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Physicochemical Characterization of Settling Particulate Matter and Sediments

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Abstract

The thrust of this research study was to ascertain the physicochemical characteristic in settling particulate matter and sediments of samples collected from the wellington industrial estate flood plains; the main of objectives are as follows: to determine the hydrogen ion index (pH) of the samples collected in the study area, to determine the electrical conductivity (EC) of the samples collected from the same location. Samples were collected from six locations (at varying depths of 0 - 5 cm and 5 - 10 cm) sample area 1 (Wellington Industrial Estate Area 1) WIEA1 WIEA 2, WIEA 3, WIEA 4, WIEA 5 and WIEA 6 and were given laboratory treatment. A laboratory thermometer was used to determine temperature of the samples when collected; (Dakton model) pH meter equipment and a Toledo electrical conductivity meter were used to determine the pH and EC respectively. The results indicated that the samples were acidic (low pH) and the conductivity of the samples was of medium and low range. This therefore expressed low levels of soluble metal ions in the environment that have effect on plants, animals and other organisms, agricultural and domestic activities in the environment under investigation. Hence bioconcentration and biomagnification are highly likely in these locations.

Keywords

Conductivity, Deposition, Environment, Particulate, Sediment

1. Introduction

Settling particulate matter consists of extremely small particles; sediment on the other hand is a layer of substance (organic or inorganic) that forms at the bottom of a liquid. Settling particulate matter and sediment generally occur on

flood plains where the flow of water is not as rapid as that of slopes. As a result, materials transported by the flowing water are deposited. The accumulations of such materials encourage biological activities which include development of microbes that enhance decaying activities and the release of nutrients to the environment. The release of nutrients encourages the development of plants such as algae and phytoplankton which are effective in trapping heavy metals.

It was indicated that the sediments by the stream near a gold mining area in southern Columbia has levels of heavy metal such as Ni, Cr, Pb, Zn, Cd [1]. The concentration, size, class and organic carbon content of particulates play a major role in how much dissolved metal will complex to solid material [2]. Most metals can be absorbed through the gut in invertebrates (e.g. earthworms) reptiles, birds and mammals... [3]. Metals and metalloids can be released and or coprecipitated at the sediment/water interface rendering them more or less bioavailable depending upon the prevailing redox conditions [4]. Although Arsenic exists predominantly as the inorganic form species in surface waters, detection of methylated forms is often correlated with phytoplankton activity [5]. Cadmium is readily available for uptake in grain, rice and vegetables, and there is clear association between the Cd concentration in soil and in the plants grown on that soil... The uptake in plants increases with decreasing pH, thus the acidification of the environment may increase the cadmium content in the grain [6]. Some species accumulate metals to high levels (e.g. zooplankton), while other species such as fish closely regulate internal concentrations or sequester the metal with cellular binding proteins like metallothionines [7]. Inspite of low levels of mercury in natural systems, bioaccumulation occurs because mercury when methylated is very effectively absorbed by aquatic organisms, which they accumulate from food, water and sediments [8].

In as much as particulate matter falls through the water column, metals are scavenged and subsequently incorporated into the bottom sediment; with time such sediments and their associated metals and non-metals are buried at certain depths leading to accumulation whereby hardness will be experienced in aquatic life. Acid status situation is linked to low pH values with a tendency reducing the availability of some metal; also low electrical conductivity implies generally that soluble ions are low all of the two factors effect on the growth and development both plants and other organisms in the environment and may even lead to agricultural problems and definitely causing health hazards in terrestrial life of animals. The Wellington industrial estate flood plains are among others in Sierra Leone where settling particulate matter and sediments is found to express deposition. It is highly advisable for industrial effluents to readily and regularly be detoxified, closely monitored, and biomonitors be introduced to give an indication of the presence of toxic metals. The various factories which include the soap and detergent production, paint production and other may deposit alkaline slurry in the flood Palins; hence soluble salts will be likely deposited and these will transfer in other water bodies nearby.

The intended target of this study therefore was to ascertain the physicochemical parameter of settling particulate matter and sediments in the wellington industrial estate flood plains. The under mentioned objectives are indicative of the study, physicochemical characteristic of the settling particulate matter and sediments:

1) To determine the hydrogen ion index (pH) of samples collected in the study area.

2) To determine the electrical conductivity (EC) of samples collected in the area under investigation.

2. Materials and Method

2.1. Description of Study Area

Wellington (Figure 1) is located in the East end of the capital city, Freetown (Figure 2). This place is situated at an important commercial, industrial estate which provides the city and its whole country infrastructural needs. It is facing northwards by the Sierra Leone river. The river to a large extent provides domestic, industrial, transportation and trading facilities for the area.

Westwards is the famous Calaba water which has its source at the foot of the peninsula and empties into the Robis stream. Effluents of the industries and other wastes are usually deposited into the Calaba water. The Robis stream is used for domestic purposes like bathing, cooking and bathing. Operational industries in the Wellington Industrial Estate (Figure 3) include; Paint Factory, Jolaks Manufacturing Company, Nail Factory, Match Factory, National Confectionery Factory, R.K Distilleries Limited, Sierra Leone Brewery Limited, Soap and Detergent Factory. From the east and north stretches a fertile plain which extends about a few kilometers towards the south.
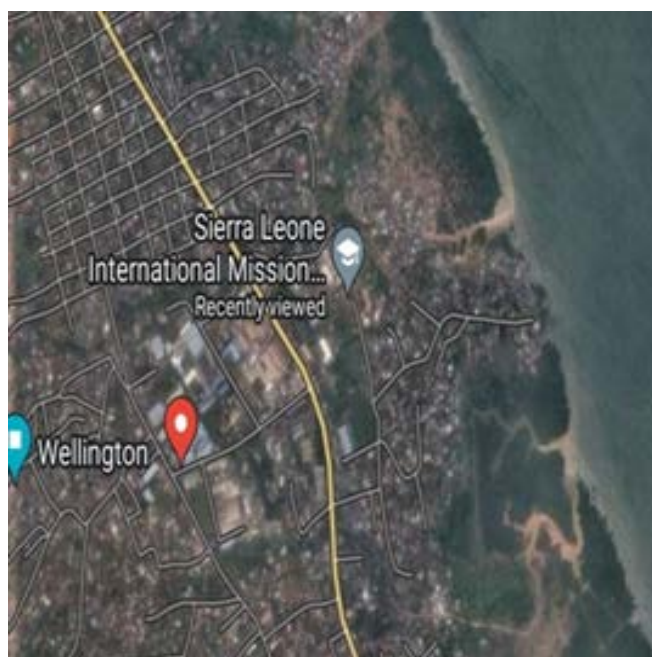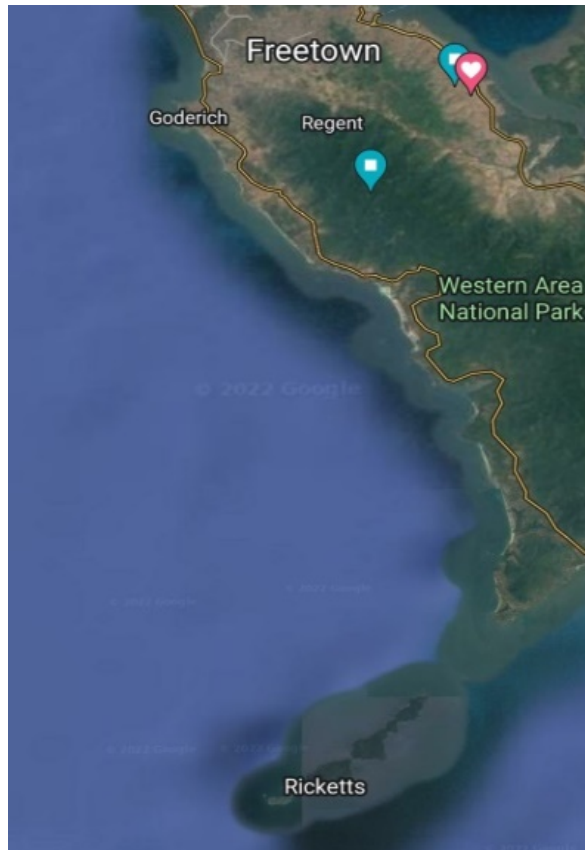

Figure 1. Wellington.

Figure 2. Map of freetown.

Figure 3. Wellington industrial estate.

This area is good for gardening; it is the second largest crop production area in the city. It is a relatively level area as such it has few locational attributes which include housing construction, road network and excellent administrative centers. On the surrounding of Wellington there are patches of isolated hills, overlooking this area are mountains with inhabitant villages.

2.2. Sample Site and Sample Collection

Samples were collected along the Calaba water, located in the Wellington Industrial Estate Area (WIEA), latitude 8.4423704, longitude −13.1656933 in decimal degrees (DD); Latitude N 8°26'32.535", longitude W 13°9'56.4942" in degrees, minutes, seconds (DMS), six (6) sample areas were chosen. Sample area 1 (Wellington Industrial Estate Area 1) WIEA1 was one hundred and fifty (150) meters from source, the other areas namely: Wellington industrial Estate WIEA 2, WIEA 3, WIEA 4, WIEA 5 and WIEA 6 were chosen at regular distances about hundred (100) meters from each other. Two samples were collected at depths 0 - 5 cm and 5 - 10 cm respectively from all six (6) stations. Surficial soft bottom sediments and particulate 0 - 5 cm depth were collected using a scoop. The 5 - 10 cm depth samples were collected using gravel free auger. Temperature measurements were taken at the different spots for each sample using an ordinary laboratory thermometer.

2.3. Sample Treatment

Samples were spread on drying trays in the laboratory. Stones and undecomposed materials were removed; large aggregates were broken up in a dust free room. Each tray was labeled to avoid identification error. The samples were immediately prevented from sunlight. After drying, the samples were crushed with porcelain pestle and mortar and sieved through 2 mm sieve. The samples were then transferred to labeled polythene bags and stored under cool and dry condition.

2.4. Hydrogen Ion Index (pH)

Preparation of Buffer Solution

Buffer 4, 7 and 10 tablets were ground separately and dissolved into a 100 ml volumetric flask and were used to calibrate the pH meter.

pH Measurement

20 g of samples were transferred into a 100 ml wide mouth polythene vessel.

50 g of distilled water were added and shaken for two (2) hours. pH readings were taken using a (Dakton model) pH meter equipment. After removing the protective cap, the electrode was rinsed in distilled water and blotted using soft absorbent paper. The electrode was then be placed in a fresh buffer solutions and after stabilization the pH reading was adjusted to the pH of the buffer solutions (pH = 4, pH = 7, pH = 10). The electrode was rinsed again with distilled water and blotted dry. Once calibrated, the pH meter was used to measure the pH directly by placing the electrodes in well water sample immediately after it was ob-

tained. After recording the observed reading the electrode was rinsed again in deionized distilled water and placed in its protective cap immediately. The readings were allowed to stabilize after the electrode was immersed before taking the reading.

2.5. Electrical Conductivity (EC)

20 g of air-dry 2 mm sieved samples were transferred to 100 ml polythene vessel. One standard sample and two blanks included with each series included with each series. 50 ml of distilled water were added and shaken length wise in a horizontal position in a mechanical shaker (150 revolutions per minute, r.p.m) at room temperature for 2 hours. The electrical conductivity (EC) measurements were taken using a Toledo electrical conductivity meter was that was calibrated before operated. The electrode of the Toledo electrical conductivity meter was dipped into the container of distilled water for sterilization until a stable reading of zero was obtained. The conductivity of the samples was now measured by immersing the electrode in the sample of solution of interest. The reading was taken and recorded after stabilization of the instrument in few minutes; the electrode of the Toledo electrical conductivity meter was re-rinsed with distilled water before subsequent reading of each sample was taken, two readings (duplicates) were taken for each sample solution at a time following same procedure for each sample before any reading was taken and recorded. The electrical conductivity (EC) or specific conductance was recorded preferably at 25˚C in µS/cm.

2.6. Statistical Analysis

- Q-test was used to accept or reject Outliers from data of samples [9].
- Standard Error (SE) of data was determined [10].

3. Results and Discussion

Table 1 and Table 2 are the mean values of pH and EC respectively, indicative of the physicochemical property of the samples; Table 3 is the Electrical conductivity classification standards.

Table 1. pH Determination in a soil water extract at a ratio 1:2:5.

Station (WIEA)	Depth (cm)	pH Readings		
		1st trial	2nd trial	Mean ± 0.01
1	0 - 5	4.14	4.14	4.14
1	5 - 10	4.15	4.13	4.14
2	0 - 5	4.15	4.16	4.15
2	5 - 10	4.26	4.24	4.25
3	0 - 5	4.20	4.20	4.20
3	5 - 10	4.29	4.30	4.30

Continued

4	0 - 5	4.47	4.47	4.47
4	5 - 10	4.79	4.79	4.79
5	0 - 5	4.80	4.80	4.80
5	5 - 10	5.00	4.98	4.99
6	0 - 5	4.73	4.73	4.73
6	5 - 10	4.98	4.99	4.99

Table 2. Electrical Conductivity (EC) measured at 25°C.

Station (WIEA)	Depth (cm)	Conductivity Readings (µSm/cm)			
		1st trial	2nd trial	Mean (±0.01)	Mean × 1413 µSm/cm (Cell Constant)
1	0 - 5	0.18	0.19	0.19	268.47
1	5 - 10	0.18	0.18	0.18	254.34
2	0 - 5	0.75	0.74	0.75	1059.75
2	5 - 10	0.72	0.71	0.72	1017.36
3	0 - 5	0.90	0.89	0.90	1271.70
3	5 - 10	0.84	0.85	0.85	1201.05
4	0 - 5	0.95	0.92	0.93	1314.09
4	5 - 10	0.94	0.93	0.94	1328.22
5	0 - 5	0.55	0.57	0.56	791.28
5	5 - 10	0.51	0.50	0.51	720.63
6	0 - 5	0.17	0.19	0.18	254.34
6	5 - 10	0.17	0.19	0.18	254.34

Table 3. Electrical conductivity classes.

Calibration level µSm/cm	Very low	Low	medium	high	Very high
Saturation extract	<500	500 - 1000	1000 - 2000	2000 - 3000	>3000

Source: [11].

The samples are acidic, that is their pH values are less than 7 (Table 1) and the pH values do not vary considerably with depth although in some of the samples there is slight increase with depth; such pH values have the tendency of reducing the availability of some metals. Cu, Zn, Mn are definitely affected by pH, organic matter content, oxidation-reduction status of soils. He added that at pH 6.5 and above, these metals tend to only slowly available by plants. Most soils will take up relatively large quantities of elements it the soil pH is high. This in-

dicates that Zn, Cu, Mn and Ni are in relatively low levels in the soil. However, certain elements such as B, Cu, Fe, Zn are always in great quantities in moderately acidic soils, although Fe, Al are highly mobilized in acid soils [12]. The low pH status of the particulate and sediments will also attract metal uptake in plants as was reported that; Cadmium is readily available for uptake in grain, rice and vegetables, and there is clear association between the Cd concentration in soil and in the plants grown on that soil... The uptake in plants increases with decreasing pH, thus the acidification of the environment may increase the cadmium content in the grain [6].

The electrical conductivity of the samples varies from place to place. Stations 1 and 6 have very low conductivities. The other stations have medium specific conductance (Table 2), this classification was based on [11] (Table 3). The higher electrical conductivity implies high concentration of metal ions in the sample. The results show that the levels of soluble ions are generally low. Although some stations show medium conductivities, this difference in conductivities might be as a result of some parameters example salinity. The results when compared with pH revealed that cations are low in the samples. However salinity also has effect on metal mobility as Estate.

Hence, the effects of the accumulation of soluble salts on physical and chemical properties of soil are well recognized [13] [14]. Excess of sodium ions negatively affects soil structure, aggregate stability and soil hydraulic properties. A high sodium concentration leads to degradation of soil due to the dispersion of clay and slaking. This can affect the flow of water and air as well as root penetration [15]. The accumulation of salts reduces plant growth and the activity of microorganisms. Microbial processes such as nitrogen cycling, emission of greenhouse gases, including carbon dioxide and methane, are affected [16].

4. Conclusion

Settling particulate matter and sediment can accumulate toxic materials to levels that can be hazardous to the environment. The Wellington flood plain is an industrial area and most of the industries empty their effluents in the Calaba water. Agricultural activities that take place also lead to the deposition of nutrients to the stream. This empirical investigation revealed the physicochemical properties which characterize the nature of the settling particulate matter of the study locations and their effect on both categories of plants and humans that are interdependent on one another. However results obtained from this research study expressed low pH values indicative of acidity in addition low and medium range specific conductance of the samples in the study locations that were collected systematically and analyzed procedurally in the laboratory. These properties of the samples showed that the settling particulate matter and sediment will have significant impact on the environment in question. Hence, this research study serves as a recipe towards remediation strategy to setting the industrial effluents within optimum standards as may be required.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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