WATER TRANSFORMED: SUSTAINABLE WATER SOLUTIONS FOR CLIMATE CHANGE ADAPTATION

MODULE C: INTEGRATED WATER RESOURCE PLANNING AND MANAGEMENT

This online textbook provides free access to a comprehensive education and training package that brings together the knowledge of how countries, specifically Australia, can adapt to climate change. This resource has been developed through support from the Federal Government’s Department of Climate Change’s Climate Change Adaptation Professional Skills program.

CHAPTER 5: INTEGRATED WATER RESOURCE PLANNING IN A CHANGING CLIMATE - WATER SUPPLY AND DEMAND MANAGEMENT

LECTURE 5.3: PROTECTING EXISTING SUPPLY – PREVENTING AND ADDRESSING WATER POLLUTION.
Acknowledgements

The Work was produced by The Natural Edge Project supported by funding from the Australian Government Department of Climate Change under its ‘Climate Change Adaptation Skills for Professionals Program’. The development of this publication has been supported by the contribution of non-salary on-costs and administrative support by the Griffith University Urban Research Program, under the supervision of Professor Brendan Gleeson, and the Australian National University Fenner School of Environment and Society and Engineering Department, under the supervision of Professor Stephen Dovers.

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**Lecture 5.3: Source Protection - Protecting Existing Supply – Preventing and Addressing Water Pollution.**

**Educational Aim**

The aim of this lecture is to show how to manage the risks from climate change to water quality. Water quality is a major issue affecting the health of populations, the health of the environment and the livelihoods of other water users such as farmers and industry. This lecture will look at the major risks to water quality from climate change and overviews strategies to prevent water pollution and contamination. This lecture provides an overview of the tools available and is supported by extensive detailed further reading resources.

**Key Learning Points**

1. Changes in the quantity and timing of surface water runoff can be expected as a result of climate change. Most models point to the dry tropical and mid-latitude regions experiencing reduced runoff. With the added complication of water pollution, such reductions in precipitation and runoff will impact significantly upon the security, quantity and quality of water. Addressing these issues is critical. Moderate to high water shortages are already impacting one third of the world’s population. For instance, in Bangladesh and India millions of people are drinking water contaminated with arsenic. This is even true of very wealthy countries like the USA where lax efforts by regulators over the last 8 years have resulted in millions drinking contaminated water in many states of the USA.  

2. Climate change is also expected to lead to higher intensity of rainfall events and greater risks of intense flooding events in the tropics and sub-tropics. Higher rainfall patterns over the catchment can also negatively affect the quality of water flowing into supplies. Not only can unusually heavy rainfalls flush pollutants from catchment areas into reservoirs, water quality in these storages can be further compromised through the mixing of water and microbe-laden sediment. This can pose significant health risks.

3. Studies show that climate change will also affect water quality by creating conditions favourable to increasingly frequent and lasting toxic algal blooms. Not only do these directly threaten human water supplies, they pose a very real threat to marine resources and livestock. Finally, climate change can also negatively affect the quality of water supplies through the increased risk and intensity of bushfires. Bushfires burn vegetation, producing silt and ash that can contaminate water. Bushfires also enable greater levels of soil erosion, which can then lead to degradation of dam water quality, as was the case with the 2003

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Canberra bushfires. The silt and ash of the surrounding forests made the dam water turbid, so Canberra’s water supply was adversely affected. Melbourne\(^4\), Sydney\(^5\), Canberra, Brisbane, and Perth’s water catchments are largely surrounded by national parks which are vulnerable to bushfires.

4. If drinking or bathing water supplies become contaminated with microorganisms or toxic chemicals, illness can result. Disease causing micro-organisms carried by water are a significant threat to health, causing gastrointestinal infection, diarrhoea or even death. People can become ill after drinking contaminated water just once. Failure to provide safe drinking water can have catastrophic impacts on a community or city. The preventative and proactive identification and management of threats to drinking water quality is clearly articulated in the *Australian Drinking Water Guidelines*. This is achieved through a systematic analysis of risks from source to consumer, together with a likelihood and impact assessment for each identified risk.

5. Major hazards to water quality that can affect human health include a number of organisms, chemical and radioactive substances. This include the following:

- Microorganisms in human and animal faeces are responsible for most waterborne diseases. Diarrhoea associated with dysentery, hepatitis, cholera and other water borne diseases is a major cause of illness and death in many parts of the world. As Sydney’s ‘water crisis’ of 1998 highlighted, the developed world is not immune to the threat posed to potable water supplies by parasites. Cryptosporidium\(^6\) and Giardia, the issue for Sydney in 1998, are single cell parasites known as protozoans. They are not only prevalent in surface water, they are also resilient, and as such pose a significant challenge for the water supply industry.

- Blue-green algae - While exposure to the toxins produced by blue-green algae (cyanobacteria) may cause reactions as mild as a skin rash, serious liver and nerve damage can also result. As a further complication, cyanobacterial toxins can persist in water supplies after removal of the bacteria. Special treatment is required to remove the toxins from water contaminated by blue-green algae.\(^7\)

- Chemical contaminants - Agriculture, industry, household activities and runoff from roads can contaminate water with chemicals such as nitrates, pesticides, fertilisers, heavy metals, solvents and volatile organic compounds, such as petroleum products. Health effects from potentially harmful chemical and radioactive contaminants in drinking water tend to only become evident after long exposure (typically many years).

- Radioactive contaminants - The health effect most strongly associated with radioactive contaminants is cancer.

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6. Water quality is kept to safe levels through a combination of protection and treatment. No single intervention is sufficient to deliver safe, high quality drinking water to consumers. Water treatment plants alone are not considered to be sufficient to ensure absolute protection. Treatment systems fail for many reasons. Recent examples include a fluoride overdose due to combination of plant failure and human errors in Brisbane\(^8\), the death of seven persons at Walkerton, Canada due to contamination of the water supply from animal manure combined with plant failure and human error\(^9\) and the 1998 Sydney incident where a boil water notice was issued on three occasions for the whole city resulting in estimated direct cost to the water corporation of $30M.\(^{10}\) In Victoria in 1987 approximately 6,000 persons in Sunbury were affected by an outbreak of gastroenteritis due to contaminated water from a surface water supply directly affected by livestock.\(^{11}\)

7. To ensure water quality and reduce the risk of failure The Australian Drinking Water Guidelines 2004 (ADWG)\(^{12}\) require water authorities to implement a multiple barrier approach and monitor and evaluate the performance of each barrier. In theory, this ensures that if one barrier fails, the others will ensure that water quality standards are still maintained. The barriers usually used include source and reservoir protection, disinfection and treatment, and protection and maintenance of the water distribution system.

8. **Source Protection – Protecting Water Quality in Water Catchments:**

The condition of the catchment is critical.\(^{13}\) It not only determines the quality of water that feeds into the system, but the level of treatment required to make it potable. Clearly, water which originates from an undisturbed natural catchment will require significantly less treatment than water which originates from watch catchments which have heavy industry or agriculture. The **Australian Drinking Water Guidelines** provide guidelines for the management of water catchments, the first barrier for water quality protection. It urges water authorities and relevant stakeholders to protect source water from pollution as much as possible. The quality of water available to any water supply system is obviously dependent on activities performed in the water catchment. Water authorities have a statutory and moral obligation to take every precaution to provide safe drinking water. In Victoria the Safe Drinking Water Act 2003 (SDWA) places a statutory obligation on water authorities to identify risks and have a risk management plan in place that extends from catchment to tap. But there are limits to what water authorities can do, given that regional and local governments and planning authorities also have jurisdiction over what activities are approved to be performed in water catchments. Land use planning controls, which exist in every state and territory of Australia, provide a mechanism whereby new or proposed activities on land within a catchment area or aquifer intake area can be managed with a focus on water quality protection.

9. **Resting Water in Reservoirs –** Water running off the catchment area is stored in protected reservoirs before being drawn off for treatment and distribution. Storing water in reservoirs

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\(^{10}\) Ibid p351-352

\(^{11}\) Ibid p 186-187


(from 1 month to several years) delivers several key benefits. Not only does natural UV radiation act to destroy numerous micro-organisms, but over time contaminants also settle out of the water and predators consume remaining microbes. Furthermore, being able to draw off from various levels helps to ensure that water of the highest quality is sent for treatment.

10. Treating the water: Numerous options exist for treating water. While treatment usually focuses on eliminating sediment and contaminants, and on disinfection, options also exists to alter the water’s taste, colour and smell. The factors that determine which option is employed include water source, contaminants present, and an assessment of the savings from disease prevention compared to treatment costs. Australian water authorities generally employ a combination of flocculation, sedimentation, coagulation, filtration and disinfection to achieve water of potable quality. The most important element of water treatment is disinfection, as it inactivates micro-organisms. It is usually the final step in the treatment process, as the cleaner the water, the more effective the disinfection. While some authorities use chlorine dioxide, ozone or UV irradiation, chlorine and chloramine are most commonly used in Australia. Each of these methods has advantages and disadvantages. However, while some of the by-products of disinfection can pose health risks in the longer term, these are outweighed by very real immediate term risks of not disinfecting drinking water. The regrowth of micro-organisms in the distribution system is prevented by maintaining a level of residual disinfectant within the system.

11. Water Quality Monitoring and Reporting: Water authorities undertake regular quality and safety monitoring to ensure their treatment and protection regimes are effective. However, as screening for specific or indicator micro-organisms provides only a limited view of treatment effectiveness, other secondary indicators are monitored for that can point to underlying issues. These secondary indicators include colour, pH, E.Coli counts, disinfectant residuals and turbidity (cloudiness). Best practice guidelines exist to assist improve efforts in water quality monitoring and reporting.14 (See Further Reading)

**Brief Background Reading**

As explained in the key learning points, climate change will increase the risks of poor water quality in numerous ways. As the key learning points explained the major ways climate change will negatively influence the risks of poor water quality are as follows:

- Changing the quantity and timing of surface water runoff. Water supply quality can be affected by increased rainfall over catchments. Not only can unusually heavy rainfalls flush pollutants from catchment areas into reservoirs, water quality in these storages can be further compromised through the mixing of water and microbe-laden sediment. This can pose significant health risks.15
- Creating conditions favourable to increasingly frequent and lasting toxic algal blooms.
- Increasing the risk of major bushfires and their associated degradation of the quality of dam water, e.g. the 2003 Canberra bushfires.

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In addition, climate change is predicted to lead to reduced rainfall in many areas of the world, hence it is even more imperative that we ensure that the remaining water remains free of pollution. Preventing water pollution is already a major concern into which significant resources are being invested. If drinking or bathing water becomes contaminated with microorganisms, or toxic chemicals, illness can result. Disease causing micro-organisms carried by water are a significant threat to health, causing gastrointestinal infection, diarrhoea or even death.

Whilst there is consensus globally on the need to prevent water pollution and improve water quality, one of the biggest barriers to enabling that to happen is the perception that the measures needed cost too much. But as the following shows the costs of inaction are huge compared to action on reducing water pollution and improving water quality.

**Costs of Inaction versus Action on Reducing Water Pollution and Improving Water Quality**

A range of expert institutions now warn that water scarcity and water stress could increase from 1 billion to affect over 3 billion people by 2030 partly due to climate change.\(^{16}\) In 2004, 17% of the world’s population did not have reasonable access to a non-contaminated water supply and 41% lacked access to basic sanitation and sewage treatment. This situation is forecast by the OECD to worsen with population growth. By 2030, the OECD predicts that more than 5 billion people (67% of the world population) are expected to be without a connection to public sewerage if no further action is taken over the coming decades. A 2007 scorecard showed the Millennium Development’s 2015 sanitation goal of halving the numbers of people without access to clean water was likely to be missed by 600 million people worldwide on current trends. Already levels of unsafe water sanitation and hygiene are causing 3% of all deaths and 4.4% of all disability-adjusted life years (DALYs) around the world.\(^{17}\) Virtually all of these deaths and DALYs occur in developing countries; with 9 out of 10 of those dying being children. Indeed, unsafe water is the world’s biggest cause of child mortality. As a result, in non-OECD countries, the costs of inaction with respect to water pollution and unsafe water quality are particularly acute. In addition to the direct health impacts, the resources (time and money) devoted to obtaining safe drinking water can have appreciable positive impacts on employment opportunities and schooling. Achieving the MDG of halving the population without access to water and sanitation by 2015 is expected to cost about US $10 billion per year. The economic multiplier benefits from investing in water sanitation in the developing world are huge. This new capability has resulted in a new report, *Investing in environmental wealth for poverty reduction*,\(^{18}\) by the late UK environmental economist David Pearce. This report finds that rates of return on investments in environmental assets, in increasing access to water supply and sanitation for example, can yield very high rates of return, with benefit-to-cost ratios in the range of 4:1 to 14:1.

\(^{16}\) OECD (2008) *OECD Environmental Outlook to 2030*. OECD. Available At [http://www.oecd.org/document/20/0,3343,en_2649_37465_39676628_1_1_1_37465,00.html](http://www.oecd.org/document/20/0,3343,en_2649_37465_39676628_1_1_1_37465,00.html) Accessed 21 April 2010


\(^{18}\) Pearce, D. (2005) *Investing in environmental wealth for poverty reduction*, prepared on behalf of the Poverty-Environment Partnership: UNDP, UNEP, IUCN, IIIES, World Resources Institute. These are among some of the findings from *Investing in Environmental Wealth for Poverty Reduction*, prepared on behalf of the Poverty-Environment Partnership (PEP) for the 2005 World Summit that was held at the headquarters of the United Nations in New York. One of the Summit’s aims was to review the status of the Millennium Development Goals (MDGs) covering poverty eradication and the provision of safe and sufficient supplies of drinking water up to the reversal of the spread of diseases and the empowerment of women. Launched in 2000, these internationally agreed goals are set to be met by 2015. The partnership, which includes the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), organisations such as IUCN - the World Conservation Union - and government agencies, are planning how the environment can be mainstreamed in national poverty reduction strategies in order to better achieve the Goals.
Even in OECD countries, the number of disease outbreaks and droughts reported in the last decade demonstrates that, despite substantial advances in recent years, access to safe drinking water and ensuring water availability are major challenges.\textsuperscript{19} In Australia and Asia declining water availability and water stress are already significant issues and likely to become more acute due to climate change this century as outlined in Chapter 1 and in the introduction to this chapter. Whilst OECD water quality and safety is significantly better than the water quality in most developing countries outbreaks of disease have occurred in many OECD countries in the last couple of decades. In 1993, a major outbreak of gastro-intestinal illness caused by a parasite commonly harboured by cattle, cryptosporidium, was reported in Milwaukee, the largest city in the US state of Wisconsin. Some 400,000 residents were infected, and it caused more than 60 deaths. Cost estimates for this outbreak alone exceeded $54 million. The outbreak occurred in water that met guidelines for traditional indicators of microbial contamination. It revealed the vulnerability of OECD urban water systems. For OECD countries, the Milwaukee outbreak underscored the severe consequences of waterborne diseases. More recent outbreaks have involved E. coli O157:H7. In spring 2000 in Walkerton, Ontario (Canada), one such outbreak resulted in over 2,300 cases of infection and six deaths. There was probably a mix of reasons for the outbreaks: the discharge of greater quantities of wastewater, the ageing of water treatment infrastructure, inadequate treatment, and the increasing occurrence, or perhaps the increasing recognition and detection, of organisms resistant to conventional disinfection. Contamination of water distribution systems can be caused via cross-connections, back-siphonage, corrosion, or construction and repairs of the distribution system. Waterborne epidemics can also be caused by contaminated groundwater. This was probably the case in Sweden when from 1980 to 1999, 116 outbreaks of waterborne diseases were reported, affecting about 58,000 people. And between 1991 and 2000, 41 outbreaks were reported in the UK, with more than 3,768 reported cases of illness. Most of these outbreaks were due to campylobacter and cryptosporidium, an emerging pathogen that many water supply systems struggle to cope with. Even if no illness is detected the perception that the water supply system is not safe can destroy a community’s trust in its water supplier. This can take years to restore. The economic costs to the community and to the utility (in both financial terms and use of internal resources that could have been better utilised elsewhere) will be very large.

Investment to improve water quality by effectively removing water pollutants is economically efficient. The studies reviewed by OECD’s reports\textsuperscript{20} show that national measures to reduce agricultural runoff and storm water management – including introducing targeted measures to reduce a variety of different pollutants such as arsenic and nitrates could result in health benefits costed to be in excess of US$100 million for large OECD economies. Recreational water quality improvements through sewage treatment in France, Portugal, the US and the UK, and drinking water quality improvements in the US, show that health benefits of drinking water quality and sewage treatment often outweigh the costs of policy implementation.\textsuperscript{21} A 2006 US Environmental Protection Agency study calculating the annual cost of the Long Term 2 Enhanced Surface Water Treatment Rule to improve drinking water quality found that the policy cost between US$93 and 113 million to implement.\textsuperscript{22} However the US EPA also found that such investment was more than

\textsuperscript{22} US EPA (2006) National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water
justified from an economic efficiency perspective since the annual health benefits range from US$177 million to US$2.8 billion. Georgiou et al.\(^{23}\) showed a similar cost benefit result for the UK’s compliance with EU Bathing Water Directive.

**Table 5.3.1 Health Effects Associated with Selected Water Pollutants**

<table>
<thead>
<tr>
<th>Disease/Pollutant</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bacterial</strong></td>
<td></td>
</tr>
<tr>
<td>Amoebic dysentery</td>
<td>Abdominal pain, diarrhoea, dysentery.</td>
</tr>
<tr>
<td>Campylobacteriosis</td>
<td>Acute diarrhoea</td>
</tr>
<tr>
<td>Cholera</td>
<td>Sudden diarrhoea, vomiting. Can be fatal if untreated.</td>
</tr>
<tr>
<td>Cryptosporidosis</td>
<td>Stomach cramps, nausea, dehydration, headaches. Can be fatal for vulnerable populations.</td>
</tr>
<tr>
<td><strong>Chemical/Heavy Metal.</strong></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>Impairs development of nervous system in children; adverse effects on gestational age and foetal weight; blood pressure.</td>
</tr>
<tr>
<td>Arsenic</td>
<td>Carcinogenic (skin and internal cancers)</td>
</tr>
<tr>
<td>Nitrates and nitrites</td>
<td>Methaemoglobinaemia (blue baby syndrome)</td>
</tr>
<tr>
<td>Mercury</td>
<td>Mercury and cyclodienes are known to induce higher incidences of kidney damage, some irreversible.</td>
</tr>
<tr>
<td>Persistent organic pollutants</td>
<td>These chemicals can accumulate in fish and cause serious damage to human health. Where pesticides are used on a large scale, groundwater gets contaminated and this leads to the chemical contamination of drinking water</td>
</tr>
</tbody>
</table>

(Source, OECD\(^{24}\), 2008)

**Overview of an Action Plan to Reduce Water Pollution and Ensure Water Quality**

There is a high degree of confidence in the quality of water supplies in Australia. Members of the public expect that at all times their tap water will be of the highest quality. It is therefore not surprising that any suggestion of drinking water contamination is met with intense media scrutiny and public indignation. Water supply authorities are responsible for providing safe drinking water. This can be challenging for authorities, as frequently they are drawing water from catchments they do not manage. Also, with water production being a continuous process, water authorities are not able to simply recall their product should a quality or safety issue arise.

This emphasises the urgency of reviewing the effectiveness and reliability of methods, management approaches, and technologies for guaranteeing the safety of drinking water. The World Health Organisation and OECD have produced a guidance document as a basis for risk analysis.

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\(^{24}\) OECD (2008) *OECD Environmental Outlook to 2030*. OECD. Available At [http://www.oecd.org/document/20/0,3343,en_2649_37465_39676628_1_1_1_37465,00.html](http://www.oecd.org/document/20/0,3343,en_2649_37465_39676628_1_1_1_37465,00.html) Accessed 21 April 2010
management decisions at every point in the system.  

The aim is to control each treatment step so as to prevent contaminants from reaching the consumer. Consideration is also given to tolerable risk, water-quality targets, public health status, and education. Thus, risk management can no longer be confined to a single organisation or agency; national, regional and local governments, water authorities, water supply agencies, and public health authorities all play a role. This creates significant challenges for co-ordination as well as production of useful and compatible data since each of these stakeholders has specific responsibilities and information needs. A similar set of guidelines has been created for Australia in The Australian Drinking Water Guidelines.

These guidelines point out that the greatest risk posed to drinking water quality, and by extension public health, is posed by pathogens. Given the profound consequences of a pathogenic contamination of drinking water, public health must be the highest priority for water authorities. A key component in the provision of safe drinking water is the use of multiple barriers. A system of multiple barriers can tolerate some degree of failure without compromising water quality. Early detection of the failure of a barrier, and procedures to rectify the problem as soon as possible, are essential components of the system. Contamination of the final product is likely to only result when multiple barriers have failed and not been detected, or when the significance of the contaminant has not been appreciated. But systems of barriers are not enough, detection techniques also have to be improved. Molecular methods are making a significant contribution by increasing the chances of detecting a pathogen from an implicated source of drinking water, particularly in the case of viruses with no readily available or rapid method of culture. These include the likes of rotaviruses, astroviruses, caliciviruses, and the hepatitis A virus. Traditional methods for detecting viruses are based on tissue-culture techniques that can take several weeks. Thanks to rapid advances in molecular methods through advances in nano-technology and biotechnological research of the last few years, a wide range of new genetic (nucleic-acid-based) and immunological tools are now available and some molecular techniques appear particularly promising. They can offer faster, more sensitive and specific ways of detecting micro-organisms. For example, genotyping, or molecular characterisation, is a powerful new tool for identifying the source of microbial contaminants and is already in routine use for detecting Cryptosporidium in some OECD countries. Other nano-technological options for the monitoring of water quality include biosensors.

Clearly, establishing a system of multiple barriers to contamination, together with the continual development and refinement of measurement and surveillance techniques, is central to managing a safe system of water supply. However, as with any system, the quality of the inputs is directly related to the quality of the outputs. The first barrier in such a safe water system is the protection of source water.

Routine testing for all water borne hazards is impossible, as there are so many. For example, in Australia there are in excess of 50,000 industrial chemicals used, not to mention those used in the ever more competitive horticultural sector. This makes the task of testing for indicators increasingly complex, as they clearly do not behave in the same manner for all substances they represent. For example, viruses spread much faster in soil than their associated indicator bacteria.

While water treatment, disinfection and testing are extremely important aspects of water quality management a risk management plan is not complete unless it contains source protection. To minimise risk, source water should be protected as far as possible from pollution.

**Protecting Source Waters - Catchment Management and Source Water Protection.**

Catchment management and source water protection is a vital first step to protect water quality. The condition of the catchment — the area over which rainwater is caught and drains into a water supply — significantly affects the quality of water. Effective catchment management and source water protection include the following elements:

- developing and implementing a catchment management plan, which includes preventive measures to protect surface water and groundwater. The *Australian Drinking Water Guidelines* provide information for water authorities on how to set out careful catchment management plans.

- understanding the characteristics of the local catchment or aquifer, and identify and manage the scenarios that could lead to water pollution.

- ensuring that planning regulations include the protection of water resources from potentially polluting activities, and are enforced

- promoting awareness in the community of the impact of human activity on water quality.

In surface water catchments, preventive measures to protect water quality can include31:

- exclusion or limitations of uses (e.g. restrictions on human access or restrictions on chemicals, fertilizers and pesticide use in agriculture)

- protection of waterways (e.g. fencing out livestock, management of riparian zones)

- use of planning and environmental regulations to regulate potential water polluting developments (e.g. urban, agricultural, industrial, mining and forestry)

- use of industry codes of practice and best practice management

- regulation of community and on site wastewater treatment and disposal systems

- stormwater interception.

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Effective catchment management has additional benefits. By decreasing contamination of source water, the amount of treatment and quantity of chemicals needed is reduced.\(^{32}\) This may lead to health benefits through reducing the production of treatment by-products, and economic benefits through minimising operational costs.

**Resting Water in Reservoirs**

Water running off the catchment area is stored in protected reservoirs before being drawn off for treatment and distribution. Storing water in reservoirs (from 1 month to several years) delivers several key benefits. Not only does natural UV radiation act to destroy numerous microorganisms, but over time contaminants also settle out of the water. Furthermore, being able to draw off from various levels helps to ensure that water of the highest quality is sent for treatment.

**Water Treatment**

Numerous options exist for water treatment.(See Lectures 6.1, 6.2, 6.3 and Lectures 7.1-7.3) While they generally focus on removing contaminants and sediments, along with killing potentially harmful microorganisms through disinfection, they can also address aesthetic issues. These can include improvement of drinking water’s colour, taste, and smell. Treatment selection is based on factors such as the water’s origin and potential contaminants. Public health is also a consideration, with the cost of water treatment balanced against the savings associated with disease prevention. Water treatment options are improving in line with technical developments and knowledge of contaminants and associated risks, not to mention public expectations of safety and quality. However, Australia predominantly relies on the proven combination of coagulation, flocculation, sedimentation, filtration and disinfection to achieve drinking quality water treatment standards.

**Coagulation and flocculation**

When used in conjunction, coagulation, flocculation and sedimentation remove 99% of viruses, bacteria, organic material and a range of chemicals. Coagulants bind fine particles (e.g. clay, silt and algae) into larger masses called flocs. These flocs are then removed via filtration. Some dissolved materials can remain after this process, such as chemicals/toxins that impact on water aesthetic and support microorganisms and byproducts of disinfection, which necessitates a further treatment. Such treatment usually takes the form of mechanical or chemical purification, for example, via the use of activated carbon.

**Filtration**

Filtration can effectively remove fine suspended solids and larger microorganisms. The process involves passing water through a bed of fine sand. While the filter media physically filters out contaminants, activated carbon can be added to absorb unpleasant odours and tastes. Filtration is effective in combination with coagulation and flocculation, but can also be effective on its own if there is a low concentration of suspended material in the source water. Membrane technology has made some major advances in recent years and now has broad application. Membranes are available in four main types (in descending order of pore size: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). The latter two are particularly effective at removing salts, dissolved solids, large organic molecules and pathogens.

\(^{32}\) Ibid.
Disinfection

While disinfection is considered highly effective at eliminating bacteria from source water, it is also considered reasonably effective at the inactivation of viruses and numerous protozoa. Chlorination and chloramination are the most commonly applied methods of disinfection. However, chlorine dioxide, ultraviolet radiation and ozone are also used. While these methods are effective against bacteria, typical concentrations of chlorine and chloramines do not inactivate Cryptosporidium. There is, though, evidence to suggest ultraviolet irradiation is effective, and that inactivation can be enhanced by combining disinfectants.

Residual chlorine throughout a water distribution system is important for limiting regrowth and protecting against contamination, so long as consideration is given to disinfectant byproducts.

One of the challenges inherent in water treatment is ensuring that the chemical process of treatment and the nature and construction of the delivery system does not negatively impact upon the quality of the output drinking water. The World Health Organisation has developed a training program to address this very issue.33

A similar program, the Guidelines for Clearance of Water Treatment Chemicals and Processes34, was first introduced in Australia in 1988. These guidelines outlined and standardised the requirements for the assessment of the safety and effectiveness of drinking water treatment chemicals (DWTC). While they were endorsed by the National Health and Medical Research Council (NHMRC), they were not regulatory requirements, and since the mid 1990s, Australia has lacked a practical apparatus for the assessment and approval of DWTC.

To address this deficiency, the NHMRC’s Health Advisory Committee established the Drinking Water Treatment Chemicals Working Party (DWTCWP), with a view to developing a national approach. Its focus is two fold. Firstly, ensuring public health is protected by ensuring chemicals used to treat drinking water are safe and appropriate. Secondly, to provide guidance on DWTCs to water authorities, in 2002, the working party published the Overview of National and International Guidelines and Recommendations on the Assessment and Approval of Chemicals used in the Treatment of Drinking Water35.

Water quality monitoring

Water quality levels are mandated by state government bodies, and take the form of acceptable levels of impurities for a given system. It is the responsibility of water authorities to monitor the safety and quality of the water they distribute to ensure their protection and treatment processes are effective. However, it is not practical to monitor for all known harmful microbes as, by the time effective test have been done and the microbe identified, the community will already have been exposed.

An effective alternative is to monitor for indicator organisms that are present where harmful microorganisms are found. Testing for these indicator organisms is relatively quick and easy, and target specific bacteria found in the human gut – human faeces are the main source of harmful

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34 NHMRC (1988) Guidelines for clearance of water treatment chemicals and processes, NHMRC 105th Session, June 1988, National Health and Medical Research Council

microorganisms in water. However, even this method of testing means there are delays between contamination and a test result indicating the presence of the contaminant. Hence, such tests are not used to manage water quality on a daily basis, but rather to verify the effectiveness of treatment and other barriers.

For daily management of water quality, authorities rely on indicators including turbidity (cloudiness), colour, pH, and disinfectant residues. These provide much more immediate feedback on quality and, as opposed to tests for indicator organisms, can be monitored during the treatment process. This enables detection and remediation of quality issues before the water reaches the end user.

**Key References**

**Climate Change and Water Quality**


**Protecting Source Waters - Catchment Management and Source Water Protection**


**Water Treatment - Drinking Water Quality**


**Bathing and Recreational Water Quality**


**Water Quality – General**


**Bacterial Hazards**


**Water Borne Pathogens**


**Chemical hazards in drinking-water**

See World Health Organisations *Guidelines for Drinking-Water Quality* at


http://www.who.int/water_sanitation_health/dwq/WH03.06fulltext.pdf Accessed 21 April 2010

**Disinfection – Managing the Use of Chemicals to Treat Drinking Water**

Drinking Water Treatment Chemicals Working Party at

Monitoring
PIMC – NRMMC (2000) Australian Guidelines for Water Quality Monitoring and Reporting. PIMC-
NRMMC. At
http://www.mincos.gov.au/publications/australian_guidelines_for_water_quality_monitoring_and_re-
porting

Other Useful Links
- See Commonwealth Department of Environment, Water Resources, Heritage and the Arts
April 2010
- See Queensland Government’s Water Quality Indicators at
water_quality/water_quality_indicators/ Accessed 21 April 2010
- See World Bank Water Supply and Sanitation portal at
- See the UN Global Environment Monitoring System at http://www.gemswater.org/ Accessed
21 April 2010