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Determination of Biological, Physical and Chemical Pollutants in Mudi River, Blantyre, Malawi

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ABSTRACT

Contamination of river water by physical and chemical agents; and microbial pathogens has potential to affect the environment and health of people; and may lead to morbidity and mortality especially in vulnerable populations most at risk for water-related diseases. After observing the deteriorating state of Mudi River, the level of pollution was assessed to assist in designing control measures. The assessment was done during the rainy season a period during which the levels of pollution are at their lowest as the water in the river is diluted by rain so as to capture the minimum levels to which the Mudi River is subjected.

Samples of water were collected and analyzed using standard methods. Sampling was done at five different points depending on suspected pollution source. Sampling was done at source, three points as the river passes through industrial site and in the outskirts of the city. Water samples were collected by grab sampling technique.

Total bacterial count ranged from 1433 to 1800+ colonies per 100ml. Except for the source which had 59,266 coliform colonies, all the other sampling points showed coliforms to be Numerous to Count (NC) colonies per 100ml. Biological Oxygen Demand (BOD) ranged from 29.20 to 89.20mg/l. The pH found in the river ranged from 7.02 to 8.23. Conductivity and Temperature ranged from 148.77 to 542.67Ns and 21.13 to 23.67 ^{0}C respectively. Turbidity and Total Dissolved Solids (TDS) ranged from 28.93 to 130.37 NTU and 69.17 to 271.67 ppm respectively. Lead ranged from 0.21 to 0.93 mg/l, cadmium ranged from 0.00 to 0.02 mg/l, chromium ranged from 0.10 to 0.46 mg/l, zinc ranged from 0.05 to 0.18 mg/l, copper ranged from 0.04 to 0.12 mg/l and nitrates ranged from2.56 to 15.64 mg/l.

Most parameters were higher than European Commission Standards of 1994 for maintenance of aquatic life, irrigation and domestic use. Most parameters were lower at source as compared to other sampling points. There is need to trace possible sources of chemical, biological and physical pollutants which showed high levels.

KEYWORDS: pollution, water quality, Mudi River, water standards, parameters, urban area.

INTRODUCTION

Contamination of river water by microbial pathogens, physical agents, chemical compounds or radiologic agents has the potential to affect the environment and the health of millions of people; and may lead to morbidity and mortality especially in vulnerable populations most at risk for water-related diseases[1,2]. Microbial pathogens include bacteria, viruses, rickettsias, helminthes, fungi and protozoa. The common sources of microbial contaminants into rivers are wild and domesticated animals, and humans. Human sources are particularly dangerous because of the transmissibility of the pathogens from one person to another[3]. Animal sources are equally harmful because some animals harbor certain disease causing pathogens e.g. waterfowl that host influenza viruses[1]. River water that is contaminated by microbes is hazardous to the health of humans that use the water for domestic purposes[4]**.** River water that has microbial pathogens, if used for drinking, would cause diarrhoeal diseases such as cholera, dysentery and typhoid. At the moment diarrhoea diseases are the third leading cause of deaths among under-five children in developing countries[5,6].

Physical contaminants are basically waste materials that are disposed into the rivers. Urbanization and population growth has led to the disposal of these wastes into water bodies. This has gradually led to the deterioration of the water quality[7]. Chemical contaminants find their way into the rivers mostly from municipal sewage, industrial waste water discharges, and seasonal run-off from agricultural activities[8]. Industrial wastes have the potential to contribute strong acids to water bodies and may cause dented effects on both flora and fauna[7]. The common chemical contaminants found in rivers are trace metals and these pose a threat to aquatic life and plants. In addition, cultivation along river banks and the increasing use of fertilizers in the production of crops has led to increases in the concentration of Cadmium (Cd), Lead (Pb), Phosphorous (P), Copper (Cu), Zinc (Zn) and other

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heavy metals in the soils. Some chemicals disposed in water accumulate in nature and may be found in the food chain without noticing and may cause severe outcomes in human beings[9].

Considering the description of water pollutants and their effects as outlined above, it can be seen that prevention of water pollution is vital to a nation's health. An investigation of the physical, microbiological and chemical quality of the water in Mudi River was done in March, 2011 to determine the current state of pollution in the river.

MATERIALS AND METHODS

The study area

Malawi is one of the least developed countries found in the sub-Saharan Africa with an estimated population of about 14,000,000[10]. The country is divided in three regions; North, Central and South[11]. Blantyre City is found in the southern region of Malawi. It is the oldest urban centre in Malawi established by the Scottish Missionaries in the 1870s and declared a planning area in 1897. It is the hub for communication, commercial activities and cooperation in Malawi[12]. Meanwhile the presence of industries has attracted a lot of people such that the population has increased rapidly over the past few years[13]. The rapid population growth, weak institutional governance and legal framework and inadequate physical planning are leading to environmental degradation, pollution, deforestation and uncontrolled development on fragile lands. Recently, there has been an increase in discharging of industrial waste and sewage from broken pipes into the Mudi River and this has brought severe environmental pollution[14,15]. Only 20% of Malawi's population is classified as urban, making the country one of the least urbanized countries in Africa. However, Malawi is one of the most urbanizing countries in Africa at 6.3% per annum, three times the global rate and nearly twice the Africa rate of 3.5%[15]. The rapid growth of the city has not kept pace with the national economy. The most visibly affected areas of this increase in population are access to adequate clean water, solid waste collection and disposal, sanitary and sewerage facilities[16].

Pollution of rivers has been a notable activity believed to be propagated by high population in Blantyre City. Mudi River is one of the rivers that run through the centre of Blantyre City and there are visible signs of practices that affect the quantity and quality of water in the river. The most visible practices are cutting down of trees and cultivation along the buffer zone of the river; and discharge of solid and liquid waste from the market, industries and sewer pipes. Blantyre City is a watershed to many rivers; this means pollution in the city affects not only people in Blantyre but also those who use the rivers that originate from the city. Mudi River is a major source of water for domestic and other uses for communities that live down the stream.

Sampling points

Mudi River flows in a North to South direction through Makata industrial area which is suspected to contribute to high levels of minerals in the river. Although some industries treat their effluent others are suspected of discharging residues into the river. Five sampling points were located in an effort to isolate the polluting sources. These included the source, Escom power house, Private Hire Vehicle Organization (PVHO), Blantyre Market (BT Market) and Namiwawa where a broken sewer line discharges into the river (Figure 1). Sampling was done for three consecutive days. During each day, three samples were collected from each sampling point. In total fifteen (15) samples were analyzed for each parameter, three (3) per sampling point for five (5) sampling points.

Analytical procedures

Polyethylene (PE) bottles were used for sampling after being sanitized by soaking in 50% Hydrochloric Acid (HCl) for three days and rinsed with deionised water [24]. Acidified samples (pH2) were used for the determination of heavy metals. Samples were immediately taken to the laboratory at 4℃ awaiting further analyses. Temperature, conductivity, pH and dissolved oxygen (DO) were determined on site. Table 1 shows a summary of the parameters that were analyzed and techniques used for analysis.

Table 1: Parameters that were measured and the techniques employed using recommended methods of analysis [25, 26]

PARAMETER	ABBREVIATION	TECHNIQUE	UNITS
Biological Oxygen Demand	BOD	5 day BOD test	mgO_2l^{-1}
Conductivity	COND	Conductometry	$\mu mhocm^{-1}$ (Ns)
Temperature	Temp	Potentiometry	℃
pH	pH	Potentiometry	pH units
Total Dissolved Solids	TDS	Drying at 180℃/weighing	Ppm
Turbidity	TURB	Potable turbidity meter	NTU
Most Probable Number	MPN	Plate count	Units
Faecal coliform	FC	Indole test	
Lead	Pb	Spectrophotometry (AAS)	Mg/l
Chromium	Cr	Spectrophotometry (AAS)	Mg/l
Zinc	Zn	Spectrophotometry (AAS)	Mg/l
Copper	Cu	Spectrophotometry (AAS)	Mg/l
Nitrates	NO	Spectrophotometry (AAS)	Mg/l
Dissolved Oxygen	DO	Potentiometry	Mg/l

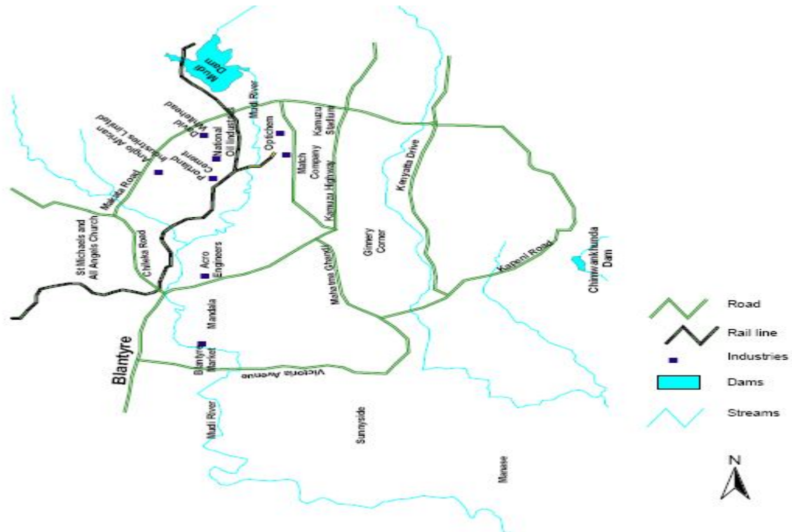

Figure 1: Map of Blantyre City showing Mudi River and sampling points

RESULTS AND DISCUSSIONS

Table 2 indicates the average values of the parameters for Mudi River from source up to Namiwawa.

Table 2: Overall Means of Parameters

Parameter	Mean	Std. Deviation
Biological Oxygen Demand (BOD)	77.35 mg/l	±19.16
Conductivity	428.69 Ns	±155.17
Temperature	22.60 ^{0}C	±0.89
pH	7.46	±0.30
Total Dissolved Solids (TDS)	211.43 ppm	±79.28
Turbidity	62.99 NTU	±57.72
Most Probable Number	>1727	±234.42
Lead	0.56 mg/l	±0.29
Chromium	0.22 mg/l	±0.14
Cadmium	0.01 mg/l	±0.01
Zinc	0.12 mg/l	±0.05
Copper	0.07 mg/l	±0.05
Nitrates	9.79 mg/l	±5.47

The BOD was 77.35 mg/l which is much higher as compared to the standard for the maintenance of aquatic life. The requirement is between 3 and 7 mg/l[17]. The mean parameters for all sampling points indicated that TDS, faecal coliforms and copper (Table 3) were above standard for freshwater quality for the maintenance of aquatic life, drinking, domestic use and for fishing[17,18,19,20]. The high levels of TDS and faecal coliforms at source could be attributed to agricultural activities that take place at the source. People engaged in agricultural activities also use the water for bathing and washing.

Table 3: Means (standard deviations) for specific sampling points of parameters other than heavy metals and nitrates

Sampling Points	BOD (mg/l)	Conductivity (Ns)	Temperature. (^{0}C)	pH	TDS (ppm)	Turbidity (NTU)
Source	29.20 (±1.96)	148.77 (±13.16)	21.13 (±0.32)	7.41 (±0.09)	69.17 (±13.10)	51.98 (±67.56)
Behind PVHO	89.20 (±13.04)	542.67 (±56.76)	22.60 (±0.20)	7.91 (±0.28)	271.67 (±28.91)	44.50 (±12.05)
Escom Power House	78.70 (±9.46)	445.33 (±19.50)	22.63 (±0.35)	7.14 (±0.11)	217.00 (±3.61)	28.93 (8.72)
BT Market	86.97 (±3.62)	495.33 (±78.55)	22.97 (±0.15)	7.42 (0.17)	246.00 (±39.96)	59.18 (±45.01)
Namiwawa	77.70 (±1.30)	511.33 (65.01)	23.67 (±0.42)	7.40 (±0.17)	253.33 (±33.29)	130.37 (±85.11)

Table 4: Means for specific sampling points of parameters other than heavy metals and nitrates

Sampling Points	MPN	Plate Count	Indole (E. Coli)
Source	1433.33	59266.67	Negative
Behind PVHO	1800+	NC	Positive
Escom Power House	1800+	NC	Positive
BT Market	1800+	NC	Positive
Namiwawa	1800+	NC	Positive

Note: NC stands for numerous to count and 1800+ means more than 1800

BOD was highest Behind PVHO (89.20mg/l) and at BT Market (86.97mg/l) while the lowest was at source (29.20 mg/l). Except for the source, all sampling points recorded higher BOD contrary to Kuyeli and others[16]. BOD was higher than the WHO and local standards[22,23,20,19].

Conductivity and Temperature were also lowest at source, 148.77 Ns and 21.13 ^{0}C respectively (Table 3). The increase in conductivity and temperature as the river leaves the source confirms the increase in biochemical pollution taking place. Turbidity was highest at Namiwawa (130.37 NTU) and lowest at Escom Power House (28.93 NTU). For specific sampling points, the source showed lower levels for most parameters than the other sampling points. This shows that most water pollution occurs within the central business area of the city.

Table 5: Means (standard deviations) for specific sampling points of heavy metals and nitrates

Sampling Points	Lead (mg/l)	Cr (mg/l)	Cd (mg/l)	Zn (mg/l)	Cu (mg/l)	Nitrates (mg/l)
Source	0.21(±0.11)	0.46 (±0.02)	0.00 (±0.00)	0.05 (±0.00)	0.04 (±0.03)	2.56 (±0.86)
Behind PVHO	0.75 (±0.17)	0.17 (±0.01)	0.01 (±0.00)	0.10 (±0.03)	0.04 (±0.06)	14.25 (±2.61)
Escom Power House	0.56 (±0.10)	0.23 (±0.02)	0.01 (±0.00)	0.09 (±0.04)	0.09 (±0.07)	15.64 (±2.56)
BT Market	0.93 (±15)	0.10 (±0.02)	0.02 (±0.00)	0.15 (±0.04)	0.12 (±0.01)	10.53 (±1.97)
Namiwawa	0.35 (±0.10)	0.13 (±0.14)	0.02 (±0.00)	0.18 (±0.04)	0.08 (±0.02)	5.98 (±3.08)

Lead levels were highest at BT market (0.93 mg/l) followed by Behind PVHO (0.75 mg/l) and were lowest at Source (0.21 mg/l). It was noted that Chromium levels were highest at source (0.46 mg/l) and the levels kept decreasing along the sampling points and were lowest at BT Market (0.10 mg/l) and Namiwawa (0.13 mg/l). Cadmium was absent at source and little amounts of not more than 0.02 mg/l were recorded in other points. Copper and Nitrates were lowest at source. The levels of copper were above the standards for fish[18]. For Zinc, the levels at BT Market and Namiwawa were higher than the standards[18].

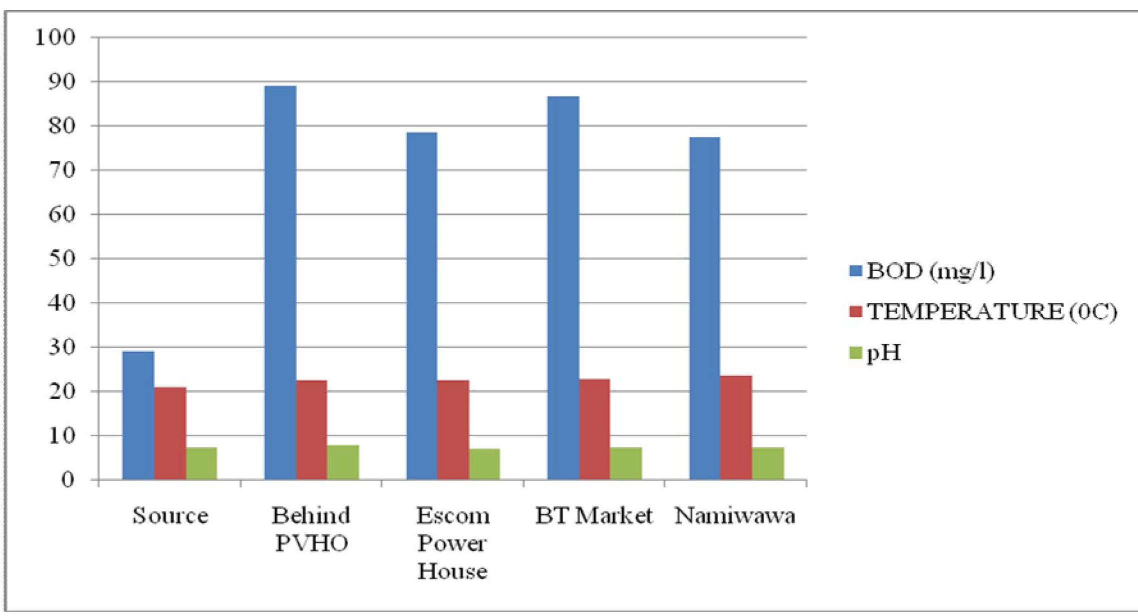

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Figure 2: Variations of BOD, Temperature and pH among sampling points

From Figure 2 above, BOD levels increased by a factor of more than two (29.20mg/l at source to 89.20mg/l behind PVHO) while temperature and pH were stable across the five sampling points. Temperature was slightly higher in the four sampling points as compared to the source.

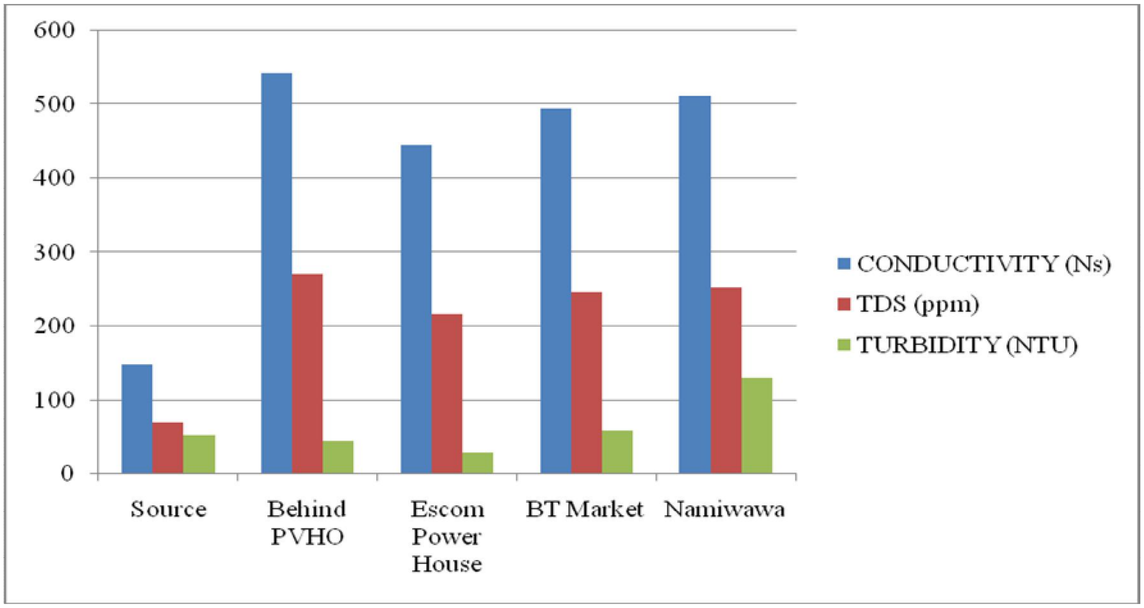

Figure 3: Variations of Conductivity, TDS and Turbidity among sampling points

From Figure 3, conductivity and TDS were much higher in the four sampling points as compared to the source. Turbidity was highest at Namiwawa and lowest at Escom Power House.

Table 6: Biological indicators for five sampling points

Sampling Points	MPN	Plate Count	Indole (E. Coli)
Source	1433.33	59266.67	Negative
Behind PVHO	1800+	NC	Positive
Escom Power House	1800+	NC	Positive
BT Market	1800+	NC	Positive
Namiwawa	1800+	NC	Positive

The source indicates that it was not highly polluted as compared to other sampling points despite the figures being very high as compared to standards[18]. For example, it tested negative for all samples for E.Coli and also showed low counts for both MPN and Plate Count (Table 6).

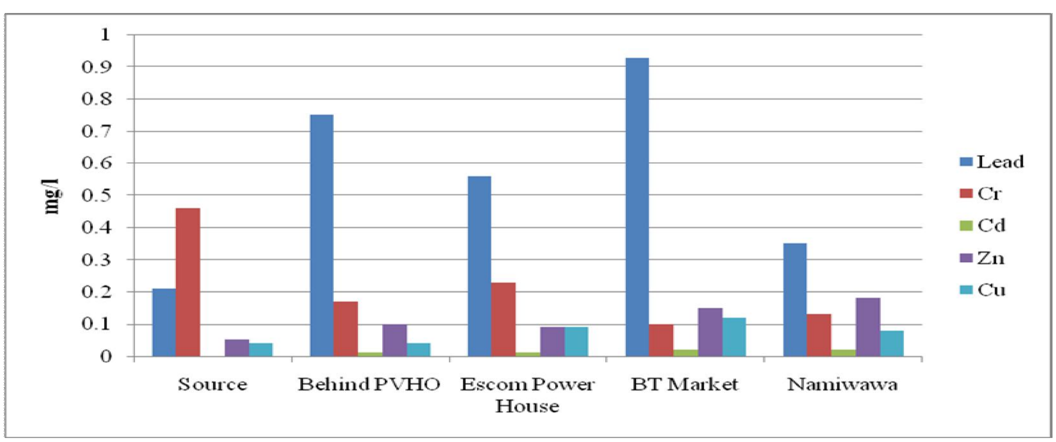

Figure 4: Variations of levels of heavy metals among sampling points

From Figure 4 above, the amount of lead increased downstream of the source reaching the highest level at BT Market. Zinc and Copper were also lowest at source as compared to other sampling points. Cadmium was highest at Namiwawa and Behind Blantyre Market. Chromium was found to be highest at source as compared to the other sampling points.

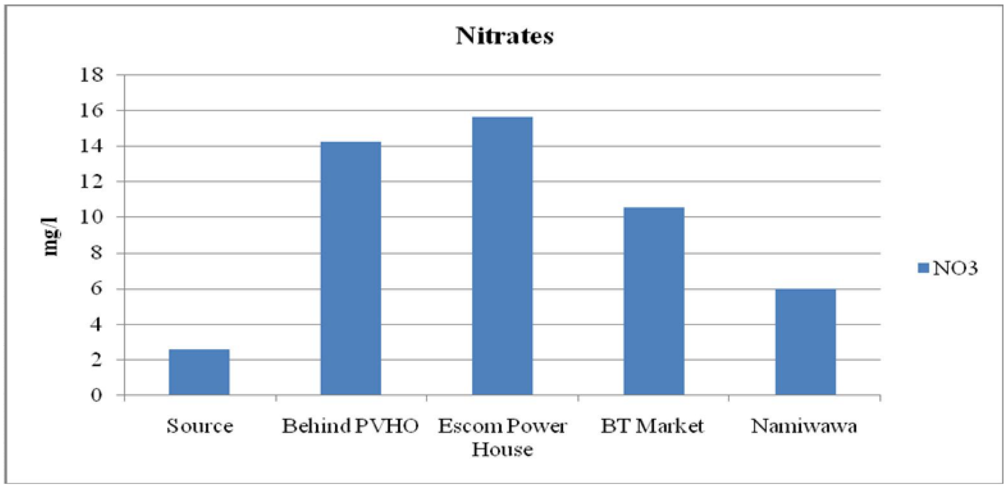

Figure 5: Variations of levels of nitrates among sampling points

The nitrates were lowest at source and highest Escom Power House and behind PVHO. The levels started declining at BT Market and declined further at Namiwawa (Figure 5). These results concur with Kuyeli and others[21] who also found the average concentration of nitrates in the Mudi river of 16.0 mg/l. The levels of nitrates are expected to be higher in the dry season.

Conclusions and recommendations

More stringent control of water pollutants and higher quality standards apply to water intended for drinking than for other uses. Water quality analysis for the rivers in Blantyre City helps the City Council protect the health and safety of those who use the water for washing, bathing, irrigation, livestock watering and drinking downstream outside the city. It also helps conserve aquatic life like fish, frogs, other animals and plants.

According to the WHO Guidelines, standards for the water aimed at protection of aquatic life take into consideration complex physical and biochemical interactions that exist within aquatic ecosystems. It only considers physico-chemical parameters. In this paper, protection of aquatic life, aesthetic properties and other uses by people other than drinking were considered. Most parameters were lower at the source as compared to other sampling points. This confirmed that water is mostly polluted after leaving the source. There was a very big difference in levels at source as compared to other sampling points for biological and physical parameters.

Maintaining the sewage pipes, discouraging cultivation along river banks, open defaecation and disposal of waste in the river will reduce the levels of biological and physical contamination of water in Mudi river in Blantyre. There is also need to investigate the possible sources of chemical pollutants which showed very high levels at sampling points other than the source. These chemicals are lead, chromium, zinc and copper.

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