Correlation of water quality with farming activities

Hydrochemical characteristics of the Bonsma Dam, KwaZulu-Natal

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Abstract
Pressure to increase productivity of agricultural systems in order to meet domestic and international demand has resulted in the intensification of agriculture, exploitation of more land and greater reliance on pesticides, fertilisers, and imported animal feedstuff. Sources of pollutants from agricultural systems include livestock grazing, nitrates and phosphates in fertilisers, metals, pathogens, sediments and pesticides. Excess Nitrogen and phosphates accelerate algal production in receiving surface water, resulting in a variety of problems including fish kills and reduced recreational activities. To investigate the impact of farming activities (mainly dairy farming) on water quality, water samples were collected from the Bonsma Dam in KwaZulu-Natal and analysed for hydrochemical variables. The study showed that the concentrations of most of the metals, TDS as well as the pH and electrical conductivity values, met the water quality requirements for domestic, agricultural, livestock and aquatic ecosystem uses. Of concern were nitrates, chloride, aluminium and iron as they exceeded the guidelines set by the Department of Water Affairs and Forestry (DWAF) (1996) for irrigation and aquatic ecosystem uses. The iron and aluminium content of the dam water also did not meet the requirements for domestic use. Metals such as iron and aluminium could be detrimental to the health of humans and animals when they are present in excessive quantities.
Keywords: Agriculture, water quality, nutrients, eutrophication

1. Introduction

South Africa has a robust agricultural industry, comprising of a well-developed commercial sector and a predominantly subsistence-oriented sector in the rural areas. Agricultural activities range from intensive crop production and mixed farming in winter rainfall and high summer rainfall areas, to cattle ranching in the bushveld, and sheep farming in more arid regions. However, agriculture has both direct and indirect effects on the quality of surface and groundwater and is among the leading causes of water quality degradation, mainly from nitrate, in many parts of the country. Agricultural practices can cause pollution of water bodies and lead to the depletion of water quality over time due to the cumulative effects of several years of practice (Addiscott et al, 1992). Typical sources of water pollution associated with agricultural systems include livestock grazing, nitrates and phosphates in fertilisers (also K, Na, Mg and Ca), metals, pathogens, sediments and pesticides. To address the increased concerns about water quality degradation due to agricultural practices, water quality investigations were carried out with an aim of investigating the impact of farming activities, mainly dairy farming, on the Bonsma Dam.

2. Study area background

Bonsma Dam is situated in Underberg, which is a town located beneath the Southern Drakensberg mountain, on

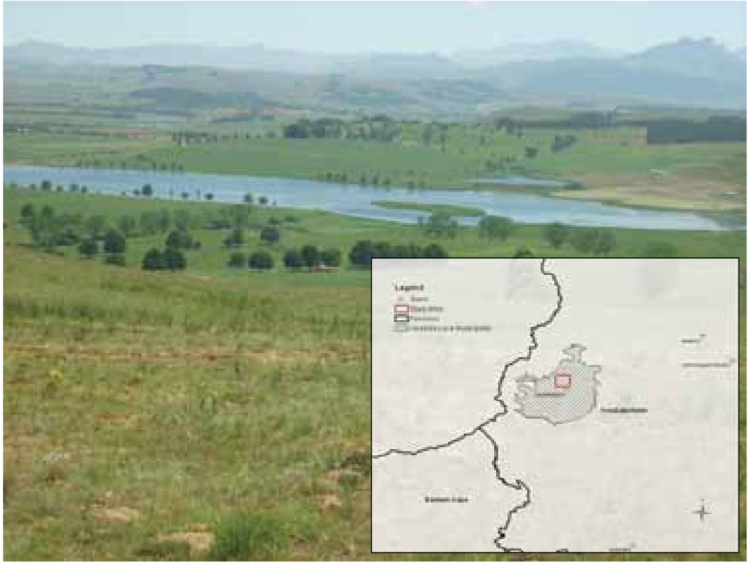


FIG 2.1 Picture of the Bonsma Dam. The insert is the map of Underberg

the Umzimkhulu River. It started out as a single store built to serve the settlers who had started farming there in 1886. It is a predominantly farming community whose livelihood depends on activities such as grazing, dairy, crops and timber farms, with its main economic activity being cattle and sheep ranching. Much of the grassland is grazed by livestock, providing its people with meat and dairy products, employment and a source of income, which is central to the local economy. The Bonsma Dam provides drinking water for stock and irrigation waters for crops to the surrounding farms. Its location, among farmlands, makes it vulnerable to pollution associated with agricultural activities, and this raises the probability that the quality of the dam water has also been compromised.

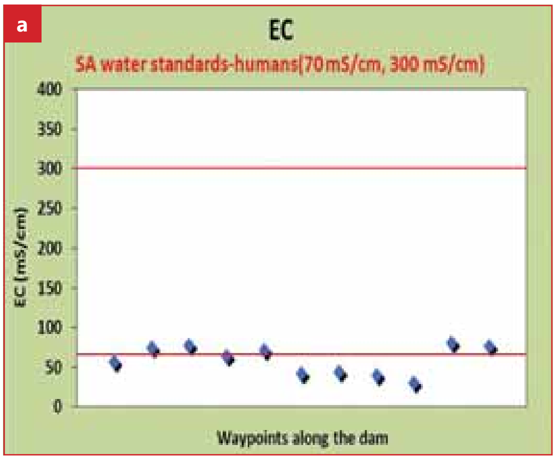
3. Methodology

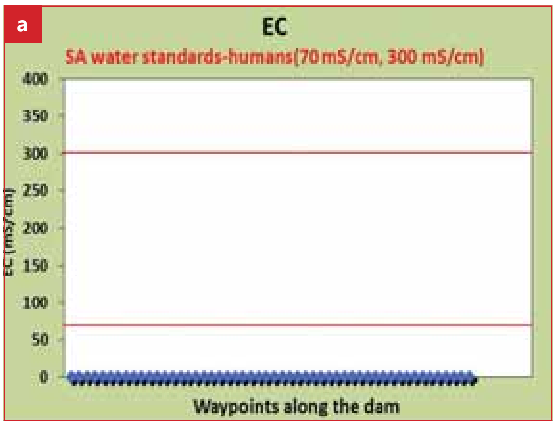
The sampling of the Underberg Dam was conducted in March 2011 (after the wet season) and October 2011(after the dry season). This was done in order to monitor changes in water quality brought about by seasonal hydrological cycle. Results obtained will be useful in determining the relationship between water quality and seasonal patterns. A total of 100 samples were collected in and around the dam using the global positioning systems (GPS) to locate appropriate sampling points. Water samples were collected at a depth of 30 cm below the water surface using previously acid-washed high density polyethylene (HDPE) bottles, chilled to between 3 and 5°C and despatched in a cooler box to the Council for Geoscience and the Tshwane University of Technology laboratories for analysis. Physical parameters such as pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured in the field using portable, multi-sensor meters. Cations were analysed using inductively coupled plasma mass spectrometry (ICP-MS) and anions by ion chromatography (IC). The Oasis montaj software was used for mapping and processing of data. The results are presented in the following section.

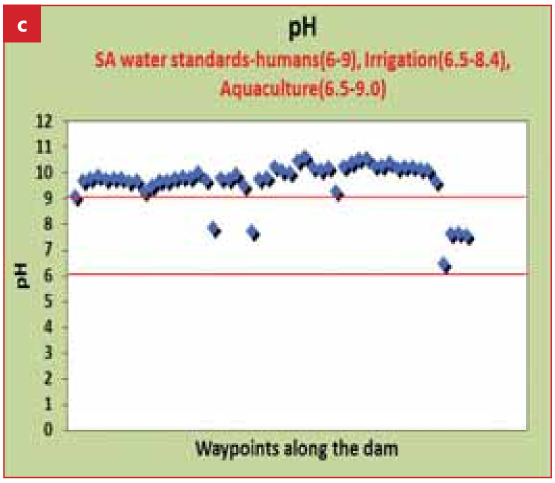
4. Results and discussion

The suitability of water for any particular use can be determined by the total concentration of dissolved mineral constituents in that water. The macro elements are partly used for determining the water quality as well as what the concentrations of constituents in the water is doing over a time frame period (trend analysis) or over an area (spatial analysis). Measurements showed that the electrical conductivity of the dam was still within the minimum and maximum allowable limit (70 to 300 mS/cm) as set by the DWAF (1996, with higher values being observed in the wet season and lower values in the dry season (Fig 4.1)). The high EC values can be attributed to the recharging of the dam during the wet season, which can lead to a build up of salts and nutrients, and therefore increased conductivity (Brainwood et al, 2004). Low EC values following the dry season can be caused by the dilution effect of groundwater as it enters the water body, as well as the uptake of nutrients by aquatic plants. Discharge into streams can also change the conductivity. Agricultural runoffs would raise the conductivity because of the presence of chloride, phosphate and nitrate.

Measurements done following the wet season showed that pH values were within the South African water standards, which is a pH between 6 and 9 (Fig 4.1). Following high rainfall in summer, the dam is diluted with rainfall and runoff thus explaining the low pH values. In the dry season the dam water was highly alkaline (pH>9). This indicates that the water was hard and can cause aesthetic problems. A possible explanation for the highly alkaline







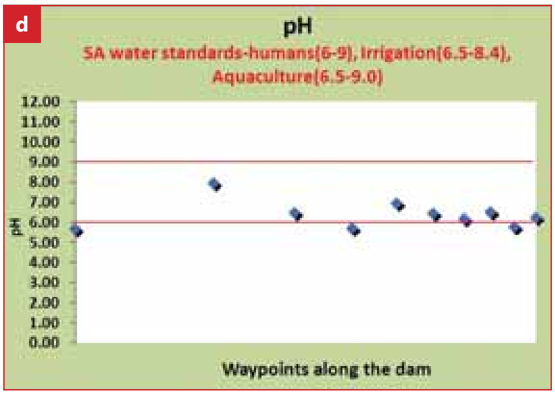
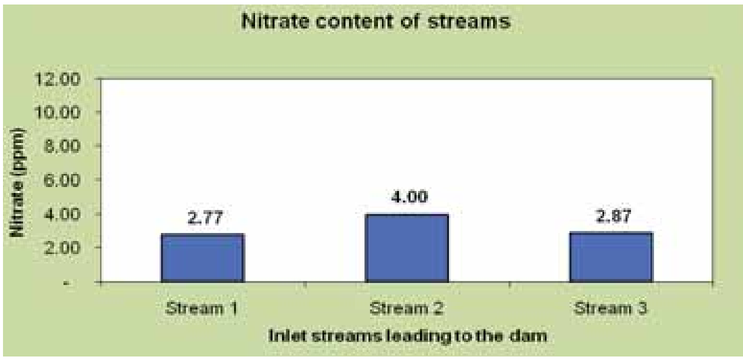


FIG 4.1 Seasonal variation of the EC and pH in the dam: (a) EC – wet season; (b) EC – dry season; (c) pH – wet season; (d)pH – dry season .Red lines indicate the minimum and maximum allowable limit

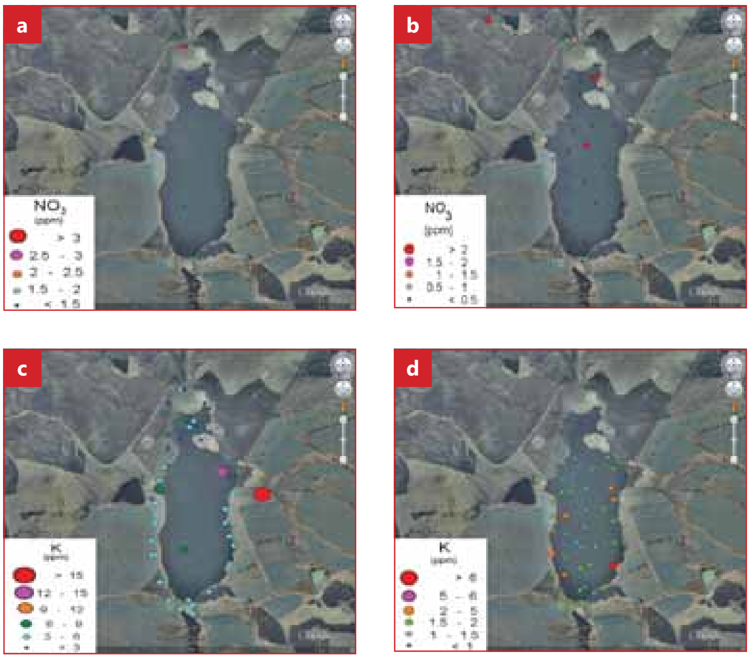
FIG 4.2 Nitrate content of the inlet stream leading to the dam, wet season



water is the use of calcium-based fertilisers by farmers in the area, as well as addictives such as agricultural lime.

Nutrients, mainly nitrogen (N), potassium (K), and phosphorus (P), are applied in croplands in a form of fertilisers to promote plant growth. Excessive amount of these nutrients causes water quality problems when they enter the water systems. Analysis of the water samples from the Bonsma Dam showed that the concentration of N, K and P was within the target water quality range (TWQR) for domestic, irrigation and aquatic ecosystem uses. Nitrate concentrations were slightly elevated following the wet season (fig 4.3a), when compared to the dry season (fig 4.3b). This can be attributed to the combined use of livestock manure and mineral fertilizer by farmers in the Underberg area, which results in considerable enrichment of surface soils with salts and nutrients (Daniel et al, 1993) that are then washed into water bodies during runoff events. Therefore, nitrate concentrations tend to be highest in spring in conjunction with high runoff events/rainy season (Brainwood et al, 2004). This also explains why potassium concentrations were higher after the wet season (fig 4.3c). In the dry season (fig 4.3d) where there is no rainfall, nutrients (N, P, K) level remain within the ranges for natural waters. The nitrate content of the inlet streams leading to the dam were also high following

FIG 4.3 Proportional symbol map showing the distribution of the concentrations of nitrate and potassium along the dam: (a) nitrate – wet season (b) nitrate – dry season (c) potassium – wet season (d) Potassium – dry season. At the background is the satellite image of the dam



the wet season (fig 4.2), which rendered the water body eutrophic (2.5 to 10 mg/ℓ). During periods of high rainfall, these streams carry nutrients leached from soils, fertilisers from crops and animal faecal matter into surface waters, which explains the elevated nitrate concentration found in them.

The concentration of major metals such as Mg, Ca and Na were within their TWQR for domestic, irrigation, livestock and aquatic ecosystem uses, as set by the DWAF (1996). Of concern was the Al, Fe and Cl content of the dam (Fig 4.4.), which did not meet the TWQR for some of the uses shown in the table below.

Table 4.1: Target water quality range for Al, Fe and Cl, DWAF (1996).

Element	Concentration range of element in the dam (ppm)	TWQR (ppm) Domestic	Irrigation	Livestock watering	Aquatic ecosystem
Al	0.1 – 1.4	0 – 0.15	0 – 5	0 – 5	0.005
Fe	0.01 – 1.7	0 – 0.1	0 – 5	0 – 10	NA
Cl	0.7-18	0-100	0-1	0 – 3 000	NA

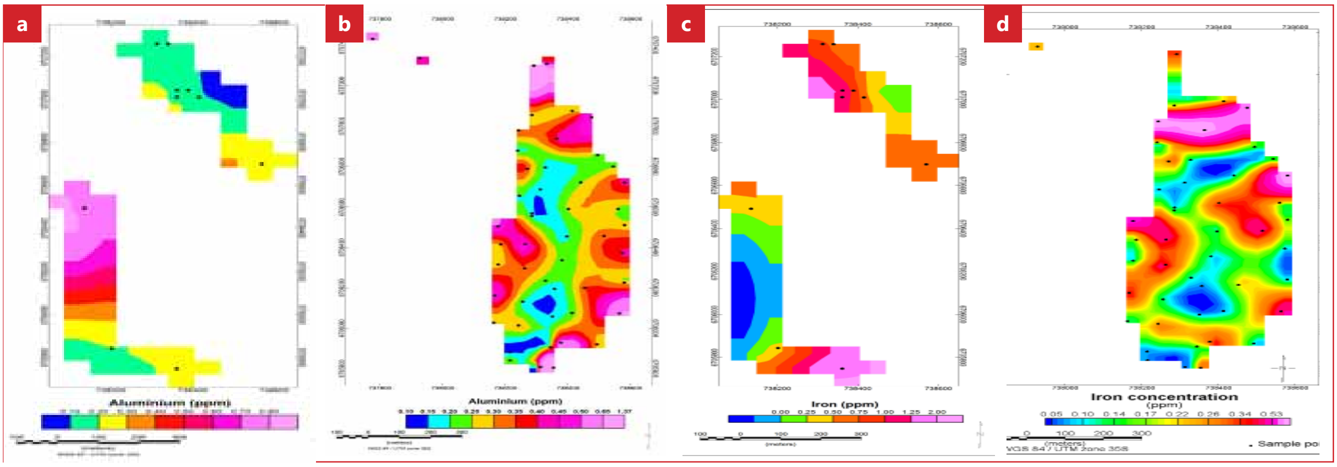


FIG 4.4 Colour map showing the distribution of the concentrations of selected elements in the dam: (a) Al – wet season (b) Al – dry season (c) Fe – wet season (d) Fe – dry season (e) Cl – wet season (f) Cl – dry season.

5. Conclusion

The analysis of nitrate occurrences in the Bonsma Dam showed that agricultural applications of manure and fertilisers are a potential source of nitrate contamination of the water. The highest nitrate concentrations were found in the inlet streams leading to the dam. Probable explanation is that overland flow from areas that are intensively fertilized, manured and grazed contains relatively high levels of nutrients such as N, P, K, organic matter and suspended particles (Khaleel et al, 1980). Macro element analysis showed that nitrates, potassium, calcium and chloride were more concentrated in the dam after the wet season. The overall ionic conductivity and total dissolved solids values were also higher in the same season, while the pH was lower in the dry season. High intensity storm events that occur in the wet months (spring) mobilise more salts and nutrient laden sediments than low intensity rainfall experience in the dry months (winter), which explains the elevated concentrations of the nutrients, organic matter and suspended solids found in the dam following the wet season. The geology of the area can also have a great influence on the overall water quality, as the weathering processes of rocks may contribute to the content of metals, nutrients and sediments in the dam.

Overall, the concentrations of most of the metals, TDS, pH and electrical conductivity values met the water quality requirements for domestic, agricultural, livestock and aquatic ecosystem uses as set by the Department of Water Affairs. On the other hand, nitrates, chloride, aluminium and iron were a concern, as they exceeded the guidelines set by the DWAF for irrigation and aquatic ecosystem uses. The iron and aluminium content of the dam water also did not meet the requirements for domestic uses. 3S

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