Long-term nitrate and phosphate loading of river water in the Upper Manyame Catchment, Zimbabwe

J Nyamangara[1]*, N Jeke[2] and J Rurinda[2]

[1]International Crops Research Institute for the Semi-Arid Areas, Matopos Research Station, P.O. Box 776, Bulawayo, Zimbabwe

[2]Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P.O. Box MP167, Mount Pleasant, Harare, Zimbabwe

ABSTRACT

Urbanisation and agriculture represent a dramatic example of human interference in catchment hydrology. The impact of agricultural, domestic, industrial and municipal activities on river flow and water quality within the Upper Manyame Catchment Area (UMCA) was assessed using 7-year nitrate, phosphate and water flow rate data, collected by the Environmental Management Agency (EMA). Water samples for nitrate and phosphate analysis were collected at 8 points along the Manyame (2 points), Marimba (2 points) and Mukuvisi (4 points) rivers, and runoff volume was recorded at the mouth of each river. Annual runoff of each river was closely related to rainfall amount, with the lowest runoff being recorded during drought years. High nitrate and phosphate concentrations were recorded directly downstream of residential, municipal and industrial areas suggesting that these were the major sources of the pollutants found in the river water. For example, phosphate concentration at 2 sites along Mukuvisi River (downstream of domestic and industrial areas) exceeded the statutory limit (0.5 mg/ℓ) for 'safe' or good quality water ('blue' category) according to the Zimbabwe Water (Waste and Effluent Disposal) Regulations, and ranged from 0.78 mg/ℓ during the dry season to 2.23 mg/ℓ during the wet season. In the Marimba River phosphate concentration at Site 4 (downstream of domestic, industrial and sewage processing plant) also exceeded the safe water quality standard by 4–6 times. Although Marimba River contributes the lowest proportion of runoff (relative to the other two rivers sampled) entering Lake Chivero, it contributed the highest nitrate (114 840 kg/yr) and phosphate (84 324 kg/yr) loading. It was concluded that anthropogenic activities within the UMCA were the major sources of nitrate and phosphate pollution in the three rivers and pose a serious threat to the ecological sustainability of the rivers and lakes downstream, and to the economic wellbeing of nearby cities which rely on the water for potable uses.

Keywords: effluent, nutrient load, river water flow rate, urban agriculture, water pollution

INTRODUCTION

Increasing loads of nitrogen (N) and phosphorus (P) in water bodies has become one of the major environmental problems facing the world (Howarth et al., 1996; Seitzinger et al., 2010). A worldwide assessment (946 rivers) showed that, although most rivers displayed nitrogen export profiles (N fraction distributions) reflecting pristine conditions, nitrate export to rivers that passed through human settlements was related to human population density (Alvarez-Cobelas et al., 2008). Although P discharges into coastal waters have stabilised or reduced in Western Europe, after unprecedented contamination during the second half of the 20th century, N trends have not attenuated and are still increasing in some places (Thieu et al., 2010). In the Tibetan Plateau, which is the water source for 40% of the world's population, anthropogenic impacts (addition of metal and non-metal ions, including ammonium ions from mining and untreated municipal wastewater) on river water quality have been recorded in some locations in the Mekong River and Yarlung Tsangpo basins (Huang et al., 2009). In sub-Saharan Africa (SSA), most rivers that pass through municipal, industrial, mining, domestic and agricultural areas are polluted and pose an environmental concern (Nyamangara et al., 2008; Arimoro, 2009; Emeka et al., 2009). The concentration of pollutants in river water is exacerbated by weak institutions that fail to effectively regulate and enforce safe disposal of wastewater and other pollutants (Nhapi, 2009).

Urban and peri-urban agriculture is also a major non-point source of water pollution. Non-point sources of pollution are challenging to control because they derive from activities which vary in space and time. For example, during the 2008/09 cropping season 50% of households in Harare, the capital city of Zimbabwe, grew maize to support their food requirements (Zimbabwe Vulnerability Assessment Committee, 2009). The increase in the number of people that have been growing crops inevitably results in increased use of N and P fertilisers. Some of the fertiliser remains in the top soil (e.g. P) where it can be washed away by runoff water, and some (e.g. N) leaches into groundwater. Besides causing environmental damage, loss of N and P from arable fields constitutes an economic loss to urban and peri-urban farmers, some of whom are very poor and live below the poverty datum line of 1 USD per day.

Most of the industrial activities in Zimbabwe, including agro-processing and fertiliser manufacture, are concentrated in Harare and its satellite towns. These urban settlements are located in the Upper Manyame Catchment Area (UMCA). Increased concentrations of pollutants that include nitrate and phosphate, have been reported in rivers that drain the UMCA (Mapanda, 2003; Nhapi et al., 2004; Nyamangara et al., 2008). Nutrients in river water cause a plethora of problems such as proliferation of algae and water hyacinth (*Eichhornia crassipes*), fish kills due to loss of oxygen, reduction of biological diversity, difficulties in potable water treatment, and clogging of irrigation pipes. For instance, periodic fish kills in the rivers

* To whom all correspondence should be addressed.
☎ +263 772 234 965/+263 712 617 063; fax: +263(0)383 8253 or 8307; e-mail: j.nyamangara@cgiar.org

Received 7 November 2012; accepted in revised form 19 September 2013.

http://dx.doi.org/10.4314/wsa.v39i5.7
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 39 No. 5 October 2013
ISSN 1816-7950 (On-line) = Water SA Vol. 39 No. 5 October 2013