Chapter 37: Economic cost of cyanobacterial blooms

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Abstract

Cyanobacterial blooms impact upon the water quality, environmental and ecological status of water bodies and affect most of the uses we make of water. The extent of the impact depends upon the type, size and frequency of the blooms, the size of the water body affected, the uses made of the water and the treatment options available to respond to the blooms. The impacts therefore vary considerably from place to place. Overall costs should also account for the planning and remedial actions taken to prevent future blooms.

Problem

Safe and aesthetically acceptable water is a critical need in a modern society. Good water quality is also a key prerequisite for sustainable environments. Cyanobacterial blooms impact the environmental health of water resources and effect how the water can be used. In particular cyanobacteria may damage human and animal health and impair the recreational value of the water bodies.

Benefits of Bloom reduction

The benefits of reducing cyanobacterial blooms are the reduction in damages and adverse effects. The benefits can be valued by the costs that may be avoided or by using willingness to pay estimates**.**

Improved Human Health

It is the fundamental requirement of a water utility to ensuring that the water provided for drinking is safe. Cyanotoxins clearly have the potential to impact on the health of consumers and are therefore not acceptable in drinking water supplies or in water used to irrigate crops and water stock. Cyanobacteria can also produced unacceptable taste and odors. As prevention of health impacts is so fundamental to water supplies it is difficult to put a figure value of the benefits of preventing cyanobacterial blooms. The best estimate is therefore the cost of controlling blooms as detailed in section III.

Improved Recreational Opportunities

Water–based recreation is an increasingly important consideration and in many areas forms the basis of the tourist industry. Cyanobacterial blooms can render a water body unsuitable for swimming, fishing, water skiing. This will impact on the businesses that cater for those activities with knock on effects for other businesses. The blooms can therefore impact negatively on the attraction of the general area as a tourist destination. Isolated blooms may result in short–term losses. Recurring blooms impact on the reputation of the area resulting in long–term decline in tourism.

Walker and Greer (1992) conducted detailed studies of the impact of cyanobacterial blooms on recreational activities in New South Wales in 1991/92. The methodology considered the following costs:

- those associated with recreation and tourism such as accommodation, transport and tourism;
- those associated with commercial recreation facilities such as caravan and tourist parks;
- those associated with the amenity value including aesthetics; and
- long–term costs related to permanent loss of trade.

Case study 1 Darling River 1991

In 1991 a bloom of neuro–toxic *Anabaena* covered 1000 km of the Darling River in central Australia. The affected region is a sparsely populated agricultural area in central Australia, however, the area is popular with tourists who enjoy pursuits such as fishing, swimming, camping, sight–seeing and hunting. All of these activities are impacted by cyanobacterial blooms. From surveys of two representative towns it was estimated that losses to the tourist industry were around $1.5 million.

Case study 2 Nepean/Hawkesbury River

The Hawkesbury Nepean River is located near Sydney in the state of New South Wales. The area supports a number of aquatic recreational facilities with activities including swimming, fishing, water skiing, canoeing, camping and picnicking. The proximity of the area to Australia's largest city ensures that the region receives high numbers of visitors. A series of blooms of cyanobacteria occurred over the 1991/1992 summer between Windsor and Wiseman Ferry. The assessment of their impact included estimates of the costs to consumers of traveling to other sites. From a survey of tourist facilities it was estimated that the revenue was $6.7 million lower than the previous year when no blooms had been present. It is noteworthy that the blooms were not classified as toxic and the reduction in revenue was the result of negative publicity about the blooms.

Case study 3 Various storages in New South Wales

In 1991, nine water storages in New South Wales that are used for recreation were seriously affected by algal blooms. The economic loss was estimated at $1.2 million.

A number of other cyanobacterial blooms had significant impacts on tourism but those costs have not been established. Examples include:

- Lower River Murray – Periodic *Anabaena* blooms ;
- Lake Alexandrina– *Nodularia* blooms, 1989 – 1992
- East Gippsland Lakes – *Nodularia* bloom in 1987/88;
- Peel Harvey Inlet – Periodic *Nodularia* blooms;
- Lance Creek – *Anabaena* bloom 1990;
- Candowire Reservoir Philip Island – *Anabaena* bloom 1991;
- Paskeville Reservior Yorke Peninsula – *Phormidium* bloom 2000.

All of the above incidences occurred during peak tourism periods and caused considerable disruption. The publicity has political as well as economic consequences.

Improved agriculture and fishing

There is a considerable body of evidence for the death of livestock as a result of drinking cyanobacterial contaminated water. There have been thirteen documented cases of stock deaths related to cyanobacterial blooms in Australia (Steffensen *et al* 1999). During the *Anabaena* bloom in the Darling River, 1600 livestock deaths were reported (Dept Water resources 1992). Using contaminated water for crop irrigation is also a concern as the impact of toxins on the crops and also on livestock who consume the crops is uncertain.

Toxins can accumulate in fish and shellfish with potential health risks to consumers. Humpage et al (1993) discussed the possible accumulation of saxitoxins from *Anabaena* in freshwater mussels. Falconer et al (1992) reported toxicity in mussels in the Peel Harvey Inlet at the time of a *Nodularia* bloom. However, there is a paucity of information on this issue and assessment of the economic impact is not possible.

Improved Environment

Cyanobacterial blooms are an indicator of environmental degradation and are often associated with reduced bio–diversity and greater instability. While it is difficult to place a value on the maintenance of a natural ecosystems there may be impacts fisheries, agriculture and tourism.

Control Costs

Immediate costs of cyanobacterial blooms

Monitoring and testing

Critical factors to be considered when assessing the risks related to a cyanobacterial bloom include the type and amount of toxin present and the likely progression of the bloom. Investigation of these factors requires intensive monitoring and testing. The costs involved in assessing the nature and extent of the bloom will depend on its size and the facilities available for testing the toxins. Toxicity tests may cost over $1,000 per sample. Furthermore, cyanobacterial blooms can be highly patchy and unpredictable. Intensive monitoring may be required to predict the course of a bloom.

Blooms in small isolated storages may be relatively easily monitored and cost a few thousand dollars per annum. Blooms in large water bodies that connect with other water bodies may cost hundreds of thousands to adequately assess. An example of the latter is Lake Alexandrina in South Australia which is subject to toxic *Nodularia* blooms, some lasting several months. The Lake has an area of 75,000 hectares (180,000 acres) and has a number of water extraction points for domestic and agricultural use. It is also heavily used for recreation including swimming, boating and fishing. In 1989, Lake Alexandrina experienced the first major toxic cyanobacterial bloom in South Australia. The size of the lake, the number of extraction points, the variety of water uses and inexperience in dealing with blooms of this size caused difficulties in assessing and controlling the bloom. Assessing the risks posed by the blooms involved intensive sampling over a wide area using boats and shore based personnel. Aerial photography was also used to map the extent of the bloom and proved to be a very valuable tool.

Another example of a large toxic bloom occurred in the Darling River in Australia in 1991. This bloom of toxic *Anabaena* covered a 1000 km length of the river and affected water off–takes for a number of towns and numerous agricultural extraction points. The remoteness of the river increased the monitoring costs. It has been estimated that the cost of monitoring for cyanobacteria and for contingency planning to deal with blooms in Australia is $8.7 million per year (Atech, 2000).

Risk Assessment

Health risks from cyanotoxins are the major concern for water utilities and health authorities. Water quality guidelines have been proposed for some toxins and others are under consideration. These provide a basis for assessing immediate risks to health but are of little value in assessing the risk of an incident occurring. Also, the focus on toxins ignores other significant issues such as taste and odours, filter clogging and oxygen depletion which are also caused by cyanobacterial blooms. Furthermore these problems are often associated with other groups of phytoplankton. One can look at a hierarchy of risk assessment as follows.

- What is the risk of excessive phytoplankton growth?
- What is the risk that they will be cyanobacteria?
- What is the risk that they will be toxic?

This hierarchy moves from general environmental considerations to more specific factors that influence the occurrence of toxic species and the degree of toxicity. This broad risk assessment approach fits into the Water Quality Management Framework that has been adopted in the 2004 Australian Drinking Water Guidelines. A similar approach has been adopted by the World Health Organization. The main elements of the framework are:

- assessment of the likely severity and frequency of the impacts from all possible risks;
- selection of critical control points;
- development of management plans to mitigate those risks and
- a monitoring program to assess the success of those mitigation strategies.

This provides multiple barriers for the protection of the water supply. Cost benefit analysis can be used to prioritise the management options.

Control Measures

The actions taken to manage a toxic bloom can involve measures taken within the water body, after extraction of the water or the provision of alternative supplies.

In–water measures

The in–water measures may include artificial mixing to disperse the bloom, the use of booms to protect water off–takes, application of algicides, and release of water up stream to flush out blooms. The cost of these measures is very site specific and difficult to generalize.

Algicides are commonly used in some areas but banned in other areas. The most readily used algicides are copper based. In South Australia treatment of a bloom in a water supply reservoir with algicides may cost $20,000 to $50,000 for reservoirs ranging from 1,300 to 26,000 ML. SA Water spends in excess of $1 million a year using algicides to treat blooms and dispose of the copper contaminated water treatment sludge. As copper has impacts on a wide range of aquatic organisms it is not recommended for use in natural water bodies.

Stratification of water bodies creates favourable conditions for the growth of cyanobacteria. Artificial mixing is a common measure used to disrupt stratification and can be useful in dispersing cyanobacterial blooms. The most common approach is bubbling compressed air into the bottom of the water bodies but mechanical mixers can also be used. In small water bodies it may be possible to install temporary systems as an immediate response. For larger water bodies or for permanent systems the lead time precludes artificial mixing as a reactionary procedure for rapid response. It is also necessary to understand the factors that influence the stratification of the particular water body which requires research into the local conditions. The costs for destratification vary according the situation but large systems can cost several hundred thousand dollars in capital with running and maintenance costs about 10% of the capital costs.

In regulated rivers there may be scope for releasing water from up–stream storages to flush out blooms. Sydney Water has released water from Lake Burragorang to flush blooms from the Nepean/Hawkesbury River. Releases of up to 70,000ML of water have been made but this is regarded as an extreme action. Releases have also been made from the Menindee Lakes to the Murrumbidgee and Darling Rivers. In 1999, 480ML of water was released from Kangaroo Creek Dam to flush a *Microcystis* bloom out of Lake Torrens in Adelaide. This approach has not been used in subsequent blooms in Lake Torrens as it was not regarded as an appropriate use of water. In recent years frequent droughts in Australia have required careful use of water resources. These conditions, combined with the competition for water from agricultural users, have limited the use of water for flushing toxic blooms.

Water Treatment after extraction

Untreated water supplies are the most vulnerable to the impacts of cyanobacterial blooms. Supplies that are disinfected with an oxidant may give some protection against some toxins. Conventional water treatment such as flocculation, filtration and disinfection will remove the cyanobacterial cells and the toxins they contain provided that the cells are removed intact and a chlorine residual is maintained after treatment. Use of oxidants prior to flocculation and filtration is not recommended as it lyses the cells and releases the toxins. However, conventional treatment will have little effect on dissolved toxins. Additional treatment such as activated carbon or powerful oxidants such as ozone are needed to remove or destroy dissolved toxins. Most water treatment plants in parts of Australia that are subject to cyanobacterial blooms now have the capacity to dose with powdered activated carbon (PAC) and in some cases have granular activated carbon (GAC) filters. The use of these additional treatments increases the capital and operating costs compared with conventional treatment.

Provision of alternative supplies

If adequate treatment is not available alternative supplies may need to be provided. This may involve isolation of the contaminated source and the re–routing of other sources into the distribution system. Where that option is not available water may need to be tankered in or bottled water provided for drinking. In South Australia this has happened in two areas. During the *Nodularia* blooms in Lake Alexandra mentioned above, water was tankered in and made available at distribution points or used to fill existing water tanks. In 2000 a bloom of toxic *Phormidium* a reservoir servicing a small town in South Australia was forced off–line during a busy holiday period. Bottled water was provided to consumers and temporary treatment facilities installed at some commercial businesses.

Long Term Costs

Prevention of future problems can involve dealing with the factors that cause blooms or improving the treatment of the water once the bloom occurs.

Environmental Flows

Increasing flows in regulated rivers to flush out existing blooms has been successful in some circumstances. Consideration has also been given to using increased flow to prevent blooms from forming. The feasibility of using this approach largely depends on the volumes of water required and competition for water from other users. Maier *et al (*2001) reviewed the options for managing cyanobacteria in the River Murray in South Australia. Blooms in that area of the river are associated with periods of thermal stratification. It was estimated that additional flows of 10,000 ML per day would be required to halve the risk of thermal stratification. If the flow was required for 1 month, the cost of the water would be $15 million. Mitrovic *et al*. (2003) reported on a similar study in the Darling River. That study indicated that flows of 0.05 ms^{-1} would preclude *Anabaena* blooms in the weir pools. In the reach of river studied, this related to discharge rates between 100 and 450 ML day^{-}1. Flow rates often fall below those stated in summer resulting in frequent blooms. However, it is not clear whether additional flows would be available to prevent blooms in summer. While environmentalists are a calling or greater environmental flows for rivers in Australia the competition from other users is rising making increasing flow to control cyanobacterial blooms more difficult. The introduction of water trading has further increased the competition for water.

Covering storages

For small storages cyanobacteria can be eliminated by removing light. Following a major cyanobacterial incident in small open storages, SA Water covered three storages at a total cost of $7.1 Million. The capacities ranged from 64 ML to 150 ML.

Environmental improvement

In Australia the increase in cyanobacterial blooms has intensified the attention on eutrophication and on nutrient reduction. Significant expenditure has been allocated to improve waste water treatment and to find alternative routes that will divert discharges away from rivers and lakes. Nutrient reduction, especially phosphorus is the main driver for treatment works upgrades. Improved land management including better management of riparian strips is also relevant. It is not always clear to what extent the environmental improvement programs are due to cyanobacterial blooms or the result of more general concerns about eutrophication. Atech (2000) estimated that in Australia the cost of environmental protection schemes attributable to cyanobacteria was $121 million per year. This included urban sewage and stormwater ($43 mill), agriculture and industrial waste water ($33 mill), and rehabilitation of land and water resources ($45 mill).

Overall costs

Atech (2000) put the overall costs in Australia related to cyanobacteria in $ millions per year as:

Cost Category	Cost ($)
Joint Management costs	9
Urban extractive users	35
Rural extractive users	30
Non–extractive users	76–136
Total	180–240

Confidence levels for cost estimates

Direct costs to the agencies responsible for managing blooms such as monitoring, treatment and the provision of alternative water sources can be determined relatively easily. Costs to tourism and agriculture are more difficult to assess due to the range of people and activities that may be affected. Estimating the value of aesthetic appeal and environmental values is especially difficult. What value do we place on clean water as opposed to unsightly smelly scums?

The cost of engineering works for prevention or management of blooms such as additional treatment, installation of mixers and roofing of storages can be estimated with reasonable confidence. It is more difficult to assess the costs and benefits of environmental measures such as improved waste water treatment. The extent to which these programs are initiated by concerns about cyanobacteria and the whether they will resolve the problem is often unclear.

Atech (2000) argued that the willingness of the community to pay for prevention of blooms is an indicator of the economic impact. This study also suggested that the cost of the environmental improvement programs is a conservative estimate. The estimate was based on the consideration that the programs should partially reverse costs currently incurred and would not completely resolve the problem. They proposed a multiplier of 1.5 to 2 which places the annual economic impact at $180 million to $240 million.

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