University of Venda

Assessment of the Efficiency of Wastewater Treatment Facilities and the Impact of their Effluents on Surface Water and Sediment in Vhembe District, South Africa

By

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ABSTRACT

Wastewater treatment facilities are among the known sources of freshwater pollution. This study was carried out to assess the removal efficiencies of some selected contaminants in two wastewater treatment facilities (WWTFs) in Vhembe District of South Africa. The likely effects of the discharge of effluents from these facilities onto freshwater courses were also investigated. Novel approaches for trace metals removal from aqueous solution and wastewater using synthesised chitosan from land snail shells, mucilaginous leaves and stem from *Diceriocaryum eriocarpum* plant (DEP) are proposed.

Physico-chemical parameters such as electrical conductivity (EC), pH and turbidity were measured onsite using appropriate meters. Anions concentrations were determined using an automated ion chromatograph (IC) (Metrohm, Switzerland), while faecal indicator organisms were enumerated using membrane filtration method. Trace metals and Polycyclic Aromatic Hydrocarbons (PAHs) concentrations were analysed using inductively coupled plasma optical emission spectrometer (ICP-OES) and Gas Chromatograph Time of Flight Mass Spectrometer (GC-TOF-MS), respectively. Compliance of these parameters was performed by comparing the values obtained in this study with the recommended guideline values of the South African Department of Water Affairs (DWA) for wastewater discharge, Department of Water Affairs and Forestry (DWAF) for various uses of water, World Health Organisation (WHO), United States Environmental Protection Agency (US EPA) and Canadian Council of Ministers of the Environment sediment guidelines (CCME).

The pH of the effluent from both WWTFs fell within the recommended values of 5.5-9.5 stipulated by DWA for wastewater discharge onto watercourse. EC values in the WWTFs ranged between 24.3-125.3 mS/m. Reduction efficiency values of EC were in the range of 8-34% in Thohoyandou wastewater treatment plant (WWTP) and 34-54% for Siloam waste stabilisation ponds (WSPs), although no reduction in EC values was obtained in some sampling months. There was EC compliance with the DWA guideline for wastewater discharge (150 mS/m) for both treatment systems. Reduction efficiencies for turbidity in the WWTP was in the range of 86-94% but the WSPs were unable to reduce turbidity levels as no reduction was obtained. Thohoyandou WWTP is discharging effluent with lower chemical oxygen demand

(COD) concentration (50-150 mg/L) in comparison with Siloam WSPs, which discharges effluent with high COD concentration (82-200 mg/L) which exceeds the DWA limit of 75 mg/L for wastewater discharge. Inconsistent removal of metals, anions and faecal indicator organisms were determined for both wastewater treatment systems. Majority of the anions complied with DWA effluent discharge standard except for F^- and NO_3^- in some sampling months for both wastewater treatment systems.

The concentrations of Al, Cu, Fe, *E. coli* and *Enterococci* exceeded the DWA threshold values for wastewater discharge throughout the study period in both WWTFs. However, the concentrations of Pb, Mn, Cr and Zn exceeded the threshold values in some sampling months for both systems. Low concentrations of anions in the acceptable range were determined in both river waters. The average concentrations of all the metals investigated in Nzhelele and Mvudi Rivers waters exceeded the guideline values of DWAF for the protection of aquatic life. The concentrations of Al, Cr, Fe and Mn exceeded the recommended guidelines for domestic water use, while the concentration of Pb fluctuated below and above the threshold limit of 0.01 mg/L. The concentrations of Cd, Cu and Zn complied with the DWAF and WHO standards for domestic water use for all the sampling months. The levels of metals determined in the water and sediments of both rivers varied significantly except for Cd. The levels of metal contamination in both rivers is comparable as their mean difference did not differ significantly ($p>0.05$). However, the mean difference in the levels of Al, Cd, Cr, Fe and Mn in the sediments of both rivers varied significantly. The trends observed for trace metal contamination of sediments in Nzhelele and Mvudi Rivers were Al>Fe>Mn>Cu>Zn>Cr>Pb>Cd and Fe>Al>Mn>>Cu>Cr>Zn>Pb>Cd, respectively.

E. coli counts varied between 80 to 3 $x10^4$ cfu/100 mL and 1 x 10^2 to 8 x 10^4 cfu/100 mL, in Mvudi and Nzhelele Rivers, respectively. The average *E. coli* were higher in the wet season (5.04 x 10^3 cfu/100 mL) than in the dry season (4.34 x 10^3 cfu/100 mL) but this difference did not vary significantly. In Nzhelele River, *E. coli* counts were lower in the wet season (9.06 $x10^2$ cfu/100 mL) than in the dry season (1.68 x 10^4 cfu/100 mL) and the mean difference for both seasons varied significantly ($p<0.01$). *Enterococci levels* varied between 1 x 10^2 to 6 x 10^3 cfu/100 mL and 1 $x10^2$ to 5.7 x 10^3 cfu/100 mL, in Mvudi and Nzhelele Rivers, respectively. The levels obtained in both rivers were higher in the wet season than in the dry season and their mean difference varied significantly ($p<0.01$) for both seasons in both rivers. The levels of faecal

indicator organisms enumerated exceeded the threshold values of DWAF and WHO for domestic water use. Other physico-chemical parameters obtained fell within the recommended guidelines of the DWAF and WHO for domestic and recreational water use for both seasons except for turbidity.

PAHs concentrations in water and sediment samples from all the sampling sites in both Mvudi and Nzhelele Rivers were in the range of 13.174-26.382 mg/L and 27.10-55.93 mg/kg, respectively. Moderate concentrations of PAHs were determined in the effluent of both treatment facilities. High molecular weight PAHs were more prevalent than the low molecular weight PAHs. Diagnostic ratios linked pyrogenic sources as the major source of PAHs. The application of novel biosorbents for the removal of Pb^{2+} from aqueous solution and wastewater samples showed that synthesised chitosan was more effective than mucilaginous leaves followed by mucilaginous stem of DEP. In conclusion, the WWTFs are not functioning properly and are releasing ill-treated effluents into both river systems. The river waters are contaminated and unfit for domestic purposes and are possible threats to public health because of the non-compliance of the microbiological parameters. The three biosorbents show the potential for use in removing Pb^{2+} and other metals from aqueous solution.