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ANALYSIS OF THE CURRENT STATE CONTAMINATION AND POLLUTION LEVEL OF STREAMS IN PORT HARCOURT METROPOLIS

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ABSTRACT

This is a geomorphic study that focused on analysis of the current state contamination and pollution level of streams in Port Harcourt metropolis. It experimentally evaluated contamination and pollution levels in urban fluvial environment. Egbelu, Rumuolumeni, Ntawogba, Waja, Woji and Elemenwo streams were sampled for the study in which physicochemical parameters like pH, TDS, SO_4^{2-} , NO_3^- , Cu, Cr, Pb, Fe, Cd, and Zn were analyzed in the samples for their concentration levels. Analysis of sediments media was based on the regulatory framework of DPR-EGASPIN (2002), and the APHA standards methods were employed for laboratory analyses of the parameters. Arrival at the current state of contamination and pollution of the sediments media was based on evaluation of their mean and range. In suspended sediments the mean values ranged between 0.0045 in Cu and 5.25 in pH. In bed sediments the mean values ranged between 0.056 in Pb and 5.52 in pH. The mean and range values showed acidification of streams from suspended and bed sediments. Values from the assessment of contamination and pollution using multi-geoindices such as contamination factor (CF), geoaccumulation index (Igeo), enrichment factor (EF), ecological risk index (Eir), risk index (RI), and modified risk index (MRI) showed that Pb, Cd, and Zn are the heavy metals to monitor in order to control their contamination impact on the aquatic ecosystem, and water quality. Referential to Pb in suspended sediments the values are CF (0.00294), Igeo (0.0004), EF (0.013), Eir (0.105), MRI (0.525); in bed sediments the values are CF (0.0058), Igeo (0.0063), EF (0.105), Eir (0.013), and MRI (0.065) based on corresponding streams. Hence continuous monitoring of sediments quality as indicators of streams quality was recommended by the study.

Keywords: Current-State, Contamination, Pollution, Environmental Governance, Environmental Quality.

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INTRODUCTION

Emphasis on the current-state of contamination and pollution of sediments in streams of the Port Harcourt metropolis is consistent with environmental goals to check adverse impacts of socio-economic development. The projection the current-state of contamination and pollution of streams in the area is based on the characterization of suspended and bed sediments in some of its major streams. The current-state of contamination and pollution, or quality index of an environment is required for composite governance of a geo-environment which requires a flow of informed information between the various interacting channels of engagement-decisions, and regulatory coordination. These channels are stakeholders for the achievement goals regarding the sustenance of environmental quality. Environmental governance must be understood to include governments, businesses, civic stakeholders, and citizens operating with a systemic management profile. The profile upholds structure committed to accountability and responsibility involving ethics, risks control, and administrative compliance. Data on current-state assessment of contamination and pollution vis-à-vis environmental quality is organic to systemic environmental protection, conservation; legislation, regulation policing, and control, monitoring and, management. The geo-environment must be understood as a generic ecosystem of processes that act and react against the equilibrium functions of the environmental subsystems. If left unchecked, unobserved, unmitigated such activities and processes in the environment could exact trophic damages otherwise unwholesome deleterious impact on resource quality, the organic ecosystem and human health. Now consider neglect of the current-state data and information on environmental quality and add that to the concern by Budnukaeku and Oku (2021) who conceded that the rate of contamination and pollution and desecration of the environment remains high in Nigeria notwithstanding the number of environmental laws of international standards available in country.

The relevance of water for economic socio-development processes covers suitability for sustainable development programs processes, agricultural development processes, sustainable climatic state, habitat goals and livelihood processes of the environment, and for the sustenance of the balance of moisture and climatic budget of an urban neighborhood. Others include environmental conservation, protection and management of biodiversity processes. While it is nearly impossible to discuss life without water as it provides food, energy and habitat for living organisms, the source-conditions or quality of water for specified uses justifies the importance of characterizing sediments in aquatic environment to evaluate their impact on water quality, environmental health, and quality. It is common to recourse to physical factors in an environment as the first point of evaluation of its contamination or pollution problems.

At a global scale the importance of the imperativeness of objective assessment of current-state status of contamination, pollution, and cognate environmental quality is thrust up by European Environment Agency. It put up the Water Framework Directives (WFD) in the year 2000 (Kaika, 2003; Quevauviller et al., 2008; European Environmental Agency, 2018). The framework validates the necessity of information and data on the current-state assessment of an environment's quality with the aim of easing pressure on resource extraction and utilization (European Environmental Agency, 2018). It is praised as the most significant legislative instrument touching the science and resources of water and is tenable globally. The framework recognizes the need for accountability by emphasizing the recognition of the immediate implications of sediment impact on water quality, and the impact of long term accumulation of sediment on ecosystem health (Lundy & Wade, 2011). It serves as inspiration and program

benchmark for integrating environmental management with regulatory goals for preventing unrestrained deterioration and degradation of water bodies and sources, and for the protecting and enhancing the status of aquatic ecosystems and particularly for tropical regions and wetlands. Among the aims of the EU water framework directives is promoting sustainable water consumption and for the mitigation of the effects and impacts of droughts and floods” (Quevauviller et al., 2008; Ahlf et al., 2008; Förstner et al., 2008). Scholarly opinions are strong on the needs for strong, effective, efficient, and reliable legislations, and enabled administration machinery for environmental management.

The relevance of current-state contamination and pollution of streams in the perspective of this study is to help ascertain the physiochemical-geomorphic status of suspended sediment concentration in the urban streams. Additionally, it is relevant as a referential geomorphic data for future ‘current-state’ inquiry on suspended sediment and for spatial and temporal comparison for the area and as maybe empirically feasible. It is also relevant for advising on stream/river water quality and recovery practices and processes. That empirical knowledge of suspended sediment concentration serves as an indispensable and important database on water quality parameter, just as the understanding of sediment fluxes are important for sustainable management of river catchment, and designing processes, and project for river recovery is promoted by Woodward and Foster (1997). As such the current-state contamination and pollution of streams as in this study is relevant for environmental monitoring – the effect of human activities on suspended and bed sediment condensates associated with accumulation and flocculation of heavy metals, chemical composites and pathogens. Data on the current-state contamination and pollution of streams and the geo-environment serve as secondary source of information and inferences from geoindices used in given studies at different times. The benefits reach a broad range of uses such as for policy and management processes stream resourcefulness, and environmental impact assessments for water quality and stream protection and related conservation projects. That does not exclude usage by scholars who require base data for subject reviews.

Panagos et al. (2013) validated the need for current state data on environmental quality based on the thematic strategy for soil protection program of the EU. Soil contamination has been identified and prioritized by the European Commission as a continental concern. This has been done by collecting relevant soil data for policy purposes all across Europe. They highlighted the need to develop soil-related indicators as imperative for collecting and establishing data on soil quality status across Europe for harmonized soil management policies across their continent. They focused their work on health implications of contaminated soils in industrial sites by analyzing data submitted by countries involved in the program with results they obtained from sites of contaminates.

Armah et al. (2014) reviewed 1004 studies from online sources like SCOPUS, PubMed, MEDLINE, and EMBASE for researches on toxicant levels in the environmental media of air, soil, water; and biota in Ghana. A high degree of variability in the heavy metal concentrations in human subjects in the studies reviewed is likely due to heterogeneity in physiological states, excretion profiles, and body burdens of individuals. These, in turn, may be a product of genetic polymorphisms influencing detoxification efficiency.

The quality of streams, rivers, and aquatic systems as regulators of environmental conditioning, and as modifiers of environmental and ecosystem health is determined measurably

by the quality of their sediment loads. The mineralogical constitutions and quality of sediments are determined basically by the geology viz-a-viz the geophysical and geochemical characteristics of stream catchments and watersheds (Whitmore et al., 1997; Shaghude et al., 2006; Takemura et al., 2017; Gao et al., 2020). These in addition to the geomorphological configuration (Zhang et al., 2015; Yang et al., 2021; George et al., 2019; Ologhadien, 2018; Aisuebeogun & Ezekwe, 2014) of the catchments and watersheds and the stream basin and channel as induced by cognate geo-environmental forces such as biogeographical indices and climatological parameters influence the flux of sediment discharges, delivery and deposition in stream channels.

The immediate beneficiaries of stream quality are the populations of the aquatic ecosystem primarily; next after which is the human population who draw from the fluvial bodies water for development, livelihood and health. The current state of contamination and pollution of streams in any environment indexes the indicated quality status based on evaluation with certain geoindices; and thereby provides reference data for temporal variation. Thus current-state characterization of contamination and pollution justifies comparative time reference validation of changes and makes for requisite predictions and policy changes. In other words, changes across time and seasons, site and location maybe tracked where current-state data are available.

The characterization of suspended and bed load sediments provides useful indicators for the management of land, water and environmental quality within a given area of study. Naturally or by human actions, an environment may change from time to time and possibly with unforeseen deleterious consequences aggravated by anthropogenic pressure on resources. Polluted sediments sustain the degradation of water quality in stream systems. Lundy et al. (2017) admitted that many contaminants in polluted waters are commonly adsorbed to suspended particles in the water column and others to bed sediments. Consequently, they serve as specimen material for the forensic analysis of pollutant DNA in order to determine and trace contaminant sources within the environment. Bed load sediment rather than suspended sediment are a more stable medium or geomorphic environment for tracing pollutants and contaminants particularly heavy metals. Alex et al. (2019) opined that ‘riverbed sediments are ‘enteric virus reservoirs’ that impact significantly on ‘water column contamination, especially during rainfall events.’ In this regard characterization of bed and suspended sediment consistently identifies the geomorphic medium as pollutant sinks and reference sources for contamination and source of data for inferential overview of changes in an environment. Characterization of bed and suspended sediment in streams in the Port Harcourt, would provide a number of ideas and offer useful geomorphic inferences on the matter for a variety of uses including knowledge of the current-state variability of tested parameters for water quality suitability, data would serve as useful intelligence material to advise needful amendment of existing environmental laws, and to inform on river recovery and management.

Study Area

Between the geographical coordinates of longitudes 6.0551° and 7.0551° E and latitudes 4.0351° and 5.0101°N of the equator is located the Port Harcourt on the lowland areas of Niger delta. Its climate is classified on the Koppen (1923) scheme as Am. The metropolitan area is a rapidly expanding metropolis with hubs of new and emerging neighbourhoods. Contiguous rural communes are gradually being sorbed into the urban centrifuge. Being a major political city in the geographical south eastern coastal area of Nigeria, the metropolis has its unique share of

environmental problems from cognate environmental geosphere, atmosphere, biosphere and hydrosphere. This in addition to anthropogenic problems induced by urbanization, economic and industrial development activities. The petro-carbon industry being not only a major player, but a glaring associate and contributor to environmental problems in the Port Harcourt region.

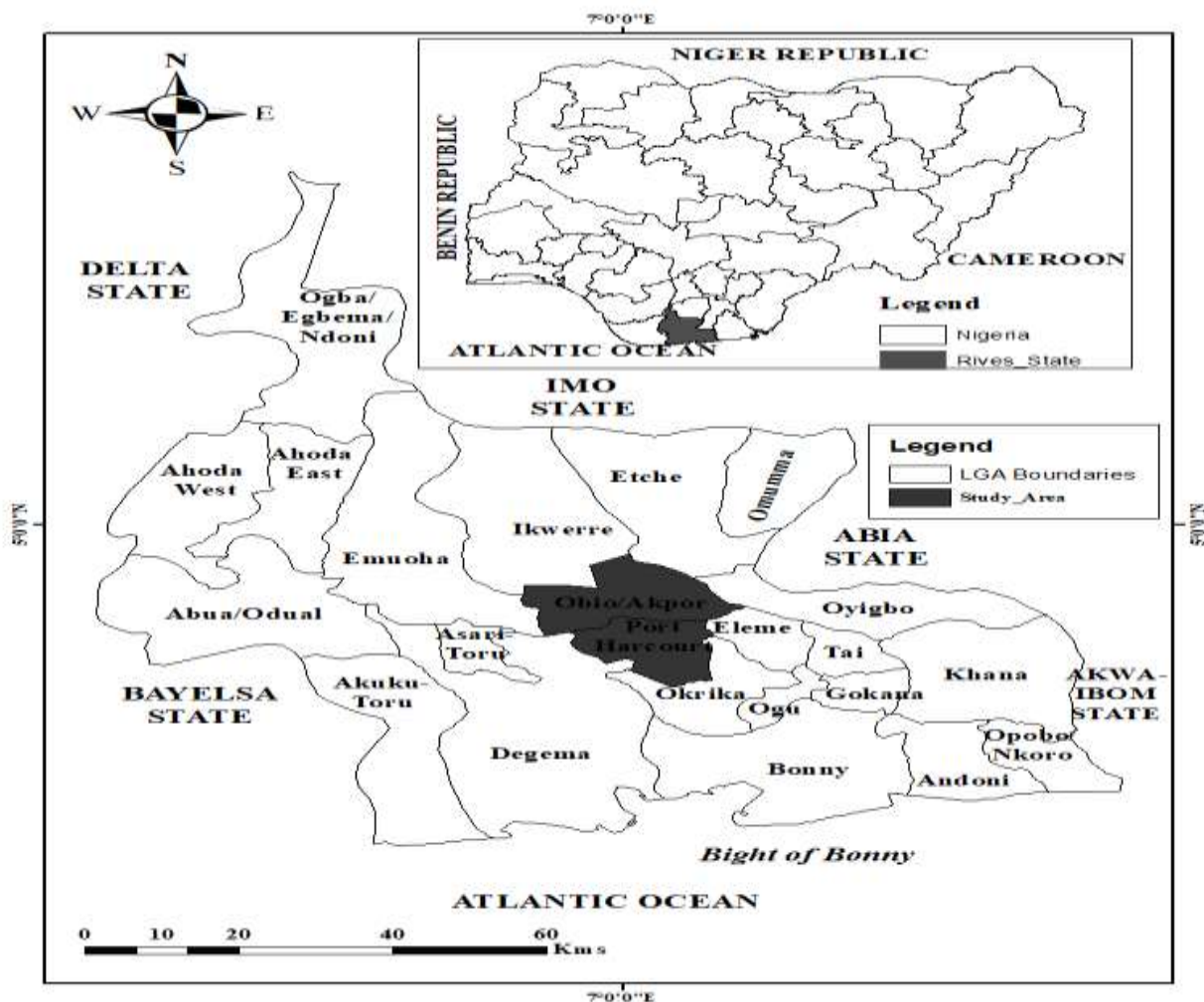


Figure 1: Rivers State, Nigeria. Showing Port Harcourt Metropolis
Source: researcher's fieldwork 2021/2022

METHODOLOGY

Five samples each for suspended and bed sediments were collected for analysis from each stream at a sample interval of 50 meters apart on a 1000m stretch downstream. The laboratory analysis was based on the DPR-EGASPIN framework using the APHA standard methods physicochemical parameters. In this study, the streams are coded as 1-6 where for instance ¹Egbelu stream, and ⁶Elelenwo stream. The mean, and range for all the parameters were evaluated but the heavy metals the current state data was based on CF, Igeo, EF, Eir, and MRI based on their respective conventional formula.

Contamination Factor

$$CF = \frac{C_{\text{metal}}}{C_{\text{background}}} \quad \text{Equation 1}$$

Where CF=contamination factor. C_{metal} is concentration of metal in sediment sample; $C_{\text{background}}$ is concentration of metal in geological background.

Contamination Degree (CD)

Contamination Degree is calculated with the given formula:

$$CD \text{ or } DC = \sum_{i=1}^n CFI \quad \text{Equation 2}$$

Modified Contamination Degree (mCD)

The modified contamination degree as proposed by Håkanson (1980) is calculated with the given formula:

$$mCD = \sum_{i=1}^n \frac{CF_i}{n} \quad \text{Equation 3}$$

Geoaccumulation Index

Geoaccumulation index (Igeo) is calculated with:

$$I_{\text{geo}} = \log_2(C_n / 1.5 B_n) \quad \text{Equation 4}$$

Where I_{geo} is geo-accumulation index; C_n – the concentration of the element in question in bottom sediments; B_n – geochemical background for the metal in question; 1.5 – coefficient expressing the natural variation in the content of the metal in question in the environment.

Enrichment Factor (EF)

$$EF = \frac{(Me/Fe - \text{sample})}{(Me/Fe - \text{background})} \quad \text{Equation 5}$$

Where the numerator= is the ratio of heavy metal to Fe concentration in the sample; and the denominator= is the natural background value for the ratio of heavy metal to Fe.

Ecological Risk Assessment

Individual Ecological Risk Index (Eri)

This is calculated with:

$$Eri = Tr \times CF \quad \text{Equation 6}$$

Ecological Risk Index (RI)

This is used to calculate for each metal and the given formula is:

$$RI = Tr \times CF \quad \text{Equation 7}$$

Where Tr is the toxicological response factor of particular heavy metals.

Modified Risk Index

Modified Risk Index mRI is calculated with:

$$\text{mRI} = \text{Tr} \times \text{EF} \quad \text{Equation 8}$$

Where EF is enrichment factor, and Tr is the toxicological response factor of particular heavy metals.

RESULTS AND DISCUSSION

Suspended Sediments

Table 1: Concentration Levels 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

Table 2: Summary Table for Mean and Range of Concentration Levels, and Highest CF, mCD, Igeo, EF, Eir, mRI Values in Suspended Sediments

	Mean	Range	CF	CD	mCD	Igeo	EF	Eir	RI	mRI
pH	5.25	4.96 – 5.75	-	-	-	-	-	-	-	-
TDS	148.8	71.3 – 282.0	-	-	-	-	-	-	-	-
SO ₄ ²⁻	26.57	12.73 – 50.36	-	-	-	-	-	-	-	-
NO ₃ ⁻	0.08	0.020 – 0.089	-	-	-	-	-	-	-	-
Cu	0.0045	0.002 – 0.009	² 0.00032	-	-	¹ 0.00006	¹ 0.014	³ 1.78	-	³ 1.78
Cr	0.0135	0.002 – 0.031	³ 0.00033	-	-	^{2,3} 0.00006	² 0.005	¹ 0.038	-	¹ 0.076
Pb	0.0065	0.001 – 0.009	⁴ 0.00294	-	-	¹ 0.0004	³ 0.013	¹ 0.105	-	¹ 0.525
Fe	0.216	0.028 – 1.012	² 0.0182	-	-	³ 0.04	-	-	-	-
Cd	0.00635	0.001 – 0.009	³ 0.0162	-	-	³ 0.016	⁵ 21	¹ 21	-	¹ 630

Zn	0.218	0.021 – 1	³ 0.014	-	-	⁶ 0.633	² 0.138	² 0.0138	-	² 0.138
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In suspended sediments, the highest CF value for Cu occurs in ²Rumuolumeni stream; the highest CF value for Cr occurs in ³Ntawogba stream; the highest CF value for Pb occurs in ⁴Waja stream; the highest CF value for Fe occurs in ²Rumuolumeni stream; the highest CF value for Cd occurs in ³Ntawogba stream, and for Zn its highest CF value occurs in ³Ntawogba stream. Cu has the highest Igeo value in ¹Egbelu stream; Cr has the highest Igeo value in ²Rumuolumeni and ³Ntawogba streams; Pb has the highest Igeo value in ¹Egbelu stream; Fe has the highest Igeo value in ³Ntawogba; Cd has the highest Igeo value in ³Ntawogba; and Zn has the highest Igeo value in ⁶Elelenwo. Cu has the highest EF value in ¹Egbelu stream; Cr has the highest EF value in ²Rumuolumeni stream; Pb has the highest EF value in ³Ntawogba stream; Cd has the highest EF value in ⁵Elelenwo stream; and Zn has the highest EF value in ²Rumuolumeni stream. Cu has the highest Eir value in ³Ntawogba; Cr has the highest Eir value in ¹Egbelu stream; Pb has the highest Eir value in ¹Egbelu stream; Cd has the highest Eir value in ¹Egbelu stream and Zn has the highest Eir value in ²Rumuolumeni. Cu has the highest mRI value in ³Ntawogba stream; Cr, Pb and Cd have the highest mRI value in ¹Egbelu stream; and Zn has the highest mRI value in ²Rumuolumeni.

Bed Sediments

Table 3: Concentration Levels in Bed Sediments
Bed Sediments

	pH	TDS	SO ₄ ²⁻	NO ₃	Cu	Cr	Pb	Fe	Cd	Zn
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	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

Table 4: Summary Table for Mean and Range of Concentration Levels, and Highest CF, mCD, Igeo, EF, Eir, mRI Values in Bed Sediments

	Mean	Range	CF	CD	mCD	Igeo	EF	Eir	RI	mRI
pH	5.25	4.46 – 5.86	-	-	-	-	-	-	-	-
TDS	-	-	-	-	-	-	-	-	-	-
SO ₄ ²⁻	6.35	4.67 – 9.32	-	-	-	-	-	-	-	-
NO ₃	1.76	1.63 – 1.96	-	-	-	-	-	-	-	-
Cu	0.087	0.037 – 0.141	² 0.021	-	-	^{1,2,3} 0.006	¹ 1.78	¹ 0.02	-	¹ 0.014
Cr	0.065	0.016 – 0.095	¹ 0.001	-	-	⁴ 0.0003	² 0.038	¹ 0.005	-	¹ 0.01
Pb	0.058	0.012 – 0.099	² 0.0058	-	-	⁶ 0.0063	³ 0.105	⁴ 0.013	-	⁴ 0.065
Fe	3.711	1.067 – 8.491	² 0.996	-	-	⁵ 0.953	-	-	-	-
Cd	0.063	0.011 – 0.120	⁶ 1.4	-	-	² 0.257	⁵ 21	¹ 2.41	-	¹ 72.3
Zn	0.853	0.519 – 1.459	³ 0.0217	-	-	² 0.035	² 0.138	⁵ 0.04	-	⁵ 0.021

In bed sediments Cu the highest CF value in ²Rumuolumeni stream; Cr has highest CF value in ¹Egbelu stream; Pb has highest CF value in ²Rumuolumeni stream; Fe has the highest CF value in ²Rumuolumeni stream; Cd has highest CF value in ¹Egbelu stream and Zn has the highest CF value in ³Ntawogba stream. Cu has the highest Igeo value in ¹Egbelu stream, ²Rumuolumeni stream, and ³Ntawogba stream; Cr has the highest Igeo value in ⁴Waja stream; Pb has the highest Igeo value in ⁶Elelenwo stream; Fe has the highest Igeo value in ⁵Woji stream; Cd has highest Igeo value in ²Rumuolumeni stream, and Zn has the highest Igeo value in ²Rumuolumeni stream. Cu has the highest EF value in ¹Egbelu stream; Cr has the highest EF value in ²Rumuolumeni stream; Pb has the highest EF value in ³Ntawogba stream; Cd has the highest EF value in ⁵Woji stream; Zn has the highest EF value in ²Rumuolumeni stream. Cu has the highest Eir value in ¹Egbelu stream; Cr has the highest Eir value in ¹Egbelu stream; Pb has the highest Eir value in ⁴Waja stream; Cd has the highest Eir value in ¹Egbelu stream; and Zn has the highest Eir value in ⁵Woji stream. Cu has the highest mRI value in ¹Egbelu stream; Cr has the highest mRI value in ¹Egbelu stream; Pb has the highest mRI value in ⁴Waja stream; Cd has the highest mRI value in ¹Egbelu stream; and Zn has the highest mRI value in ⁵Woji stream.

FINDINGS AND CONCLUSION

The concentration levels of the parameters are higher in bed sediments than in suspended sediments. Consequently, from the assessment geoindices employed in the study, the results are higher in bed sediments than suspended sediments. Across the streams, the incident of sediments media acidification is noticed. Ntawogba posts the highest indication of sediments contamination from Cd in the two sediments media. Ntawogba has the highest indication of Igeo for Pb, Rumuolumeni has the highest Igeo indication for Cd and Zn in bed sediments. Cd poses the most potentially ecological risk in suspended and bed media across the streams. The study concluded that there is a gradual rise in heavy metals concentration levels in streams sediments across the metropolis. With rise in population the impact of heavy metals from anthropogenic activities may increase. The study recommended for continuous monitoring of sediments monitoring as indication of stream quality assessment in order to provide current state information on pollution and contamination of the streams.

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