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The physic-chemical assessment of urban river basin using macroinvertebrate indices for the environmental monitoring of urban streams

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ABSTRACT

BACKGROUND AND OBJECTIVES: The major sources of pollution along the Mukuvisi River are industrial effluents from Msasa, Graniteside, and Southerton industrial sites, sewage effluent from Firle sewage works, pesticide and fertilizer runoff from Pension and surrounding farms, and domestic and diffuse pollution from residential areas. The primary objective of this study was to assess the impact of point and non-point pollution sources on macroinvertebrates variability and investigate the seasonal water quality deterioration along the Mukuvisi River. To evaluate macroinvertebrate community diversity using South African Scoring System 5 protocol for rapid bioassessment of water quality. The combined application of benthic macroinvertebrates and physic-chemical parameters was the focus of this research to validate the water quality status of the urban River systems concerning emerging pollutants in urban areas.

METHODS: According to the Harare municipality pollution control strategy and surveillance, only twelve accessible sampling points were chosen along the river. Macroinvertebrate samples and physic-chemical measurements were collected once or twice a month, according to the city of Harare's sampling schedule. The ancillary information, temperature, pH, and conductivity were measured on-site with a mercury bulb thermometer, a pH meter, and a conductivity meter, respectively. The standard South African Scoring System 5 sampling protocol was used for the sampling and identification of the macroinvertebrates community.

FINDINGS: The early assessments showed that water pollution was, in the 1st place and as a primary issue, a biological matter, and its primary effects could have been traced to living organisms. Eutrophication in Manyame catchment, Harare, Zimbabwe is subjected to prolonged and cumulative ecosystem stress because of human activities, sewage disposal, and industrial discharges, among other pollution sources. The Phosphorus-P, Biological Oxygen Demand, Chemical Oxygen Demand, and Ammonia-NH_3 (from 0, 6.9, 118, and 0 to 3.8, 81.9, 840, and 31 mg/L respectively) concentration increases downstream in both seasons. The Dissolved Oxygen saturation was 75% and 67% upstream in the dry-and-wet season and was reduced to 0% downstream in both seasons. The evaluation of macroinvertebrate diversity provided evidence that Mukuvisi River water was polluted based on the South African Scoring System, especially in the dry season.

CONCLUSION: The physic-chemical parameters were significantly related to macroinvertebrates diversity. In the assessment of river water quality, both macroinvertebrate indices and physio-chemical parameters can be sampled together to avoid bias. The results indicated that human activities from the upstream were inducing water pollution. Industries need to adhere to the wastewater discharge guidelines.

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INTRODUCTION

Water is unquestionably the most valuable natural resource and the demand for this water is already exceeding the supply in many parts of the world, and as the world population continues to rise, so too makes the water demand. When it is unfit for its intended use, water is considered polluted (El Sayed *et al*., 2020). Exaggerated irrigated agriculture, large scale-mining, power generation, heavy industries, and inadequate domestic sewage treatment have seen rivers turn into pollution drains (Golfieri *et al*., 2018; Phiri, 2000). In Africa, some water reservoirs are experiencing somewhat different forms of environmental impact, the like as Lakes Victoria, Tanganyika, and Malawi (Nemery *et al*., 2018, Alin *et al*., 1999). Global statistics indicate that more than two-thirds of the urban population is below the poverty line (Tacoli *et al*., 2015; Duque *et al*., 2015; Chant and Datu, 2015). Seventy percent of cities' inhabitants live in slums (Wu *et al*., 2013; Chen *et al.,* 2013; Bhattacharya *et al*., 2012), with insufficient water and sanitation setups, poor health environments, and a lack of social cohesion or individual rights. The growth and development of urban areas are affecting the water quality, leading to the eutrophication of several water bodies (Kibena *et al.,* 2014; Palamuleni *et al*., 2011). Consequently, Zimbabwe is not an exception, the city of Harare is facing heavy pollution with the high growth of invasive plants in several water bodies including rivers and lakes (Dube *et al*., 2018). Lake Manyame and Chivero are amongst the polluted water bodies with high eutrophication status (Shekede 2008; Chawira 2013). The source of contamination originates from the disposal of industrial and domestic wastes, as well as agricultural runoff (Dube *et al.,* 2018). The major sources of pollution along the Mukuvisi River are industrial effluent from Msasa, Graniteside, and Southerton industrial sites, sewage effluent from Firle sewage works, pesticide, and fertilizer runoff from Pension and surrounding farms, and domestic and diffuse pollution from residential areas. Different materials are being discharged into the receiving waters such as still wastes, fertilizers, and heavy metals from industrial sites as well as nutrients from wastewater treatment systems (Muserere *et al*., 2014; Masere *et al.,* 2012). Other researchers concluded that high population growth and agricultural and industrial contaminations contributed to the pollution of Manyame River being in the same catchment under study. Additionally, turbidity, nitrates, phosphates, and Dissolved Oxygen (DO) were greater than the Zimbabwe National Water Authority (ZINWA) maximum allowable concentrations (Masere *et al*., 2012). The primary objective of this study was to assess the impact of point and non-point pollution sources on macroinvertebrates variability and investigate the water quality deterioration along the Mukuvisi River. In other ways, as water is a resource that requires to be conserved, monitored, and restored, one of the most effective ways to establish river basin health is through the benthic macroinvertebrates assessment as biological indicators. This is due to their ease of collection for quick valuations and their sensitivity to a range of stress including sewage pollution (Khatri *et al*., 2021). Among other biological variables, benthic macroinvertebrates are the most used all over the world. To quantify biological status in rivers, biotic indices are applied as numerical expressions combining quantitative measures of species diversity with qualitative information on the ecological sensitivity of individual species (Medupin, 2020). To evaluate macroinvertebrate community diversity using South African Scoring System 5 protocol (SASS 5) for rapid bioassessment of water quality (Dickens and Graham, 2002; The Water Wheel, 2018) and its relationship to the physic-chemical parameters. The availability or absence of certain species determines the water quality of the sampling site because different species have considerably different pollution tolerances. This research study aims to offer how the macroinvertebrate taxa occurrences will be analyzed in different pollution levels and identify some specific taxa that potentially indicate certain levels of pollution along the Mukuvisi River. Our findings will provide information pharmacy to ecologists, water managers, stakeholders, and policymakers when decisions are to be made on upcoming studies on different rivers, lakes, dams, and streams to combat water contamination for monitoring exercises. The similarity index was used to categorize the comparison between the selected sample sites and the diversity of that area along the river. The combined application of benthic macroinvertebrates and physic-chemical parameters was the focus of this research to validate the water quality status of the urban River systems concerning emerging pollutants in the city. Additionally, the natural and anthropogenic trends were to be determined to provide the current River status for future management and monitoring of pollution from the surrounding industries. . Additionally, the natural and anthropogenic trends were to be determined to provide the current River status for future management and monitoring or pollution from surrounding industries. To achieve the objectives of this study, the research was conducted in the capital city of Zimbabwe, Harare, from 2018 to 2019.

MATERIALS AND METHODS

Study area

The Mukuvisi River originates close to the City of Harare just below the Cleveland dam, rises to the east of the city, and drains into Lake Chivero. The Upper Manyame Sub-catchment (UMSC), the catchment (Fig. 1b) in which the capital city Harare lies, experienced significant population growth from 2 million in 2010 (Chirenda *et al*., 2020) to over 2.7 million in 2012 (ZIMSTAT, 2012). Given an average annual growth rate of 2% for Harare (ZIMSTAT, 2012), its population was estimated at 2.92 million in 2016. During the wet season, the mean annual rainfall is approximately 820mm, with a range of 440-1200mm, characterized by high intensities falling between November and March (Chirenda *et al*., 2020), unlike during the cool and warm dry season, May to October.

Physic-chemical data collection and measurement

Twelve accessible sampling points were chosen along the river, following the Harare Municipality surveillance and protocol of streams water quality monitoring strategy as shown in Fig. 1a. Macroinvertebrate samples and physic-chemical measurements were collected once or twice a month, according to the city of Harare's sampling schedule, from each site. Water samples were collected from each site and transferred to the laboratory and stored in a refrigerator for later analysis. Ancillary data was measured on-site to avoid deterioration of the sample. The ancillary information, temperature, pH, and conductivity were measured on-site with a mercury bulb thermometer, a pH meter, and a

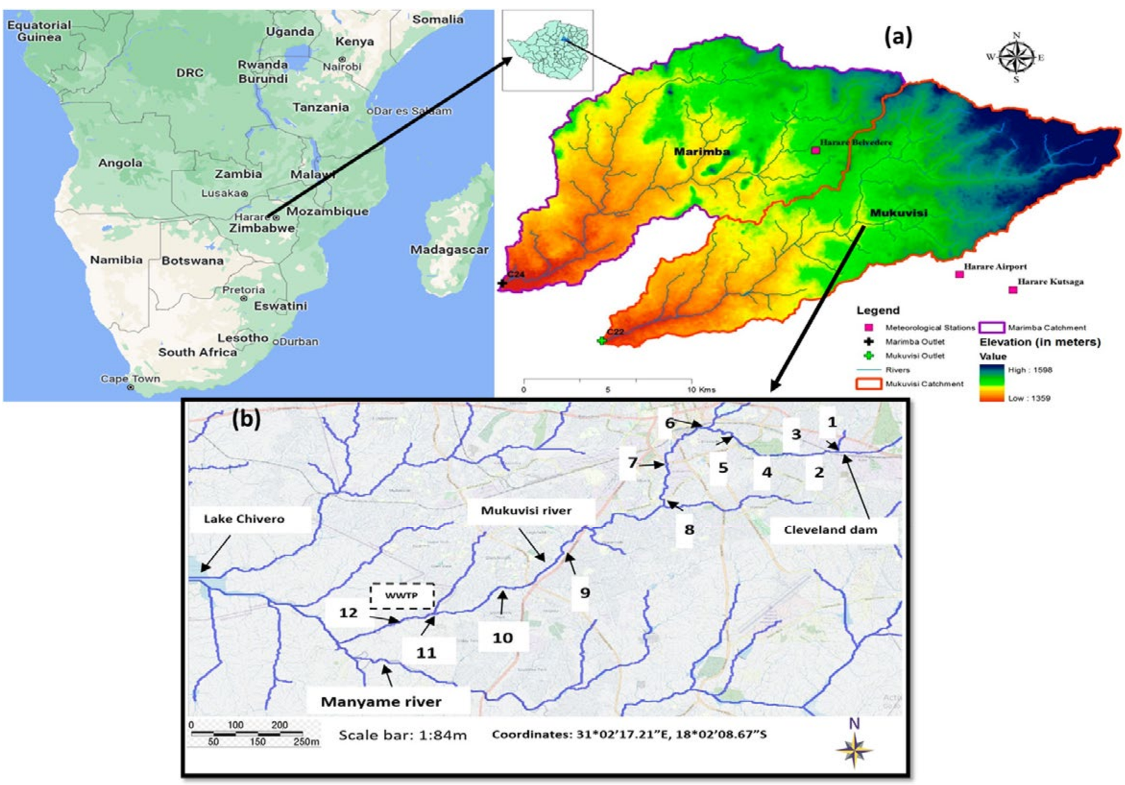

Fig. 1: 1a, a detailed aerial view of Mukuvisi River showing the sampling sites; 1b, show DEM for Mukuvisi River catchment (Google, 2022: Gumindoga *et al*., 2014).

conductivity meter, respectively. In addition, DO was also fixed on-site in 300 ml bottles using Manganous Sulphate and alkaline iodide solution as the reagents. The Biochemical Oxygen Demand (BOD) was fixed and determined using the dilution method (Dube *et al*., 2018) in the laboratory. Nitrates, ammonia, and phosphate concentrations were determined by titration. The concentrations of suspended solids were determined by filtering a 200 ml sample of water and evaporating it slowly in an oven at approximately 103 -105ºC on a pre-weighed filter paper. Turbidity and color were also determined using a turbidity meter and a comparator, respectively. The collected water samples were stored in 1-liter dark glass bottles, and immediately stored in a Cooler box (Therapak; Coleman, OR, USA) and transported to the laboratory as soon as possible. In the laboratory, samples were stored at 4◦C until laboratory analysis within 24 h after sampling as suggested by World Health Organization. The water chemistry was measured through a DR3500 Hach Lange lab spectrophotometer (HACH Company, Loveland, CO, USA) and Hach Lange kits to measure, nitrate-nitrogen, orthophosphate, Chemical Oxygen Demand (COD), nitrate-nitrogen, and ammonium-nitrogen. In addition to this, independent analysis and external quality control were carried out by Harare water and ZINWA, as accredited laboratories.

The sampling and identifications of macroinvertebrates

(Kebede *et al*., 2020; Gumindoga *et al*., 2014) elucidated that the surface current velocity at each site was determined by measuring the movement of a float over at least five meters. At first, a float was thrown into the flowing river water and a stopwatch was used to measure the time spent along the river for five meters this can give the flow velocity. This helps to understand the condition of each site and the organisms that can be found under different flow velocities as well as levels of contamination according to ZINWA among other pollution levels.

The standard SASS 5 sampling protocol was used (AQUASTAT, 2003). For the sampling and identification of the macroinvertebrate community, organisms were identified at the family level with the aid of macro-invertebrate identification field manuals (Molineri *et al*., 2020; Wan *et al*., 2018). Taxon number SASS 5 score and Average Score Per Taxa (ASPT) were calculated as stipulated in the SASS 5 manual (AQUASTAT, 2003). Samples were identified on-site as stipulated by SASS 5 protocol and only those that could not be identified on-site were taken to the laboratory for identification after preservation in 70% alcohol as suggested by Wan *et al*., (2018). Moreover, the total impact of human activities was determined and corresponded on a scale between 0 to 10. The selected sampling sites were again classified into three different groups (low, mid, and high) of human activity impact derived from these established scores. So, the Scores were varying from 0 to 2 for severe impact sites; 2 to 5 for reasonable or mid-level impact, and >7 for safe site conditions. A kick sampling net was used to collect the macroinvertebrates with a square hand net with a mesh size of 0.5 mm and the measurements were conducted within 5 mins on each site. For each site, 3 collection replicates were conducted, each time, the collected sample was washed and rinsed to remove other microhabitats (macrophytes, sand, mud, and stones) and later conserved in a 95% ethanol. All the macroinvertebrates were identified at family levels with a stereo Olympus SZX10 (LED-light) microscope (Olympus, Tokyo, Japan).

Analytical framework

A hierarchical method, the average linkage cluster analysis, was applied to the mean values of the invertebrates for each site (Kebede *et al*., 2020; Karrouch *et al*., 2017). Hierarchical classification groups similar sites together, indicating relationships among these groups along a stream (Golfieri *et al*., 2020; Cohen *et al*., 2006). Thus, the number of different taxa in each sample was determined, counts from samples of each site were pooled and the relative percent abundance of each taxon was calculated. As suggested by Karrouch *et al*. (2017); Chant and Datu, (2015) the South African Scoring System Version 5 protocol, a rapid method for water quality assessment developed along the lines of the British Biological Monitoring Working Party 7 (Palamuleni *et al*., 2011; Phiri 2000), was applied to the macroinvertebrate samples. An Average Score Per Taxon (ASPT), the mean rating for all the families in the sample, was calculated (Nemery and Nkulu 2020; JICA, 1996). The condition of each site was then determined using the SASS score, No. of taxa and the ASPT (Ruiz-Picos *et al*., 2017).

GenStat 10.3 DE Regression analysis for data analysis

The GenStat (Vers. 21.1 DE) was used to run a regression model to show the relationships between macroinvertebrates diversity and physic-chemical variables along the Mukuvisi River. The physic-chemical parameters were regressed against the ASPT for dry and wet seasons. The coefficient of determination (R^2) was established with the trend line fitted. Figures, graphs, and statistical analysis were produced by R-Software (vers. 4.1.2.).

RESULTS AND DISCUSSION

Water physic-chemical trend analysis

The water physic-chemical characteristics of each site are shown in Tables 1 and 2. The pH was generally basic in all sites along the stream for both seasons except site 3, which had acidic conditions in both seasons and is not within the acceptable limits of pH 6.0-9.0 according to the Zimbabwe National Water Authority (ZINWA) standards. In the dry season, sites downstream had acidic conditions of pH<6.0, probably influenced by industries through which this river passes. In both seasons, the ranges of temperature values were within the acceptable limits in most sites, as shown in Tables 1 and 2 except for sites 10, 11, and 12 in the dry season, which had higher values. Electric Conductivity (EC) concentration was in the permissible range in most sites in the dry season.

However, sites 3, 10, 11 and 12 values were greater than the maximum acceptable concentration for Zimbabwean raw water, which is <1000 dS/cm. The EC concentration was above the normal standards in most sites in the wet season, as shown in Table 2, and this mostly decreases as we approach the lower sites. This could be due to intermittent increases in daily temperatures during the rainy season or otherwise the rising of underground water levels having an impact on the impoundment. Therefore, the dilution effect from rainfall tends to reduce the concentrations of nutrients hence the downstream sites be disposed to have lower EC than in sites above as well during the dry season.

Levels of turbidity and suspended solids (SS) fluctuated greatly above the acceptable limits in all seasons. However, sites 3 and 12 had values above the normal standards. The discharge of chemical effluent might induce this from the Zimphos industry

Table 1: Averages of physicochemical water variables at sites on the Mukuvisi River during the dry season

SITE	PH	EC	TEMP	DO	NO_3	NH_3	PO_4	COD
1	6.075	450.5	19.875	4.2	0.01	0.6	0.2	213
2	5.945	630.5	22.75	3.4	0.1	0.6	0.2	358.225
3	2.9925	3023.75	24.25	2.6	0.08	0.5	2.4	998.2
4	6.0875	670.75	20.625	4.8	0.26	0.78	1	358.35
5	7.605	520.5	20	4.8	0.4	0.8	0.2	456.175
6	6.0675	636.5	24.5	3.9	0.2475	0.79	0.2	653.05
7	6.9	570.75	24.25	5.2	0.175	0.6	0.1525	356.375
8	6.145	611.25	23.875	3.7	0.01	0.6	0.53	405
9	4.89	1450.5	23.625	4.5	0.1	0.61	1.2	714.1
10	4.98	1590.25	26	0.7	0.02	0.5	2.6675	906.675
11	5.89	1490.75	25	1.6	0.16	0.62	1.2	539.675
12	4.89	2100.9	28.375	0	0.025	0.5	3.12	2227.325

Table 2: Averages of Physico-chemical water variables at sites on the Mukuvisi River during the wet season

SITE	PH	EC	Temperature	DO	NO_3	NH_3	PO_4	COD
1	5.6	3500.6	20.675	5.95	0	0	0	117.75
2	6.68	1560.01	22	2.8	0.1	9.5	0	290.895
3	4.2	4120.55	21.5225	5.1775	0.19	9.505	0.6225	598.48
4	4.25	3100.5	22.1	4.675	0.1025	8.23	0.06	310.4125
5	6.3	1250.11	21.85	4	0.7	9.3925	0.015	322.025
6	6.4	1350.99	21.75	4.1975	0.135	4.5	0	267.89
7	6.125	1500.6	22.75	3.85	0.14	4.7	0	270.1025
8	6.7	1450.02	21.75	5.45	0.1	8.5	38.225	299.835
10	7.0875	500.56	22.6	3.225	0.0675	18.94	0	490.735
11	6.975	976.25	22.35	0.725	0.07	16.95	0.5225	458.55
12	8.325	1005	25.87	0	0.05	31.115	3.81	840.415

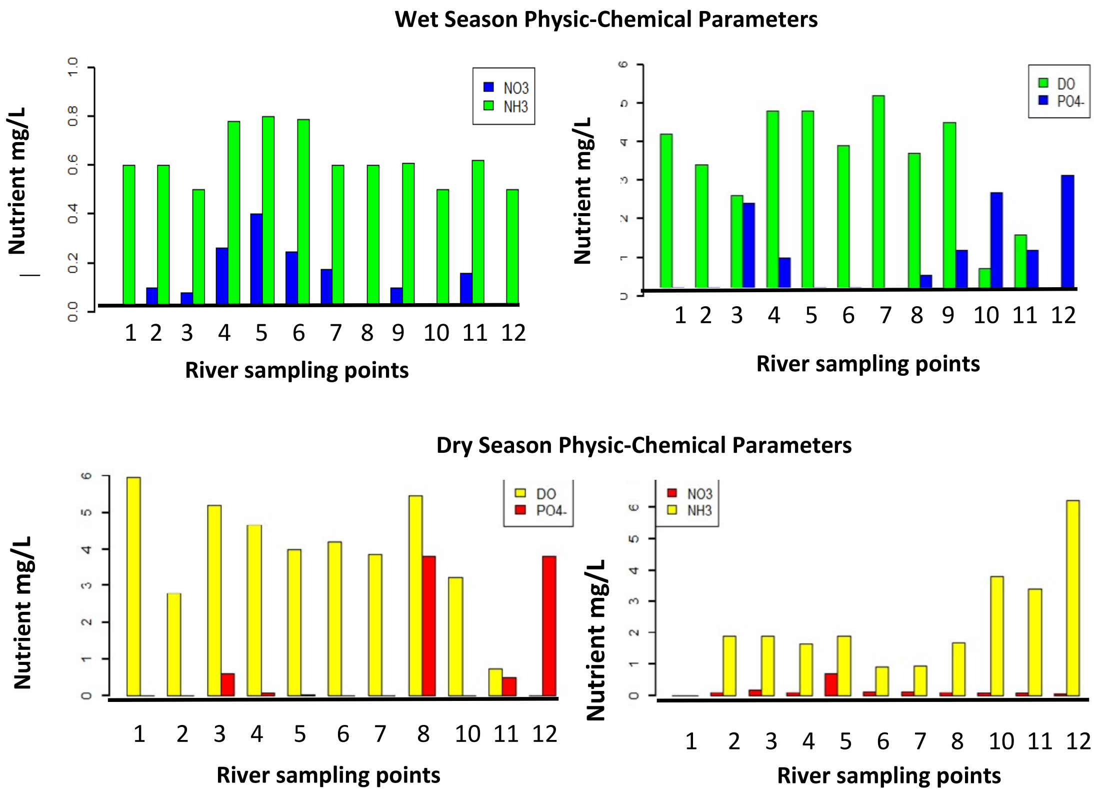

Fig 2: Seasonal variations in water quality along Mukuvisi River, 2018-2019

Table 3: The results show DO percentage saturation in dry and wet seasons

	SITE	1	2	3	4	5	6	7	8	9	10	11	12
DO %	**Dry**	75	52	94	61	59	48	100	68	66	9	7	0
SATURATION	**Wet**	67	19	59	54	46	48	40	63	ns*	36	1	0

Key= ns*-no sample

and the Firle sewage treatment works. In the dry season, ammonia was slightly above the normal standards of raw water, which is < 0.5 mg/l, in some sites and increased downstream as shown in Fig. 2. Few sites had these high values of ammonia in the wet season with concentrations above normal limits and also increased towards site 12. P concentrations were generally lower than normal standards, that is <0.5 mg/l, though they increased towards site 12 in both seasons. On-site 8 phosphates were above the acceptable levels in both seasons. Nitrate was very low, in all seasons, and was within the sensitive and normal standards of the raw water of Zimbabwe, that is <3 mg/l. Almost no nutrient was found on site 1 during the rainy season with the possibility of the dilution effect and limited access to agricultural discharges or runoff. The COD was determined and found to be very high above expected values of <30mg/l in all seasons. The COD levels continued to increase downstream, as in Fig. 2. The DO % saturation was found in the normal acceptable range in most sites along the river as shown in Table 3, and as indicated in the ZINWA guidelines. Generally, the DO levels decrease downstream up to nil in site 12 in both seasons.

Macroinvertebrate community

Three groups of sites showed similarity in the macroinvertebrate diversity obtained. Sites 5, 6, and 1 showed that the water quality was excellent,

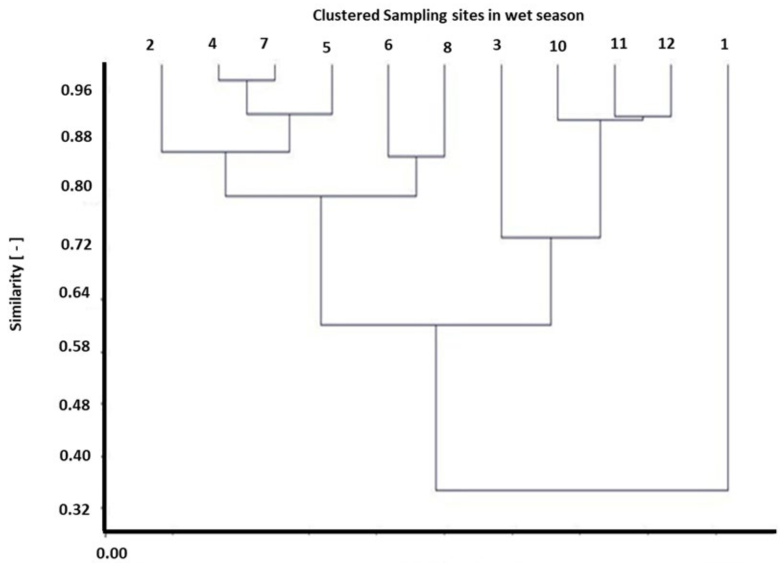

Fig 3: Cluster Dendrogram of 11 sampling sites based on the average linkage cluster analysis of macroinvertebrates in the wet season.

especially site 1, which is at the mouth of the Cleveland dam, as shown in Fig. 1. The other groups were composed of sites 3, 10, and 12. The last group consists of sites 2, 4, 7, 8, 9, and 11 show a minimum pollution percentage likeness to other sites considering the macroinvertebrate diversity. Generally, the three groups show that the percentage similarity of the first group to others is lower, by 40%, and the other two are almost above 60%. This deviation can be due to the limited availability of water in the dry season, so the self-purification of wetlands (Patang *et al*., 2018) found along the river channel, might be very high since the wetlands were able to purify minimum available water in other sites.

Wet and Dry season

A dendrogram is a tree structure used to visualize the results from hierarchical clustering (Arief *et al*., 2017) and it was used to gather site similarity or linkage clustering in both dry and wet seasons. Three groups were established in the wet season, using a cluster dendrogram software, where site 1 stood on its own being different from other sites with a percentage similarity of less than 5%. This simply means that site 1 is not significantly polluted, as indicated in Fig. 3.

Site 9 was not sampled because of inaccessibility due to the bridge under construction along Beatrice Road. Generally, there were more macroinvertebrate families obtained in the wet season than in dry Fig. 4, apart from sites 1, 5, 6, and 8 which had numbers comparable to those in the wet season. In the dry season, sites 1, 5, and 6 seem to share similar characteristics of better quality over others as indicated in Fig. 4.

The Mukuvisi River quality status based on the SASS 5

A summary of SASS Scores, number of taxa, and ASPT is shown in Table 4. Site 1 in the dry season had the highest SASS score and the number of taxa hence shows good conditions as indicated in Table 5 and site 5 had the highest ASPT. In the dry season, Site 3 has the lowest SASS score, No. of taxa and the ASPT meaning poor conditions of water quality however, site 12 indicated the same ASPT for both seasons.

Macroinvertebrate and physic-chemical relationships

The invertebrate sample scores and the ASPT were significantly correlated to the water conductivity and DO as well as pH, temperature, ammonia, nitrate, COD, and phosphates.

Selected sites along the Mukuvisi River greatly differed concerning the selected physic-chemical variables. Generally, the water quality decreased along the course of the Mukuvisi River mostly in the dry season but did not change much in the wet

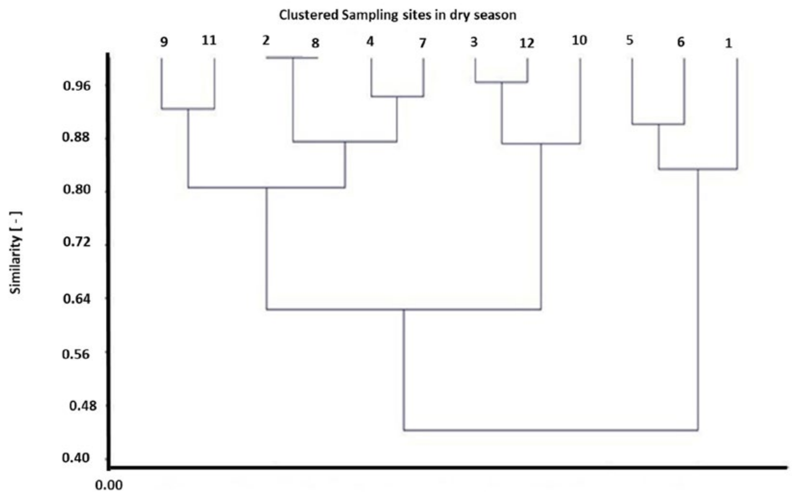

Fig 4: Cluster Dendrogram of 12 sampling sites, based on the average linkage cluster analysis of macroinvertebrates in the dry season

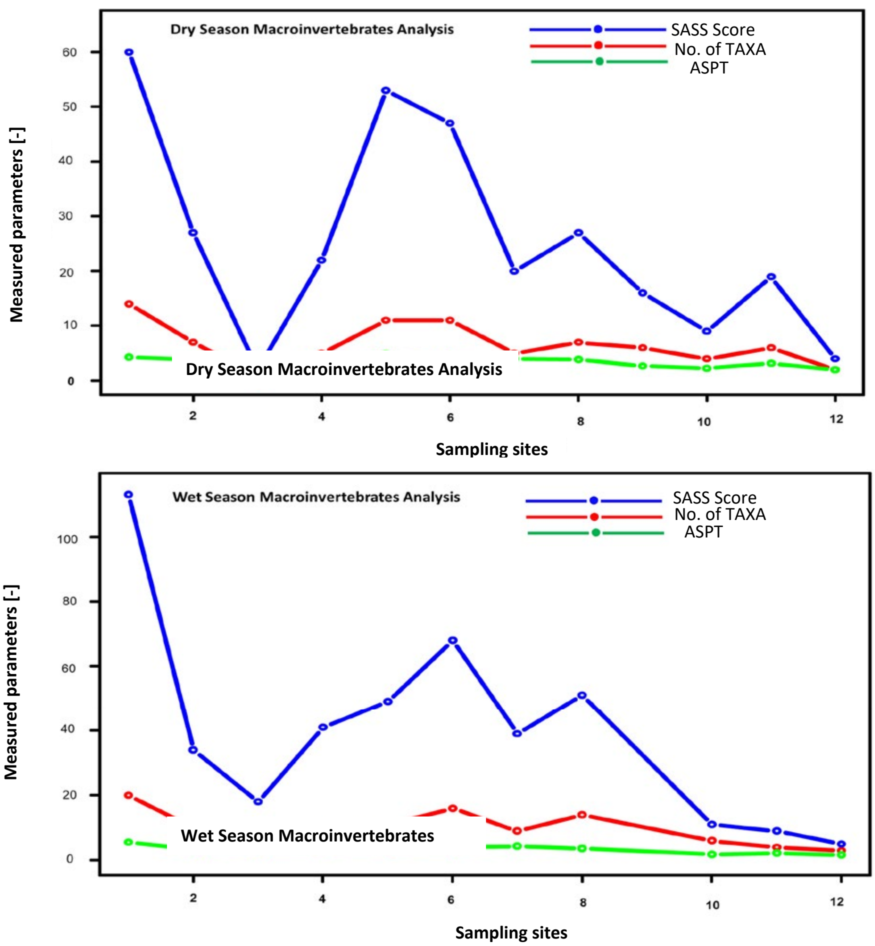

Fig 5: Results of macroinvertebrate scores, number of Taxa, and the average score per taxon (ASPT) in dry and wet seasons on the Mukuvisi River based on SASS 5.

Table 4: The scores used to determine the condition of a site using SASS 5 (Ollis *et al.,* 2006)

Condition	Habitat score	Sample score	ASPT
Excellent	>100	>140	7
Good	80–100	100–140	5–7
Fair	60–80	60–100	3–5
Poor	40–60	30–40	2–3
Very poor	<40	<30	<2

Table 5: Results of macroinvertebrate scores, number of Taxa, and the Average Score Per Taxon (ASPT) in dry and wet seasons on the Mukuvisi River based on SASS 5.

		DRY SEASON			WET SEASON		
Site	**Site description**	**SASS Score**	**No. of Taxa**	**ASPT**	**SASS Score**	**No. of Taxa**	**ASPT**
1	Dam mouth	60	14	4.29	113	20	5.56
2	Mutare road bridge	27	7	3.86	34	10	3.4
3	Zimphos	2	1	2.00	18	4	4.5
4	Msasa railway cross	22	5	4.40	41	9	4.56
5	Chiremba road bridge	53	11	4.82	49	11	4.45
6	Seke road bridge	47	11	4.27	68	16	4.25
7	Cripps road bridge	20	5	4.00	39	9	4.33
8	Boshoff road bridge	27	7	3.86	51	14	3.64
9	Beatrice	16	6	2.67	NS*	NS*	NS*
10	Amalinda road bridge	9	4	2.25	11	6	1.83
11	Above Firle	19	6	3.17	9	4	2.25
12	Below Firle	4	2	2.00	5	3	1.67

*NS-No sample, was inaccessible due to weather

season. The variances in the quality of water from the twelve sites reflect the differences in the activities conducted. Industrial sources, domestic and sewage effluent disposals, as well as anthropogenic activities, are the leading causes of a decrease in the water quality along the Mukuvisi River as revealed by Phiri (2000). The benthic community in lotic water is strongminded by the existing flow speed, the substrate, physic-chemical variables of the water, and the zoogeographical region (Jerves-Cobo *et al*., 2020). Measurement by observing the changes in the number of taxa defines ecosystem degradation by pollution, which is a more responsive measure than other ecological measures such as the number of organisms (Akay and Dalkıran, 2020; Masere *et al*., 2012). Mollusks are some of the least tolerant macroscopic invertebrates to heavy metal pollution and Chironomidae larvae usually dominate the macroinvertebrate communities of sites that are glossily polluted by heavy metals (Molineri *et al*., 2020; Wan *et al*., 2018). Subsequently, the relationship between the observed variables showed an increase in conductivity as water flow increased signifying the effect of point source pollution, which is a robust connection between discharge and the Manyame catchment area advocates for the impact of urban runoff and other point source pollution. Such contributions could have led to the dominance of the Chironomidae larvae family. Moreover, the results from several sites exhibited that Baetidae, Tubificidae, and Chironomidae were plentiful during the dry season when the Mukuvisi River discharge was less, however, it could be found in less abundance during the end of summer when the river flow was maximum. The concentration of DO was at its peak during the wet season when the river discharge was high.

The high relative abundance of oligochaetes on sites 7, 8, 9, and 10 may be seen as evidence of organic pollution. A positive correlation (R^2=0.5873 and R^2=0.6908) was attained with the ASPT in dry and wet seasons, respectively, as in Fig. 5. The sources of the DO might be the atmosphere, tumbling water mix, rooted aquatic plants and algae and probably these increase its concentrations. However, the levels decrease downstream where there is much sewage effluent with high COD levels, and few macroinvertebrates can survive. There was a weak positive correlation between nitrates and the ASPT with regression coefficients R^2=0.3747 and R^2=0.0595 in dry and wet seasons.

CONCLUSION

The water quality trends deteriorated downstream due to heavy industrial activities and high domestic wastewater discharges into the Mukuvisi River, especially in the dry season. Higher concentrations of pollutants were found where there was a point source, a case of site 3 at Zimphos and site 12 just below Firle sewage works. The evaluation of macroinvertebrate diversity provided evidence that the Mukuvisi River water is polluted based on the SASS 5 protocol, especially in the dry season. The physic-chemical parameters were significantly related to macroinvertebrate diversity. Conclusively, in the assessment of river water quality, both macroinvertebrate indices and physio-chemical parameters can be sampled together to avoid bias. The results indicated that human activities upstream are causing pollution in the river and proper controls on agriculture should be monitored to avoid injurious impacts. Industries need to adhere to the wastewater discharge guidelines and exercise caution when discharging unpleasant wastewater from the factories. The availability of oligochaetes downstream clearly exhibited organic pollution, and this implicates DO levels and affects aquatic species in the river system and reservoirs downstream. This bio-assessment technique is cheap and affordable, and it should be conducted so often to monitor the urban stream's health status. Therefore, it is concluded that the connection between the observed benthic macroinvertebrates along the Mukuvisi River and its physicochemical variables designates those geomorphologic differences co-vary with the river flow, its substrate, and the conductivity alongside the river sites which somehow impacted their fauna collection. The results also exhibit that domestic pollution is not a major challenge in the Mukuvisi River, apart from the higher concentration (mg/L) of PO_4^{3-}-P but anthropogenic activities along the riverbanks. The results also can be a foundation for low-cost and ideal solutions to support administrative procedures in the Manyame catchment in the long term. As a future view, there is a need to monitor the diversity and trend analysis of these macroinvertebrates using Bayesian statistical analysis to validate the data obtained and be able to predict the future estimations through model simulations. These endeavors might safeguard the conservation of water quality in Lake Chivero and the Manyame catchment at large. It is, therefore, recommended that (1) The City of Harare should improve its sewage reticulation system to cater to the increased population in Harare, (2) Industrial effluent should be monitored, and the City of Harare-Harare Water should control the treatment of the effluent prior to discharge into the environment, (3) EMA should enforce the policy of permits on industries by enforcing serious charges and ensuring that their pre-treatment plants are working properly.

AUTHOR CONTRIBUTIONS

O. Gotore performed the literature review, and experimental design, analyzed and interpreted the data, and prepared the manuscript text, and manuscript edition. A. Munodawafa and T. Itayama conducted the supervision of this work and resources as well as the data check. R. Rameshprabu, T.P. Masere, and V. Mushayi helped in the literature review and manuscript preparation, English grammar and spelling check.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

ASPT	Average Score Per Taxa
EC	Electric Conductivity
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
SS	Suspended Solids
SASS	South African Scoring System protocol
UMSC	Upper Manyame Sub-catchment
ZINWA	Zimbabwe National Water Authority

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