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Chemical Determination of Base Status Metals in Soil Sediments and Particulate Matter in Wellington Industrial Estate Location

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Abstract

This research study explored the levels of base status metals in soil sediments and particulate matter in the wellington industrial estate location; the main objectives were to: 1) determine sodium and potassium, 2) determine calcium and magnesium, 3) determine available iron. The following hypotheses were put forward; H_{0a}: there is no significant difference in the concentration levels between Ca and Mg in the study area, H_{1a}: there is significant difference in the concentration levels between Ca and Mg in the study area, H_{0b}: there is no significant difference in the concentration levels between Na and K in the study area, H_{1b}: there is significant difference in the concentration levels between Na and K in the study area. Six locations were used to collect samples with the aid of scoop and gravel free auger (at varying depths of 0 - 5 cm and 5 - 10 cm) which are Wellington Industrial Estate Area 1 (WIEL 1), (WIEL 2), (WIEL 3), (WIEL 4), (WIEL 5), (WIEL 6); the samples were given laboratory treatment. Flame photometer, EDTA, and Spectrophotometer were used in the determinations of sodium and potassium, calcium and magnesium, and available iron respectively. The results indicated that levels of potassium were in medium range (moderately high); sodium levels were generally low when compared to Brook's classification table. Levels of calcium were generally low and those of magnesium were moderate based on Brook's table of classification. Levels of available iron which fall within the range of Quijano-Guerta (2003) were high; this implies such levels can lead to toxicity. In all locations, there was decrease in the levels of each metal in the samples with (5 - 10 cm) depth.

Keywords

Deposition, Environment, Particulate, Sediment, Toxicity

1. Introduction

Soil sediment is a layer of substance (organic or inorganic) that forms at the bottom of a liquid; Particulate matter consists of extremely small particles. In accordance with [1], particulate organic matter (POM) constitutes all soil organic matter (SOM) particles less than 2 mm and greater than 0.053 mm in size. Soil sediment and particulate matter generally occur on flood plains where the flow of water is not as rapid as that of slopes; consequently 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. Problems of settling particulate matter are known to occur in many parts of the world. A research carried out by [2] showed that: the sediments by the stream near a gold mining area in Southern Columbia have level of heavy metals such as Ni, Cr, Pb, Zn, Hg, Cd, As. According to [3] it was reported that at an abandoned mine tips in Cornwell and Devon in South east England, Arsenic levels indicated 6,640 ppm in the herb Jasionemontana, 4,130 ppm in the healthier Callunavulgaris, and 3,470 ppm in the grass Agrostistenius. 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]. 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 [6]. Due to its toxicity, selenium has been of greater importance in animal nutrition than as essential. In some areas selenium is found in the soil at such concentrations that plants become toxic to livestock, grazing animals may suffer acute selenium poisoning [7]. In spite of low levels of mercury in natural systems, bioaccumulation occurs because of mercury when methylated is very effectively absorbed by aquatic organisms, which they accumulate from food, water and sediments [8]. Most metals such as lead, copper, chromium, zinc, cadmium, arsenic and selenium, often occur in naturally elevated levels in soils overlying mineralized areas and ore bodies. There are many reported cases of plants that have evolved to tolerate and thrive in such soils [9]. According to [10], it was investigated that cadmium is readily available for uptake in grain, rice, and vegetables, and there is a clear association between the cadmium concentration in soil and in the plants grown on that soil. The relative contribution to the cadmium pollution of soil from fertilizers depends on the type of fertilizer, amount of cadmium in the fertilizer as well as cadmium content in soil prior to fertilization. The uptake in plants increases with decreasing pH; thus, the acidification of the environment may increase the cadmium content in grain. [11] reported that most metals can be absorbed through

the gut in invertebrates (e.g. earthworms), reptiles, birds and mammals. For example, uptake of metals via ingestion for earthworms is by transport from the gut lumen, through the gut wall and into the fluid. Considering the fact that 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; these factors have 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 sediments and particulate matter (PM) is found to express deposition. It is highly advisable for industrial effluents to be readily and regularly detoxified, closely monitored, and biomonitors be introduced to give an indication of the presence of toxic metals. This research was conducted to determine the levels of base status metals that exist in soil sediments and particulate matter (PM) at the industrial estate location in Wellington; the null (H_0) and alternative (H_1) hypotheses were indicated thus:

H_{0a}: There is no significant difference in the concentration levels between Ca and Mg in the study area.

H_{1a}: There is significant difference in the concentration levels between Ca and Mg in the study area.

H_{0b}: There is no significant difference in the concentration levels between Na and K in the study area.

H_{1b}: There is significant difference in the concentration levels between Na and K in the study area. Additionally the under mentioned are indicative of the research objectives:

- To determine the levels of sodium and potassium
- To determine the levels of calcium and magnesium
- To determine the level of available iron.

2. Materials and Methods

2.1. Description of Study Area

Wellington is located in the East end of the capital city, Freetown and other residential communities (**Figure 1**). Its coordinates are 8˚26'55"N and 13˚10'10"W in DMS (Degrees Minutes Seconds) or 8.44861 and −13.1694 (in decimal degrees). It is located at an elevation of 80 meters above sea level. 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

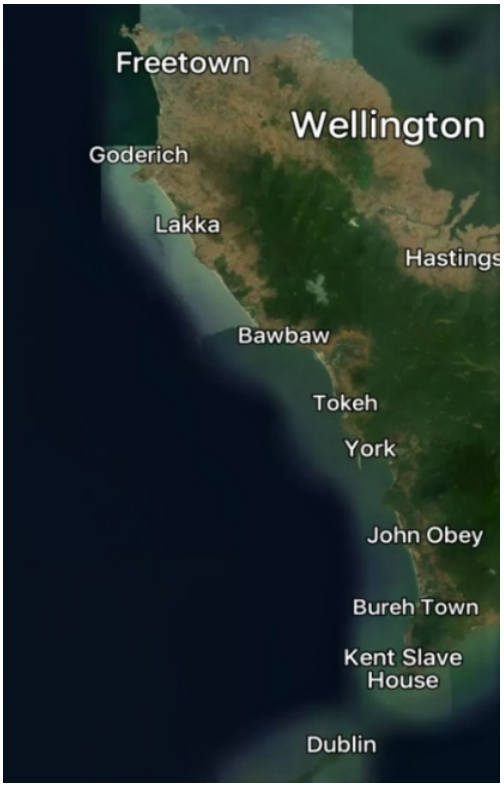

Figure 1. Map of Freetown showing Wellington and other communities.

like cooking and bathing. Demographically Wellington is densely populated. From the east and north stretches a fertile plain which extends about a few kilometers towards the south. This area is good for gardening; it is the second largest crop production area in the city. It is a relatively level area and 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 (**Figure 2**). Wellington is home to several industrial estates, and several minor industries found in the country. These include the Sierra Leone Brewery Limited, Marika Palm Kernel Enterprises, National Confectionary Factory (NATCO), and Nail Factory among others. Therefore this industrial estate provides infrastructural needs for the ethnically diverse population of the city and the Country as a whole (**Figure 3**).

2.2. Sample Site and Sample Collection

Samples were collected along the Calaba water, six (6) sample areas were chosen. Both systematic and stratified sampling planning was employed in the sample collection process; hence this implies samples were collected at regular interval of time and divided into distinct state respectively [12]. Sample area 1 (Wellington Industrial Estate Location 1) WIEL1 was one hundred and fifty (150) meters from source, the other areas namely: WIEL 2, WIEL 3, WIEL 4, WIEL 5 and WIEL 6 were chosen at regular distances about hundred (100) meters from each other.

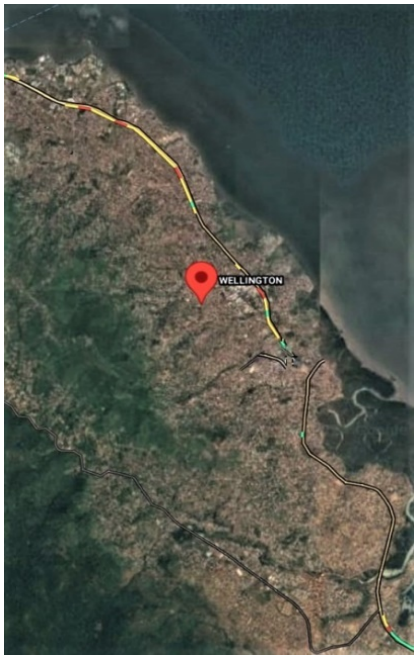

Figure 2. Map of Wellington.

Figure 3. Wellington industrial estate location.

Two samples were collected at depths 0 - 5 cm and 5 - 10 cm respectively from all six (6) stations. Surficial soft bottom soil 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 undecom-

posed 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 at ambient temperature.

2.4. Sodium and Potassium

1) Sodium

KCl was left to dry overnight in electrical oven at 105˚C. It was removed and cooled in a desiccator. 7.46 g of dry KCl was removed and transferred in a volumetric flask. 10 ml of concentrated HCl was added and made up to the mark with distilled water. This solution contained 100 me/l solution, to make 10me/l solution; 100 ml of the 100 me/l potassium solution was pipetted into and made up to 1 litre with 1% HCl.

2) Potassium

NaCl was left to dry overnight in electrical oven at 105˚C; it was cooled in a cabinet desiccator. 5.84 g NaCl was added and made up to 100 ml with distilled water. This solution contained 100 me/l, to make 10 me/l; 100 me/l solution was pipetted and made up to 1 litre with 1% HCl. The various standards of K and Na solutions were made by transferring the volume shown below of the 10 me/l solution into a volumetric flask and made up to the mark.

Na or K me/l	Volume of 10 me/l
0.1	2.5
0.2	5.0
0.3	7.5
0.4	10.0
0.5	12.5
0.6	15.0
0.7	17.0
0.8	20.0
0.9	22.5
1.0	25.0

Method—Preparation of Sample Extracts

10 g of sample extracts was weighed in a 100 ml beaker and 50 ml 1 M ammonium acetate at pH 7.0 was added and stirred intermittently for the first hour. The mixture was covered with a watch glass and allowed to settle overnight. The supernatant was filtered into a 200 ml beaker and an aliquot of 50 ml ammonium acetate extracting solution was added into the beaker containing the sample.

The content was stirred at intervals of 10 minutes for one hour, and was allowed to stand for five minutes and then filtered. The process was repeated for a second time and with the aid of a wash bottle the sample was transferred into a funnel containing ammonium acetate pH 7. The filter was allowed to empty by

each and this process was continued until 200 ml of extracting solution was collected. 300 ml beaker containing the filtrate was transferred to a hot plate and evaporated to dryness.

20 ml of 10% HCl was added to this residue and covered with a watch glass. This was heated slowly for thirty (30) minutes but not allowed to boil. The solution was filtered through a Whatman No. 42 filter paper into a 200 ml volumetric flask and made up to the mark. The emission of the extract and the standard solution were determined using a flame photometer. A blank reading was also obtained.

Calculation

Na and K

$$\text{Cmol/Kg} = \frac{(\text{conc. from graph} - \text{Blank}) \times \text{dilution} \times 200 \times 100}{1000 \times 10}$$

where:

200 = total volume of sample extract

100 = per 100 g sample

1000 = per litre

10 = Weight of sample used for extraction.

2.5. Calcium and Magnesium by EDTA (Ethylenediaminetetra Acetic Acid)

Preparation of reagents

Standard EDTA

0.02M was prepared

Eriochome Black T (EBT)

10 g of oven dried NaCl was weighed dissolved in 250 ml of distilled water mixed with 570 ml of concentrated ammonia solution and diluted to 1 litre with water.

4.03 g MgO was weighed in a conical flask and covered with funnel, 25 ml distilled water and 8.5 ml concentrated HCl was added. When all the MgO has been dissolved, it was then filtered on a number 42 Whatman filter paper. This was washed with distilled water and made up to the mark in a 1 litre volumetric flask.

Triethanolamine (TEA)

A 1:4 dilution of triethanolamine was prepared.

Potassium Cyanide (KCN)

1% solution was prepared.

Patton and Reader's Reagent

10 g oven dried NaCl was weighed and mixed with10 g HHSN

Method

1) Ca + Mg Determination

25 ml aliquot of the extracting solution was pipetted into a 1000 ml conical flask. The solution was adjusted to pH 10.5 by adding 10 ml of the buffer solu-

tion. The following interference removing reagents were added: 1 ml KCN, 5 ml 1:4 triethanolamine solution and 1 ml Mg EDTA.

The mixture was stirred and then a small quantity of EBT indicator was added. The solution was titrated immediately with standard EDTA.

2) Ca Determination

A soluble aliquot of the extracting solution was pipetted in a 250 ml conical flask. 5 ml of 2.5 M NaOH was added to adjust the pH and the mixture was stirred. This was swirled for two (2) minutes and a small quantity of HHSNN indicator was added. This solution was then titrated with EDTA until the colour changes from purple to green.

Calculation

$$\text{Cmol/Kg Sample} = \frac{\text{molarity} \times \text{volume} \times 200 \times 100}{25 \times 10}$$

where:

200 = volume of extract prepared

100 = mass of sample

25 = volume of extract used

10 = mass of sample used

(Ca + Mg) – Ca = Mg.

2.6. Iron (Fe)

Preparation of Reagents

Standard Fe Solution

0.70 g of ferrous ammonium sulphate was dissolved in 100 ml of 3.6M sulphuric acid and the solution was diluted to 1 litre in a volumetric flask

Extraction solution (1M ammonium acetate pH 4.8)

102 ml of glacial acetic acid and 70 ml of concentrated ammonia were added to 75 ml distilled water. The pH was adjusted to 4.8 by adding concentrated ammonia and diluted to 1 litre.

Orthophenanthroline

0.3 g Orthophenanthroline monohydrate was dissolved in water. The mixture was heated to 80˚C and the sodium was cooled, followed by the addition of 100 ml water.

Method

10 g of sample was weighed in a 125 ml conical flask and 50 ml of the extracting solution was added. The flask was well closed and shaken for thirty (30) minutes on a mechanical shaker. The suspension was filtered with a Whatman No. 42 paper and 100 ml portion of filtrate was titrated into each of the 25 ml volumetric flasks. To the first flask 2 ml of 10% hydroxyl ammonium chloride and to the second flask, this served as a blank for the first, was added 2 ml of hydroxyl ammonium chloride and made to 25 ml.

Standard series of 0, 0.4, 0.8, 1.2, 1.6, 2.0, and 2.4 were prepared by pipetting 0, 1, 2, 3, 4, 5 and 6 ml of the 1000 ppm Fe standard solution into 250 ml volume-

tric flasks, subsequently 20 ml of 10% hydroxylaminehydrochloride, 100 ml of orthophenanthroline reagents were added and made to the mark with distilled water. The extinctions of the solutions were measured on spectrophotometer at 510 nm.

Calculation

Available Fe in ppm was calculated using the formula below:

$$\text{Available Fe in mg/l} = \frac{25 \times 50 \times \text{conc. in test solution (ppm)}}{a \times 10}$$

where: a = the aliquot of sample that was pipetted.

2.7. Statistical Analysis

- Q-test was used to accept or reject Outliers from data of samples [13].
- T-test function via Microsoft excel was used to guide whether to accept or reject a hypothesis at $p < 0.05$.
- Coefficient of variation (CV) via Microsoft excel was used to assess the variability in the data set.

3. Results and Discussion

Table 1, Table 3, Table 5, Table 6, and Table 8 are the concentrations of sodium, potassium, calcium, magnesium, and iron respectively indicative of the levels of metals as analytes in the samples; Table 2, Table 4, and Table 7 are the classification levels of the metals according to [14].

Sodium levels are generally low (Table 1) when compared to Brook's classification (Table 2). The pH gives an indication of theses levels; soils with low pH

Table 1. Determination of sodium (Levels of Sodium, Na^+).

Station (WIEL)	Depth (cm)	Emission				conc. from graph	Conc. of Na^+ Cmol/Kg
		1st Reading	2nd Reading	Mean (±0.1)	Mean-Blank		
1	0 - 5	8	8	8.0	6.0	0.065	0.13
1	5 - 10	6	7	6.5	4.5	0.050	0.10
2	0 - 5	6	6	6.0	4.0	0.045	0.09
2	5 - 10	5	6	5.5	3.5	0.040	0.08
3	0 - 5	7	6	6.5	4.5	0.050	0.10
3	5 - 10	5	4	4.5	2.5	0.030	0.06
4	0 - 5	4	4	4.0	2.0	0.025	0.05
4	5 - 10	2	2	2.0	0.0	0.000	0.00
5	0 - 5	9	8	8.5	6.5	0.070	0.14
5	5 - 10	8	6	7.0	5.0	0.055	0.11
6	0 - 5	6	6	6.0	4.0	0.45	0.09
6	5 - 10	4	4	4.0	2.0	0.25	0.05
Blank	-	2	2	2.0	-	-	-

Table 2. Classification of exchangeable sodium levels.

Class	Very low	Low	Medium	High	Very high
Exchangeable Potassium Cmol/Kg	<0.1	0.1 - 0.3	0.3 - 0.7	0.7 - 2.0	>2.0

Source: Brook (1983).

are expected to have low levels of sodium. The level of sodium on the lower sample station 4 was undetectable, this does not imply there is no sodium in the sample but level is too low to be detected by the flame photometer. The result is also indicative of negligible contamination from anthropogenic sources if not non-existent. The CV = 46.43% for sodium (Na) during the period of the study. This analysis of sodium is indicative of low sodium fluctuations in the study locations, hence low variability of sodium within the period of exploration of sodium.

The levels of potassium are in most cases at medium level, the upper values of the samples of stations 1 and 2 show slightly high level of potassium (Table 3). Generally the level of potassium in acid status soils are expected to be far lower than those obtained. This high level can be attributed to both agricultural and industrial activities; as indicated in the top soil of station 1adjacent the agricultural area and station 5 which is adjacent the Sierra Leone Brewery Limited factory (Table 4). However, the CV = 21.81% for potassium (K) during the period of the study. This analysis of potassium is indicative of very low potassium fluctuations in the study locations, hence low variability of potassium within the period of exploration of potassium in the study locations. The increased levels of potassium will therefore have impact on both plants and animals in the study location; it was indicated by [15] that when soil potassium concentrations become elevated, forage grasses and alfalfa will take up this potassium in direct proportion to its concentration in the soil, far beyond the amount required for normal growth of the crop. This process is often referred to as "luxury consumption". The result is forages with potassium levels much higher than normal. When potassium concentrations in the diet exceed 3.5%, the potassium interferes with the uptake of calcium and magnesium in the cow's digestive tract. The cow is not able to keep these nutrients at the desired level in her body as there is so much competing potassium. This imbalance of calcium and magnesium can lead to many health problems in dairy cows including milk fever, calving problems and displaced abomasums. Dry cows are particularly sensitive to high potassium concentrations in forage.

The significance of the difference in levels of concentrations between sodium (Na) and potassium (K) in the study locations was determined by considering the p-value. The significance level α (alpha) is allowed up to 0.05 (95% confidence level). If the p-value is higher than the significance level α, H_0 is accepted ($p > 0.05$). Accepting H_0 ensures that there is no trend in terms of difference, while if the p-value is less than the significance level α, H_0 is rejected. In this case

Table 3. Determination of potassium (Levels of Potassium, K^+).

Station (WIEL)	Depth (cm)	Volume of 0.1MHCl				Conc. from graph	Conc. of K^+ Cmol/Kg
		1st Trial	2nd Trial	Mean (±0.1)	Mean-Blank		
1	0 - 5	20	21	20.5	20.5	0.210	0.42
1	5 - 10	15	15	15	15	0.155	0.31
2	0 - 5	15	16	15.5	15.5	0.160	0.32
2	5 - 10	11	12	11.5	11.5	0.120	0.24
3	0 - 5	18	18	18.0	18.0	0.185	0.37
3	5 - 10	12	12	12.0	12.0	0.125	0.25
4	0 - 5	14	14	14.0	14.0	0.145	0.29
4	5 - 10	10	10	10.0	10.0	0.100	0.20
5	0 - 5	20	21	20.5	20.5	0.210	0.42
5	5 - 10	18	17	17.5	17.5	0.180	0.36
6	0 - 5	17	18	17.5	17.5	0.180	0.36
6	5 - 10	14	14	14.0	14.0	0.145	0.29
Blank	-	0	0	0.0	-	-	-

Table 4. Classification of exchangeable potassium levels.

Class	Very low	Low	Medium	High	Very high
Exchangeable potassium Cmol/Kg	<0.1	0.1 - 02	0.2 - 0.4	0.4 - 0.8	>0.8

Source: Brook (1983).

the *p*-value is 0.0000000001940 or 0.00000001940%. Being far lower than 5%, the *p*-value does provide strong evidence against the null hypothesis; the alternative hypothesis (H_{1a}) was accepted indicative of significant difference in the levels of concentration between (Na) and (K) in the study locations and therefore the null hypothesis (H_{oa}) which stated that there is no significant difference in the levels of concentration between (Na) and (K) was rejected.

Levels of calcium are generally low and those of magnesium are moderate (Table 5 and Table 6). This generalization is based on Brook (1983) (Table 7). For both Calcium and Magnesium there is a similar decrease in levels with depth, however the magnesium samples from station 5 show a higher concentration with depth in contrast to the other stations. Calcium and Magnesium are also base status minerals which are expected to be low in acid status soils. Nevertheless, the coefficient of variation (CV) for calcium (Ca) and magnesium are respectively 25.09% and 12.02% during the period of the study. As such the analysis of calcium and magnesium is indicative of very low fluctuations in the study locations of both calcium and magnesium, hence low variability of calcium and magnesium within the period of investigation. Furthermore, the *P*-value = 0.0000003821 or 0.00003821%, there is statistically significant difference in the levels of concentrations between calcium (Ca) and magnesium (Mg) in the study

Table 5. Calcium determination (Levels of Calcium, Ca^{2+}).

Station (WIEL)	Depth (cm)	Volume of 0.02M EDTA (E)			E-Blank	Ca^{2+}Conc. Cmol/Kg
		1st trial	2nd trial	Mean ±0.01		
1	0 - 5	1.00	1.10	1.05	0.85	1.28
1	5 - 10	0.90	0.90	0.90	0.70	1.12
2	0 - 5	0.80	0.80	0.80	0.60	0.96
2	5 - 10	0.60	0.60	0.60	0.40	0.64
3	0 - 5	0.90	0.90	0.90	0.70	1.12
3	5 - 10	0.80	0.80	0.80	0.60	0.96
4	0 - 5	0.60	0.60	0.60	0.40	0.64
4	5 - 10	0.60	0.60	0.60	0.40	0.64
5	0 - 5	1.10	1.10	1.10	0.90	1.44
5	5 - 10	0.90	1.00	0.95	0.75	1.28
6	0 - 5	1.00	0.90	0.95	0.75	1.28
6	5 - 10	0.70	0.80	0.75	0.55	0.88
Blank	-	0.20	0.20	0.20	-	-

Table 6. Magnesium determination (Levels of Mg^{2+}).

Station (WIEL)	Depth (cm)	Volume of 0.02M EDTA (X)			X-Blank	Ca^{2+} + Mg^{2+} conc.	Mg^{2+} conc. Cmol/Kg soil
		1st trial	2nd trial	Mean ± 0.01			
1	0 - 5	3.00	3.00	3.00	2.70	4.32	3.04
1	5 - 10	2.50	2.40	2.45	2.15	3.36	2.24
2	0 - 5	2.50	2.60	2.55	2.25	3.52	2.56
2	5 - 10	2.40	2.30	2.35	2.05	3.28	2.64
3	0 - 5	2.90	2.90	2.90	2.60	4.16	3.04
3	5 - 10	2.60	2.60	2.60	2.30	3.68	2.72
4	0 - 5	2.40	2.50	2.45	2.15	3.36	2.72
4	5 - 10	2.00	2.10	2.05	1.75	2.96	2.32
5	0 - 5	3.40	3.30	3.35	3.05	4.96	3.52
5	5 - 10	3.00	3.00	3.00	2.70	4.32	3.04
6	0 - 5	2.90	2.90	2.90	2.60	4.16	2.88
6	5 - 10	2.40	2.50	2.45	2.15	3.36	2.48
Blank		0.30	0.30	0.30	-	-	-

Table 7. Classification of exchangeable calcium and magnesium.

Class	Very low	Low	Medium	High	Very high
Exchangeable Calcium Cmol/Kg	<0.5	0.5 - 2.0	2.0 - 4.0	4.0 - 6.0	>6.0
Exchangeable Calcium Cmol/Kg	<0.3	0.3 - 1.0	1.0 - 3.0	3.0 - 6.0	>6.0

Source: Brook's (1983).

locations thus accepting the alternative (H_{1b}) hypothesis, and therefore the null hypothesis (H_{ob}) which stated that there is no significant difference in the levels of concentration between (Ca) and (Mg) was rejected.

Generally, the CV = 23.32% for iron (Fe) during the period of the study, thus this indicates very low fluctuations of iron in the study locations, hence low variability of iron within the period of examination of iron in the study locations. The determination of available iron gives an account of soluble iron in the soil. This is the form, in which iron is absorbed by living systems, When the concentrations of iron are high it creates toxic effects. However, levels of available iron that can be classified as toxic have not been clearly specified according to [16] the reported values of iron toxicity levels in soil solution range from 10 - 100 mg/l. He stated that the wide range indicates the specific criteria for iron toxicity. Toxic effects of available iron depend on the tolerance level of a species. From the results obtained by this study it was found that the entire top soils (0 - 5 cm) and some of the lower soils (5 - 10 cm) have levels of iron greater than 10 mg/l (**Table 8**), these values fall within the range given by [16]. This indicates that there is a tendency of toxicity existing in the area; which according to [17] Iron toxicity in plants is believed to be associated with the regulation of iron uptake and transport. Iron uptake in plants is facilitated by specific transporters that are regulated by the concentration of iron in the soil plants need to maintain iron (Fe) in the concentration of 10^{-4} to 10^{-9} M to achieve optimal growth [18]. Nevertheless, excessive iron uptake can lead to iron toxicity, causing damage to the plant's cell membranes, reducing growth, yield, and affecting the overall health

Table 8. Available Iron (Levels of Iron, Fe^{2+}).

Station (WIEL)	Depth (cm)	Absorbance Readings (A)			Conc. from graph	Conc. from graph - Blank	Conc. (mg/L)
		1st Reading	2nd Reading	Mean ±0.01			
1	0 - 5	0.66	0.63	0.65	1.54	1.48	18.50
1	5 - 10	0.33	0.33	0.33	0.78	0.72	9.00
2	0 - 5	0.42	0.42	0.42	1.00	0.94	11.75
2	5 - 10	0.31	0.32	0.32	0.76	0.70	8.75
3	0 - 5	0.58	0.58	0.58	1.38	1.32	16.50
3	5 - 10	0.48	0.48	0.48	1.14	1.08	13.50
4	0 - 5	0.49	0.50	0.50	1.18	1.12	14.00
4	5 - 10	0.38	0.38	0.38	0.90	0.84	10.50
5	0 - 5	0.59	0.60	0.60	1.42	1.36	17.00
5	5 - 10	0.50	0.52	0.51	1.20	1.14	14.25
6	0 - 5	0.53	0.52	0.53	1.26	1.20	15.00
6	5 - 10	0.42	0.42	0.42	1.00	0.94	11.75
Blank	-	0.02	0.02	0.42	0.06	-	-

of the plant [19]. Excess Fe accumulation can disrupt the nutrient balance of plants, leading to deficiencies in other essential nutrients such as zinc, copper, and manganese. Nutrient deficiencies can further increase the effects of Fe toxicity, leading to reduced plant growth, chlorosis, and necrosis. It can have a significant impact on crop productivity and quality [20]. Levels of available iron obtained from station 1 which has no industrial influence indicates that iron is predominantly coming from the underlying and adjacent rock materials. The levels of iron at station 2 are low, this area has no industrial influence but activities such as laundry and agriculture are predominant. This indicates that these activities can lead to consumption of iron.

4. Conclusion

Soil sediment and particulate matter (PM) generally occur on flood plains where the flow of water is not as rapid as that of slopes. As a result, materials are transported by flowing water and deposited. These soil sediments and particulate matter (PM) can accumulate toxic materials to levels that can be hazardous to the environment. The industries in the Wellington industrial location empty their effluents in the Calaba water. Agricultural activities that take place also lead to the deposition of nutrients to the stream. Based on the results obtained from this study, levels of potassium were medium (moderately high) and levels of available iron were high with an indication of toxicity in the environment. This research study therefore quantified the level of toxicity introduced in the study location by anthropogenic activities and hence served as a conduit of remediation to introducing biomonitors in the industrial effluent areas. Additionally, farmers must be educated to acknowledge the negative influence of the increase in concentration of nutrient levels of metals on one another that it will impact the growth of plants consequently affecting expected yield.

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Conflicts of Interest

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

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