CATCHMENT MANAGEMENT

Water pollution – Are farmers bearing the cost of poor catchment management?

Glynn Pindihama from the University of Venda elaborates on a study investigating the threats of eutrophication to irrigated farming.

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Eutrophication refers to the enrichment of a water body by nutrients and minerals. Eutrophication of lakes is a natural process and takes place over centuries. However in recent years, human activities have enhanced the eutrophication process due to discharges of nutrients (nitrogen and phosphorous) from various sources into the waterways (Chislock ***et al***., 2013).

Over the last few decades, aquatic scientists have related algal blooms to the enrichment of waters by nutrients as a result of human related activities such as industrial activities, disposal of sewage and agriculture. Among the unfortunate consequences of cultural eutrophication is the proliferation and the dominance of blue-green algae (cyanobacteria). These blooms reduce the aesthetic value of recreational waters, affect drinking water and deprive lakes of oxygen. Figure 1 shows some of the main causes and effects of human-induced eutrophication.

Some species of these cyanobacteria also have the ability to produce toxins, such as microcystins, nodularins, saxitoxins and cylindrospermopsin. Among the most common toxin producing cyanobacteria in South Africa are ***Microcytis***, ***Anabaena*** and ***Oscillatoria*** (***Planktothrix***).

Irrigated agriculture takes up about 60% of South Africa's available water resources, thus making it the largest consumer of water in the country. South Africa's water resources have deteriorated in recent years due to climate change, a rapidly growing population, poorly maintained and depilating wastewater treatment facilities (Mudaly and van der Laan, 2020). The increase in water shortages in South Africa makes management of this key resource of paramount importance.

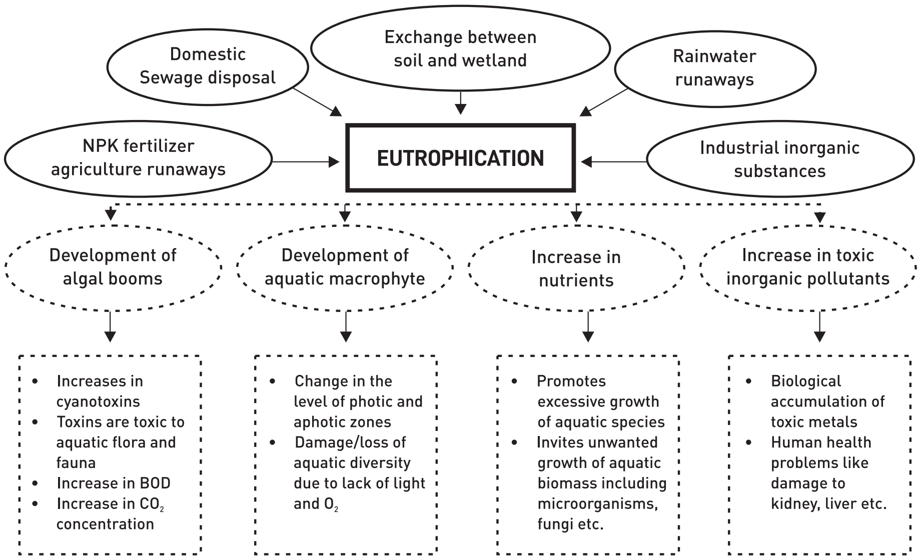

Figure 1: *The causes and effects of eutrophication (Adapted from Paul et al., 2020).*

The cost of eutrophication induced damage in the United States is estimated at around $2.2 billion annually (Chislock ***et al***., 2013). In South Africa, an example is the Loskop Irrigation Scheme, where approximately R73.4 million per year is spent on mitigating eutrophication-related problems due to algae-related problems (Mudaly and van der Laan, 2020).

While emphasis and efforts have been placed on the impacts of eutrophication and the resultant algae on water quality related to drinking and recreation, little attention has been given to water intended for irrigation purposes. With the prevailing eutrophication levels in the country and lack of monitoring and legislation to govern the use of such water for agricultural purposes, there could be an inherent chronic threat to human health due to the exposure of low levels of cyanotoxins via food crops irrigated with cyanotoxin-contaminated water.

A current research project (**WRC Project No. K5/2972//14**) funded by the Water Research Commission under the research management of Prof Mugera Gitari, and led by a team (namely, Glynn Pindihama, Dr Rabelani Mudzielwana, and Salphina Sathekge) from Environmental Remediation and Nano Science (EnviReN), Department of Ecology and Resource Management, University of Venda, is investigating the effect of multiple stressors on the uptake of cyanotoxins by plants irrigated with cyanotoxins infested water and the potential health risks associated with consumption of such contaminated plants.

Cyanobacterial toxins do not occur in the aquatic environment separately, but they naturally interact with other toxicants. Terrestrial food crops could be exposed to numerous anthropogenic pollutants and other stressors, such as linear alkylbenzene sulfonate (LAS) and toxic metal species, which may enhance their accumulation from the surrounding environment after irrigation.

Figure 2 shows the multiple factors which need to be considered to make an informed decision about the suitability of the available water for irrigation use. There is a need to start with understanding irrigation water sources, their quality (particularly eutrophication status) and the prevalence of cyanobacteria and the resultant cyanotoxins. When plants are exposed to cyanobacteria-infested water, they are likely to be exposed to cyanotoxins, and these are likely to be taken up and bio-accumulate in the plant tissue. Plants have mechanisms to metabolize toxins and the ability to breakdown/eliminate these toxins.

However, this depends on the levels and frequency of exposure. When exposed to cyanotoxins, food plants can accumulate these toxins. In turn, these will be transferred to human beings through the ingestion of these plants and hence pose human health risks (particularly in the long term). To foster policy formulation, a better understanding of the quality of irrigation water, impacts on the irrigated plants and the health risks posed by consuming contaminated plants, there is a need to understand the impact of joint effects of multiple cyanotoxins stressors and the ecotoxicological risk of cyanotoxins in combination with other environmental stressors.

An effective and reliable monitoring system for these toxins in the irrigation and source water is also of importance in the evaluation and understanding of the threats posed by irrigating food plants with cyanobacteria infested water and the health risks posed by consuming contaminated plants.

In this project, the research team monitored water intended for irrigation (canals and farm dams) from Roodeplaat and Hartbeespoort dams from the June, 2019, to February 2020. Parameters monitored included physico-chemical parameters (pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), turbidity, and temperature), nutrients (nitrates and phosphates), metal elements (in water and soils), cyanobacterial biomass (as chlorophyll-a), microcystins (MCs) and linear alkylbenzene sulfonate (LAS).

Results showed that the irrigation water from both dams was alkaline, with water from Roodeplaat Dam exceeding the DWAF (1996) and Ayers and Westcot (1985) guidelines. TDS and EC of Roodeplaat Dam water were also found to be non-compliant with the two regulations in the sampling of winter of 2019. Irrigation water from Hartbeespoort was found not to be

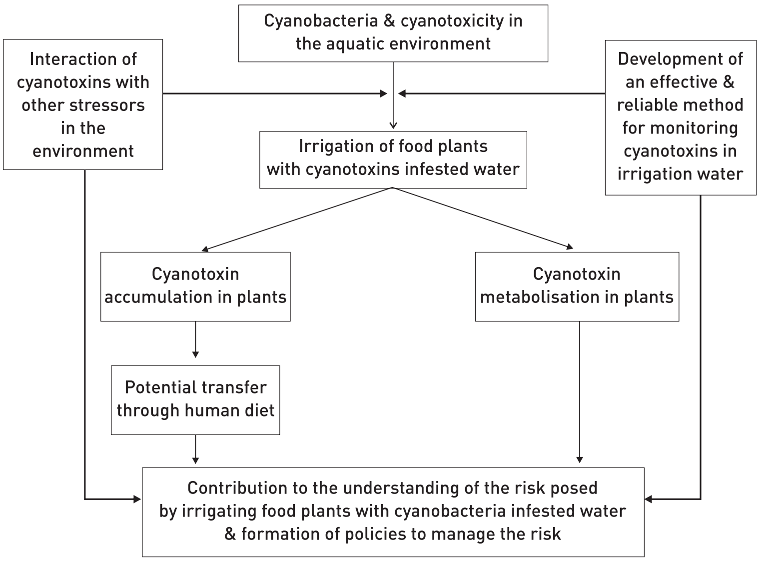

Figure 2: *Conceptual framework for the study and factors to be considered leading to policy formulation.*

compliant with the two regulations for TDS in the June 2019 and February 2020 sampling and EC was non-compliant in all the three sampling events. Water from Hartbeespoort was also non-compliant for nitrates in spring of 2019 and late summer (2020) sampling.

Chlorophyll-***a*** was used to estimate algal biomass. Algal biomass as chlorophyll-***a*** was relatively high in the two sites over the sampling period, ranging from 49.86±76.26 to 153.70±177.54 µg/L. Such high chlorophyll-a levels, places the two dams in the upper hypertrophic category (>56.00 µg/L).

In terms of metal elements, soils from the Roodeplaat site had nickel and copper exceeding the South African or the FAO (Food and Agriculture Organisation of the United Nations) guidelines for agricultural soils, whereas zinc was within the set thresholds for the sampled period. All the three essential elements (nickel, copper and zinc) exceeded the South African or the FAO guidelines for soils used for agricultural purposes at the Hartbeespoort site. The other elements reported to be high were hexavalent chromium (Cr (VI)), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg), which are regarded to be non-essential and are toxic both to the plants and the consumers. Of these non-essential elements, only Hg was within the permissible limit for agricultural soils based on the South African and/or FAO guidelines.

Findings of the study also showed that levels of metal elements were higher in the spring sampling compared to the winter sampling for most of the elements. This could have been as result of the excessive irrigation during the winter months resulting in the accumulation of the metals which were detected in spring before the rains leach most of these elements from the soils. The levels of metal elements in the irrigation water from the two dams showed that all the elements (essential and non-essential) are in trace levels and none of them exceeds the DWAF (1996) and FAO (1985) (Ayers and Westcot, 1985) guidelines for these elements in irrigation water.

Levels of linear alkylbenzene sulfonate (LAS), an anionic surfactant found in detergents and discharged in wastewaters was recorded in the seven sampling points and ranged from 0.065±0.007 to 3.430±0.085 mg/L for Roodeplaat water and 0.010±0.000 and 0.215±0.021 for Hartbeespoort water. Microcystins (MCs) were detected in the irrigation water in farm dams and canals receiving water from both dams (Roodeplaat and Hartbeespoort). MCs levels ranged from 0.12 to 2.84 µg/L, with sampling points in Roodeplaat having higher levels of MCs compared to Hartbeespoort points and the winter season having higher levels compared to spring.

These findings imply a potential risk of contamination of crops irrigated with water from Roodeplaat Dam than from Hartbeespoort. These may impact both the health of the plants and also have potential health implications on the consumers of the plants. This is because cyanotoxins have been reported to affect the germination of seeds and general plant growth/health and thus impacting on the farmers' yields.

Cyanotoxins may also accumulate in the parts of the irrigated crops and thus indirectly affect human health. Future studies will thus need to investigate the effects of cyanotoxins on different crops grown in a particular region and farmers getting advice on the best crops to grow based on the available irrigation water quality. Research also need to look at the effects of LAS on cyanobacterial biomass and effects of LAS on the uptake of MCs by plants when irrigated with water from eutrophicated water bodies since previous studies have demonstrated a positive correlation of these factors (Wang ***et al.***, 2012; Wang ***et al.***, 2015).

Lani van Vuuren

Algae visible on the surface of the Loskop Dam.

Lack of policy and regulation in South Africa

The bioaccumulation potential of cyanotoxins in food plants led to the World Health Organization (WHO) to propose a tolerable daily intake of microcystins-LR (MC-LR) for humans. According to the WHO the TDI of MC-LR in humans should not exceed 0.04 mg/kg body weight (bw) per day (Herschy, 2012). However, this guideline is for MC-LR only since there is still lack of data for other toxins (Mokoena, Mukhola and Okonkwo, 2016). This is regardless of the fact that total concentrations of MCs can range from 1 mg/L to 29,000 mg/L in surface waters and recent studies have shown that levels above the stipulated TDI can accumulate in food plants exposed to MCs under environmental relevant concentrations ((Bittencourt-Oliveira ***et al.***, 2016).

The research findings demonstrated an inherent risk of cyanotoxins and other pollutants accumulating in food crops if eutrophicated waters are to be used for irrigation. In a country like South Africa, water for irrigation of agricultural plants is essential yet it is becoming less available and its quality is deteriorating. Controlling harmful cyanobacterial blooms seems to be the best management practice to eliminate risks to agricultural productivity and human health. However forecasts predict an increase in proliferation of toxic cyanobacterial blooms (Machado ***et al***., 2017) and this presents challenges to regulatory authorities.

South Africa does not have water quality guidelines for cyanobacteria and cyanotoxins in recreational water bodies, in water intended for livestock consumption or for irrigation of food crops. The only regulation that guides and addresses irrigation water quality in SA is the South African Water Quality Guidelines Agricultural Use: Irrigation Volume 4 of 1996 (DWAF, 1996). However these guidelines only cover physicochemical aspects and coliforms bacteria and how these impact on crops and human health. Cyanobacteria and their toxins are not covered in these guidelines.

In the absence of legislation, farmers are encouraged to employ better practices such as reporting to the DWAS whenever they notice a blue-green bloom or blue-green colour in irrigation water, a layer of foul extraneous matter, a rotten plant-like odour in irrigation water. Blooms typically occur during late summer or early fall, when warm temperatures and low rainfall facilitate growth, but blooms can also occur anytime during the year. Blooms are also common in slow-moving waters or stagnant ponds and in waters with elevated nutrient levels.

Photo supplied

The research team monitored water intended for irrigation (canals and farm dams) from Roodeplaat and Hartbeespoort dams from the June, 2019, to February 2020.

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