolated pieces of legislation, with little or no cross-references. The previous DWD 80/778/EEC only makes a reference to one piece of EU legislation which is the Council Directive on the Quality of Surface Water intended for the abstraction of Drinking Water (75/440/EEC). The current DWD refers to a number of other Directives that are related to the Directive or have interactions with the Directive:

- the Plant Protection Directive (91/414/EEC) and the Biocides Directive (98/8/EC) both relevant for the pesticides parameter in the Directive; and
- the Construction Products Directive (89/106/EEC), relevant for materials and appendages used in the production and distribution of drinking water.

In future revisions of the DWD attention will be paid to an integrated approach to EU water legislation as the Directive has to be brought in line with important developments such as the Water Framework Directive and the European Acceptance Scheme (under development) for materials in contact with drinking water.

Integration of EU water legislation does not only imply compliance with the requirements of various related Directives but will also involve harmonisation and streamlining of reporting requirements. Reporting requirements will have to address compliance, state of and trends in the quality of aquatic environments.

Principles of the Drinking Water Directive

The underling principle for the previous DWD was not specified other than the objective of “setting standards for human health protection”. The current DWD aims to protect human health from the adverse effects of contamination of water intended for human consumption by ensuring that it is “wholesome and clean”. It applies to all water intended for human consumption, as well as water used in the production and marketing of food, under certain exceptions. Member States are required to monitor the quality of drinking water, and to take measures to ensure that it complies with the minimum quality standards. It also lays down a number of requirements for reporting to the Commission, and for making information available to the public, regarding the quality of drinking water. The Directive is based on a number of principles that have been laid down in the Treaty such as the subsidiarity principle and the precautionary principle. Unlike the early Community legislation the new Treaty of the European Union states that no Community legislation should go beyond what is necessary to achieve the objectives of the Treaty. For drinking water legislation this implies that the high number of parameters in the previous Directive has been reduced to better focus on what are essential and health related parameters in the whole European Union, leaving Member States free to add other parameters if they see fit. A HACCP-based Directive might reduce the number of parameters even further.

Other principles of the current Directive are the precautionary principle, sustainable use of water and water source protection, and of course the political compromise that goes hand in hand with the process of adoption of new legislation by the Member States. If future legislation should be based on risk assessment and risk approach, the added value of such an approach should be made clear. Also such an approach should offer at least the same protection level as the current legislation in force. Other basic principles of the Directive are the stand-still principle, implying that the implementation of the Directive should not result in deterioration of the current level of protection offered in the member States. Also water source protection and sustainable use of water are important aspects of the Directive. And as in all legislation, compromises are made to accommodate political aspects in the various Member States. Future legislation will evidently have to be based on the principles as worded in the Treaty, but after careful weighting of advantages and disadvantages of a risk analysis based approach the principals of such an approach could be added to the Directive.

Types of water covered by the Drinking Water Directive

The previous Directive covered all water intended for human consumption except natural mineral waters, medicinal waters and water used in the food industry not affecting the final product. The current Directive covers the same types of waters and knows the same exceptions, but also makes it possible for Member States to exempt other types of water from the Directive such as e.g. hot tap water, second grade water for non-ingestive uses and supplies supplying less than 10 m^3/day. As yet it is unknown if there is a need to change the coverage of the DWD in future revisions of the Directive.

Parameters and parametric values

The previous DWD listed more than 62 parameters often together with parametric values such as MAC's, guideline values and minimum levels. Parameters included: organoleptic, physico-chemical, undesirable substances, toxic substances, microbiological and minimum requirements for water that had been subject to water conditioning processes to remove hardness. Not all parameters actually had a parametric value in the Directive and also no mention was made of scientific background for the parameters and the values in the Directive. Substances that were used in the preparation of drinking water should remain in the water at values below the parametric value for these substances. One of the main reasons for the revision of the old Directive was to restrict the number of parameters, and only to include essential and health related parameters that are of importance in many areas of the European Union. It is then left to Member States on the basis of the subsidiarity principle to add parameters or to set stricter values as and where necessary; however, no breaching the Treaty with respect to the rules of fair trade within the EU. The number of parameters is restricted to total of 48 (microbiological, chemical and indicator) parameters. All parameters that are included in the Directive have a parametric value of mention of the fact that it "should be acceptable to consumers and no abnormal change" should occur. All parametric values are mandatory and guide level values do no longer exist in the Directive. For future revisions of the DWD discussions could result in new and additional parameters or in even less parameters. New parameters might be e.g. endocrine disrupting chemicals, pharmaceuticals, protozoa such as Giardia, Cryptosporidium or Legionella. In a risk analysis based approach it might also be possible that one parameter knows more than one parametric value in various parts of the whole production and supply process.

Parameters in DWD 98/83/EC

In the DWD a balance is struck between microbiological and chemical risks. Disinfection of drinking water carries the risk of disinfection by-product formation that are harmful to humans such as trihalomethanes and bromate. However, disinfection reduces the risk of exposure to pathogenic bacteria in the water. Water quality is more than the 48 parameters in the current Directive and some of the parameters that might cause a threat to human health are not yet even known. Therefore the DWD has in line with the precautionary principle an important Article (4(1)a), which states that water intended for human consumption should be wholesome and clean. Article 10 of the DWD ensures that chemicals used in the preparation of drinking water should not remain in the final product in concentrations higher than absolutely necessary. Another important aspect of Article 10 is the reference to the Construction Products Directive on materials in contact with drinking water during distribution. This is to avoid adverse effects on the quality of drinking water e.g. by pipe materials.

Basis of parametric values

In setting the parametric values for the various parameters both short term/acute and long term chronic effects have been taken into account as and where appropriate. Basic principles are that the quality of the water is such that consumers can drink and use water for domestic purposes for a lifetime without the risk of adverse health effects. Also special attention is paid to the protection of vulnerable groups such as children and pregnant women e.g. in setting the values for lead, nitrate and nitrite (babies). WHO Guideline Values for drinking water adopted in 1992 were used as a basis for setting parametric values in the DWD, that is where there was a health-based Guideline Value available. For some parameters a different approach was used and for others advice was asked of the CSTEE (Scientific Advisory Committee). Parameters in the last category were: lead, PAH, pesticides, tri and tetra, copper and boron.

Microbiological parameters

The parametric values for microbiological parameters are zero as any positive result indicates the presence of pathogenic micro-organisms and calls for an immediate response.

Carcinogenic parameters

For genotoxic carcinogens there is normally no threshold below which there is no risk to human health. The WHO applies a criterion for individual carcinogens which implies that there should be no more than one excess cancer in a population of 100.000 resulting from a lifetime exposure. In the DWD a stricter criterion was used that implies that there should be no more than one excess cancer in a population of 1.000.000 resulting from a lifetime exposure.

Other considerations

A very practical consideration in setting parametric values is the availability of analysis methods at the required detection level. For three parameters – epichlorohydrin, acrylamide and vinylchloride – in the DWD it was at the time of adoption not possible to detect the substances at the level that sufficiently protect human health. For these three substances a parametric value was adopted that was below the achievable limit of detection. For these parameters it was decided to regulate levels in drinking water through product specifications. A second principle for setting parametric values is the availability of treatment methods to ensure that the required removal of the substances could be achieved with the available treatment techniques. Finally a balance was struck between the risk to human health from the consumption of water not meeting the high standards foreseen in the DWD and the risk from interruption of the water supply (sometimes values not as strict as that corresponding to the one in a million criterion).

Sampling and monitoring

The previous DWD 80/778/EEC defines minimum monitoring requirements with an input effort that is related to the amount of water supplied. A distinction is made between current monitoring, periodic monitoring and occasional monitoring. The current DWD 98/83/EC uses a similar approach where minimum monitoring effort is defined in relation to the amount of water supplied. A regular check of the water quality is defined for some key parameters in the so-called check monitoring and a more comprehensive check of the water quality including all other parameters is carried out with a much lower frequency in the so-called audit monitoring. The main difference between both Directives is the fact that in the current DWD sampling and monitoring is carried out at the consumers' tap unless it concerns parameters that do not change between the production plant and the tap. Sampling and monitoring in the DWD is in principle a check at the last minute and is in principle always too late. In the case water does not comply it has already been supplied to the customer and been consumed. A risk assessment and risk management based approach could well cause a major change in sampling and monitoring strategies for drinking water. Moving the place of check and control further back in the production chain from raw water source to tap.

Quality control and assurance

Quality control in the 80/778/EEC DWD was restricted to the mention of analytical reference methods. The current DWD goes much further by making ISO/CEN methods compulsory and by defining performance criteria for (most) chemo-physical parameters. Furthermore Member States need to have some quality control (QC) and quality assurance (QA) in place in the reference laboratories for drinking water analyses. At the time of adoption of the DWD it was judged as not possible to require an accreditation system for all Member States, but that will be an additional requirement in the near future. As future regulation might well be based on a risk analysis approach, a QC/QA system is of vital importance not only to control process performance but also to validate and guarantee the quality of drinking water at the tap.

Revision of the DWD and WHO guidelines

WHO has adopted the HACCP based approach for drinking water in the so called "Water Safety Plans". The European Commission is currently considering whether it would be appropriate to follow this concept in the revision of the DWD.

Issues that will be addressed by the experts in the revision will include basic questions as how can the underlying principles of the Treaty (and the DWD) be maintained and safeguarded in a risk assessment approach:

- subsidiarity principle;
- stand-still principle; and
- precautionary principle.

But the main question is of course how can the same or an even higher level of protection of European citizens be continued to be guaranteed.

Conclusions

The EU regulation on drinking water has contributed significantly to the supply of safe and wholesome drinking water to European citizens. The current DWD 98/83/EC even improves on that by setting requirements for the quality of drinking water at the consumers' tap. Council Directives on drinking water are to a large extent based on WHO Guidelines, and it is therefore logical that any developments in these Guidelines will have to be considered in the revision of the DWD. It is expected that the underlying principles of the current DWD will be further strengthened by a HACCP like approach. When applied properly and consistently the added value of a risk assessment based approach, together with the existing framework of the Directive will be a powerful tool to address new and as yet partly unknown threats to drinking water such as e.g. pharmaceuticals, endocrine disrupting chemicals, algal toxins and micro-organisms as Cryptosporidium, Giardia and viruses. Extending the control of water quality from the final product at the tap to the whole production process will, when accompanied by adequate information to the public, boost the confidence of European consumers in the safety and wholesomeness of their drinking water. Close co-operation between the European Commission and WHO is a pre-requisite to achieve this target.

Does the Customer Believe it is Safe?

Bob Breach

Severn Trent Water, United Kingdom

An invited international workshop in Bonn in October 2001 took a fresh look at how we might "Assure the quality of drinking water in the 21st Century". The workshop identified as the primary goal of any water supply system:

"*The provision of good safe drinking water which has the trust of customers.*"

The conclusions from the workshop have been developed as a set of principles which strongly support the concept of a much more holistic, risk-based approach to managing quality using HACCP methodology in conjunction with a core set of conventional water quality standards.

Emerging discussions between water professionals are leading to the development of some very sophisticated technical approaches to maintaining the safety and quality of drinking water. However, water is a fundamental and basic need of human existence and thus it is a much more challenging task to ensure that the drinking water supply has the trust of customers. That is because when water customers take a view on the safety or otherwise of their drinking water their judgement is as likely to be based on emotional perceptions as it is on scientific fact. Water professionals ignore this emotional dimension at their peril. This paper therefore explores some of the broader issues connected with achieving the trust of customers in the safety of their drinking water. It is based on issues that arise in a wealthy European country, but while the customer perceptions of safety may vary between different countries it is believed that the broad concepts remain the same.

The management of water supply has always been an integrated task that requires both the quality and quantity of drinking water to be reliably maintained 24 hours a day, seven days a week. This is the minimum that customers expect, but in practice companies need to go a lot further to earn the trust of their customers in the water they supply.

If customers are asked what they want from their water supply it would be that it must:

1. be safe i.e. free from harmful bugs and chemicals;
2. taste and look good;
3. be continuously available at the right pressure; and
4. be affordable.

The problem for water companies is that the definition of "safe" from a customer perspective is very different to that which a technical expert might use. As scientists, it is normal to talk about quantitative risk assessment based on sophisticated analysis and modelling, but in the end it is recognised that science is never absolute. However, non-experts do not normally use such a rational approach.

This problem is reflected in other customer conscious industries such as food, as witnessed by the huge expansion in the range of organic foods (and indeed other products) that are now sold in supermarkets. Whilst scientifically there is little difference between the safety of organic products and any other equivalent products, public perception is such that people are willing to pay a premium for food that has been produced "naturally". This reinforces the view that sophisticated consumer orientated societies judge the safety of things using criteria that go beyond a rational scientific discussion of risks. Such judgements are often fuelled by media discussion that tends to paint issues in very black or white terminology. A product or a substance is either safe or it is not. There are no degrees of relative risk because customers increasingly demand the goal of absolutely safety in everything. The fact that this is scientifically impossible does not mean that we discount customer perception simply because it is based on emotional responses.

Even the very words that scientists use can cause concern. What to specialists may be normal everyday language, to non-experts becomes confusing and even worrying. This can particularly arise when trying to describe risk assessment for substances that can be measured at extremely low concentrations. Going beyond science into the realms of customer perception is a much more complex area which water professionals still need to do more to address. It is particularly important that we try to deal openly with questions relating to how we prove a negative. How can we demonstrate that modern treatment processes and other control techniques provide robust barriers against a whole range of micro contaminants, even if we cannot physically measure all of the many components that might be present in trace quantities? Happily the approach of using water safety plans and quality systems for managing drinking water quality may provide a substantial part of the answer.

The principles developed at the Bonn workshop identified a number of issues which are necessary to ensure that all stakeholders work together to provide water supplies which have the trust of customers.

The core principle is that water should be managed as an integral process from the raw water catchment through to the customer tap. This recognises that whilst water companies have a pivotal role to play, it is critical to ensure that other stakeholders are also involved. Reliable quality management therefore requires the establishment of effective institutional arrangements and clear definitions of the relative responsibilities for all stakeholders involved in the water supply process. This includes for example those that are responsible for managing water catchments and those providing advice and regulation relating to customer plumbing systems.

Whilst the Bonn workshop recognised the continuing importance of conventional "output control" monitoring against a relatively small number of statutory standards or operational values, it was also stressed that in parallel it is vitally important to introduce "input control" quality or HACCP systems aligned to the WHO Water Safety Plan concept.

One of the key benefits of adopting the HACCP approach is to be able to demonstrate the effectiveness of broad-spectrum treatment barriers against substances that we cannot easily measure. This principle of effective multi-barrier treatment has been well established in water supply operation for many years. The classic example is control of disinfection which, if undertaken properly, can give a high degree of certainty that no pathogenic bacteria or viruses will penetrate into the water supply system, even though such organisms are not individually assessed on a routine basis. Similarly the effectiveness of conventional clarification/filtration processes as measured by turbidity can give very effective demonstration of barriers against penetration of protozoal parasites.

In public health terms these barriers are absolutely essential and remain at the core of any reliable water supply system. However to achieve customer trust we also need to investigate whether a similar approach can be used in other areas of concern to customers such as trace organic compounds. This is where the benefit of broad-spectrum treatment processes such as advanced oxidation; absorption on activated carbon or perhaps in the future the use of selective membranes must play a part. Already research is showing that if such barriers are properly designed and operated then they can provide a very high degree of assurance against penetration of organic substances such as pesticides, algal toxins or endocrine disrupters. One of the challenges for water treatment scientists is to be able to demonstrate to customers that if such barriers are in place they can have confidence in the perceived as well as the actual safety of their water supply system.

However, in parallel with demonstrating that water is safe in terms of parameters of actual or perceived health concern it is also crucially important to understand the importance of providing water which is aesthetically acceptable. If customers do not like the taste or appearance of water how can they trust the things that they cannot detect? It is for this reason, that the delivery of water which is consistently pleasant to use is increasingly becoming the benchmark by which customers judge the overall quality of water supplied and thus the trust that they have in their supply system. For that reason proper programmes to maintain and clean distribution networks, and minimise the underlying factors which give rise to taste complaints are all critical.

Finally in dealing with the continuing challenge of reassuring our customers about the quality of tap water it is important not only to have in place the correct technical measures, but also to think differently about the way that we as water professionals communicate with customers. Scientists are often very poor at describing complex issues to people who are non-experts. We therefore need to think more about the words we use when we communicate. We should not be afraid to borrow approaches from the marketing world and learn from other industries such as food where customer perception of safety is equally important. We have to understand and address the customer's fear of the unknown. They are not technical experts so how do we persuade them that they can have trust in their water and who will they believe when we tell them it is safe? We must therefore learn how to address the emotional as well as the rational criteria that customers use when they judge our performance.

Customer confidence is very fragile; it can only be built over many years but can be lost almost overnight by one act of carelessness. Providing 21st century water supplies requires not only 21st century technology but also a different way of thinking.

Disclaimer

The views expressed in this paper are those of the author and are not necessarily those of Severn Trent Water.

ANNEX A

Presentation slides of Jamie Bartram, Remy Bastiment and Roslyn Vulcano

Slide 1

Dr Jamie Bartram

World Health Organization

Slide 2

Water Quality - A Health Concern World-wide

- Global burden of disease
- Outbreaks of disease
- Macro economic impacts
- Poverty and development links
- Cost-effective health interventions
- MDGs and the right to water

Slide 3

WHO Guideline for Drinking-water Quality (3rd edition)

1950's - 1970's: International Standards for Drinking-water Quality

1984: Guidelines for Drinking-water Quality, first edition

1993: Guidelines for Drinking-water Quality, second edition

1997/8/9: addenda to second edition

2003: Guidelines for Drinking-water Quality, third edition

Slide 4

WHO Guidelines for Drinking-water Quality

- Guidelines, not standards
- Basis for standards in developing and developed countries
- Best available evidence, expert consensus
- Science based with practical knowledge
- Health focus
- Microbial, chemical, radiological hazards
- All types of water 'supply'

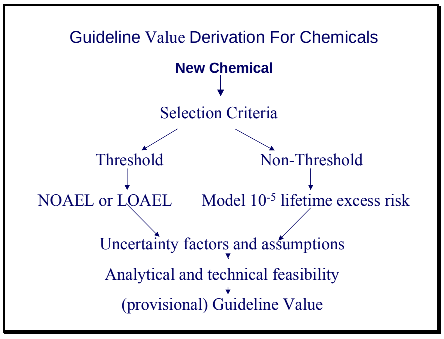
Slide 5

Microbial Aspects in GDWQ

Established approaches (1950s-1990s)

- Multiple barrier principle
- Source protection
- Treatment related to quality
- Faecal indicators and sanitary inspection

Slide 6



Slide 7

Guidelines for Drinking-water Quality

Major developments in third edition

- Improved process
- Management approach - *Safe Water Framework*

Slide 8

Why Water Safety Framework?

- Ongoing water-borne disease
- Outbreaks
- End-product testing: too late to act
- Systematising long-established principles
- Building on scientific and managerial developments
- Catchment to consumer

Slide 9

Safe Water Framework

Health-based targets

Water safety plans

- system assessment
- operational monitoring
- management plans

Independent surveillance

Slide 10

Health-based targets

From national public health authority
Quantitative public health benchmark
Different types for different situations and purposes

- specified technology
- specified performance targets
- water 'quality' targets
- health outcome targets

Slide 11

Water Safety Plans

1) **System assessment (catchment to consumer)**

Can the "system" deliver water meeting the health based targets?

- Identify hazards and threats
- Which steps prevent or reduce contamination?
- Do their combined efforts lead to water safety?
- Outcome defines system improvements

Slide 12

Water Safety Plans

1) System assessment

2) Operational monitoring

Monitoring control measures and ensure system consistently meets targets?

- monitoring at each step identified in system assessment
- different approaches (visual inspection, quality testing)
- frequency appropriate to step

Slide 13

Water Safety Plans

1) System assessment
2) Operational monitoring
3) Management plans

Documenting system assessment (including upgrading plans) and monitoring and describing management in normal and incident conditions including communication plans.

- procedures for routine management (SOPs)
- management procedures for emergencies and 'incidents'
- communication lines and information flow

Slide 14

Independent Surveillance

Systematic independent surveillance to verify the Water Safety Plan is operating properly.

Different approaches
- audit based
- direct investigation

Slide 15

Microbial Aspects in GDWQ

3rd Edition developments:
- Quantitative health-based target derivation
- Individual organism factor sheets

Supportive documents:
- pathogen risk assessments
- pathogen occurrence in source water
- groundwater assessment and management
- surface water assessment and management
- treatment effectiveness
- quality change in piped distribution
- household water quality management
- indicators (with OECD)

\+ emerging issues in water and infectious disease

Slide 16

Chemical Aspects in GDWQ

3rd edition developments:

- prioritising amongst many hazards
- rigorous assessment of need for GVs
- international peer reviewed documents
- integrated into WSP approach
- categorise chemicals by management
- detailed changes to GVs

Slide 1

technique

WATER SAFETY:
RISK MANAGEMENT STRATEGIES FOR DRINKING WATER

« Application of HACCP principles in drinking water
SAUR Experience »

Berlin April 28-30 2003

SAUR / Direction Technique / R. Bastiment / Berlin 28-30 April 2003 / Risk Management Strategies for Drinking Water

Slide 2

technique

IMPLEMENTATION OF HACCP IN DRINKING WATER CATCHMENT AND PRODUCTION

SAUR Group 's Approach and Definitions

DANGERS are :
physical, chemical et micro-biological agents potentially harmful to public health:

Agents listed as « Water quality standards and targets » by the French regulation

RISKS are :

Breach of set standards and limit targets

3 PHASES IMPLEMENTATION:

1) Identifying dangers / prioritise at every process stage
2) Identifying likelihood of occurrence at every stage
3) Setting monitoring and control procedures

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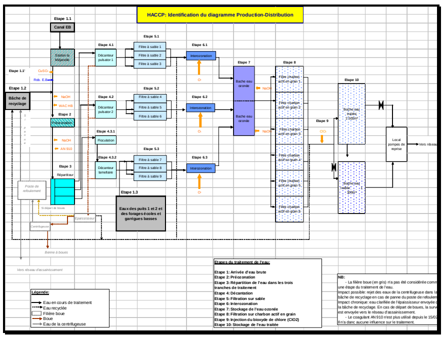
Slide 3



Slide 4

technique

IMPLEMENTATION PHASE 1

HACCP SPECIFIC TOOLS CREATED

➢ Guidance manual describing every agent in water potentially harmful

➢ Risk Factor Matrix: Rating **= S*O*D**

1) **S**everity rating of these agents consequences for public health
2) Likelihood of **O**ccurrence rating for every agent at every flowsheet stage
3) Rating of actual capability to **D**etect these agents

➢ Standard frame for risk factor rating

RESULTS PHASE 1

Major DANGERS are identified if Risk factor > 5

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EXAMPLE OF PESTICIDES

Risk Factor Rating

Paramètre	Etape de la production	Relation avec le risque sanitaire	Criticité du danger pour l'étape considérée				Cotation de la priorité du danger
			F	G	D	**IC**	Majeur si IC>5
Pesticides	1.1 et 1.2:	Directe	1	2	2	**4**	**Mineur**
Pesticides	1.3: Puits et forages	Directe	1	2	3	**6**	**Majeur**
Pesticides	2 à 7	Directe	1	2	2	**4**	**Mineur**
Pesticides	8 à 10	Directe	2	2	3	**12**	**Majeur**

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IMPLEMENTATION PHASE 2

AIM : Identify physical location where dangers must be kept under control

MEANS : Scrutinise every flowsheet stage influence on major dangers

TOOLS : - Rating of process stage efficacy
(Positive or negative influence guidance provided)
- Guidance manual describing potential causes of occurence
- Codex decision tree

RESULTS PHASE 2: Identification of CCPs
CCP = (microbiological, physical or chemical agent; location)

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EXAMPLE OF PESTICIDES

CCPs Identification

Etape de la production	Q1: Existe t-il un danger pour la sécurité sanitaire à cette étape ? Si OUI passer à Q2. Si NON passer à l'étape suivante	Q2: Des mesures préventives sont-elles prises pour le danger identifié? Si OUI passer à Q4. Si NON passer à Q3	Q3: La maîtrise à cette étape est-elle nécessaire à la sécurité sanitaire du produit? Si OUI prendre des mesures préventives sur l'étape, il y a PCC. Si NON passer au danger suivant ou à l'étape suivante	Q4: Cette étape élimine t-elle l'arrivée du danger à un niveau acceptable? Si OUI alors il y a PCC. Si NON passer à Q5	Q5: La contamination par le danger identifié peut-elle intervenir ou augmenter jusqu' à un niveau inacceptable? Si OUI passer à Q6. Si NON passer au danger suivant ou à l'étape suivante	Q6: Une étape suivante peut-elle éliminer le danger identifié ou réduire sa réalisation à un niveau acceptable? Si OUI passer au danger suivant ou à l'étape suivante. Si NON alors il y a PCC	Point de Contrôle Critique (ou PCC)
Pesticides							
1.1: Exhaure	Oui	Oui		Non	Oui	Oui	**Non**
1.3: Puits et forages	Oui	Oui		Non	Oui	Oui	**Non**
8: Filtration sur charbon actif en grain	Oui	Oui		Oui			**PCC**
9: Injection de bioxyde de chlore	Oui	Non	Non				**Non**
10: Stockage de l'eau traitée	Oui	Oui		Non	Non		**Non**

Slide 8

technique

IMPLEMENTATION PHASE 3

AIM: Ensure identified CCPs are kept under control

MEANS: Deviation detection and monitoring

TOOLS:
- Set adequate CCPs surveillance
- Set CCPs thresholds
- Predetermine actions to be undertaken when deviation

RESULTS PHASE 3:

- Close CCPs surveillance programme
- Immediate reactions plan
- Long term improvement action plan
- Information and record keeping
- Set adequate surveillance of other agents not the included in CCPs surveillance

Slide 9

technique

EXAMPLE OF PESTICIDES

CCPs Control Procedures

Etape	Mesures préventives			Limites critiques aux CCP	Surveillance des CCP			Actions correctives		Plan de pilotage existant exerçant une surveillance des CCP		
	En place	A améliorer	Proposition de solutions		Moyen de surveillance	Fréquence	Responsable	Nature	Responsable	Moyen de surveillance	Fréquence	Responsable
Pesticides												
8: Filtration sur charbon actif en grain (CAG)	périmètre de sécurité, biefs, possibilité de coupure de l'alimentation du canal, et analyse en EB et en ET tous les deux mois	Maitrise de la fréquence de renouvellement (IT n°43) . Maitrise de l'ozone nécessaire		valeur du décret 2001-1220, apparition de sous-produits, volume filtré, calcul de charge adsorbée	surveillance analytique et comptage	analyse de labo mensuelle et kit pesticides hebdomadaire en période de crise	chimiste de centre	Plan d'urgence (IT gestion des non conformités), investigation des causes de saturation, modification du planning de surveillance, renouvellement anticipé du CAG	chimiste de centre, responsable d'exploitation	voir IT n°43	voir IT n°43	chimiste de centre

Slide 10

EXAMPLE OF PESTICIDES

CCPs Control Procedures

RESULTS for CCP = (pesticides; GAC filtered water):

- Existing pesticides and by-products analysis by laboratory using standard methods (but time delay)
  ⇒ used as calibration for on site measurements

- Raw water and GAC filtered water monitoring (as, close as possible to continuous with telemetry)
  ⇒ GAC retention capacity evaluation
  ⇒ early regeneration
  ⇒ PAC injection when deviation from treshold

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Slide 11

IMPLEMENTATION OF HACCP IN DRINKING WATER CATCHMENT AND PRODUCTION

SAUR Group 's Experience

Order of magnitude for surface water treatment works and catchment:

◆ Nb of agents to be controled included in CCP:
15 to 20

◆ Nb of CCP as couple (agent; location):
20 to 30

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Slide 12

CONCLUSIONS

Water safety plans are powerful tools for SAUR to:

- Identify and minimise sanitary risks benefiting from SAUR 's Quality Assurance System
- Focus on weak areas of a catchment-production-distribution system
- Co-ordinate and liaise with the French health authorities

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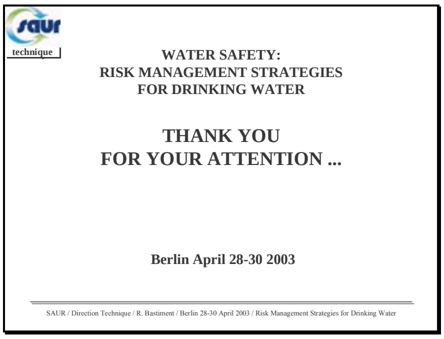
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WATER SAFETY:
RISK MANAGEMENT STRATEGIES
FOR DRINKING WATER
THANK YOU
FOR YOUR ATTENTION ...
Berlin April 28-30 2003
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Slide 1

SMALL AND MEDIUM WATER SUPPLIES IN THE NORTHERN TERRITORY AUSTRALIA

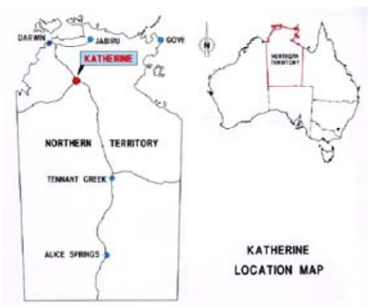
Roslyn Vulcano
Northern Territory, Australia

Slide 2

Why Small and Medium NT Water Supplies ?

- Northern Territory (1.3m km^2)
- Small to medium water supplies
  - Largest water supply in the NT serving population of approx. 100,000
  - Majority of NT community water supplies serve populations of 50 – 2,000
- Management generally focused on multiple barriers and compliance with bacteriological parameter guidelines

Slide 3



Slide 4

Trialing a System for Management of Drinking Water Safety - A learning opportunity

- Australia's Draft Framework for Management of Drinking Water Quality
- Encompassing the whole system
  - catchment to tap
- Applying HACCP principles

Slide 5

Katherine Water Supply

- Small community water supply
- Population 10,000
- Two sources of water
  - surface and ground water
- Treatment and blending of river and bore water
- Chlorination for disinfection and fluoridation for dental health
- Open surface water catchment - subject to tourism, mining and farming activities.

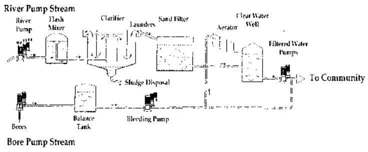
Slide 6

Trialing a "Water Safety" Framework

- Trial participants
  - water supplier
  - health regulator
  - water resource regulator
- Weekly meetings - "warts and all"
- Site visit & Simple flow diagrams – both proved invaluable tools to aid the understanding of the water supply system

Slide 7

HACCP principles
- a simple flow diagram



Slide 8

What the "Water Safety" Framework Highlighted

- Operational staff were very familiar with water supply system
- Documentation was not a strong point
- Analysis of data was inconsistent
- Different ideas of hazards and risks
- Regulatory issues outstanding between agencies

Slide 9

What the "Water Safety" Framework Highlighted
(continued)

- Integration with current management systems possible and necessary
- Responsibilities were not clear (internal and external)
- Communication channels were predominately informal
- More senior management support was required
- Consumer feedback has an important role to play in the delivery of quality drinking water

Slide 10

The Key Learning

- Water quality management is important in the delivery of drinking water
- Compliance is not the key objective of drinking water quality management
- Understanding the whole system and being pro-active is essential in the delivery of consistently good quality drinking water

Slide 11

Summary of a "Water Safety" Framework

- Encourages preventative rather than reactive management
- Interrelatedness of the framework elements encourages holistic management of the drinking water system
- Useful tool for increasing senior management awareness of water quality management issues

Slide 12

Summary of a "Water Safety" Framework

(continued)

- Provides a mechanism to progress outstanding issues between agencies
- Flexible and can be tailored to suit individual water supply systems
- Encourages an integrated approach to catchment management
- Useful for water suppliers and regulators

Slide 13

Conclusion

- Water Safety Plans can be an extremely effective tool for managing small & medium sized drinking water supplies from catchment to consumer.
- What is important is to START putting a water safety plan in place & not expect it to be perfect 1st time around - it should be a living plan.

ANNEX B

Report on workshop results and the concluding discussion

Results of the workshop discussions on Monday, 28th April

Delegates and speakers met for 1,5 hours in 5 working-groups to discuss basic aspects of how Water Safety Plans work and what their advantages are. The following points were reported back to the plenary:

Advantages emphasised in workshop discussions were:

- The structured approach provided by the WSP
- The support in setting priorities
- The WSP as a tool for better information about potential risks by regularly requiring that you "know your system" and document this.

Needs identified for developing WSPs in the workshop discussions were:

- Clarification of language and terminology: With respect to WSP and HACCP it became clearer that WSPs are based on HACCP principles, but follow a broader approach, using a larger number of CPs (control points) rather than single CCPs (critical control points) as in HACCP.
- Training and encouragement of staff: Strong emphasis was put on good communication with staff in utilities, enabling them to develop understanding of the concept, but also understanding their concerns, reasons for reacting with reservations, etc. This is particularly relevant to small supplies with less experience in e.g. documenting standard operating procedures. Guidance and training will be in high demand.

Prerequisites identified were a supportive environment, particularly at the institutional level and from senior management, political support and involvement of the public.

Questions proposed for further discussion and clarification were:

- What have water suppliers really changed in the way they do things through introducing HACCP/WSP-type approaches?
- Is there a need for harmonisation of the risk matrix (given in the new WHO guidelines, but also with a more quantitative scoring approach by others), or is there no problem with using different approaches, as long as they all help identify priorities for the respective supply system?
- Does the WSP/HACCP approach help in any way to cope with transboundary problems?
- Is any benefit recognised from WSP-certification, as compared to HACCP certification in the food industry?
- Which quality targets are appropriate?

"Getting started" is more important than perfection! This was a strongly perceived message, particularly for countries with more strongly limited resources. Discussions showed that it is important to convey WSPs as tool to help find problems and create transparency. By no means should they be communicated with an "accusing" connotation, i.e. for identifying negligence. Particularly in settings with well-developed awareness of inadequacies, WSP's can be used as tool to improve the situation, e.g. by identifying priorities. Many steps can indeed be performed on a rather simple level (and be sophisticated later on). The 80/20 rule was mentioned: 80 % of the benefit can often be achieved at only 20 % of the effort and investment.

Results of the workshop discussions on Tuesday, 29th April

Delegates and speakers met in 5 working-groups to discuss different aspects of implementation of the Water Safety Plan concept. The following points were reported back to the plenary:

1. Is there additional benefit of WSPs as compared to Good Practice in Water Supply?

This workshop clearly affirmed that additional benefits arise from implementing a WSP because

- it is a framework that provides a structure to organise risk-based management (which goes well beyond Good Practice);
- it supports multi-agency and multi-stakeholder involvement and communication, as it requires an approach from catchment to consumer, thus requiring inclusion of players outside the immediate remit of supply companies, e.g. other catchment users or plumbers;
- WSP's are of value on all levels up to senior management in demonstrating due diligence and justifying decisions;
- the improved system understanding through a WSP reduces uncertainty in decision-making;
- WSP's change the way of thinking ("change of mindset"), and this has more general impact on the culture of the organisation;
- having a WSP is positive for the reputation; and
- for small supplies, a WSP may be a resource, i.e. instrumental in using resources more efficiently.

2. Does the "Deutsches Regelwerk" cover all steps of a Water Safety Plan?

In Germany, drinking-water supply is highly regulated, not only through implementation of the EU-directive (as national Drinking-water Directive), but also as this states the requirement of applying a wide array of technical standards and specifications (including around 280 specifications developed by the German Association for Gas and Water – DVGW - for a wide range of individual aspects of water supply, structured in a system termed "Technical Safety Management", i.e. TSM). This raised the question whether any new, additional approach could be of any use.

The workshop initially found it difficult to compare the German regulatory framework to the WSP/HACCP approach, as the approaches presented by the different speakers varied and reflected different understandings of WSP / HACCP. However, the following benefits were identified:

- Having a WSP "covers your back" for decisions in the utility, as it demonstrates due diligence and makes transparent the reasons behind decisions.
- WSPs are a way to reach out beyond the remit of the supplier and improve interlinking with catchment management and household installations, thus

including other players (e.g. government) in system assessment and priority-setting.

- This discussion revealed a need for better clarification of who should set up and initiate HACCP-type systems such as a WSP – the public authority or the utility?
- A need for honesty in assessing systems was noted as crucial basis (see the Monday workshop report about the purpose of WSPs not being to accuse, but rather to identify priorities for improvement).
- The workshop reached a consensus that the German TSM could easily be developed to incorporate the WSP approach, as it currently does not make transparent the assessments leading to decisions, as it does not cover hazard analysis and does not explicitly identify control points.

3. Are there special requirements for the development of Water Safety Plans for small systems?

The workshop defined "small systems" as those with little or thinly-spread expertise, therefore requiring outside assistance to develop a WSP.

- It was agreed that the basic principles of WSPs apply to small as well as large supplies, but the levels of approach are different.
- Assistance must be aimed at putting in place a framework that allows small communities / supplies to operate the system **themselves**, and thus actually **use** the WSP.
- Outside assistance must aim at developing ownership. This requires developing capacity locally for preparing and implementing the WSP in order to reach the motivation that is so critical for acceptance.

4. How can the HACCP /WSP approach be made sufficiently flexible for application in developing countries?

The workshop discussed the specific aspects of implementation in what was termed "scarcity-based economies". Points raised are:

- Capacity building, legal, institutional and policy changes are needed.
- For donor funding of water supply projects, setting up a WSP could be made part of the program or even a prerequisite for funding in order to achieve more risk-based (rather than high-tech investment based) approaches.
- Political will is essential, and international advocacy is seen as instrumental in developing political will.
- The socio-economic and ecological background needs to be taken into account when developing the WSP.
- A need for a "cost-tag" was strongly perceived with respect to targets: e.g. achieving a lower standard for arsenic would require a certain amount of investment, i.e. have a price. This needs to be assessed in relation to other targets, and priorities have to be set. The costs involved with achieving targets need to be understood for this process.

- The need for improving public access to scientific information regarding health hazards from unsafe water was highlighted as an important point. A handicap for setting health-based targets locally is often the lack of understanding of the hazards which are present.

5. Is quantitative microbial risk assessment (QMRA) a necessary basis for Water Safety Plans?

The workshop was led by a group currently studying QMRA in the context of an ongoing EU-funded research network. Points reported to the plenary were:

- QMRA could change a WSP by identifying priorities not perceived as such previously.
- Therefore, QMRA is a tool to use for analysing a WSP and for updating it.
- If no specific local data are available, general scientific knowledge can be applied. Thus, QMRA can be used in setting up a WSP for supplies that would not have the financial capacity to conduct their own QMRA.
- QMRA has the benefit of preventing “over-design” of utilities by providing a sound scientific basis for the assessment of the type of treatment needed. It can also help find a balance between microbial risks, chemical risks, and costs for their reduction.

Conference outcomes, conclusions and suggestions for further discussion

The conference showed widespread interest in the new approach of using a Water Safety Plan and HACCP elements, as proposed by the new WHO Guidelines for Drinking-water Quality. This focus on the specific supply system from catchment to consumer, on prevention, and on process control was seen as a tool for improving public health protection, use of resources and asset management.

The conference was only the beginning of the necessary process of widespread discussion of this approach. To carry this approach forward, the following needs were identified:

- To document the outcome of this meeting.
- To share existing experience in more depth, i.e. understanding what water supplies using a WSP or other HACCP elements now do differently than before, and understanding the approaches to these tools taken in different countries in more depth and detail.
- To develop and make available practical tools and guidance, e.g. for training courses.
- To continue and improve networking and dissemination, for example through a web network and collaboration within e.g. IWA.

The concluding discussion looked at how these needs could be met and developed the following suggestions:

1. The information presented at this conference would be quickly and informally made available to participants through a CD distributed by mail with the presentations of the speakers, and only a few weeks later through a volume of extended abstracts of the contributions also mailed to participants.
2. In-depth evaluation of existing experience with the WSP / HACCP approach in drinking-water would be desirable with respect to similarities and differences in approaches taken and reasons for them.
3. A strong demand for a specific focus on applying Water Safety Plans in "scarcety based economies" was expressed to share experience with system assessment, control measures and management that have proven effective under such conditions. Potentially, targeted meetings can be organised back to back with the WEDC conferences.
4. A pronounced need was recognised for national and local discussions of the new approach, and for its adaptation to local and regional settings. This was seen as something each delegate would largely initiate on his or her own, but support through materials and potentially through guest speakers would be desirable. For the latter, the conference address list provides the beginning of a network. Materials and documentation from other countries would be helpful, and a number of files as well as references to printed material are provided on this CD.
5. In-depth guidance material is needed for those aiming to develop Water Safety Plans. This involves "instruction materials" for training courses on how to perform hazard analysis, risk ranking, identification of control measures and systems for their monitoring, verification and validations. For this purpose, some material provided from Melbourne Water is available on this CD. It would be desirable to establish a web site for such materials. WHO and UBA will explore options for this.

6. Further development of methods for risk ranking and Quantitative Microbial Risk Assessment was considered desirable. Currently, the EU-Project led by Gertjan Medema is moving this ahead (see presentation on this CD).
7. The discussion of whether or not a need exists for regular international Water Safety Plan Conferences (in analogy to food HACCP conferences) led to the conclusion that at this point in the development, WSP could be a focus at a regular international drinking-water conference, e.g. the IWA meetings.

ANNEX C

Conference programme

Monday, 28 April 2003		**Speakers**
08:30 – 09:30	***Greeting and registration***	
09:30 – 09:50	***Opening***	
	Federal Environmental Agency	Thomas Holzmann
	Federal Ministry of Health and Social Security	Klaus Theo Schröder
9:50 – 10:00	Introduction into scope and structure of the conference	Ingrid Chorus
	Drinking-water targets for public health	
10:00 – 10:20	The third edition of WHO's Guidelines for Drinking-water Quality (2003)	Jamie Bartram
10:20 – 10:40	Drinking water quality – what and how?	Michael Rouse
10:40 – 11:00	Is there a need for better drinking-water quality management?	Martin Exner and Thomas Kistemann
11:00 – 11:15	Discussion	
11:15 – 11:45	*Coffee break*	
	Water Safety Plans: HACCP principles for safe drinking water	
11:45 – 12:15	HACCP: a successful quality management system in the food industry	Lüppo Ellerbroek
12:15 – 12:45	Water Safety Plan: the WHO approach	Melita Stevens
12:45 – 13:00	Discussion	
13:00 – 14:15	*Lunch break*	
	Experiences with the application of HACCP principles in drinking water	
14:15 – 14:35	Melbourne Water: implementation from catchment to consumer	Kevin Hellier
14:35 – 14:55	Integrating HACCP principles into environmental risk management frameworks	Daniel Deere
14:55 – 15:15 15:15 – 15:35 15:35 – 15:55	Application of HACCP principles in drinking water: the French experience	Sylvie Metge Remy Bastiment Jean-Claude Joret
15:55 – 16:10	Discussion	
16:15 – 17:45	***Coffee workshops I*** Moderated groups on different topics. Experts of sessions above available for questions and invitation for short presentations of participants.	

Tuesday, 29 April 2003		**Speakers**
09:00 – 09:15	Summary of day 1	
	Experiences with the application of HACCP principles in drinking water (continued)	
09:15 – 09:35	*United Utilities Water*: adoption of HACCP principles for water safety with particular reference to Cryptosporidium	Alan Godfree
09:35 – 09:55	*Industrielle Werke Basel*: realisation of specific HACCP principles	Richard Wülser
09:55 – 10:15	Application of the HACCP principles in the *Water Supply Zurich*	Ulrich Bosshart
10:15 – 10:30	Discussion	
10:30 – 11:00	*Coffee break*	
	Applications of Water Safety Plans in small systems and developing countries	
11:00 – 11:20	Development of Water Safety Plans for urban utility water supplies in Uganda	Guy Howard
11:20 – 11:40	Small and medium sized water supplies in the Northern Territory	Roslyn Vulcano
11:40 – 12:00	The Thailand Safe Tap Water Certification Programme	Theechat Boonyakarnkul
12:00 – 12:15	Discussion	
12:15 – 13:30	*Lunch break*	
	HACCP in relation to further approaches for quality management systems in drinking water	
13:30 – 13:50	How does HACCP integrate into modern quality management systems utilised in water supplies?	Walter Girsberger
13:50 – 14:10	Principles of the German drinking water sector	Hans Mehlhorn und Mathias Weiß
14:10 – 14:30	The Technical Safety Management of the DVGW as a tool for quality management systems for drinking water supply in Germany	Horst Schlicht
14:30 – 14:50	Towards public health risk management plan implementation in New Zealand	Chris Nokes
14:50 – 15:10	Interaction between risk assessment and risk management	Gertjan Medema
15:10 – 15:40	*Coffee break*	
	Specific aspects of quality assurance	
15:40 – 16:00	Assuring the microbial safety of drinking water	Mark LeChevalier
16:00 – 16:20	Quality assurance in distribution systems	Katherine Martel
16:20 – 16:40	Quality assurance in Berlin's unchlorinated distribution system	Dietmar Petersohn
16:40 – 16:55	Discussion	
17:00 – 18:15	***Coffee workshops II*** Moderated groups on different topics. Experts of sessions above available for questions and invitation for short presentations of participants.	

Wednesday, 30 April 2003		**Speakers**
09:00 – 09:15	Summary of day 2	
	Assessing risks for chemicals	
09:15 – 09:35	Can HACCP principles be applied to chemicals in drinking water?	John Fawell
09:35 – 09:55	Chemicals in drinking water - assessing priorities for risk management	Han Heijnen
09:55 – 10:15	Arsenic and fluoride in drinking-water	Kumar Jyoti Nath
10:15 – 10: 30	Discussion	
10:30 – 11:00	*Coffee break*	
	Implications for regulation and surveillance	
11:00 – 11:20	Quality management recommendations from the Walkerton Inquiry	Steve Hrudey
11:20 – 11:40	Experiences and assessment: viewpoint of Swiss' public health authorities	Hans Sepp Walker
11:40 – 12:00	Application of the Australian risk management framework: a public health authorities' perspective	David Cunliffe
12:00 – 12:20	Drinking-water inspection in Ghana	Nii Kotei
12:20 – 13:30	*Lunch break*	
13:30 – 13:50	Assessment of the suggested risk management strategies for drinking water hygiene in Baden-Württemberg	Doris Waschko
13:50 – 14:10	The EU Drinking Water Directive - past, present and future	Pierre Hecq
14:10 – 14:25	Discussion	
14:25 – 14:45	***Does the customer believe it is safe?***	Bob Breach
14:45 – 15:45	***Concluding plenary discussion***	

ANNEX D

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