



**International Journal of Economics,
Environmental Development and Society
(IJEEDS)**

CHARACTERIZATION OF SUSPENDED AND BED SEDIMENTS FOR STREAMS IN THE PORT HARCOURT METROPOLIS, NIGERIA.

David E. UWA-SAMUEL

Ignatius Ajuru University of Education, Port Harcourt, Nigeria

ravdafxmuel@gmail.com

<http://orcid.org/0009-0004-6429-6303>

Hyginus B. OKU

Ignatius Ajuru University of Education, Port Harcourt, Nigeria

okuhyginus744@gmail.com

ABSTRACT

Suspended and bed sediments were examined for their concentration levels and spatial spread in the streams across the study area. The study was based on determine concentration levels of some physicochemical parameters (pH, TDS, SO_4^{2-} , NO_3^- , Cu, Cr, Pb, Fe, Cd, and Zn) in the suspended and bed sediments media. For this paper the objectives were to evaluate the spread of the concentration levels and determine the relationship between the parameters in the suspended and bed sediments. The sediments were sampled from the Egbelu stream, Rumuolumeni stream, Ntawogba stream, Waja stream, Woji stream and Elelenwo stream in Port Harcourt metropolis. With a sample frame of 1000 meters of the lower reaches of each stream, a sample interval of 50 meters was adopted per stream, and 5 sampling points of each stream were taken at random using the table of random numbers. Suspended sediments samples in water were fetched, and grab samples of bed sediments taken for laboratory analyses. The regulatory framework of DPR-EGASPIN (2002), and the APHA standards methods were employed for laboratory analyses of the parameters. The highest and lowest ranges of concentration values in suspended sediments were observed for 71.3-282.0 for TDS and 0.009-0.002 for Cr; and in bed sediments were 4.67-9.32 for SO_4^{2-} , and 0.012-0.099 for Pb across the streams. The laboratory results were bench-marked against permissible limits of WHO (2008), FAO (2010), NESREA (2007), NDWQI (2007), and DPR-EGASPIN (2002). The results showed the concentration levels of the parameters below permissible limits of world and national standard guidelines. The Pearson correlation coefficient (PCC) was employed to test for correlation between the concentration levels of the parameters. The results in most cases showed very strong positive correlation between parameters in bed and suspended sediments as follows there is strong correlation between pH/TDS (0.62), pH/ SO_4^{2-} (0.57), pH/Pb (0.67), pH/Fe (0.65), pH/Cd (0.64), and pH/Zn (0.64). The study hence recommended water treatments for portable uses, stream restoration for aquatic ecosystem recovery, sediment mining for heavy metals, and sediment security as a geo-security appendage for others.

Keywords: Suspended, Bed Sediments, Concentration Levels, Spatial Spread, Portable Uses, Heavy Metals, Sediment Mining, Sediment Security, Ecosystem Recovery.

Reference to this paper should be made as follows:

Uwa-Samuel, D. E., & Oku, H. B. (2024). Characterization of Suspended and Bed Sediments for Streams in the Port Harcourt Metropolis, Nigeria. *International Journal of Economics, Environmental Development and Society*, 5(4), 408-419.

Copyright © IJEEDS 2024 [ISSN: 2992-5614].

INTRODUCTION

It has to be understood that notwithstanding the interdisciplinary research interests in sediments—suspended and bed, the material are basically geographical phenomena with geomorphic nature and background. From a geoscience perspective, one regards sediments as geological fragments degraded by processes of denudation from geomorphic landscapes into such micro sizes in mass and weight to be pliable to transport by activities of air, water, and bio-organisms are regarded as sediments. As migrant micro-geomorphic landforms, their environmental quality and value can be reduced by reactive and active chemicals agents in their transitional host environments to the extent of being contaminated, or polluted. Such quality depreciation posits reasonably measurable impact on the environment and ecosystem. Again, they possess physical, chemical and biological characteristics due to deleterious substances that inundate fluvial environments with contaminants and pollutants. These sediments exist mainly as dissolved, solution, suspended, and, bed loads (Li et al., 2021) particularly in marine and aquatic environments.

As micro scale geomorphic environments (Li et al., 2010) they are regarded in geo-environmental science as geo-spatial DNA substrate for determining the sources (Lundy et al., 2017) of pollutants and contaminants into aquatic environments and ecosystems. Aeolian sediments contribute to air pollution. Contaminants and pollutants mostly from anthropogenic sources fuse into sediments and act to alter the geomorphic characteristics of fluvial environments. The necessity of characterizing suspended and bed sediments is driven by the fact that they are important, and necessary components of fluvial geo-environments. The impact is linked to the fact they are natural to the fluvial mix for the thriving and sustenance of aquatic ecosystems providing habitats and nutrients to aquatic invertebrates including zoo and phytoplanktons. The significance of sediments is tied particularly to the variability in quantity and quality in streams and rivers systems across geographic space and seasons. The fact remains that without stream and river systems receiving mineral nutrients in sediments from across the watershed and cycling same in fluvial energy mix, the bloom and spread fish-life and other aquatic lifeforms would be impossible. Insufficient sediments in a fluvial mass on one hand, and excessive inundation of sediments in a fluvial mass with attendant over exposure of species pose negative ecological consequence on the aquatic lifeforms.

In urban areas sediments are generated and contaminated from human activities. The scale of water security launches from the neighborhood, local area, and city, national to global scale. Urbanization is recognized as the leading cause of risk to water security. Across the globe, water is not available in such quality and quantity as to ensure equitable distribution or water security for human and ecosystem needs; in some cases water governance is nonexistent. The need to have and to maintain water sources and resources particularly of streams in the urban and rural areas is paramount to livelihood, and wildlife conservation. The importance of water in good quality and quantity as an index of water security for the sustainability of growing urban population, livelihood and ecosystem sustenance is acknowledged by Gray and Sadoff (2007), Zeitoun (2011) and Bakker (2012). Interests in the suitability of water for diverse uses and availability in desirable quantity are global and as well the upscale in advocacy and interventionism for water security (Global Water Partnership, 2009). Interest parties include global ecological conservationists, public space influencers, public office holder, wildlife enthusiasts, core geo-environmentalists and geomorphologists.

Locally Arimieari et al. (2014), Nwankwoala and Angaya (2017), Otene and Alfred-Ockiya (2021) have acknowledged the environmental burden of sediments to the stream

watershed and ecosystem, and as well the negative impact on water quality for human consumption. They opine that the physical and ecological changes as a result of catchments urbanization. They also associated waste dumping, canalization and unregulated housing development in the channel corridors to the burden of sediments load on the urban aquatic ecosystem and environment. They concluded that spike in sediments contamination and pollution is tied anthropogenic activities. At the upper reaches of the Bonny Estuary, Akankali and Davies (2021) examined the distribution of heavy metal water (suspended sediments), (bed) sediments and biota (*Callinectes amniciola*)

Study Area

Port Harcourt metropolis is located approximately between the geographical coordinates of longitudes 6.0551° and 7.0551° E and latitudes 4.0351° and 5.0101° N of the equator. The study area is categorized as tropical wet or humid climate characterized with high average annual temperatures and small temperature ranges, and a high rainfall that is over 2000mm. Based on the modified Koppen-Geiger classification model the area is typified as Am with the mean annual temperature is 26.0°C | 78.8°F ; an annual rainfall (precipitation) is about 2719 mm | 107.0 inch. Specifically there are three stratigraphic units recognized in geology for the study area. From bottom to top they are the Akata formation, the Agbada formation, and the Benin formation. This geologic warp is believed to have started evolving in the paleocene period upto the present geological age.

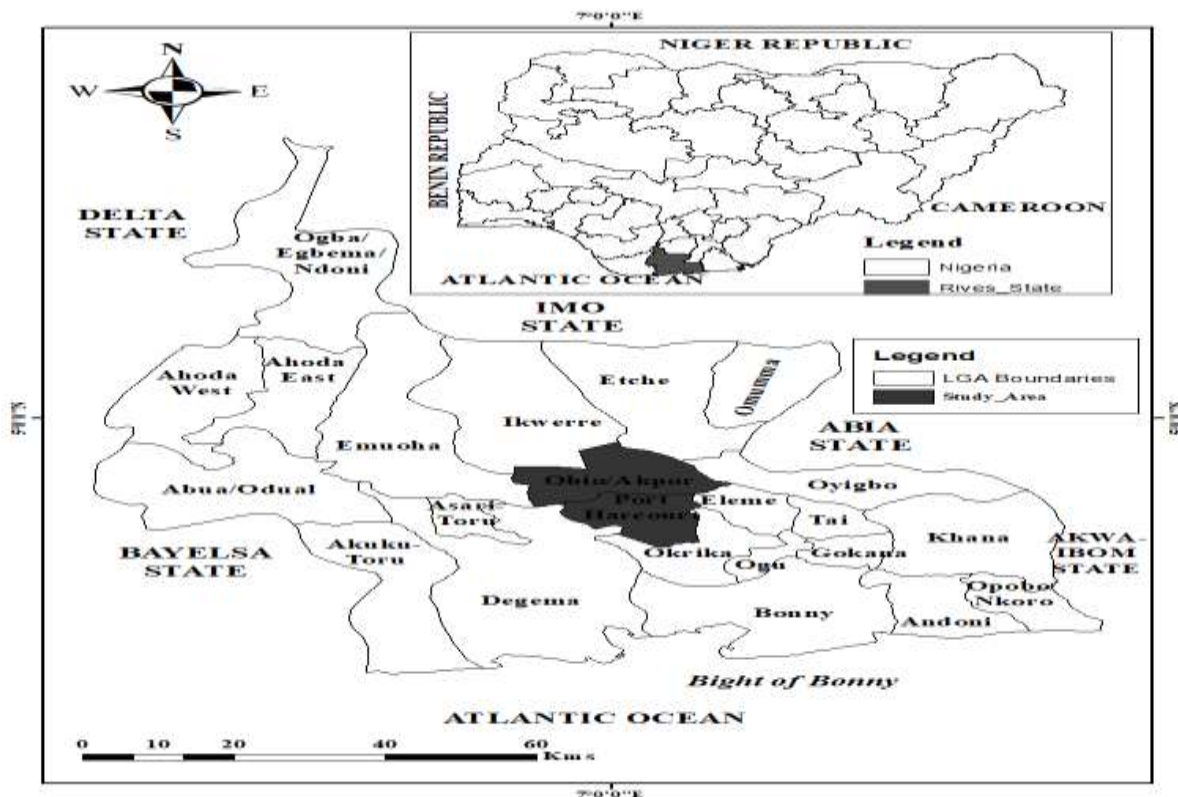


Figure 1.1: Rivers State, Nigeria. Showing Port Harcourt Metropolis
Source: fieldwork 2021/22

Study Methods

The study was based on experimental design as primary and secondary data were appropriated to justify the design. A total of 60 samples making 30 samples each for suspended and bed sediments were collected on November 3, 2021 from the aforementioned from the streams of Egbelu, Rumuolumeni, Ntanwogba, Waja, Woji, and Elelenwo being the major six streams in the metropolis. A sample frame of 1000m along the lower stretch of the streams with sample intervals of 50m was adopted for this study. The suspended sediments were collected by fetching as recommended by the US Geological Department and stored in the precleaned laboratory water bottles. The grab method was used for collection of bed sediment samples which were stored in pre-cleaned laboratory bottles. The global positioning system was used to locate and identify the precise sample point. After capture, the bottles containing the samples were immediately covered tightly against spillage and stored in cooler under controlled temperature condition and conveyed to the laboratory for experimental physicochemical analyses.

Laboratory Methods

The following - pH, total dissolved solids (TDS), sulphate (SO_4^{2-}), nitrate (NO_3^-), copper (Cu), Chromium (Cr), lead (Pb), iron (Fe), cadmium (Cd), and zinc (Zn) were the physicochemical parameters analyzed in the suspended and bed sediments. Five composite samples were prepared for analysis to determine the concentration levels of the observed parameters. The regulatory framework by Department of Petroleum Resources Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (DPR-EGASPIN) guided the laboratory work which used the APHA (American Public Health Association) standard analytical test methods for all the parameters. Thus the APHA 4500 H-B was used for pH using the electrometric method; the ASTM International (2013) D5907-13 method was used for TDS based on the APHA 2540C standards; the turbidimetric method was used for sulphate (SO_4^{2-}) based on the APHA 4500E- SO_4^{2-} standards; the cadmium reduction method used for nitrate based on the APHA 4500- NO_3^- E; APHA 3111C was used for Cu; APHA 3111D was used for Cr; the APHA 3111C was used for Pb; APHA 3111C was used for Fe; the APHA 3111C was used for Cd and the APHA 3111C was used for Zn based on the atomic absorption spectrometry (AAS) method. The Pearson Correlation coefficient was used to test the hypotheses on the relationships between the physicochemical parameters in the suspended and bed sediments.

Statistical Methods

The Pearson product moment correlation coefficient analysis was used to test the relationship between sample parameters of suspended and bed sediments. The formula is given below:

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]} \quad \text{Equation 1}$$

Where, r = Pearson Coefficient; n = number of the pairs of the stock; $\sum xy$ = sum of products of the paired stocks; $\sum x$ = sum of the x scores; $\sum y$ = sum of the y scores; $\sum x^2$ = sum of the squared x scores; $\sum y^2$ = sum of the squared y scores.

RESULTS AND DISCUSSIONS

Table 1: Concentration Levels of Physicochemical Parameters in Suspended Sediments

	pH mg/l	TDS mg/l	SO ₄ ²⁻ mg/l	NO ₃ ⁻ mg/l	Cu mg/l	Cr mg/l	Pb mg/l	Fe mg/l	Cd mg/l	Zn mg/l
Egbelu	5.05	91.5	16.33	0.089	0.004	0.002	0.01	0.028	<0.001	0.039
Rumuolumeni	5.43	225.5	40.22	0.043	0.009	0.024	0.009	0.092	0.009	0.109
Ntawogba	5.09	282.0	50.36	0.054	0.007	0.031	0.022	1.012	0.072	1.000
Waja	5.20	149.5	26.70	0.020	0.003	0.014	0.005	0.076	0.003	0.009
Woji	5.75	73.0	13.04	0.065	0.002	0.006	<0.001	0.054	<0.001	0.039
Elelenwo	4.96	71.3	12.73	0.043	0.002	0.004	<0.001	0.032	<0.001	0.021

Source: researcher's fieldwork 2021/22

The Table 1 shows the spatial spread of the concentration levels of the observed physicochemical parameters in suspended sediments across the streams. The mean of the concentration levels of the observed physiochemical parameters in suspended sediments is TDS (148.8) > SO₄²⁻ (26.57) > pH (5.25) > Zn (0.218) > Fe (0.216) > NO₃⁻ (0.08) > Cr (0.0135) > Pb (0.0065) > Cd (0.00635) > Cu (0.0045) across the six streams. Specifically, heavy metals in suspended sediments have the mean of concentration levels as Zn (0.218) > Fe (0.216) > Cr (0.0135) > Pb (0.0065) > Cd (0.00635) > Cu (0.0045) - that is Zn > Fe > Cr > Pb > Cd > Cu. The results show the concentration levels are below the permissible levels of the standard guidelines

Table 2: Concentration Levels of Physicochemical Parameters in Bed Sediments

	pH mg/kg	TDS mg/kg	SO ₄ ²⁻ mg/kg	NO ₃ ⁻ mg/kg	Cu mg/kg	Cr mg/kg	Pb mg/kg	Fe mg/kg	Cd mg/kg	Zn mg/kg
Egbelu	4.45	-	4.67	1.63	0.084	0.092	0.043	1.067	0.044	0.212
Rumuolumeni	5.42	-	7.72	1.81	0.059	0.053	0.099	5.022	0.012	1.174
Ntawogba	5.86	-	9.32	1.96	0.085	0.095	0.012	8.491	0.011	1.459
Waja	5.00	-	5.07	1.69	0.115	0.016	0.089	2.012	0.065	0.519
Woji	5.45	-	5.47	1.74	0.141	0.095	0.053	3.111	0.042	1.009
Elelenwo	5.31	-	5.82	1.70	0.037	0.083	0.053	2.563	0.098	0.742

Source: Researcher's fieldwork 2021/22

The Table 2 shows spatial spread of the concentration levels of the observed physicochemical parameters in for bed sediments across the six streams. Overall the mean of the concentration levels of the observed physicochemical parameters in bed sediments are SO₄²⁻ (6.35) > pH (5.25) > Fe (0.216) > NO₃⁻ (1.76) > Zn (0.853) > Cu (0.087) > Cr (0.065) > Cd (0.063) > Pb (0.058) across the six streams. The mean concentration levels of the heavy metals specifically is in the order Fe (0.216) > Zn (0.853) > Cu (0.087) > Cr (0.065) > Cd (0.063) > Pb (0.058) – that is Fe > Zn > Cu > Cr > Cd > Pb.

The mean between the concentration levels physiochemical parameters in suspended sediments (ss) and bed sediments (bs) is as follows pH(ss)=pH(bs); TDS (not available); SO₃²⁻ (ss) > SO₃²⁻ (bs); and NO₃⁻ (ss) < NO₃⁻ (bs). Between suspended and bed sediments the mean concentrations are as follows Cu(ss) < Cu(bs); Cr(ss) < Cr(bs); Pb(ss) < Pb(bs); Fe(ss) < Fe(bs); Cd(ss) < Cd(bs) and Zn(ss) > Zn(bs).

Evaluation of the Spread of Parameter Concentration Levels

pH Concentrations

In suspended sediments Woji stream has the highest pH value of 5.75, while Elelenwo stream has the lowest pH concentration level of 4.96. The pH for the streams others fall between these values. In bed sediments Ntawogba stream has the highest pH concentration level of 5.86, while Egbelu stream has the lowest values pH of 4.67. The lower the pH acidity, the more acidic the sediment sample complex. Thus, Elelenwo stream is the most acidic in suspended sediments while Egbelu stream is the most acidic in bed sediments. In suspended sediments the magnitude of pH concentration is Woji stream 5.75 > Rumuolumeni stream 5.43 > Waja stream 5.20 > Egbelu stream 5.05 > Ntawogba stream 5.09 > Elelenwo stream 4.96. In bed sediments the order is Ntawogba stream 5.86 > Rumuolumeni stream 5.42 > Woji stream 5.45 > Elelenwo stream 5.31 > Waja stream 5.00 > Egbelu stream 4.46.

TDS Concentrations

The concentration levels of TDS are highest in the Ntawogba stream with 282.0 mg/l and is lowest in the Elelenwo stream with 71.3 mg/l. The concentration levels of TDS across the streams are as follows Ntawogba 282.0 mg/l > Rumuolumeni 225.5 mg/l > Waja 149.5 mg/l > Egbelu 91.5 mg/l > Woji 73.0 mg/l > Elelenwo 71.3 mg/l.

SO₄²⁻ Concentrations

The concentration levels of SO₄²⁻ is highest in Ntawogba with 50.36mg/l, Elelenwo has the lowest SO₄²⁻ concentration level in suspended sediments with 12.73 mg/l. The distribution of SO₄²⁻ in decreasing order is Ntawogba stream 50.36 > Rumuolumeni stream 40.27 > Waja stream 26.70 > Egbelu 16.33 mg/l > Woji stream 13.04 mg/l > Elelenwo 12.73 mg/l. In bed sediments the order of the concentration levels of SO₄²⁻ is Ntawogba stream 9.32 mg/kg > Rumuolumeni stream 7.72 mg/kg > Elelenwo stream 5.82 mg/kg > Waja stream 5.07 mg/kg > Egbelu stream 4.67 mg/kg. In suspended sediments, the concentration of SO₄²⁻ is highest in Ntawogba stream with 50.36 mg/l and is lowest in Elelenwo stream with 12.73 mg/l. In bed sediments, the concentration is again highest in Ntawogba stream with 9.32 mg/kg and lowest in Egbelu stream 4.67 mg/kg.

NO₃⁻ Concentrations

The concentration levels of nitrate NO₃⁻ in suspended sediment across the streams in descending order based on percentage is as follows Egbelu stream 0.089 mg/l > Woji stream 0.065 mg/l > Ntawogba stream 0.054 mg/l > Rumuolumeni and Elelenwo streams 0.043 mg/l > Waja stream 0.020 mg/l. Spatially the concentration level of NO₃⁻ in bed sediment in the streams is as follows Ntawogba stream 1.96 mg/kg > Rumuolumeni stream 1.81 mg/kg > Woji stream 1.74 mg/kg > Elelenwo stream 1.70 mg/kg > Waja 1.69 mg/kg > Egbelu stream 1.63 mg/kg. The concentration level of NO₃⁻ in suspended sediments is highest in Egbelu stream with 0.089 mg/l and lowest in Waja stream with 0.020 mg/l. In bed sediments, the concentration of NO₃⁻ is highest in Ntawogba stream with 1.96 mg/kg and lowest in Egbelu stream with 1.63 mg/kg.

Cu Concentrations

The concentration levels of Cu across the streams in suspended sediments across the in decreasing order of magnitude is as Rumuolumeni stream 0.009 mg/l > Ntawogba stream 0.007 mg/l > Egbelu stream 0.004 mg/l > Waja>Woji+Elelenwo streams 0.002 mg/l. In bed sediments the magnitude is as follows Waja stream 0.115 mg/kg > Woji stream 0.141 mg/kg > Ntawogba stream 0.085 mg/kg > Rumuolumeni 0.059 mg/kg > Egbelu stream 0.084> Elelenwo stream 0.002 mg/l. The concentration level of copper (Cu) in suspended sediments is highest in Rumuolumeni stream 0.009 mg/l, and jointly lowest in Waja, Woji and Elelenwo streams 0.002 mg/l. The concentration in bed sediments is highest in the Waja stream with 0.115 mg/kg, and lowest in Elelenwo stream with 0.002 mg/l.

Cr Concentrations

Across the streams the concentration levels of Cr in suspended sediments in decreasing order of magnitude is as follows Rumuolumeni stream 0.024 mg/l > Ntawogba stream 0.031 mg/l > Waja stream 0.014 mg/l > Woji stream 0.006 mg/l > Elelenwo stream 0.004 mg/l > Egbelu stream 0.002 mg/l. In the bed concentration levels is distributed thus Ntawogba and Woji streams 0.095 mg/kg > Egbelu stream 0.092 mg/kg > Elelenwo stream 0.083 mg/kg > Rumuolumeni stream 0.053 mg/kg > Waja stream 0.016 mg/kg. Consequently, the concentration levels of chromium (Cr) in suspended sediments is highest in Rumuolumeni stream with 0.024 mg/l, and lowest in Egbelu stream with 0.002 mg/l; whereas in bed sediments the concentration level is highest in Ntawogba and Woji streams 0.095 mg/kg and lowest in Waja stream 0.016 mg/kg.

Pb Concentrations

Across the streams the concentration levels of Pb in suspended sediments is distributed thus Ntawogba stream 0.022 mg/l > Egbelu stream 0.01 mg/l > Rumuolumeni stream 0.009 mg/l > Waja stream 0.005 mg/l > Woji+Elelenwo streams - <0.001. In bed sediments the concentration distribution is in order Rumuolumeni stream 0.099 mg/kg > Waja stream 0.089 mg/kg > Woji+Elelenwo streams 0.053 mg/kg > Egbelu streams 0.043 mg/kg > Ntawogba streams 0.012 mg/kg. Consequently, the concentration levels of Pb in the suspended sediments is highest in Ntawogba stream with 0.022 mg/l and jointly lowest in Woji and Elelenwo streams with <0.001. In the bed sediments, the concentration of Pb is highest in Rumuolumeni with 0.099 mg/kg and lowest in Ntawogba with 0.012 mg/kg.

Fe Concentrations

Across the streams the concentration levels of Fe in suspended sediments are distributed in the order of Ntawogba stream 1.012 mg/l > Rumuolumeni stream 0.092 mg/l > Waja stream 0.076 mg/l > Woji stream 0.054 mg/l > Elelenwo stream 0.032 mg/l > Egbelu stream 0.028 mg/l. The concentration levels of Fe in bed sediments across the streams is distributed in order of Ntawogba 8.491 mg/kg > Rumuolumeni 5.022 mg/kg > Woji 3.111 mg/kg > Elelenwo 2.563 mg/kg > Waja 2.012 mg/kg > Egbelu 1.067 mg/kg.

The concentration levels of Fe in suspended sediments are highest in Ntawogba with 1.012 mg/l and lowest in Egbelu stream with 0.028 mg/l. In bed sediments the concentration levels of Fe is highest in Ntawogba stream with 8.491 mg/kg and lowest in Egbelu stream with 1.067 mg/kg.

Cd Concentrations

The concentration levels of Cd in suspended sediments across the streams is distributed in the order of Ntawogba stream 0.072 mg/l > Rumuolumeni stream 0.009 mg/l > Waja stream 0.003 mg/l > Egbelu+Woji+Elelenwo streams <0.001 mg/l. In the bed sediments the distribution of concentration levels of Cd across the streams in order of magnitude is as Elelenwo stream 0.098 mg/kg > Waja stream 0.065 mg/kg > Egbelu stream 0.044 mg/kg > Woji stream 0.042 mg/kg > Rumuolumeni stream 0.012 mg/kg > Ntawogba stream 0.011 mg/kg. Consequently, the concentration of cadmium (Cd) in suspended sediments is highest in Ntawogba stream with 0.072 mg/l and lowest Egbelu stream with just <0.001 mg/l. In bed sediments the concentration is highest in Elelenwo stream with 0.098 mg/kg and lowest in Ntawogba stream 0.011 mg/kg.

Zn Concentrations

The concentration levels of Zn in suspended sediments across the streams is distributed in order of Ntawogba 1.000 mg/l > Rumuolumeni 0.109 mg/l > Waja 0.099 mg/l > Woji and Egbelu streams 0.039 mg/l > Elelenwo 0.021 mg/l; the concentration of by percentage for bed sediments across the streams in order of magnitude is as Ntawogba 1.459 mg/kg > Rumuolumeni 1.174 mg/kg > Woji 1.459 mg/kg > Elelenwo 0.742 mg/kg > Waja 0.519 mg/kg > Egbelu 0.212 mg/kg. Consequently, the concentration of Zn in suspended sediments is highest in Ntawogba 1.000 mg/l and lowest Egbelu with 0.039 mg/l; while in bed sediments the concentration is again highest in Ntawogba with 31.459 mg/kg and lowest in Egbelu with 0.212 mg/kg.

Analysis of Pearson's Correlation Coefficient

The strength of relationship between suspended and bed sediments parameters were tested using the Pearson's correlation coefficient. The null hypothesis was stated as: Ho - there is no correlation between the concentrations of the physicochemical parameters in suspended and bed sediments parameters in the streams.

Table 3: Pearson's Correlation Coefficient Values for Parameters in Suspended and Bed Sediments

X/Y	pH	TDS	SO ₄ ²⁻	NO ₃ ⁻	Cu	Cr	Pb	Fe	Cd	Zn
pH	0.27	0.62*	0.57*	-0.35	0.002	0.02	0.67*	0.65*	0.64*	0.64*
SO ₄ ²⁻	-0.043	0.94*	0.89*	-0.16	0.77*	0.91*	0.92*	0.83*	0.94*	0.83*
NO ₃ ⁻	0.080	0.88*	0.86*	0.77*	0.65*	0.90*	0.93*	0.89*	0.96*	0.88*
Cu	0.65	-0.32	-0.15	0.090	-0.34	-0.095	-0.096	-0.014	-0.098	-0.02
Cr	0.00035	0.32	-0.56*	0.79*	-0.085	-0.18	0.093	0.31	0.18	0.27
Pb	0.32	-0.33	-0.097	-0.55*	0.12	-0.71*	-0.40	-0.67*	-0.45	-0.65*
Fe	0.030	-0.91*	-0.87*	-0.14	0.67*	0.89*	0.89*	0.89*	0.97*	0.89*
Cd	0.028	-0.14	-0.15	-0.42	0.17	-0.11	-0.11	-0.62*	-0.40	0.61*
Zn	0.32	0.78*	0.69	-0.22	-0.12	0.79*	0.79*	0.68*	0.77*	0.67*

Source: study fieldwork 2021/22 –x=bed sediments, y=suspended sediments

There are two tailed significant correlations for asterisked (*) values at 0.05 level of significance. For bed sediments and suspended sediments, there is strong correlation between pH/TDS (0.62), pH/ SO_4^{2-} (0.57), pH/Pb (0.67), pH/Fe (0.65), pH/Cd (0.64), and pH/Zn (0.64). There is strong positive correlation between SO_4^{2-} /TDS (0.94), SO_4^{2-} / SO_4^{2-} (0.89), SO_4^{2-} / NO_3^- (0.77), SO_4^{2-} /Cr (0.91), SO_4^{2-} /Pb (0.92), SO_4^{2-} /Fe (0.83), SO_4^{2-} /Cd (0.94), and SO_4^{2-} /Zn (0.83) in the bed and suspended sediments. There exists a strong positive correlation between NO_3^- /TDS (0.94), NO_3^- / SO_4^{2-} (0.89), NO_3^- / NO_3^- (0.77), NO_3^- /Cu (0.65), NO_3^- /Cr (0.90), NO_3^- /Pb (0.93), NO_3^- /Fe (0.89), NO_3^- /Cd (0.94), and NO_3^- /Zn (0.83) in bed and suspended sediments. There is only a strong positive correlation between Cu/pH (0.65) in suspended and bed sediments. There is strong negative correlation between Cr/ SO_4 (-0.56), a strong positive correlation between Cr/ NO_3^- (0.79) in bed and suspended sediments. There is also a strong negative correlation between Pb/ NO_3^- (-0.55), Pb/Cr (-0.71), Pb/Fe (-0.67), and Pb/Zn (-0.65). There is a strong negative correlation between Fe/TDS (-0.91), and Fe/ SO_4^{2-} (-0.87); while there is a strong positive correlation between Fe/Cu (0.67), Fe/Cr (0.89), Fe/Fe (0.89), Fe/Cd (0.97) and Fe/Zn (0.89) in bed and suspended sediments. There is a strong negative correlation between Cd/Fe (-0.62), and a strong positive correlation between Cd/Zn (0.61) in the bed and suspended sediments. There is a strong positive correlation Zn/TDS (0.78), Zn/ SO_4^{2-} (0.69), Zn/Cr (0.79), Zn/Pb (0.79), Zn/Fe (0.68), Zn/Cd (0.77) and Zn/Zn (0.67).

FINDINGS

pH Mean and Range Values

The mean value for pH in suspended sediments is 5.25, and also 5.25 in bed sediments. The pH range in the two sediments media is 4.96-5.75, and 4.46-5.86 respectively showing the streams to be acidic.

TDS Mean and Range Values

The TDS analyzed for the suspended sediments samples from all the streams has mean of 148.8, and a range of 71-3-282.0, which are below the concentration levels recommended by WHO (2008) and NESREA (2007) for drinking water.

SO_4^{2-} Mean and Range Values

In suspended sediments the mean concentration level for SO_4^{2-} is 26.57, and in bed sediments is 6.35. The range in the two sediments media is 12-73-50.36, and 4.67-9.32 respectively.

NO_3^- Mean and Range Values

The mean concentration level of NO_3^- in suspended sediments is 0.08, and in bed sediments is 1.76. The range in both sediments media are 0.020-0.089, and 1.63-1.96 respectively.

Cu Mean and Range Values

The mean concentration level of Cu in suspended and bed sediments is 0.0045, and 0.087 respectively. The range is 0.002-0.009 in suspended sediments, and 0.037-0.141 in bed sediments.

Cr Mean and Range Values

The mean concentration level of Cr in suspended and bed sediments is 0.0135, and in bed sediments is 0.065 respectively. The range is 0.002-0.031, and 0.016-0.095 in the respective sediments' media.

Pb Mean and Range Values

The mean concentration level of Pb in suspended and bed sediments respectively is 0.0065, and 0.058 respectively. The respective ranges are 0.001-0.009, and 0.012-0.099.

Fe Mean and Range Values

The mean concentration level of Fe in suspended and bed sediments is 0.216, and 3.711 respectively. The respective ranges are 0.028-1.012, and 1.067-8.491.

Cd Mean and Range Values

The mean concentration level of Cd in suspended and bed sediments is 0.00635, and 0.063 respectively. The respective ranges are 0.001-0.009, and 0.011-0.120.

Zn Mean and Range Values

The mean concentration level of Zn in suspended and bed sediments is 0.218, and 0.853 respectively. The respective ranges are 0.021-1, and 0.519-1.459.

CONCLUSION AND SUGGESTIONS

The concentration levels of the observed parameters as analyzed, their means and ranges were below the permissible limits of the index values of standards appropriated for the study. Heavy metals exert reasonable impact on the quality of sediments in the streams of Port Harcourt metropolis. The observed parameters that are the leading influencers of stream sediments

degradation are from anthropogenic activities in the area. Strong positive correlation indicates that the pollutants come from the same source; whereas strong negative correlation indicates that the pollutants are not from the same source. In other words, human activities are chief source of heavy metals releases into the environment of the metropolis' watershed and stream basins. It was suggested that the identification and characterization of anthropogenic activities within the metropolis will be valuable to monitoring stream water quality.

References

- Akankali, J. A., & Davies, I. C. (2021). Heavy metals and physicochemical parameters evaluation in the upper reaches of Bonny River, Niger Delta, Nigeria. *Journal of Applied Sciences and Environmental Management*, 25(8). DOI: 10.4314/jasem.v25i8.1.
- Arimieari, L. W., Sangodoyin, A. Y., & Ereoforiokuma, N. S., (2014). Assessment of surface water quality in some selected locations in Port Harcourt, Nigeria. *International Journal of Engineering Research and Technology*, 03(7).
- Bakker, K. (2012). Water security: research challenges and opportunities. *Science*, 337(6097), 914-915. DOI: 10.1126/science.1226337.
- Global Water Partnership (2009). Global water security. *ICE/RAE/CIWEM Report to Professor John Beddington, Chief Scientific Adviser to HM Government*. Drottninggatan 33, 11151 Stockhol, Sweden.
- Grey, D. & Sadoff, C. W. (2007). Sink or swim? water security for growth and development. *Water Policy*, 9(6), 545–571. <https://doi.org/10.2166/wp.2007.021>.
- Li, Xin-Rong., He, M., Zerbe, S., Li, Xiao-Jun., & Liu, Li-Chao (2010). Micro-geomorphology determines community structure of biological soil crusts at small scales. *Journal of Earth Surface Processes and Landforms*, 35(3), 15-35.
- Li, Hong-Yi., Tan, Z., Ma, H., Zhu, Z., Abeshu, G. W., Zhu, S., Cohen, S., Zhou, T., Xu, D., & Leung, L. R. (2021). a new large-scale suspended sediment model and its application over the United States. <https://doi.org/10.5194/hess-2021-491>.
- Lundy, L., Alves, L., Revitt, M., & Wildeboer, D. (2017). Metal water-sediment interactions and impacts on an urban ecosystem. *Int J Environ Res Public Health*, 14(7), 722. doi: 10.3390/ijerph14070722.
- Nwankwoala H. O., & Angaya Y. B. (2017). An evaluation of heavy metals concentration in the choba section of the New Calabar River, Eastern Niger Delta. *Biodiversity International Journal*, 1(6), 62-68.
- Otene, B., & Alfred-Ockiya, J. F. (2021). Determination of pollution status of sediment of Elele Alimini Stream Port Harcourt Nigeria using pollution indices. https://www.researchgate.net/publication/349313281_.
- Zeitoun, M. (2011). The global web of national water security. *Global Policy*, 2(3), 286-296.

