Heavy Metals Contamination of Surface Water of Mini WHUO Stream in Port Harcourt, Rivers State, Nigeria

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ABSTRACT

The level of heavy metals in the Mini Whuo Stream in Port Harcourt, Rivers State, Nigeria was assessed. The heavy metals' analysis was performed after due digestion by the use of a Thermo Atomic Elemental Absorption Spectrophotometer. The average concentrations of the heavy metals studied in the stream were Pb; 2.594±0.76 mg/L, Cu; 1.90±0.60 mg/L, Zn; 2.50±0.74 mg/L, Cd; 0.472±0.17 mg/L, Ni; 2.785±0.87 mg/L, Cr; 4.484±0.76 mg/L, Co; 0.228±0.13 mg/L, Fe; 1.779±0.46 mg/L and As; 0.059±0.02 mg/L.The concentration of the heavy metals in the stream occurred in the order Cr > Ni >Pb> Zn > Cu > Fe > Cd > Co >>As.The pollution assessment indices used in the evaluation of the anthropogenic activities has influenced the concentration of heavy metals in the stream using WHO maximum limit as basis of decision were, contamination factor, pollution load index, contamination degree and modified contamination degree. These four indices indicated that the studied heavy metals have contaminated the stream to a high level that it was no more suitable for domestic use.

Keywords: *Contamination, heavy metals, Mini Whuo Stream, pollution, pollution indices,*

1.0 INTRODUCTION

The river is the main source of fresh water. It moves along its path and tributaries with reasonable quantity or load of both organic and inorganic matter which are in dissolved or particulate form. These loads are either from natural or anthropogenic origin (Shrestha & Kazama, 2017). Rivers play important roles in the transportation of goods and services and also help in the transportation of wastes which have arisen from municipal, domestic and industrial wastes. Runoffs originating from agricultural farmlands and other sources of pollutant which are generated are eventually deposited in water systems or rivers which eventually pollute the river (Dan'azumi & Bichi, 2010).

Due to population growth and increase in activities as a result of rapid urbanization and industrialization, wastes discharged into the aquatic environment are on the rise. Aquatic flora and fauna are always in continuous contact with water, which implies that they are directly affected by any change in water quality. The endless exploitation and exploration of the natural environment by humans without following laid down guidelines, principles or rules result in the deposition of hazardous substances in the ecological system (Kpee & Ekpete, 2014). Contaminants that originated from agricultural waste, factory wastes and effluents that are channeled from homes are discharged daily into the environment, which gives rise to the overall increase in the total contaminant burden of the environment (be it aquatic or terrestrial). Additionally, the degree and nature of the drive of contaminants is reliant on on the characteristics of the source and the environment receiving the contaminant (Gerba & Smith, 2005; Edori *et al*., 2019).

One major way through which water is polluted is through the discharge of effluents or wastewater from industries, homes, runoffs, drifts, precipitation *etc* (Al-Zubaidi, 2012). The challenges resulting from pollution and waste discharged from urban drift and industrial development are enormous and tasking. The reality and concept involved in the production waste is divers in nature and therefore, the wastes so produced can be in the form of solids and fluids (liquids and gases). To sufficiently resolve issues of pollution management, the origin and nature of the pollutant must be known. This will enable generality in the application mode and the type of treatment method to be used in the process (Edori & Kpee, 2018). Heavy metals are among the most commonly found pollutants in effluent discharged. They are found to be toxic and have the ability to accumulate in living organisms. Heavy metals do not decompose readily and undergo biological reactions slowly. They have the tendencies to produce negative results on the environment and are consequently part of the food chain of living organisms. When these organisms are eventually consumed by humans, they become poisonous and ultimately cause different types of diseased conditions (Mansourri & Madani, 2016). Heavy metals are concerned in diverse health issues such as dwarfism, developmental conditions, cancer, organs destruction and failure, nervous system damage, and in dangerous cases, death (Iyama *et al*., 2014). Contact or exposure to some heavy metals, such as mercury and lead, even low levels can cause self-destruction and breakdown of the human immune system. Lowered immune system can lead to a blend of diseases like rheumatoid arthritis, kidney diseases and brain impairment which may not be reversible.

At higher levels, heavy metals can cause irreversible brain damage (Barakat, 2010). The introduction of high concentrations of heavy metals into aquatic environment leads to grave health and environmental consequences, such as illness, wastewater treatment cost and application of the water for irrigation purposes. In nature, heavy metals are present in trace quantities in most cases. They enter into water bodies through leakage from rocks, fly ash or dust, forest fires, volcanic eruption and foliage from vegetation (Ogoyi *et al*., 2011). The wastes arising from both domestic and industrial activities are most often discharged into the water bodies like rivers, streams, estuaries *etc*. This action gives rise to pollution load and burden on the given aquatic environment that receives the discharged effluents (Edori & Kpee, 2018).

Heavy metals do not undergo degradation in any environment and with prolonged resident historical time in any setting leads to accumulation. Due to the poisonous and accumulating nature of heavy metals, they have developed into one of the most vital ecological and environmental concerns (MacFarlane & Burchette, 2014; Islam *et al*., 2015; Martin *et al*., 2015). In Nigeria, there has existed the lifestyle of direct discharge of effluents and other forms of wastes into the water bodies. This particular way of life by the dwellers along the shore (coastal communities) has greatly affected the coastline ecological systems and has caused different pollution problems to several environmental agencies in the country. Anthropogenic activities can naturally deepen the increase in heavy metals input sources in river water systems (Sánchez-Chardi *et al*., 2007; Edori *et al*., 2019).

Leachates or seepages of agro based chemicals and composts that comprise heavy metals from farm houses in most cases end up in many rivers. In the process of transportation of heavy metals in the riverine system, they can go through repeated fluctuations in concentration within the water system as a result of suspension, solubility, precipitation and adsorption processes (Adebanjo & Adedeji, 2019).

Therefore, it becomes very necessary to assess the level of contamination and pollution of the water bodies within the Port Harcourt metropolis to ascertain the effect on the aquatic dwelling organisms and the human dwellers along the creek that come in contact with it due to the daily requirements of life. This will help to minimize and reduce the degree of contamination as a result of the awareness.

The aim of this study is to determine the level of contamination and pollution of the Mini Whuo Stream by heavy metals in Obio/Akpor Local Government Area, Port Harcourt, Rivers State.

2.0 MATERIALS AND METHODS

2.1 Water Sampling for Heavy Metals

Plastic bottles previously rinsed with acid were used in the collection of water samples. The sample bottles were first washed with detergent and thoroughly rinsed with water and then allowed to dry. Dilute nitric acid was then used to rinse the dried bottles and then allowed to dry before sampling was carried out. The dried plastic bottles were then dipped into the water at a depth of 30-40cm and then covered beneath the water surface in order to prevent air interfering with the collected sample. Nitric acid was then added to the water samples that was used for heavy metals analysis and was immediately transferred to containers filled with ice pack and then transported to the laboratory for analysis.

2.2 Heavy Metals Analysis

The metal analysis was performed for the filtered digest by the use of a Thermo Atomic Elemental Absorption Spectrophotometer (model SE-71906). Different wavelengths were used for the determination of different metals and depending on the type of the hollow cathode lamp applicable for that particle heavy metal to be analyzed. The digested samples were aspirated directly into an air–acetylene flame for each of the heavy metals to be determined. The instrument was calibrated by analyzing known concentration of heavy metals (Sehgal *et al*., 2012).

After the analysis of every 10 samples, there was a re-run of blank sample in order to reduce error in the process of analysis. This procedure checkmated the performance and effectiveness. Each heavy metal was examined three times for a given sample and the results were then expressed as mean ± standard deviation (Sehgal *et al*., 2012).

2.3 Contamination factor/pollution index

The contamination factor and Pollution index are effective tools in unfolding the pollution/ contamination status of the environment under investigation. Contamination factor is a single factor investigation model for specific heavy metals, while the pollution index is an integrated evaluation models that establishes the degree of contamination/pollution of all the heavy metals examined.

The contamination factor method was first resolved by Lacatusu (2000); and the mathematical expression is given as;

Contamination Factor (CF) = $\frac{Cm}{Cb}$

The Pollution Index (PI) is expressed mathematically as:

Pollution Index (PI) = $\sqrt[n]{CF1XCF2XCF3 \dots XCFn}$

Where, CF is the contamination factor, n is the number of heavy metals examined, C_m is heavy metal concentration in studied environment and C_b is background value of the investigated heavy metal or maximum value of the heavy metal allowed in the studied environment.

The classification intervals of contamination factor and pollution index used in interpreting the degree of contamination and pollution is <0.1; very slight contamination, 0.10-0.25; slight contamination, 0.26-0.5 moderate contamination, 0.51-0.75; severe contamination, 0.76-1.00; very severe contamination, 1.1-2.0; slight pollution, 2.1-4.0; moderate pollution and 4.1-8.0; severe pollution (Lacatusu,2000).

2.4 Degree of contamination (CD)

The contamination degree is multiple evaluation index, which was originally proposed to describe the summation of all the contamination factors of the heavy metals examined in any environment. The model was originally proposed and formulated by Hakanson (1980) to establish the combined effect of contamination of any environment by the number of heavy metals studied. The level of contamination is mathematically given as:

$$\text{CD} = \sum_{i=1}^{n} C\,F$$

Where

CD = the degree of contamination

CF = contamination factor of a specific heavy metal, n is the number of heavy metals involved in the research. The category of interpretation provided for the contamination degree is CD < 8; low contamination degree, 8 ≤ CD < 16; moderate contamination degree, 16 ≤ CD < 32; considerable contamination degree and CD > 32; very high contamination degree.

2.5 Modified Degree of Contamination (mCD)

The modified degree of contamination index is used in estimating the summation of the degree of contamination of any given environment as originally formulated (Hakanson,1980). The mathematical expression for calculating mCD is given as:

$$\text{mCD} = \frac{1}{N}\sum_{i=1}^{N} CFI$$

Where N is the number of heavy metals investigated, i = i^{th} heavy metal (or contaminant) and
CF is the contamination factor.

The mathematical formula for modified degree of contamination (mCD) is given as the addition of all the contamination factors (CF) of the individual contaminants divided by the number of investigated contaminants.

The categories for interval of interpretation of mCd is mCd< 1.5; nil to very low degree of contamination, 1.5 ≤ mCd< 2; low degree of contamination, 2 ≤ mCd< 4; moderate degree of contamination, 4 ≤ mCd<8; high degree of contamination, 8 ≤ mCd< 16; very high degree of contamination, 16 ≤ mCd< 32; extremely high degree of contamination and mCd ≤ 32; ultra-high degree of contamination.

3.0 RESULTS AND DISCUSSION

The results obtained for the heavy metals investigated in the stream are provided in Table 1. The contamination factors (CF) of the various heavy metals are given in Table 2 while the pollution index (PI), contamination degree (CD) and the modified contamination degree of the various heavy metals are provided in Table 3.

3.1 Heavy Metals in Surface Water of Mini Whuo Stream

The concentrations of the different heavy metals evaluated in the surface water of the Mini Whuo Stream are provided in Table 1.

Table 1: Heavy metals Concentrations (mg/L) in Water Samples of the Rumuokoro, Eliozu and Rukpokwu axis of the Mini Whuo Stream

Heavy Metals (mg/L)	Stations/Locations			Mean±SD	WHO 2011 Limit
	Rumuokoro	Rukpokwu	Eliozu		
Lead (Pb)	3.461	2.714	1.607	2.594±0.76	0.01
Copper (Cu)	1.617	2.743	1.347	1.90±0.60	2.0
Zinc (Zn)	3.146	1.460	2.878	2.50±0.74	5.0
Cadmium (Cd)	0.694	0.429	0.293	0.472±0.17	0.03
Nickel (Ni)	3.817	1.691	2.847	2.785±0.87	0.15
Chromium (Cr)	5.144	4.891	3.417	4.484±0.76	0.05
Cobalt (Co)	0.372	0.067	0.244	0.228±0.13	0.05
Iron (Fe)	2.417	1.329	1.591	1.779±0.46	0.3
Arsenic (As)	0.075	0.043	< 0.001	0.059±0.02	0.01

Lead (Pb)

The results recorded for the concentrations of lead (Pb) in the stream during the period of investigation ranged from 1.607-3.461 mg/L with an average concentration value of 2.594±0.76 mg/L. The value recorded is higher than the value permitted by WHO (2011) for drinking water which is 0.01 mg/L. The concentration of Pb in this work was lower than those reported by certain investigators in the study of effluents discharged from the petrochemical industry into Ekerekana River (Marcus & Edori, 2017) and oily waste water effluents discharge (Wokoma, 2014). Lead (Pb) as a metal is hazardous to both plants and animals at any level. It is a known poisonous substance or toxicant even at very low concentrations (Edori & Edori, 2012). Lead (Pb) is known to be associated with several diseased conditions such as blood poisoning and reduced judgment, lesser IQ, neuro-behavioral disorder, hearing and speech deformations, growth retardation and irregular behavior in children according to Hertz-Picciotto (2000), and in adults, it results in low sperm count, and causes abortion in women (Flora *et al*., 2007).

Copper (Cu)

The results obtained in this work for the level of copper (Cu) in the stream at the time research was carried out ranged between 1.347 and 2.743 mg/L. The mean concentration value for the stations was 1.90±0.60 mg/L. The values obtained within the stations of the stream were either slightly lower or slightly higher than the 2.0mg/L permissible level of copper (Cu) by WHO, 2011 for drinking and other domestic use. The concentration values obtained for Cu in this work were higher than that obtained by Nwoke and Edori (2020) in the boreholes of five communities in Ikono, Akwa Ibom State, Nigeria. Copper is metal that is essential and necessary for the sustenance and development of human life. Copper is important in the formation of the foetus, building of human immune system, development of the brain, transmission of message through the neurons and anti-oxidative characteristics (Edori & Kpee, 2016). At high concentrations in the human body copper may cause liver and kidney damages resulting in challenges that may result in total damage to these organs (EPA, 2005). High level exposure of the human organs and systems to copper causes stomach and intestine’s irritation, health challenges and threat, mostly among people affected by Wilson disease (Spinzz *et al*., 2007; Edori *et al*., 2016).

Zinc (Zn)

The recorded results for zinc (Zn) within the stations of the stream investigated fell within the range of 1.460-3.146 mg/L. The average concentration of zinc (Zn) in the stream was 2.50±0.74 mg/L at the time the research was conducted. The value recorded in this work fell below the recommended value of 5.0 mg/L by WHO for potable water and water useful for human consumption. Ways through which Zn enter in the environment are: mining, refining and smelting process of zinc, electroplating processes in the industries and from bio-solids. Zn is very vital element in pre and post-natal development (Hambidge & Krebs, 2007). The importance of the environmental and health consequences of Zn is built on the fact of its corrosive nature to the skin and also causes irritation and damage to mucous membrane. Deficiency of Zn may lead to retardation in growth, interruptions in sexual maturity, easy contact with infection and diarrhea. The excessive intake of Zn into the human body can result into ataxia, deficiency in copper and weakness or lethargy (Hambidge & Krebs, 2007; Maret, 2013).

Cadmium (Cd)

The concentration values obtained for cadmium (Cd) in the different stations of the stream was in the range of 0.293-0.694 mg/L. The mean concentration of Cadmium (Cd) at the time the study was carried out was 0.472±0.17 mg/L. The values obtained for cadmium (Cd) within the period under investigation was carried out were all higher than the permissible limit allowed by WHO (2011) for water to be used for domestic purposes which is 0.03mg/L. The value recorded in this work is higher than that recorded by Mahre *et al*., (2007); Benson and Etesin (2008) and those of Nwineewii and Edem (2014) in similar studies. Cadmium even at very low concentrations can be toxic. At high concentrations Cd targets human organs such as the liver and kidneys, but at lower levels, the pancreas and spleen are the target organs. Cadmium is a significant factor in coastal/marine monitoring investigations; this is due to its toxic effects to fish and other aquatic dwellers, has widespread carcinogenic properties and is known as one of the most toxic elements in nature with widespread effects in humans. Cd is extensively distributed in the marine environment and has the potential to bio-accumulate at the different trophic levels and its accumulation in the livers and kidneys of fishes is a common occurrence (Sindayaigaya, *et al*., 1994).

Nickel (Ni)

The level of nickel (Ni) recorded for the various stations of the stream were in the range 1.691-3.817mg/L. The mean concentration obtained within the time the research was conducted was 2.785±0.87mg/L. These values obtained in the stations and the mean concentration were all higher than the approved concentration of Nickel in drinking water and water for other domestic uses by WHO (2011) which is 0.15mg/L. The observed values of concentrations of Ni in this work were higher than that obtained from the Elelenwo River which ranged between 0.168 and 0.195 mg/L (Edori *et al*., 2019). The reported values in this study were higher than those of Okegye and Gajere, (2015) in river water from Udege, North Central Nigeria and those of Aghoghovwia *et al*. (2018) in River Nun, Bayelsa State, Nigeria. Nickel (Ni) in the environment can be through natural anthropogenic origin. In natural aquatic environments, Ni is usually present as Ni $(H_2O)_6^{2+}$ complex (WHO, 2007). Nickel (Ni) experiences translocation from one point of the river to the other and adheres to particles that are linked with organic matter and have the ability to accumulate in living organisms such as plants like phytoplankton (Edori *et al*., 2019). The occurrence of Ni in aquatic system is lethally toxic to plant life even at very low levels of 500 µg/L according to USEPA (1976) and its potential as a possible carcinogens to animals and humans is verifiable even though there is presently no adequate information on the mode of its carcinogenicity (Edori *et al*., 2019).

Chromium (Cr)

The concentration of chromium (Cr) obtained in the stations of the stream varied from 3.417 to 5.144mg/L at the time of investigation. The mean concentration value for the stations of the stream was 4.484±0.76mg/L. The values obtained in this work from the various stations of the stream were far above the WHO required standard quantity of chromium (Cr) that should be present in water for drinking and other domestic uses which is 0.05mg/L. The level of chromium observed in this work were far above that reported by Nwineewii and Edem (2014) in the surface water of Niger Delta rivers with concentration range of 0.0010-0.4310.0mg/L with a mean recorded value of 0.180 mg/L in the wet season and 0.0220-0.4290 mg/L with an average value of 0.166mg/L in the dry season. Animals' studies have shown that chromium has the tendencies to accumulate in the liver, kidneys, spleen and bone marrow after both paternal and oral administration of several compounds. In humans, the highest levels are observed in hilar humph nodes and lungs, followed by spleen, liver, and kidneys (Janus & Kranjc, 1990). Intake of about 1-5g of "chromate" can cause severe or acute disorders like gastrointestinal effects, haemorrhagic diathesis, and also convulsions (Nwineewii & Edem, 2014).

Cobalt (Co)

The level of cobalt (Co) recorded in the stations of the stream at the time of investigation were in the range, 0.067-0.372 mg/L. The average value obtained for the different stations was 0.228±0.13mg/L. The concentrations of cobalt (Co) at the time of the study in the different stations of the stream were above the WHO recommended level in potable water which is 0.05mg/L. The level of cobalt recorded in this work was lower than the ones reported by Babatunde *et al*., (2013) where values obtained were between 0.2 -0.4 mg/L in 2011 and 0.4 - 0.6 mg/L in 2012, in the Bonny/New Calabar estuaries system of the Niger Delta.

Iron (Fe)

The level of iron (Fe) recorded in the stations of the stream at the time of research were in the range, 1.329-2.417 mg/L. The average level of iron (Fe) recorded for the different stations was 1.779±0.46 mg/L. The concentrations of iron (Fe) in the stream at the time of investigation was higher than the approved level of 0.3mg/L by WHO for domestic water usage. Iron (Fe) is a very vital metal which is essentially needed by both plants and animals for effective metabolic functions and growth (Xing & Liu, 2011). Iron (Fe) is a fundamental constituent of the blood, and it is the component that is responsible for the colour of the blood (Edori & Kpee, 2018). At concentrations above 0.03 mg/L, it gives taste and colour to water (Iyama *et al*., 2014). Iron (Fe) occurs in water bodies in the form of Fe (II) or Fe (III) states. The shortage of iron in the body can lead to anaemic situations which reduces the fighting of diseases in the human system (Banjari *et al*., 2015).

Arsenic (As)

The concentration of Arsenic (As) observed in the various stations of the Stream at the time of this work ranged from < 0.001 to 0.075mg/L. The average level of arsenic obtained in the stream at the time of this work was 0.059±0.02mg/L. The values obtained in this work were lower than those reported by Nwoke and Edori (2020) in the boreholes of five communities of Ikono Local Government Area, Akwa Ibom State, Nigeria. The existence of arsenic in the water environment create health hazard to humans and animals and contact with arsenic even at low levels could also be toxic (UNICEF, 2008). Arsenic is one environmental pollutant that is hazardous. It has the potential to occur in the +5 and +3 oxidation states and can be easily absorbed by the tract of the gastrointestinal walls (Smith & Steinmaus, 2007). Arsenicosis is a disease that has slow mode of formation and it affects humans due to the toxic nature of arsenic and shows between periods of 2 and 20 years. Peripheral neuropathy, peripheral vascular disease, hypo and hyper pigmentation are signs brought about by arsenic toxicity which affects children and adults and also inhibit the development of children intellects. The effects due to arsenic toxicity can cause skin lesion and stigmatization that may ruin an individual life during his developmental stages which eventually may affect the entire family life (UNICEF, 2013).

3.2 Pollution Indices of Heavy Metals Pollution in Nta-Wogba Stream

3.2.1 Contamination factor

The contamination factor of heavy metals in the Nta-Wogba Stream is given in Tables 4.3.

Table 2: Contamination Factor (CF) Analysis of Heavy Metals in Water Samples of the Rumuokoro, Eliozu and Rukpokwu axis of the Mini WhuoStream

Heavy metals	Sample Locations		
	Rumuokoro	Rukpokwu	Eliozu
Pb	346.10	271.4	160.70
Cu	0.809	1.372	0.674
Zn	0.629	0.292	0.576
Cd	23.133	14.300	9.767
Ni	25.447	11.273	18.980
Co	7.440	1.340	4.880
Fe	8.057	4.430	5.303
As	7.500	4.300	-

Table 2 provided the contamination factors of the investigated heavy metals in the Mini Whuo Stream. The results given in the Table revealed that contamination factors in stations ranged between 0.629 and 346.10 for Rumuokoro, 0.292 and 21.40 for Rukpokwu, 0.576 and 160.70 for Eliozu. The contamination factors of the investigated heavy metals were in the order Pb> Ni > Cd > Fe > As > Co > Cu > Zn for Rumuokoro, Pb> Cd > Ni > Fe > As > Cu > Co > Zn for Rukpokwu and Pb> Ni > Cd > Fe > Co > Cu > Zn > As. Applying the classification interval originated by Hakanson (1980), it revealed that the Nta-Wogba Stream has been severely polluted by Pb, Ni, Cd and Fe in all the stations, As was severely polluted in Rumuokoro and Rukpokwu stations and was not contaminated in Eliozu, Co was severely polluted in Rumuokoro and Eliozuand was slightly polluted in Rumuokoro and Rukpokwu, Cu ranged from severe contamination in Eliozu to very severe contamination in Rumuokoro and slight pollution in Rukpokwu. The level of contamination and pollution of heavy metals in the stations of the stream were in the order, Rumuokoro>Rukpokwu>Eliozu. The reason for the order of heavy metals contamination in the stations used in the investigation is that human activities within the stations were in the order Rumuokoro>Rukpokwu>Eliozu. This is one major reason that gave rise to the order of metal contamination observed in the stream.

3.2.2 Pollution Load Index, Contamination Degree and Modified Contamination Degree

The pollution load index, contamination degree and the modified contamination degree of the studied heavy metals in the Mini WhuoStream are given in Tables 3.

Table 3: Pollution Index (PLI), Contamination Degree (CD) and Modified Contamination Degree (mCD) in Water Samples from the Rumuokoro, Eliozu and Rukpokwu axis of the Mini Whuo Stream

Assessment Index	Sample Locations		
	Rumuokoro	Rukpokwu	Eliozu
PLI	9.090	5.127	4.836
CD	419.115	308.707	200.880
mCD	52.389	38.588	25.110

3.2.3 Pollution Load Index (PLI)

The results observed for pollution load index in the stations of the Mini Whuo Stream were Rumuokoro; 9.090, Rukpokwu; 5.127 and Eliozu; 4.836. The results obtained for the pollution load index in the stream indicated that Rumuokoro>Rukpokwu>Eliozu. Applying the interval classification of pollution and contamination revealed that the stream was severely polluted and all the stations fall within the classification range of 4.1-8.0. The PLI values obtained for the stream indicated that the level of pollution by the studied heavy metals have reached an alarming stage.

3.2.4 Contamination Degree (CD)

The results obtained for the contamination degree of the different stations of the Mini Whuo Stream were in the order, Rumuokoro>Rukpokwu>Eliozu. The levels of contamination degree were, Rumuokoro; 419.115, Rukpokwu; 308.707 and Eliozu; 200.880. Using the analysis of interval classification for contamination degree showed that the stream is at a very high contamination degree by the investigated heavy metals. The values obtained in the stream were far above the interval, CD > 32 which is for very high contamination degree.

3.2.5 Modified Contamination Degree (mCD)

The results obtained for modified contamination degree (mCD) in the various stations of the Mini Whuo Stream were in the order Rumuokoro>Rukpokwu>Eliozu. The results recorded were Rumuokoro; 52.389, Rukpokwu; 38.588 and Eliozu; 25.110. The application of interval of interpretation for the classification of modified contamination in the stream revealed that it is at an Ultra-high degree of contamination, for the results obtained in all the stations within the stream were above the classification, mCd ≤ 32 which is for ultra-high degree of contamination.

4.0 CONCLUSION

The continuous monitoring of any aquatic environment is vital in the assessment for the renewal, rebuilding, safety and fortification of the aquatic environment. This will assist in putting in place the integrity of marine plants and animals and the general environment**.**

Results of heavy metals in water samples of the stream in this study indicated that all the metals except Zn and Cu were all above the standard requirement By WHO for portable water.

Contamination index analysis revealed that the water of the stream was contaminated by all the heavy metals in varying degrees. The pollution load index used in examining the stream indicated that the stream has been polluted with heavy metals to a very high level when compared to WHO acceptable limit.

Contamination degree analysis showed that the samples from the stream had different degrees of contamination with heavy metals, while modified degree of contamination results indicated ultra-high contamination by heavy metals in the stream.

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