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Journal of Geographical Research
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ARTICLE

Mapping Seasonal Variation in the Distribution and Concentration of Heavy Metals Using Water Quality Index and Geographic Information System Based Applications

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ARTICLE INFO

Article history
Received: 15 April 2021
Accepted: 06 May 2021
Published Online: 17 May 2021

Keywords:
Environmental pollution
Fosu lagoon
Heavy metals
Public education
Seasonal variation

ABSTRACT

Incessant monitoring of water is essential in terms of heavy metals and toxic substances as it provides detailed information on aquatic resources. Majority of lagoons receive freshwater from their catchment areas containing industrial and domestic waste. The paper analysed seasonal variations in the distribution and concentrations of Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) in the Fosu lagoon in Ghana to ascertain the quality of the lagoon. Water was sampled from eighteen (18) different points on the lagoon and was analysed at the Water Research Institute (WRI) of the Center for Scientific and Industrial Research (CSIR) using Atomic Absorption Spectrometry (AAS) and the results were interpolated using kriging. The results obtained were compared with the World Health Organisation water quality index. Statistical analysis of heavy metal concentrations using Pearson's two-tailed significance correlation showed positive correlations for both seasons; between Pb and Cu (0.297; sig. = 0.232, and 0.196; sig. = 0.436), and Cd and Mn (0.119; sig. = 0.643 and 0.191; sig. = 0.447) for the wet and dry seasons respectively. A paired sample t-test on concentrations also showed statistical differences between wet and dry seasons' concentrations for Pb (t = 1.324; sig. = 0.203), Cu (t = 2.759; sig. = 0.013), and Cd (t = 3.056; sig. = 0.007), and Mn (t = -4.014; sig. = 0.001). Pb and Cd showed higher concentrations above the World Health Organisation's permissible limits. Heavy metal concentrations of water samples analysed varied widely in terms of seasons and sampling points.

1. Introduction

Coastal lagoons are critically valuable habitats. They are home to a variety of endangered species and are extremely competitive [37]. They serve as breeding grounds for marine fish and invertebrates, and as a resting place for many migratory bird species. Residents have long exploited coastal lagoons for their natural resources, particularly for fishing and aquaculture; coastal populations are depen-

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 DOI: https://doi.org/10.30564/jgr.v4i2.3100

dent on lagoons for subsistence and small-scale economic enterprise [7]. More than 70% of Ghana's population live along the coastal strip with maximum population densities occurring at the coast [7]. Although coastal lagoons play important roles, they are unambiguously delicate because they are naturally rich, spatio-temporarily disturbed, and susceptible to human and natural stresses [5]. To ensure stability and resilience, these ecosystems need to be protected. Many anthropogenic activities in third world nations, especially in Sub-Saharan Africa (SSA), have prompted environmental issues and strategic monitoring [3]. According to [16], due to their potential long-term implications for public health in both developed and developing countries, there is substantial environmental concern regarding the presence of heavy metals in water sediments and other environmental media.

Quality of water is one of the main concerns of the many, which is directly linked to human health and welfare [27,29,26]. Heavy metals are classified as compounds with a specific magnitude that is at least five times the prescribed gravity of water. Heavy metals are not eco-friendly and thus at some rates of introduction, they are toxic to plants, marine life and human health [20]. [10] is of the view that heavy metal concentrations may rise to a toxic level that has the potential to hamper human health. Water contaminated with heavy metals, anion and cations such as Cd, Pb, Cr, As, Hg, Ni, Zn, So42C, No3¡, No2¡, Cl¡, F¡, Ca2 C, NaC, Mg2 C, and KC can have harmful effects on human health due to excessive intake of contaminated water by human beings [26]. The continuous discharge of manufacturing and built-up wastewater into the Fosu Lagoon is a potential supply of contaminants in the lagoon. The Fosu lagoon is known as the third most polluted lagoon in Ghana, [9]. Because of the contaminated state of the lagoon, UNEP classified the lagoon with the designation "Dead Zones," which defines lagoons where pollution threatens fish and other aquatic life and the health of people who rely on it for their livelihood [34]. Again, it is on record that most of the research works on the Fosu Lagoon that focus on the quality of water considered the presence of heavy metals in only sediment samples of the lagoon [23,10]. These emphasize the need for thorough heavy metal analysis of the Fosu lagoon, taking cognisance of the water sample and how they are distributed across time and space. Despite [35] presents an assessment of the state of the coastal and marine waters of the West and Central African Regions from the Atlantic Ocean to the Sahara Desert, spanning across from the shores of Lake Chad to Senegal, this study bridges the gap in literature as it susses and addresses two of the principal constraints identified by [35]. As such, the study provides detailed scientific data on four heavy metals and provides a quantitative and statistical assessment of their concentrations as well as their sources to the Fosu Lagoon.

According to [6], there are several factors responsible for the prevalence of heavy metals in the environment; in their Northern Ghana report, [6] reported that mining even at a smaller scale was the amplified source of heavy metals. More to that, through principal component analysis, their findings revealed that heavy metals such as Hg came from other sources (maybe anthropogenic) compared to other heavy metals like Zn, Pb, Cd, and As in both mining regions. In their study, higher heavy metal concentrations were recorded in rainy season for both water and sediment than in dry season, except for Pb and Cd, which had higher sediment concentrations in the dry season. Also, [31] in their research, which detected concentrations of heavy metals in water and sediments from the El Guájaro Reservoir, it was found that Pb and Hg were not detected in the surface waters of El Guájaro reservoir during the dry season, nor was zinc detected during the wet season; however, the highest concentrations of heavy metals were observed during the wet season. [31] and [22] avers that the concentration of heavy metals varies with seasons. These studies suggest that heavy metals are high in the rainy season, although smaller concentrations were reported in the dry season with a few exceptions. [18] and [22] suggest that more rainfall mineralization helps to understand why heavy metals are strong in the wet season and vice versa. [38] supports this view in their research on the supply of heavy metals in soil, sediments and fish from the Damodar river basin in the Steel City. They concluded therefore that heavy metal concentrations in all the physical and chemical parameters analysed were high in the pre-monsoon period compared to post-monsoon. Spatially, the river's source was uncontaminated with the metals studied in the two seasons except for Hg, As, and Cd which has extensively contaminated the midstream and downstream ends of the river [22]. These findings point out that heavy metals are widely found in the midstream and downstream of heavy metal-polluted rivers. [12] recorded industrial activities as the main causal factor-affecting heavy metals spatial disparities. [15] also reported the distribution and concentration of heavy metals in their study. They found that Cd, Ag, and Cr have considerably elevated in oysters from the Pearl River Estuary of China in the western part, and Cu, Zn, and Ni in the easternmost section during 2011–2018. Trace metals are concentrated in industrial and downwind bloom areas in the surface sediments [42]. The above references reveal the high concentration of some heavy metals and their spatial distribution and concentrations in the environment. This paper, therefore,

DOI: https://doi.org/10.30564/jgr.v4i2.3100

analyses the seasonal variation in the distribution and concentrations of Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) in the Fosu Lagoon. It also evaluates the spatial distribution of heavy metals in the collected samples. As indicated above, it is very important to examine and analyse the lagoon to determine the distribution and levels of heavy metals' accumulation in it. Lead (Pb), Copper (Cu), Cadmium (Cd), and Manganese (Mn) were considered in this study because of the presence of potential sources of these heavy metals in proximity to the lagoon and these are established in literature. According to the [32], leaded gasoline has been a major historic source of Lead contamination, and Loranger et al. (1994) found manganese concentrations to be significantly correlated with traffic density. According to them, areas of intermediate and high traffic densities had Manganese concentrations above the natural background level of 40 ng/m^3 [14,13]. The garages and the roads close to the lagoon pose as potential sources of Lead (Pb) and Manganese (Mn). [11] adds that Cadmium accumulates in aquatic organisms such as shellfish and crustaceans and in the liver and kidneys of mammals. [40] expresses that levels of copper in running or fully flushed water tend to be low, whereas those of standing or partially flushed water samples are more variable and can be substantially higher. The study considered Cadmium for its potential accumulation in aquatic life in the lagoon, and Copper for the state of the lagoon as a standing water body that seasonally interact with the Atlantic Ocean. The paper will contribute to understanding the mechanisms that regulate heavy metals' spatial differentiation from a global perspective.

2. Materials and Methods

2.1 Site Description

Ghana's coastal zone which is 540 km^2 has been categorised into three based on [10,1,4] reflecting their geomorphological distinctiveness. They are situated on the East, Central and West coasts of Ghana. The east coast, approximately 149 km west of Prampram, stretches from Aflao (Togo Border) in the east to Laloi Lagoon in the west. The central coast stretches from the Prampram area to the Ankobra River, while the western coast stretches from Ankobra River to Elubo, the Ghana-Ivory Coast border. The current study took place in the central coastal plains of Ghana where the Fosu lagoon was studied. The Fosu Lagoon is situated in Cape Coast, the Central Region's capital city, Ghana. The geographical coordinates of the lagoon are 5°6'8.98"N, 1°15'8.58"W; 5°6'38.71"N, 1°15'49.11"W; 5°6'21.81"N, 1°15'45.34"W; and 5° 6'33.60"N, 1°15'24.98"W, as shown in Figure 1. The lagoon is a small, closed lagoon isolated from the sea by a barrier that is normally breached by heavy rain or manually as part of the typical Fetu festival activities witnessed by the people of Cape Coast [4]. The average water depth of the lagoon is 1.6 metres. The region receives two wet seasons in a year, the major one from April to July and a minor season from September to November. Cape Coast is a humid area with mean monthly relative humidity varying between 85% and 99%. The sea breeze has a moderating effect on the local climate.The lagoon is surrounded by numerous sites that serve as point sources for contaminant emission. Domestic waste discharges from a highly polluted area, a metropolis transport garage on the lagoon's northern side, and an industrial waste discharge from mechanical workshops on the lagoon's north eastern side are all included. The lagoon's surroundings include drains from an educational institution and a nearby hospital, as well as household dumping and sewage. Human activity in the study area is extensive, and nutrient enrichment has resulted in massive sediment deposition, particularly in the more populated northern sector, where one can walk for many meters on waterweeds as the lagoon has been metamorphosed into refuse and swamp land. The geological composition of the coastal zone is composed of strong granites, granodiorites, metamorphosed lava and pyroclastic rocks. Sandstones dominate sections of these coastal areas and shales from Ordovician, Silurian, and Devonian times [4]. The hilly nature of the place has greatly affected building and road construction. It also promotes erosion, especially along slopes, and sedimentation/siltation and flooding at low-lying areas. It is bounded by the sea to the south and surrounded by different vegetation cover. The land cover in the Fosu lagoon catchment is dominated by introduced vegetation with little remnant areas of mangrove vegetation. It is found in the dry semi-deciduous.

Figure 1. Map showing study areas in a regional and national context

Source: Department of Geography and Regional Planning, UCC, (2019)

DOI: https://doi.org/10.30564/jgr.v4i2.3100

2.2 Sampling Procedure

The Fosu lagoon was sampled for the study for various authors including [33] have reported pollution and contamination in the lagoon. Water samples from the lagoon were obtained at various points between May and September, and January and March. Eighteen (18) samples of water were collected during each of the seasons. In all thirty-six (36) sampling points were analysed for respective heavy metal concentrations. In Ghana, these periods are regarded as wet and dry seasons respectively. The sampling points are shown in Figure 2. Sampling sites were carefully selected to optimally and evenly cover all drains emptying into the lagoon. Location of entry channels and water sampling sites were also mapped directly from field surveys. A Global Positioning Systems (GPS) receiver, Trimble Juno SD hand-held was used for the mapping activity. The lagoon was demarcated into three sections as upstream, midstream and downstream to conform to the structure and morphology of the lagoon. The upstream consisted of the upper reaches of the lagoon, where the Siwdu sports stadium and garage area, the entry points of the various drains, and the social and economic activities around the lagoon are found. The midstream is around where the Bakano community is located, with their sewage and gutters directed into the lagoon, while the downstream is where the sand bar that ensures the intermittent mixing of the lagoon, and the main bridge that connects the Cape Coast township and enjoining communities are located.

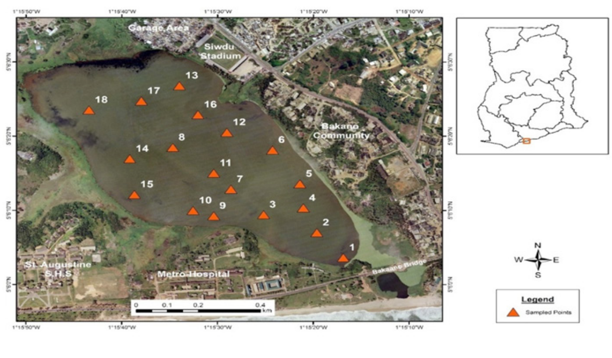

Figure 2. Sampling points of heavy metals

Source: Field Data, (2018 and 2019)

2.3 Sample Collection

Polyethene gloves were used on the hand to obtain water samples from the lagoons. High-density polypropylene bottles were rinsed with lagoon water three times at each sampling point before the water sample was collected. The rinsed bottles were submerged about 8 cm beneath the water surface [10]. Water samples collected were stored capped in the high-density polypropylene bottles and soaked with 10% nitric acid [25,24]. Until being shipped for examination at the laboratory, the obtained water samples were acidified.

2.4 Sample Preparation and Analysis

Analyst 400 Perkin-Elmer Atomic Absorption Spectrophotometer (AAS) was employed in evaluating the heavy metal constituents and concentrations. The water sample was first filtered with Whatman No. 0.45 filter paper, after which 50 ml of the filtrate was acidified with 50% nitric acid to give a pH of 1. The AAS was calibrated with regular solutions and de-ionized with water before calculating the absorption of sampled traces. The collected water samples were analysed at Center for Scientific and Industrial Research (CSIR) of the Water Research Institute (WRI) in Accra, Ghana, for interpretation and study, to establish the heavy metal content in the samples, following the procedures given by [10].

The concentrations of heavy metals were mapped using ArcGIS 10.1 to provide a spatial view of the data from samples from the lagoon. Ordinary kriging was adopted to interpolate and map the values derived for the heavy metal concentrations for the various sampling points. Ordinary kriging was adopted for this study as it has been justified by [41]; according to them, ordinary kriging is more accurate than other methods, with smaller mean relative error (MRE) which is known to be a good variable for estimating the accuracy of predictions. Kriging is based on the assumption that the parameter being interpolated can be treated as a regionalized variable. The kriging estimator is given by a linear combination of the observed values with weights [41]. The weight of ordinary kriging is derived from the kriging equation using a semi variance function. The parameters of the semi variance function and the nugget effect can be estimated by an empirical semi variance function [39]. An unbiased estimator of the semi variance function is half the average squared difference between paired data values:

$$\gamma(h)=\frac{1}{2N(h)}\sum_{i=1}^{N(h)}[z(x_i)-z(x_i+h)]^2$$

where γ (h) is the semi variance value at distance interval h; and N(h) is the number of sample pairs within the distance interval h; $z(x_i + h)$ and $z(x_i)$ are sample values at two points separated by the distance interval h.

2.5 Quality Control and Assurance

Sampling procedures were strictly followed to reduce

  DOI: https://doi.org/10.30564/jgr.v4i2.3100

mistakes, avoid contamination of samples and ensure the accuracy of tests. Again, laboratory regulations such as proper cleaning of equipment, and equipment calibration were observed to ensure the results were scientifically applicable. Standard reference materials (SRMs) used were regarded as samples themselves for measuring the performance of the equipment used and further validating the procedure.

2.6 Water Quality Index

The heavy metal concentrations of the water samples were compared to the WHO water quality index shown in the Table 1. The Water Quality Index is known to be the most effective tool for assessing water quality. The index offers a standardized variable that calculates the average water quality at a certain place and time, depending on a variety of water quality parameters. The index makes it possible to compare the different extraction positions.

Table 1. WHO Water Quality Index

Heavy metal	WHO Water Quality Index (mg/L) ≤	>
Lead	0.01	0.01
Manganese	0.4	0.4
Copper	2	2
Cadmium	0.003	0.003

Source: UNEP (2006)

2.7 Statistical Analysis

Heavy metal concentrations report from the Atomic Absorption Spectrophotometer (AAS) was coded into Statistical Package for Social Science (SPSS) V. 20. Descriptive statistics were run and the mean heavy metal concentrations, with their standard deviations, were established. Pegging confidence level at 0.95 (95%), Pearson's two-tailed significance correlation was run on the concentrations for the seasons. Finally, a paired sample t-test was run to establish the differences in seasons' concentrations of heavy metals. The results are presented in tables.

3. Results and Discussion

3.1 Concentrations of Heavy Metals and Implications

Lead (Pb)

The results indicated a minimum Pb concentration of 1.3 mg/L and 1.7 mg/L and a maximum of 2.6 mg/L and 3.2 mg/L for the wet and dry seasons respectively. These are high above the WHO standard for drinking water and the result is shown in Figure 3 and 4. The concentration of Pb found in the current study is higher when also compared with the findings of [22], who found that Pb concentrations in the Tano River ranged from below detection limits (BDL) to 0.929 mg/L. According to [43], lead-bearing fuel deposited on roads by automobiles can be transported by runoffs into water bodies and cause an increase in Pb concentrations in water. This explains why the highest Pb concentrations in the lagoon water occurred at points very close to the road and the garages around the lagoon. This confirms that the road close to these points is a source of Pb to the lagoon.

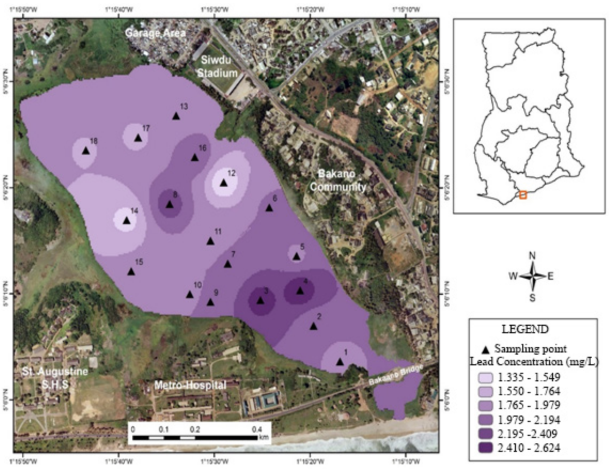

Figure 3. Pb concentration (mg/L) in the Fosu lagoon during the wet season

Source: Field Data, (2018)

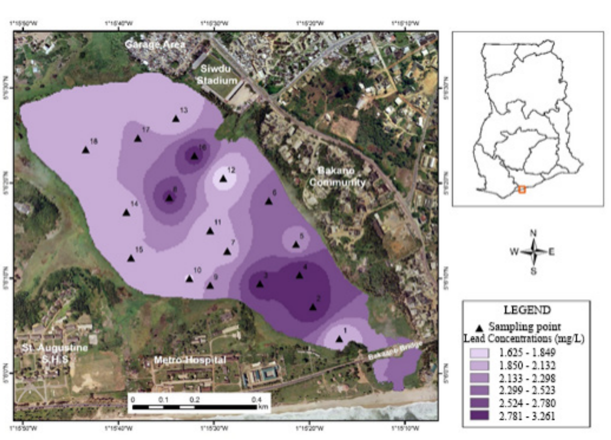

Figure 4. Pb concentration (mg/L) in the Fosu lagoon during the dry season

Source: Field Data (2019)

Copper (Cu)

Generally, Cu recorded the lowest concentrations in all samples as shown in Figure 5 and 6 respectively for the wet and dry seasons. A Cu concentration range of 0.13 mg/L - 0.40 mg/L was found for the wet season. Cu concentrations appreciably increased slightly above the levels of the wet season in the dry season's samples; ranging from of 0.13 mg/L - 0.46 mg/L. The concentrations of Cu are very low when compared with the WHO standard of 2 mg/L of Cu for drinking water, and may pose little or no threat to the health of consumers. As well, these low concentrations have little or no harmful effects on the lagoon's ecosystem. Despite this, the current study found concentrations, which are higher than [22] found, as they found Cu concentrations as below detection limits (BDL). The concentrations were mostly found at the mouth of the lagoon and this could be due to the seasonal interaction between the lagoon and the sea. The [36] suggests that geological weathering and corrosion of plumbing products and structures are the main sources of Cu in aquatic environments.

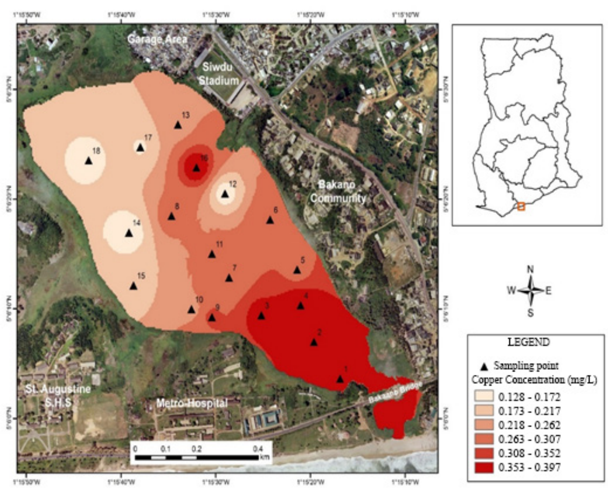

Figure 5. Cu concentration (mg/L) in the wet season Fosu lagoon

Source: Field Data (2018)

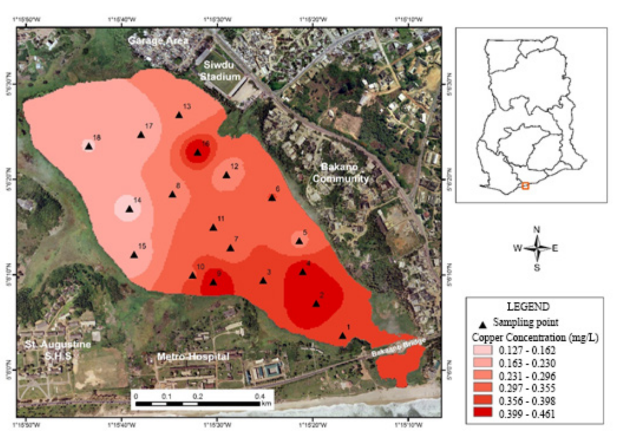

Figure 6. Cu concentration (mg/L) in the Fosu lagoon in the dry season

Source: Field Data (2019)

Cadmium (Cd)

The study found the concentration of Cd in the lagoon as ranging between 0.09 mg/L and 1.33 mg/L during the wet season. In somewhat conformity, recordings for the dry season's concentrations of Cd did not vary much from the recordings for the wet season. The presentation is shown in Figure 7 and 8 respectively. The values for Cd concentrations found for the dry season ranged from 0.09 mg/L to 1.82 mg/L. These are high above the WHO permissible limit of 0.003 mg/L. In a similar study, the range of Cd concentration levels found by [22] shows that Cd concentrations in the Tano River ranged from BDL to 0.11 mg/L. Cd is identified to be harmful to fish and other marine species in marine studies [1]. Cd is a toxic and nonessential trace element to all other organisms [17]. Cd is considered as a major hazardous environmental contaminant, especially due to its environmental persistence and ability to cumulate throughout almost the whole life span of humans [25]. Prolonged exposure to cadmium through contaminated drinking water can also cause anaemia and cancer [21,25]. In addition to natural sources, overspills from farms where phosphate is used as manure are a significant source of Cd contamination. Therefore, by dumping metal, as well as organic and other inorganic wastes around the lagoon's banks poses a potential danger to the lagoon and its resources by increasing metal toxicity in the lagoon. The industrial activities around the Fosu lagoon are gradually adding to the toxics in the lagoon. Higher concentrations of Cd were observed behind the Siwdu stadium's end of the lagoon. Here, there is a massive deposition of industrial waste. It can, therefore, be inferred that the corrosion of galvanized pipes on canoes, erosion of natural and other deposits, runoffs from waste batteries and paints from the town and nearby surroundings are the main sources of Cd contamination to the Fosu lagoon.

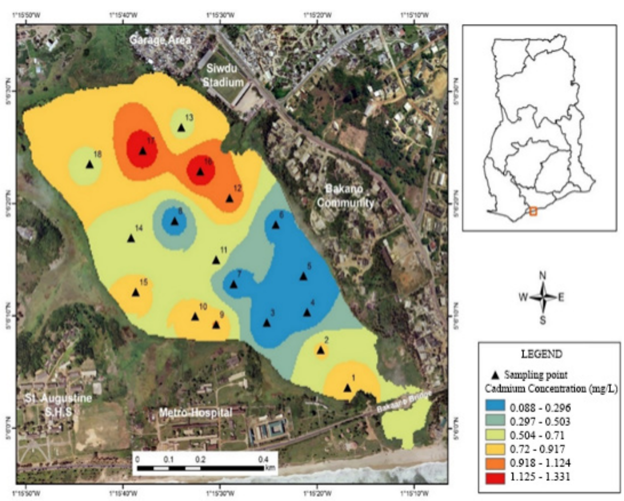

Figure 7. Cd concentration (mg/L) in the Fosu Lagoon in the wet season

Source: Field Data, (2018)

DOI: https://doi.org/10.30564/jgr.v4i2.3100

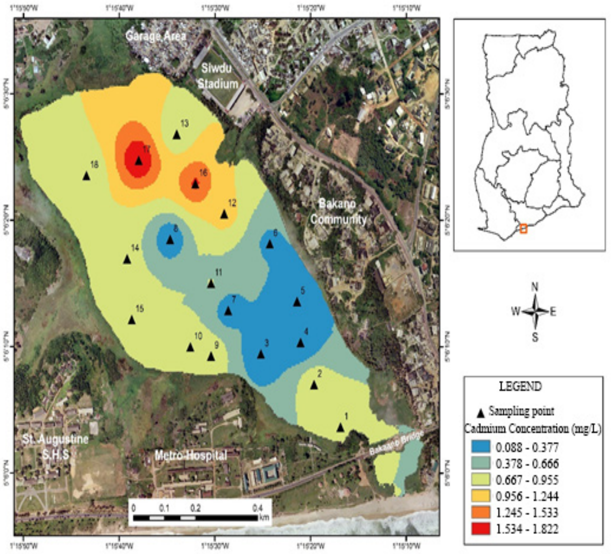

Figure 8. Cd concentration (mg/L) in the Fosu Lagoon at the dry season

Source: Field Data, (2019)

Manganese (Mn)

The concentration of Mn recorded for the wet season ranged between 0.32 mg/L - 0.57 mg/L. Seeming different from the sequence recorded for Pb, Cu, and Cd, the concentration of Mn concentration in the dry season recorded an appreciable decrease in the recordings for the wet season, this is shown in Figure 9 and 10. The findings showed a range of 0.27 mg/L - 0.46 mg/L. The concentration values observed at areas around the upstream of the lagoon for both seasons could mean that the garages close to the lagoon are releasing some metal pollutants into the lagoon of which Mn is one of them. This confirms [2] that many commercial and industrial discharges originating from the urban settlement threaten the coast's environmental quality. These toxics degrade water resources thereby increasing heavy metals in them. The relatively lower concentrations recorded along the mouth of the lagoon could largely be due to the interaction with the sea at the point of breaching. The abundance of Mn in the earth can also contribute to the high levels in the samples. The findings for Mn in the lagoon for the dry season are below the tolerance level given by the WHO and thus poses a low or no risk to the environment. However, the wet season's concentrations are slightly above the WHO's limit and may pose a danger to the environment during the wet season.

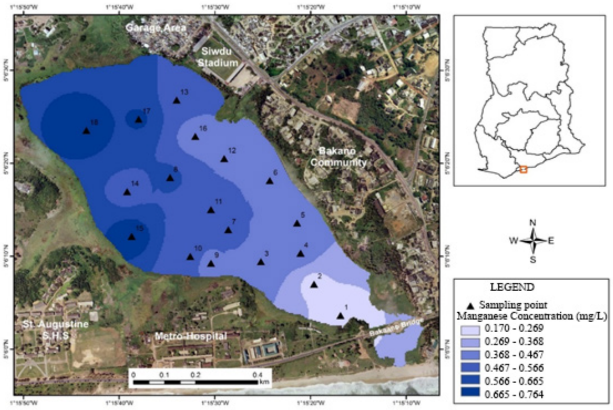

Figure 9. Mn concentration (mg/L) in the Fosu lagoon at the wet season

Source: Field Data (2018)

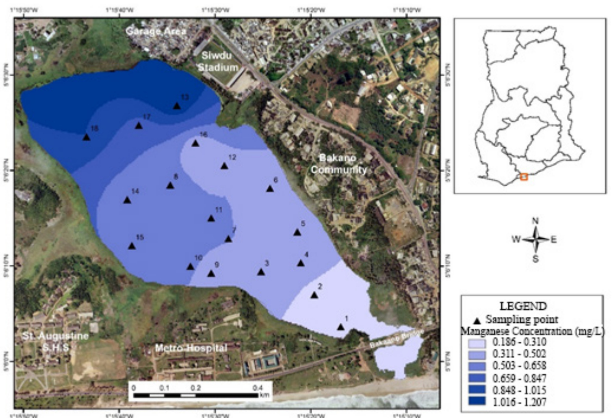

Figure 10. Mn concentration (mg/L) in the Fosu lagoon in the dry

Source: Field Data (2019)

3.2 Spatial and Seasonal Concentrations of Pb, Cu, Cd, and Mn in the Fosu Lagoon

Pb was spatially distributed with the highest average concentration of 2.71 mg/L occurring in the waters at the upstream level of the lagoon and a lowest of 2.14 mg/L concentration at downstream for both the wet and dry seasons' samples. For all two seasons, Cu had a maximum mean concentration of 0.40 mg/L at upstream and a lower concentration of 0.22 mg/L at the downstream level and this is presented in Table 2. The case of Cd was in disparity from those discussed earlier as it recorded its highest mean concentration at the downstream with a concentration value of 0.91 mg/L and a lowest of 0.44 mg/L at the midstream. Mn showed similar characteristics as the concentration pattern observed for Cd, as the highest mean concentration was recorded downstream with the value of 0.57 mg/L and lowest of 0.27 mg/L, at the upstream. [6]

suggest that heavy metal concentrations can be traced to different sources and do not tend to be at the same concentrations. Spatially there are differences in heavy metal concentrations. It should be emphasized that the presence of a potential heavy metal source at various locations and varying intensity of the occurrence answers the question of how are heavy metals spatially distributed and varied across the globe. The above assertion is consistent with the results, as spatial differences in the concentration of heavy metals have been observed.

The mean Pb concentration in the Fosu lagoon is 2.28 mg/L for the wet season and 2.32 mg/L for the dry season. This connotes a higher concentration of Pb in the dry season than in the wet season. In either season, the concentrations are higher than the WHO recommended standard for drinking water. The study found 0.27 mg/L mean Cu concentration for the wet season and the dry season, a mean concentration of 0.31 mg/L was found. This indicates higher Cu concentration in the dry season than in the wet season, all below the WHO standard of 2 mg/L for drinking water. For Cd, wet season concentration level was 0.61 mg/L, and 0.70 mg/L was found for the dry season. In this case, Cd concentrations are high above the threshold concentration for drinking water according to the WHO. This as well indicates that there are higher concentrations of Cd in Fosu lagoon during the dry season than during the wet season. Exhibiting higher wet season concentrations than the dry season, the mean Mn concentrations were 0.4835 mg/L and 0.39 mg/L for wet and dry seasons respectively. Despite Mn concentrations are higher in the wet season than the dry season, the figures are at the threshold of 0.4 mg/L according to the WHO.

Table 2. Mean seasonal concentrations and variations

Heavy metal	Wet season		Dry season		WHO standards (mg/L)
	Mean concentration (mg/L)	Std. Deviation	Mean concentration (mg/L)	Std. Deviation	
Pb	2.2757	0.4483399	2.3230	0.4873270	0.01
Cu	0.2722	0.0860047	0.3081	0.1058332	2
Cd	0.6076	0.3560361	0.6984	0.4223708	0.003
Mn	0.4835	0.1440662	0.3900	0.1261690	0.4

Source: Fieldwork, (2019)

In agreement with this study, a study on the seasonal variation of heavy metal concentrations around Tejgaon Industrial Area of Bangladesh, by [19] found that the concentrations of studied pollutants were higher during the dry season particularly in January when rainfall is comparatively low and this adjustment might have occurred because of rainfall and dilution. In their study, it was only in the case of Pb where concentration level was high during the wet season and they attributed it to the high percentage of Pb in Dhaka's air in recent time, which mixed up with rainwater during the monsoon season. With the months for the seasons for sample collection coinciding with the months in which water samples were collected for this study, [22] found the opposite to what this study found for Pb and Cd. According to them, Pb and Cd concentration in River Tano were high in the wet season than in the dry season. Generally, all heavy metals they studied in River Tano showed higher concentration in the wet season than in the dry season. Except for Mn, the current study found higher concentrations for all heavy metals (Pb, Cu, and Cd) in the dry season than in the wet season. [8] in their assessment of the Sakumo II, Chemu and Kpeshie Lagoons of Ghana, reported substantial variations in Mn concentrations in water samples collected in the wet and dry seasons. This indicates that the sources and discharge of Pb, Cu and, Cd to the Fosu lagoon are not much influenced by precipitation and the accompanied runoff, despite it may be for Mn concentration. Recording higher concentrations for Pb, Cu, and Cd and the lower concentration of Mn in the dry season does not necessarily mean there is a limit in the discharge of Pb, Cu, and Cd in the wet season. However, it can be inferred that the sources may be active and these heavy metals are released into the lagoon all year round, unlike the case with River Tano where the discharge of heavy metals limits in the dry season. Higher evaporation of the surface waters of the lagoon in the dry season may be the reason for higher concentrations of Pb, Cu, and Cd in the dry season than the wet season. This is because the more there is freshwater in the lagoon, the lesser the concentration levels will be for all solubles.

3.3 Correlations between Heavy Metal Concentration Levels

Heavy metals available in the water samples exhibit different levels of correlation with one another. Pegging the analysis at a significant level of $p < 0.05$, the Pearson two-tailed correlations were run on pairs of heavy metals uniquely for the wet and dry seasons. This analysis is shown in Table 3 below. For the wet season, Pb-Cu and Cd-Mn were the only pair that exhibited positive correlations while all other pairs of heavy metals showed negative associations. The same observation is mirrored into the results for the dry season. However, Pb-Cu showed a moderate correlation coefficient for the wet season and a weak correlation coefficient for the dry season.

DOI: https://doi.org/10.30564/jgr.v4i2.3100

Table 3. Correlation matrix of heavy metal concentrations in the wet and dry seasons

		Wet season				Dry season			
		Pb_W	Cu_W	Cd_W	Mn_W	Pb_D	Cu_D	Cd_D	Mn_D
Pb	Pearson Correlation	1				1			
	Sig. (2-tailed)								
	N	18				18			
Cu	Pearson Correlation	.297	1			.196	1		
	Sig. (2-tailed)	.232				.436			
	N	18	18			18	18		
Cd	Pearson Correlation	-.469*	-.306	1		-.430	-.185	1	
	Sig. (2-tailed)	.050	.216			.075	.463		
	N	18	18	18		18	18	18	
Mn	Pearson Correlation	-.033	-.714**	.117	1	-.050	-.516*	.191	1
	Sig. (2-tailed)	.897	.001	.643		.845	.028	.447	
	N	18	18	18	18	18	18	18	18

Source: Fieldwork, (2018)

According to [30,28], if the correlation coefficient between the studied heavy metals is higher, metals have a common source of origin with mutual dependence and similar behaviour during transport. Weak correlation among metals suggests that metals are not controlled by any single element but rather, they are controlled by a combination of geochemical support and associations. This hints that a common pollution source that discharges Pb and Cu to the Fosu Lagoon stops discharging either one of Pb or Cu with the switch from wet to dry seasons. The negative correlation coefficients express the varying dependence on pollution sources, and the interplay of processes or a combination of processes that influence the concentration and distribution of respective heavy metals in the Fosu Lagoon.

3.4 Seasonal Variations in Heavy Metal Concentrations

A paired sample t-test was conducted to evaluate the differences in heavy metal concentrations for wet and dry seasons. The analysis from Table 4 revealed a significant difference between Cu, Cd, and Mn concentrations for wet and dry seasons. However, Mn showed a very significant decrease in concentrations from the wet season to the dry season while Cu and Cd exhibited an increase in concentration levels. Pb concentrations, however, revealed no significant difference. With this, there is a statistically enough reason to conclude that Pb concentrations in the Fosu Lagoon do not vary with seasons. This confirms the results for the Pb-Cu correlation analysis; that the discharge of Cu to the Fosu lagoon declined in the wet season since the mean concentration of Cu for the dry season is higher than the mean concentration for the wet season. The higher heavy metal concentration values observed during the dry season may be the result of varying levels of evaporation and precipitation. It can therefore, be said that with the exception of Pb, seasonal disparity exists between the studied heavy metals in terms of distribution and concentration.

4. Conclusions

The levels of concentration of heavy metals (Cu, Cd, and Mn) in the lagoon were analyzed and their spatial distribution was estimated. The results show elevated Pb levels in the lagoon from the wet to dry seasons, resulting from vehicles depositing Pb on the road near the lagoon. Seasonal changes were found in the accumulation and distribution of heavy metals from samples of water analysed. While Pb and Cd concentrations in the Fosu lagoon were high during the dry season, the concentrations of Mn and Cu were close to and low respectively in comparison to the WHO standard limit and thus pose no or little danger to the lagoon's flora and fauna, as well as other users of the lagoon. Contrary, the contamination of the lagoon with Pb and Cd pose hazard to human and aquatic health, through bioaccumulation as residence may consume resources from the lagoon. This is indicated by the level of contamination in water samples collected from the lagoon as they contained relatively significant levels of the various metals. There is also increased industrial, municipal and domestic wastes emptying into these lagoons with fewer environmental guidelines. The increased heavy

Table 4. Seasonal differences in heavy metal concentrations

		Paired Differences					T	df	Sig. (2-tailed)
Mean		Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
Pair 1	Pb^W - Pb^D	.0472778	.1514533	.0356979	-.1225937	.0280382	1.324	17	.203
Pair 2	Cu^W - Cu^D	.0358611	.0551460	.0129980	-.0632846	-.0084376	2.759	17	.013
Pair 3	Cd^W - Cd^D	.0907778	.1260454	.0297092	-.1534587	-.0280969	3.056	17	.007
Pair 4	Mn^W - Mn^D	-.0935000	.0988381	.0232964	.0443490	.1426510	-4.014	17	.001

Source: Fieldwork, (2019)

metal values observed during the dry season could be in response to the difference in evaporation rate and precipitation. Heavy metal concentrations of water samples varied widely in terms of seasons and sampling points within the study area.

Recommendations

The Wildlife Commission must track the lagoon on all water quality parameters or requirements as specified by law in 'surveillance' monitoring, at least one surveillance per year. Surveillance is intended to provide a general summary of the state of the lagoon and acts as a framework for an organisational management system. Operational monitoring becomes important when the water body is at risk of failing to meet the required status or standard and monitors the quality parameters that indicate the stress causing the loss of water quality. Subsequently, investigative monitoring should be carried out if the reasons for the fall in standards cannot be identified. This means that the lagoon should be monitored constantly to provide accurate information that will assist in making decisions. City authorities (Cape Coast Metropolitan Assembly) should put up measures such as sanction of perpetrators to prevent the deposition of heavy metals, industrial waste and domestic waste into the lagoons. The numerous garages at Siwdu and the palm kernel extractors at Adisadel village should be relocated. Due to the presence of low concentrations of trace metals, periodic monitoring campaigns of the lagoon is required, in order to highlight any possible increase in contamination event and to reduce any harmful effects, employing the best environmental management practices available. The role of government is to create awareness on habitats and biodiversity values and the need to safeguard the Fosu lagoon for sustainable utilisation. This could be done by strengthening relevant governmental and nongovernmental institutions through capacity building and provision of appropriate logistics. It is worthy to note that fishing, public health, and recreation are multifaceted activities requiring cooperative management and intersectoral coordination. To accomplish the coordination requires the full involvement of all the various stakeholders and government is encouraged to spearhead this agenda of bringing the stakeholders together to ensure consensus building.

Acknowledgement

We acknowledge the GIS and Remote Sensing Unit of the Department of Geography and Regional Planning, University of Cape Coast, Ghana for assisting in the production of maps. We are also grateful to the environment and physical landscape research group.

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