State of the Nation Report

An Overview of the Current Status of Water Quality and Eutrophication in South African Rivers and Reservoirs

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Introduction

South Africa's freshwater resources, including rivers, man-made lakes and groundwater, are under increasing stress from a growing population and an expanding economy. In addition, almost all of the country's freshwater resources have now (2005) been fully allocated, while the water quality of these resources has declined due to increased pollution caused by industry, urbanization, afforestation, mining, agriculture and power generation (Ashton *et al.*, 2008). Given the current and anticipated future growth rates of the population and expected trends of socio-economic development, it is highly unlikely that South Africa's water resources will be able to sustain current patterns of water use and waste discharge (**Table 1**). It is expected that South Africa's freshwater resources will be fully depleted and unable to meet the needs of people and industry by the year 2030 (National Committee on Climate Changes, 1998). Even if South Africa's population remains static or increases slightly, pollutants will continue to accumulate in freshwater systems. Without a radical improvement in eutrophication management approaches and treatment technologies, eutrophication will continue to decrease the benefits and increase the costs associated with use of these resources.

Table 1. Actual water requirements for 1996 and projected water requirements for 2030 by different water use sectors in South Africa (adapted from Basson *et al.*, 1997).

Sector	1996		2030		Volume Increase (%)
	Volume ($10^6 m^3$/year)	Sector use (%)	Volume ($10^6 m^3$/year)	Sector use (%)	
Urban and domestic	2,171	10	6,936	23	220
Mining and industrial	1,598	8	3,380	11	112
Irrigation and afforestation	12,344	62	15,874	52	29
Environmental	3,932	20	4,225	14	8
TOTAL	**20,045**	**100**	**30,415**	**100**	**52**

This review aims to highlight the eutrophication status of South African river systems and water storage reservoirs, which comprise the core of all water supply systems and underpin social and economic development in the country. In addition, this report evaluates the available information on the presence of potentially toxic cyanobacteria in these rivers and reservoirs, draws attention to the number of toxicity events that have resulted in the death of livestock or wildlife and discusses the health risks that these organisms pose to society.

Sources of eutrophication and problems associated with toxic algae.

There are very few natural lakes in South Africa; most of these lakes are small, located in remote rural areas and are unsuitable or uneconomic as water supplies to urban areas. As a result of the paucity of natural lakes and the seasonally variable river flows, water storage reservoirs provide the major sources of freshwater for use by society. South Africa has 497 large reservoirs, each with a capacity in excess of one million cubic metres (**Figure 1**), in addition to over 150,000 smaller reservoirs and farm dams (Basson *et al.*, 1997).

South Africa is unique amongst Southern Hemisphere countries in having most of its principal metropolitan areas located on the watersheds of river catchments. The rivers draining away from these watersheds have the dual burden of providing water supplies and transporting waste material – most of which enters downstream water storage reservoirs. Because most South African reservoirs are located downstream of urban and metropolitan areas, these reservoirs have become progressively more enriched during recent decades.

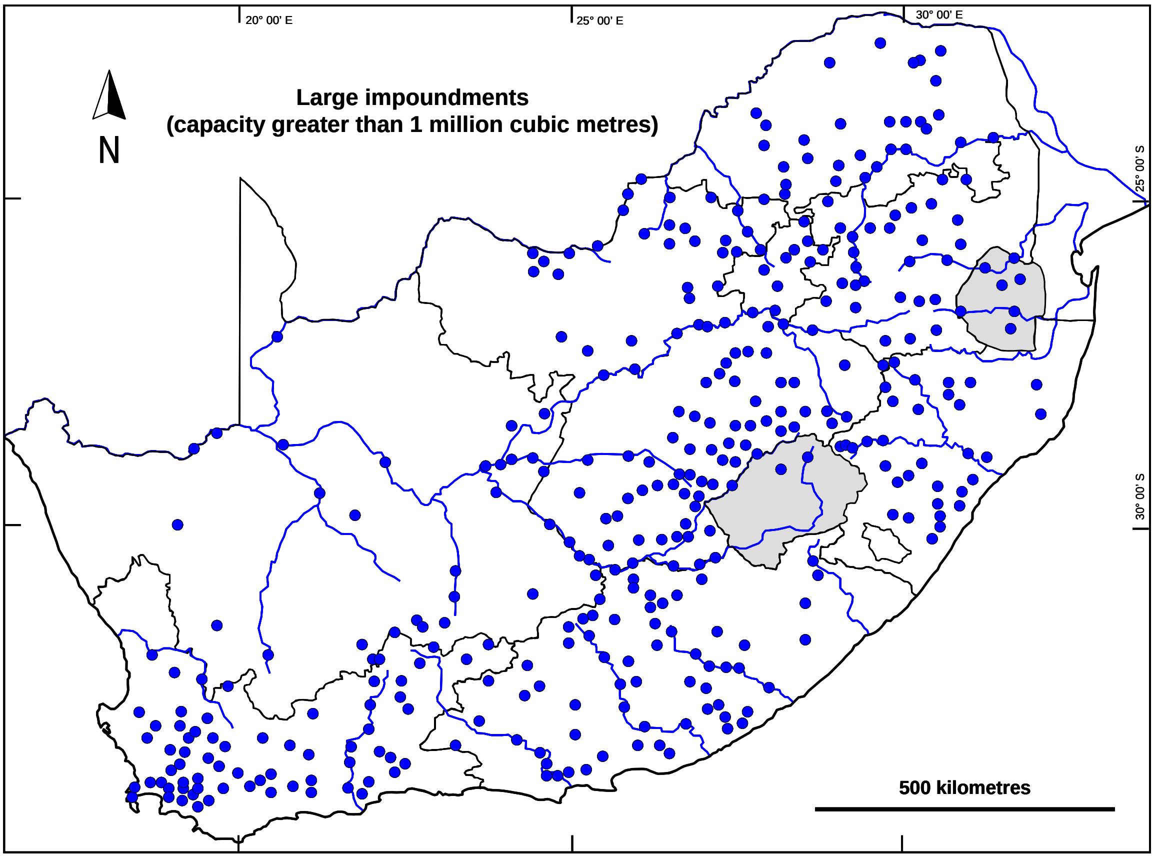

Figure 1. Map showing the distribution of large impoundments (capacity greater than one million cubic metres) in South Africa, in relation to major rivers and provincial boundaries.

A large proportion of the sewage emanating from South African urban areas is not treated properly prior to discharge, because the sewer systems are incomplete, or sewage treatment plants are overloaded. This is particularly true in densely populated areas and in those areas where summer storm runoff enters sewerage systems. Industrial development is another aspect of human activity that has left its mark on South Africa's water resources. Many industrial processes produce waste products that contain hazardous chemicals, and these are sometimes discharged directly into sewers, rivers or wetlands. Even those waste products that are disposed of in landfills or slag heaps, for example, may release substances that eventually seep into nearby watercourses (Oberholster *et al.*, 2008).

Modern agricultural practices add significantly to this environmental burden, with pesticides and fertilisers washing into rivers or leaching into groundwater (Walmsley, 2000). Freshwater pollution (in the form of Chemical Oxygen Demand) is estimated to be 4.74 tonne/km^3 while the average phosphorous concentration in the natural water resources of South Africa (as orthophosphate) has been estimated at 0.73 mg/litre (Nationmaster.com, 2003). These values indicate that South Africa's freshwater resources are excessively enriched and are considered to be moderately to highly eutrophic. Eutrophication is generally indicated by accumulation of metabolic products (e.g. hydrogen sulphide in deep waters), discolouration or turbidity of water (resulting in low or poor light penetration), deterioration in the taste of water, depletion of dissolved oxygen and an enhanced occurrence of cyanobacterial bloom-forming species. The series of interactions between natural features and human activities that lead to the development of nuisance blooms of cyanobacteria – which may potentially be toxic – is shown in **Figure 2**.

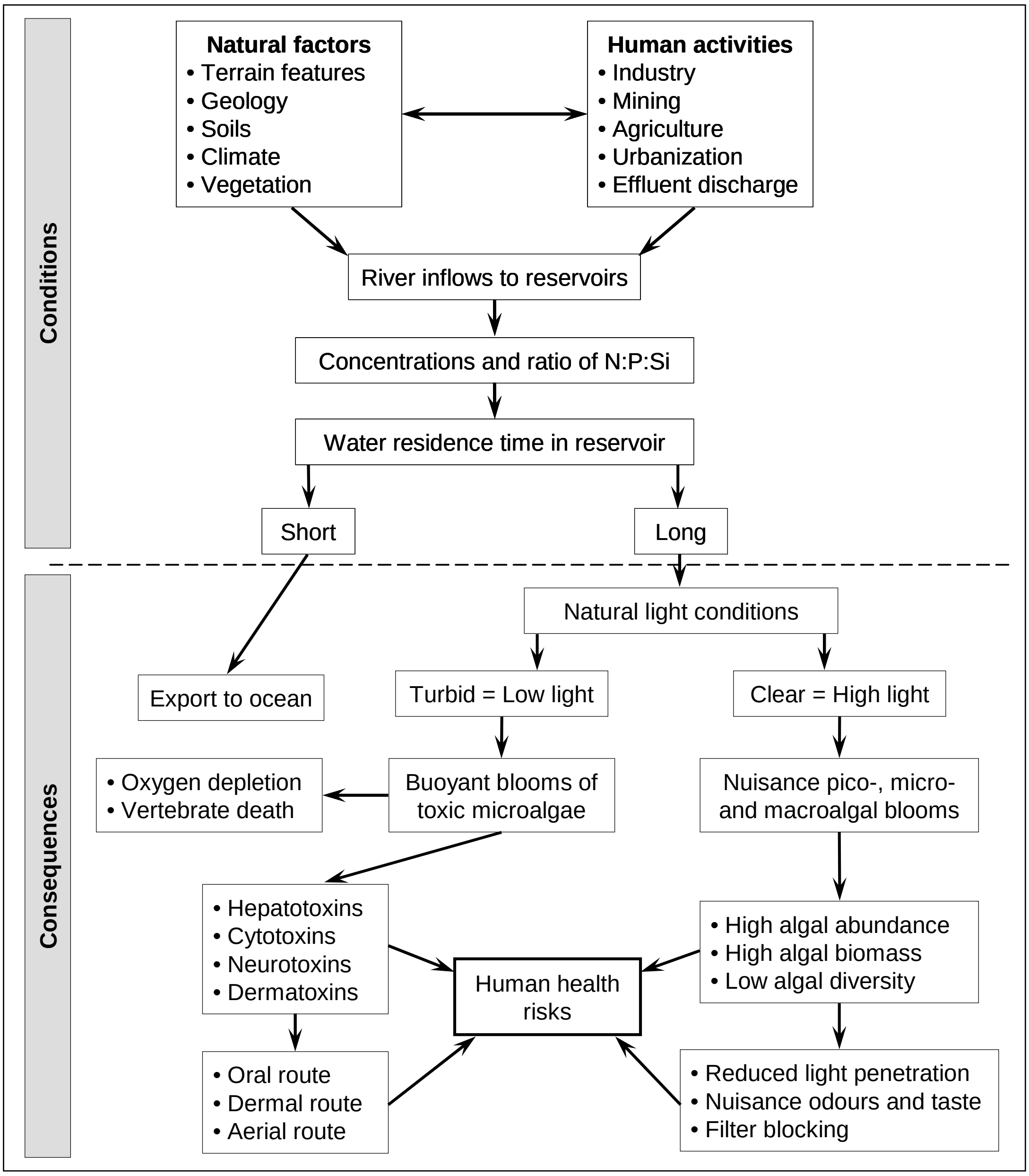

Figure 2. Overview of the sequence of interacting factors and the potential consequences of nutrient enrichment of freshwater in a man-made impoundment.

Although eutrophication is a natural slow ageing process of lakes, it can be greatly accelerated and modified to benefit nuisance algae by human intervention in the natural biogeochemical cycling of nutrients within a watershed (Rast and Thornton, 1996). Until the mid-1980s South Africa was recognized as a world-leader in eutrophication research. Unfortunately, this advantage was lost because eutrophication management in South Africa focussed on the implementation of an inappropriately high phosphorus concentration (1 mg/litre as P) for all effluents discharged from sewage treatment plants to surface water systems, and what appears to be progressive incapacitation due to an inability to transform policy into practice. In common with many other developing countries, eutrophication issues now receive low priority status in South Africa (Harding and Paxton, 2001). Thankfully, however, the importance and current extent of eutrophication in South African water bodies has been highlighted in recent reports (Van Ginkel *et al.*, 2001; Van Ginkel, 2004) and also by the development of an implementation manual for the National Eutrophication Monitoring Programme (DWAF, 2002).

In South Africa, most of the drinking water that is supplied to communities is obtained from surface water sources (rivers and reservoirs), though groundwater supplies are important in more arid areas. Cyanobacterial blooms have been recorded in many, if not most of the river and reservoir systems because of prevailing high levels of eutrophication caused by inadequate treatment of domestic and industrial effluents that are discharged in their catchments (Du Preez and Van Baalen, 2006). The development and prevalence of dense cyanobacterial blooms – particularly during the warmer summer months – is the main symptom of progressive and often uncontrolled eutrophication processes in rivers and water storage reservoirs.

Climatic conditions

South Africa’s climatic conditions, coupled with the discharge of treated and untreated sewage effluent and excessive nutrient loads in return flows from agriculture, as well as modification of river flow regimes and changing land use or land cover patterns, have resulted in large-scale changes to aquatic ecosystems that have resulted in the eutrophication of rivers and water storage reservoirs. In virtually every eutrophic river and reservoir in South Africa the dominant phytoplankton genera are usually the cyanobacteria *Microcystis* and *Anabaena* (Van Ginkel, 2004).

Large areas of South Africa are arid to semi-arid and experience erratic and unpredictable extremes of drought and floods. Lakes and reservoirs that receive point source nutrient inputs also experience high rates of evaporation as well as long periods when river inflows and outflows decline. In combination, these circumstances lead to rapid rates of eutrophication where large proportions of the inflowing nutrient loads are retained within the waterbody and its sediments, favouring the development of cyanobacterial blooms (NIWR, 1985). South Africa is located in a negative runoff zone, where annual evaporation exceeds rainfall by a factor of between 1.2 and 4 (Miller, 2002) and, on average, approximately 8 % of South Africa’s annual rainfall becomes available as surface runoff (Ashton *et al.*, 2008).

Cyanobacterial toxicity

Arguably the most alarming characteristic of cyanobacteria is the ability of many species to produce a range of extremely potent, low-molecular-weight cyanotoxins (Carmichael, 1992). These cyanotoxins are grouped according to the physiological systems, organs, tissues or cells that are primarily affected (**Table 2**).

Table 2. Cyanobacterial toxins of the most dominant species in South Africa, and their functions and mechanisms of action. (Data taken from Falconer, 1998; Sivonen and Jones, 1999; Codd, 2000).

Toxin type	Primary target organ in mammals	Cyanobacteria Taxon	Mechanism of toxicity
Hepatotoxins			
microcystins	Liver	*Microcystis*, *Oscillatoria*, *Nostoc*, *Anabaena*	Inhibition of protein phosphatase activity, haemorrhaging of the liver
Nodularins	Liver	*Nodularia*	Inhibition of protein phosphatase activity, haemorrhaging of the liver
Cytotoxins			
cylindrospermopsins	Liver, kidney, spleen, intestine, heart, thymus	*Cylindrospermopsis*	Inhibition of protein synthesis
Neurotoxins			
anatoxin-a	Nerve synapse	*Anabaena*, *Oscillatoria*	Blocking of post-synaptic depolarization
Anatoxin-a(s)	Nerve synapse	*Anabaena*	Blocking of acetylcholinesterase
Saxitoxins	Nerve axons	*Anabaena*	Blocking of sodium channels
Dermatotoxins			
aplysiatoxins	Skin	*Oscillatoria*	Protein kinase C activators, inflammatory activity
Irritant Toxins			
lipopolysaccharides	Any exposed tissue	All	Potential irritant and allergen

Concerns over the health risks that cyanotoxins pose to humans prompted the World Health Organization (WHO) to adopt a provisional guideline value for microcystin-LR in drinking water (WHO, 1998). Due to the lack of reliable analytical data, no guideline values have yet been set for concentrations of nodularin or cylindrospermopsin toxins in water. In South Africa, while a guideline value has been set for the maximum permissible concentration for cyanotoxins (1 µg/litre) in domestic water (however, this is only for microcystins), specific values are not provided for drinking water guidelines or national drinking water standards (DWAF, 1996). An examination of microcystin toxin levels in Lake Hartbeespoort by the South African Department of Water Affairs and Forestry (during the period August 2003 to May 2004) revealed that the median microcystin concentration was 580 µg/litre. In this study, the maximum value recorded was 14,400 µg/litre, while low concentrations persist thought the year at levels above 10 µg/litre (Van Ginkel, 2004).

Different exposure routes by which cyanobacterial toxins can exert effects

Ingestion (oral route) of water provided by conventional water treating plants in rural and semi-rural areas

Incidents of fatal cyanobacterial poisoning in South Africa are widespread in South African reservoirs (**Figure 3**) and have occurred almost every year. However, to date, these poisonings only involved the death of livestock, domestic animals and wildlife and no human fatalities have been recorded in South Africa. The deemed health risk to humans in South Africa is via long-term chronic exposure to low levels of cyanotoxins in water used for drinking and domestic uses because it is estimated that only 21 % of South African households have access to piped water inside their houses (DWAF, 2004).

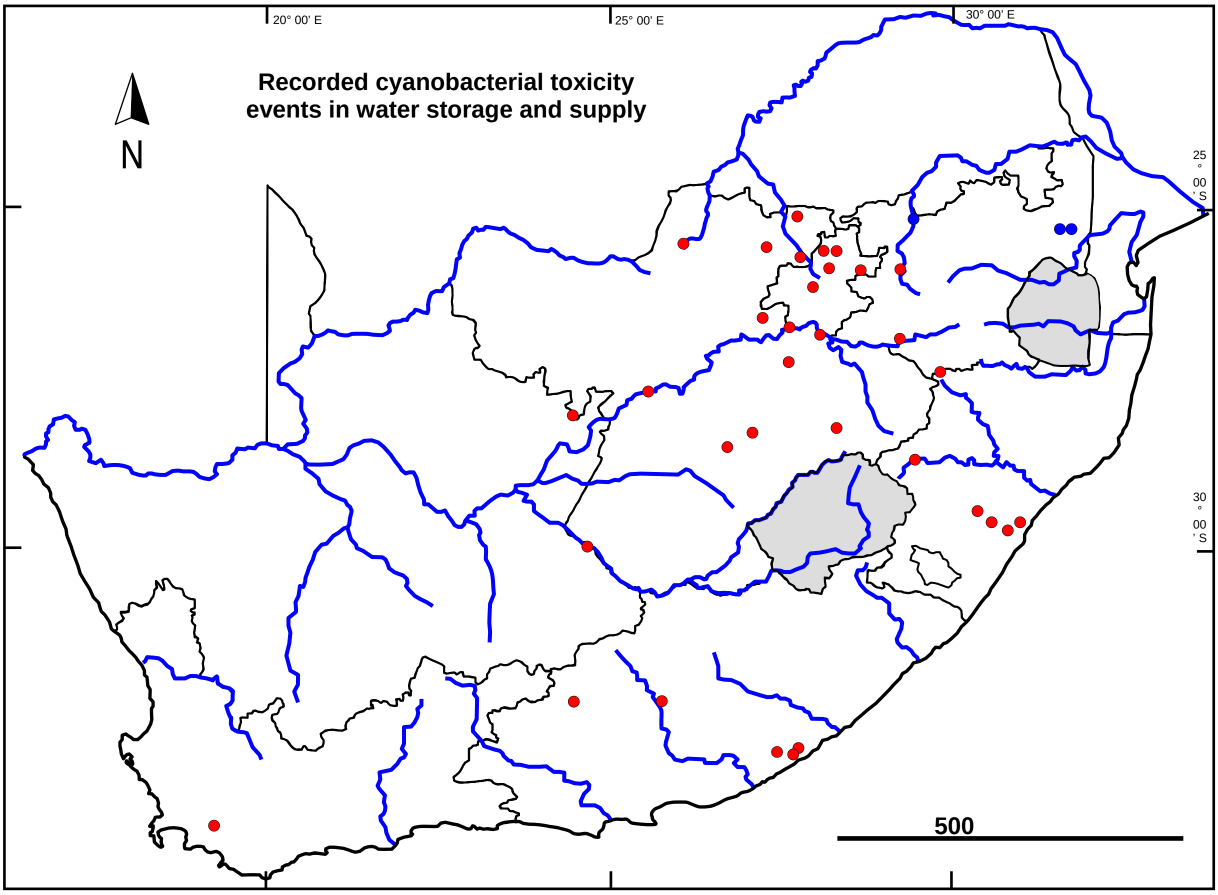

Figure 3. The distribution of recorded cyanobacterial toxicity events in South African water supply reservoirs, which caused the death of livestock, wildlife or domestic animals. (Map drawn from data in Van Ginkel, 2004 [red circles] and recent toxicity events in the Kruger National Park and at Loskop Dam [blue circles]).

Water treatment plants in rural areas are seldom able to produce reliable supplies of water of acceptable quality for domestic consumption (Momba *et al*., 2004). Long-term chronic exposure to low levels of cyanotoxins may also occur in areas that receive reliable supplies of treated drinking water because conventional water treatment processes are ineffective (not exceeding 11-18 %) at removing cyanobacterial toxins (Hoffman, 1976; Duy *et al*., 2000). In a recent study, it was observed that concentrations of cell-bound microcystins declined while extracellular toxin concentrations remained constant after flocculation and filtration in conventional water treatment plants (Hitzfeld *et al.*, 2000). Pietsch and co-workers (Pietsch *et al.*, 2002) found that flocculation and filtration resulted in an increase of extracellular toxin after experiments with *Microcystis aeruginosa* and *Planktothrix rubescens*; this suggested that turbulences in pipes and the pressure gradients in the filter bed may be the major factors contributing to elevated extracellular toxin concentrations. In addition, Hitzfeld and co-workers (Hitzfeld *et al.*, 2000) reported that while the chlorination process in conventional water treatment plants was effective in destroying intact cyanobacterial cells, the intracellular biotoxin was released into the treated water.

Ingestion of water in rural areas where no pre-treatment is available

Potable water supplies are particularly problematic in the rural areas of South Africa where poverty levels are over twice as high (70 %) as those in urban areas (30 %); this often results in poor households having no option but to use unsafe sources of water (May, 2000). In many rural areas, over 75 % of poor households have no access to treated tap water and approximately 74 % of all rural households need to fetch water from a well, stream or river each day. For approximately 21 % of these households, children of school-going age from poor households are responsible for collecting water from community taps, wells, rivers and farm dams (DWAF, 2004).

In eutrophic reservoirs where cyanobacteria occur, the cyanobacteria cells accumulate along shorelines and embayments because they are positively buoyant and are driven into shallow water or onshore by prevailing winds. These areas are often those that are most easily accessed by people collecting water for household use. If the cyanobacteria biomass is low, it is often difficult to recognise cyanobacterial cells or colonies because the cells and colonies are dispersed through out the water column. The most notable example of this is the genus *Cylindrospermopsis*, which does not form surface scums or emit strong odours such as those emitted by *Microcystis* (Fastner *et al.*, 2003) However, the occurrence of low biomass levels of cyanobacterial cells does not imply that the collected raw water contains low levels of cyanobacterial toxin. An early study (Cronberg *et al*., 1999) reported the highest rates of toxin production occurred at very low cyanobacterial biomass, suggesting that cyanobacterial species produce different amounts of toxins under different environmental conditions. Picocyanobacteria - with a typical cell diameter of 0.2-2 µm and which are common in lakes, dams and drinking reservoirs (Komarek, 1996) – co-exist with other planktonic bloom-forming cyanobacteria and can be another source of microcystin in drinking water. These small cyanobacteria are even more difficult to see and analyse, but are also able to produce microcystins or microcystin-like compounds (Bláha and Marsálek, 1999), and can easily lead to increased microcystin concentrations in water. Moreover, due to the fact that microcystins are very stable and do not readily undergo proteolytic or hydrolytic attack (Duy *et al.*, 2000), these toxins may have long-term health affects on people in rural areas where untreated supplies of water used for drinking are known to contain cyanobacteria or near-permanent aggregations of cyanobacteria.

It can be postulated that chronic exposure to low levels of cyanotoxins by people that live in rural areas, and who have compromised or suppressed immune systems due to HIV/AIDS, and possibly also suffer from other communicable and poverty-related diseases such as Tuberculosis, may experience serious social and economic consequences as a result of cyanotoxins. In 1991, it was estimated that approximately one thousand new infections of HIV/AIDS occurred each day (Doyle, 1991); this rate of new infections has continued to increase each year (Ashton and Ramasar, 2002). Furthermore, common symptoms of cyanotoxin poisoning (diarrhoea, vomiting, stomach pains) are similar to the symptoms of gastrointestinal illness caused by these bacteria, as well as other viral and protozoan infections, and are thus not immediately linked to cyanotoxin poisoning (Falconer, 1998, 2005). Nevertheless, people living near the shores of Bospoort Dam, South Africa, and drawing water from this lake experienced an outbreak of diarrhoea that was linked to the cyanobacterial species *Microcystis aeruginosa* (Harding and Paxton, 2001).

An important aspect that influences the toxicity of cyanobacterial blooms is the age of the victim that ingests water containing cyanobacteria. Children are more vulnerable for several reasons: they drink more water per unit of body weight; they are less likely to be able to make an informed choice of the source of their drinking water; and they are more susceptible to physiological damage that can take a considerable period of time to develop, such as environmentally induced carcinomas (Falconer, 1998, 2005). For children under 5 years of age, diarrhoea is the third most important cause of death after HIV/AIDS and low birth weight, and represents 10 % of all deaths in that age group in South Africa (Bradshaw *et al*., 2003). The only available estimate of the cost for the treatment of diarrhoea in South Africa is that R3.5 billion is spent every year as a direct result of diarrhoea (Pegram *et al*., 1998). However, there is insufficient evidence to confirm that chronic exposure to low levels of cyanobacterial toxins had played a role in these cases due to a lack of analytical ability. In another developing country, Brazil, a mixed bloom of *Anabaena* and *Microcystis* spp. were responsible for a lethal outbreak attributed to cyanobacterial toxins present in drinking water; this resulted in the death of 88 children from over 2,000 cases of gastroenteritis over a period of 42 days (Teixera *et al.*, 1993).

A recent study by Humpage and co-workers (Humpage *et al.*, 2000) indicated that microcystins from a cyanobacterial extract provided in drinking water to rats increased the area of aberrant crypt foci in the colon, suggesting that microcystins promote preneoplastic colonic lesions. More importantly, microcystins are potent tumour promoters (Nishiwaki-Matushima *et al*., 1991) and there is an indication that they also act as tumour initiators (Ito *et al.*, 1997). Epidemiological studies have suggested that microcystins are an important risk factor for the high incidence of primary liver cancer in certain areas of China, where people have consumed pond-ditch and river water contaminated with low levels (within the range of 0.09-0.46 µg/litre) of microcystins (Ueno *et al.*, 1996).

A survey conducted in South Africa between 2004-2007 by Botha and Oberholster, used RT-PCR and PCR technology to distinguish *Microcystis* strains bearing the *mcy* genes, which correlate with their ability to synthesize the cyanobacterial biotoxin microcystin. This study revealed that 99 % of South Africa’s major impoundments contained toxicgenic strains of *Microcystis* (Botha and Oberholster, 2007; Oberholster and Botha, 2007).

Exposure of cyanobacterial toxins via spray irrigation practices

Irrigated agriculture accounts for the largest proportion of water use in South Africa (62 %; **Table 1**). Because water supply reservoirs may contain cyanobacterial blooms and toxins, the exposure of edible crop plants to cyanobacterial toxins via spray irrigation or watering may cause these toxins to accumulate in plant tissues (Codd *et al.*, 1999). The introduction of these toxins into the human food chain is therefore a strong possibility, which may pose great concern for human health. Spray irrigation practices in first world countries have shown that the aerial parts of plants can be exposed to cyanobacterial toxins. Spray irrigation of commercially-grown salad lettuce (*Lactuca sativa*) with water containing cyanobacteria resulted in an accumulation of *Microcystis aeruginosa* colonies on the leaves after irrigation.

Immunoassay analysis of the separated lettuce leaves showed microcystin-LR equivalent concentrations that were of risk to human health if these were ingested (Codd *et al*., 1999).

Exposure via skin contact (dermal route) and aerosols containing cyanobacterial biotoxins

In South Africa, freshwater cyanobacterial blooms and scums of *Microcystis aeruginosa* have been associated with skin irritations, conjunctivitis and allergic reactions after swimming or water-contact sports in dams (Harding and Paxton, 2001). In many rural areas of South Africa, residents use farm dams and rivers for laundry purposes as well as for personal hygiene and cultural purposes – for example, baptism of church members and use of clay that may contain toxic cyanobacterial cells for cosmetic purposes. These people may therefore be exposed to above normal levels of blue-green algae and other microorganisms, which are concentrated within the water surface films and ejected with and carried into the air by droplets. This exposure route of cyanobacterial toxins may include minor morbidities such as upper respiratory and gastrointestinal symptoms as well as skin rashes, ear pain, and eye irritation (Phillipp and Bates, 1992).

Eutrophic rivers and lakes in South Africa

Despite the large amount of work that has been carried out on eutrophication in South African water supply reservoirs and lakes, our collective understanding of eutrophication in rivers remains extremely limited. Most South African river systems are turbid – containing high concentrations of suspended silts and clays – due to catchment mismanagement, erosion, siltation, unstable riverbeds and loss of in-stream fauna that feed on planktonic algae. This can easily lead to a false sense of security regarding eutrophication, since the conventional chlorophyll-nutrient relationship is significantly weakened in comparison with clear-water river systems (Hart, 2006). High suspended sediment exerts an adverse effect by generating an underwater light climate that favours toxic cyanophytes such as *Microcystis aeruginosa*. This arises from low-light-induced changes in colony size, internal buoyancy mechanisms, and a pigment content that selectively favours this species. Significant blooms of *Microcystis aeruginosa* can develop seasonally or episodically under certain hydrological conditions, even in waters that are otherwise characterised by low algal standing stocks, principally as a consequence of light limitation (Hart, 2006).

Rivers that are located downstream of eutrophic lakes are likely to show a prevalence of cyanobacteria due to the large numbers of cyanobacteria that are discharged in the outflow from these lakes. However, these cyanobacteria will only continue to show measurable growth in slow-flowing rivers that have a long retention time. In fast-flowing, turbulent, rivers with a short retention time, the cyanobacteria that are discharged from a lake will add to the total turbidity of the river water but the cyanobacterial population will not increase significantly by growth during their transit of the river.

Where potable water supplies have been provided to residents of rural areas that are located downstream of eutrophic lakes, the water supplies are frequently unreliable and insufficient. This forces residents to revert to traditional, but contaminated, river sources for their domestic purposes such as laundry, drinking and food preparation (WRC, 1993; Nevondo and Cloete, 1999). The major health risk associated with these drinking water sources relates to the fact that the water is of poor quality, as well as being contaminated with cyanobacteria and other water-borne diseases (Lehloesa and Muyima, 2000). Information from previous surveys of South African river systems that are classed as eutrophic or having the potential to become eutrophic in the near future due to their poor water quality, indicates that the most important systems are the Vaal, Jukskei/Crocodile, Mgeni, Orange, Modder and the Buffalo river systems (Allanson and Jackson, 1983; Breen, 1983; O'Keeffe, 1986, 1988, Walmsley, 2000, 2003; Pieterse and Janse Van Vuuren, 1997). The most important driving forces that cause degradation of water quality in these river systems are the dense rural population and extensive urban informal housing developments that dominate land use patterns in these catchments. Other contributing factors are contaminated run-off from rural and urban areas, discharges of raw or partially treated sewage from sewage treatment plants that are overloaded, poor agriculture management practices and solid waste dumps located on or close to river banks.

Priority areas where eutrophication research is needed in South Africa

By using overlay techniques within a GIS framework the following areas were identified as priority areas for research into the factors that lead to poor water quality and adverse human health risks:

- Eutrophic river systems such as the Vaal, Crocodile (West), Mgeni and Buffalo river systems have poor water quality and also coincide with the spatial distribution of poverty-stricken areas where there is a high HIV prevalence. The dominance of cyanobacterial blooms in the surface water of hypertrophic reservoirs such as the Roodeplaat, Rietvlei, Hartbeespoort, Smith, Bridle Drift and Laing Dams on these river systems emphasizes the high levels of nutrient enrichment in these water bodies. Furthermore the dams in the Crocodile and Pienaars River systems are all considered to be hypertrophic, which indicates excessive nutrient enrichment and exceedingly poor water quality that requires rigorous treatment before use. The average population densities in the catchment areas of these hypertrophic reservoirs exceeds 50 people per square kilometre, and the water in these reservoirs is used extensively for human consumption, recreation and a variety of socio-economic development options.

- These reservoirs and their catchments are also considered to be "hotspot" areas because previous incidents of toxic cyanobacterial blooms have occurred, which had a variety of lethal and sub-lethal effects on livestock and wildlife, as well as potentially toxic effects on humans.

- The integration of the GIS methodology into water quality assessment illustrates that potentially toxigenic strains of *Microcystis aeruginosa* occur widely in rural and semi–rural areas where water quality is poor and local residents face a high risk of exposure to strains of cyanobacteria that could be toxic.

Conclusions

Human activities have had a series of progressively worsening effects on South Africa's scarce water resources – these have accelerated during the last few decades as the population grew rapidly and the economy expanded. A visible consequence of this social and economic development has been the progressive increase in nutrient loads entering the country's river systems and water supply reservoirs and the accompanying increase in nuisance blooms of toxic cyanobacteria. Unfortunately, this situation has been accentuated by an earlier (late 1970s) official decision to institute an inappropriately high effluent phosphate standard (1 mg/litre as P) for all water treatment works situated in so-called "sensitive catchments", despite the availability of conclusive evidence that a far lower effluent phosphate concentration (< 0.1 mg/litre as P) was needed to minimize the adverse effects of eutrophication. An additional adverse effect of this decision was that it hampered further research on new phosphate removal process technologies for effluent treatment works. Since the promulgation of the effluent phosphate standard, the water quality in South Africa's rivers and reservoirs has deteriorated rapidly – fuelled by increased effluent loads discharged to rivers and the inability of water resource managers to ensure strict compliance with water quality standards at all sewage treatment works.

The natural ability of rivers and reservoirs to trap nutrients in their sediments has enabled these systems to accumulate nutrients and other contaminants – these are then readily available for uptake by nuisance algae and aquatic macrophytes. The rapid increase in nutrient concentrations in South African water supply reservoirs has resulted in an increase in the occurrence and prevalence of cyanobacterial blooms, some of which have proved to be toxic. These toxic organisms present a range of risks to human health, depending on the type of algal toxin produced and the type of water use. Conventional water treatment technologies do not remove algal toxins; carbon filtration and other forms of tertiary treatment are needed to achieve this removal and inactivation. A thorough review and revision of the country's effluent quality standards is needed if these human health risks are to be reduced. Given the widespread nature of eutrophication problems in South Africa and the rapidly increasing prevalence of blooms of toxic cyanobacteria, this problem requires urgent attention.

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