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Critical pollution levels in Umguza River, Zimbabwe

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ABSTRACT

In most countries worldwide regulatory bodies set effluent discharge limits into rivers and other natural water bodies. These limits specify the maximum permissible concentration of defined pollutants that may be discharged into the water body. This limit is conceptually based on the self-purification (assimilative) capacity of the receiving water. However, this self-purification constant is itself a function of the water's pollutant loading. Umguza River situated south west of Zimbabwe, is fed by tributaries that drain an urban catchment and as such is prone to pollution due to human activities in the catchment. This study investigated the levels of pollution in Umguza River that would affect its self-purification capacity. This was achieved by characterising the spatial distribution of a selected range of water quality parameters as well as determining the self-purification capacity of a stretch of the river. Critical pollutant concentrations were determined for some of the parameters that showed high values along the stretch. The selected parameters of interest were dissolved oxygen, suspended solids, phosphates, nitrates, COD, turbidity, ammonia, pH, alkalinity and temperature. The study was carried out from January 2014 to April 2014. The self-purification capacity was determined using a formula that compares the mass flux of a pollutant upstream and downstream of the selected stretch of the river. Statistical analysis was used to establish relationships between the pollutants and the self-purification capacity of the river. The study found that the levels of ammonia and phosphates were very high compared to the regulated limits (2 mg/l vs 0.5 mg/l; and 8 mg/l vs 0.5 mg/l respectively). It was also found that the self-purification capacity varied significantly across pollutants. It was therefore concluded that a critical pollutant concentration exists above which the river completely loses its natural ability to assimilate and decrease its pollutant load over time. It was also concluded that the self-purification capacity depends on the pollutant of concern in the river. It is recommended that the self-purification capacity of a river be determined before regulatory bodies set effluent discharge limits. It is also recommended that the water quality of water bodies draining pollution prone catchments be monitored regularly, besides just monitoring the discharge points.

1. Introduction

Water is a very important part of the environment. Surface water bodies in particular provide a range of uses for people, ranging from consumptive uses to in-stream uses. It is also common knowledge that they provide beautiful scenery and support flora and fauna. Pollution of these water bodies impairs their usefulness to humans and the other ecosystems that rely on them for survival. Rivers that drain urban catchments are very prone to pollution due to the varied human activities that contribute to pollution; for example, generation of domestic wastewater, industrial effluent and runoff from solid waste disposal sites. Freshwater ecosystems naturally filter and purify water as it moves downstream. This natural ability is termed the self-purification capacity of the water body. However this ability is impaired by excessive pollution which depletes the system of essential dissolved oxygen (Shivayogimath et al., 2012).

To protect the water bodies from excessive pollution which impairs the self-purification capacity; there are standards set to regulate the quality of waste water effluent discharged into them by potential polluters. Institutions like the environmental protection agency (EPA) in the USA and environmental management agency (EMA) in Zimbabwe are put in place to help set and enforce effluent disposal standards in an effort to protect the environment. Effluent

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limit standards fall into two categories, technology based (or effluent discharge standards) and water quality based limits (or in-stream standards) (Hammer and Hammer, 2001). A technology based standard is a minimum level of technology and pollution control performance that must be achieved by municipal wastewater treatment (Freeman, 1980). Water quality based standards, which are more stringent, are based on the water quality standards applicable to the receiving water; these are employed to protect a specific water body and they are based on the assimilative capacity of the stream (Hammer and Hammer, 2001). These are a derivative of the self-purification capacity of the stream.

In Zimbabwe, EMA sets effluent discharge standards related to the expected associated risk to the receiving water body. Table 1 shows the classification of the discharge limits according to the associated risks.

One wonders then that if institutions like EMA and EPA set effluent discharge standards, does that mean "automatic protection" of water bodies from pollution? The answer sadly is no because in developing countries, poor pollution control and poor enforcement of land use policies exposes the rivers to indiscriminate pollution (Mbuligwe and Kaseva, 2005). Besides this scenario of poor enforcement of pollution control measures, Hammer and Hammer (2001) also assert that imposing discharge limits does not guarantee the protection of the receiving water body from pollution.

Umguza River passes on the northern side of Bulawayo, the second largest city of Zimbabwe. Bulawayo municipality has eight wastewater treatment plants scattered around the city, by design none of these should directly release their effluent into the river, but it has been reported though that wastewater from burst pipes and inadequately pre-treated industrial effluent have found its way into nearby water bodies. Dube et al. (2010) reported that raw sewage was sometimes released into the Mazayi stream, a tributary to Umguza River; due to malfunctioning of a nearby wastewater treatment plant. This study sought to establish the level of pollution of Umguza River and how its self-purification capacity is being affected by these levels of pollution.

2. Material and methods

2.1. Study area

Umguza River has many tributaries that join to it before it flows out of the city of Bulawayo, some of these tributaries like Mazayi and Matsheumhlope pass through industrial areas and many residential areas. The vicinity of the river and its tributaries to the urban area exposes it to excessive pollution through sewer bursts, industrial waste and general human pollution. There are also small scale commercial farmers scattered along the river basin. Umguza River is impounded by upper Umguza dam and lower Umguza dam. These two reservoirs are used for recreational purposes as well as fishing and sustaining the Umguza nature reserve. Water downstream of the Umguza dams is used for agricultural purposes and human consumption for communities downstream. The research was carried out on a 10 km stretch of Umguza River shown in Fig. 1. The stretch starts at the confluence of the main tributary stream Matsheumhlope and Umguza River, upstream of upper Umguza dam, and ends at the start of lower Umguza dam.

2.2. Spatial variability of water quality in the river

2.2.1. Data collection

Physic-chemical water quality parameters were selected for this investigation because they were deemed adequate to give a reasonable indication of pollution levels in the river. Microbiological parameters were not considered in this study. The parameters that were measured were pH, alkalinity, total suspended solids, COD, chlorides, phosphates, turbidity, nitrates and ammonia. Grab samples were collected twice a month at selected sampling points during the study period of January 2014 to April 2014. Temperature was measured on site and recorded.

Five sampling points were selected along the river stretch for water quality analysis as shown in Fig. 1 as P1, P2, P3, P4 and P5. The sampling points for the investigation were selected to account for the following factors:

- To cover all the spots where there seems to be significant aeration in the stream, like bridges where the water is forced to fall from a height as it passes through the bridge.
- To cover all the confluences so as to account for additional discharge coming into the experimental reach.
- To cover all the sites on the experimental stretch where there is apparent retention of the water, i.e. the Upper Umguza dam.
- To achieve reasonable spread along the experimental stretch.

Table 2 gives a description of the sampling points in relation to each other and the surrounding environment.

2.2.2. Data analysis

Standard Methods of analysis for Water and Wastewater testing according to APHA (2005) were used in the laboratory to determine the concentrations of the selected parameters from the collected water samples. The concentrations obtained were analysed using a statistical package, SPSS and Microsoft Excel. SPSS was used to determine the mean concentration values of the parameters at each sampling point which were then plotted using Excel to determine the spatial trends. The mean concentrations of parameters were compared with the effluent discharge limits set up by EMA.

Table 1
Classification of discharge limits.

Discharge limits			Classification	Risk
Concentration of pollutants increase	↓	Concentration of dissolved oxygen decrease	Blue	Safe
			Green	Low Hazard
			Yellow	Medium Hazard
			Red	High Hazard

(Adapted from Government of Zimbabwe, 2007)