

Organic Carbon Speciation in Settling Particulate Matter and Sediments

Richard Tamba Simbo^{1,2*}, Maria Fe Rebecca D. Gueta², Tokunbo Abel Oladejo²,
Taoheed Olawale Bello²

¹Department of Chemistry, School of Environmental Sciences, Njala University, Freetown, Sierra Leone

²Department of Science and Mathematics, College of Arts and Sciences, William V.S. Tubman University, Harper, Liberia

Email: *tamsimbo@yahoo.com, fejs6625@gmail.com, tokabel@yahoo.co.uk, biowalex@yahoo.com

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Abstract

This research study investigated the levels of organic matter content in settling particulate matter and sediments in the Wellington Industrial Estate flood plains; the main objectives are: to determine the moisture content, moisture correction factor of the samples at varying depths, to determine the organic matter content of the soil samples at varying depths. Six locations, which are Wellington Industrial Estate Area 1 (WIEA 1), (WIEA 2), (WIEA 3), (WIEA 4), (WIEA 5), (WIEA 6), 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); the samples were given laboratory treatment. The Hesse model and Walkley Black technique were used in the determination of moisture content and organic carbon content respectively in samples collected. The results indicated that organic matter content in most of the soil samples collected are high which implies samples have high levels of metal deposition (heavy metals) and can be hazardous to the environment because of their toxic effect; it is also indicative of high level of microbial activities, these activities can also release nutrients to the environment.

Keywords

Hazardous, Microbial, Particulate, Sediment, Toxic

1. Introduction

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. This deposition depends on the gravity of the materials being transported. The transported materials consist of both

organic and inorganic substances. The accumulation of such materials attracts 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. "Algae can be used as Bio monitor of toxic chemicals since it is capable of trapping heavy metals." This implies environment where settling particulate is in high concentrations have high potentials of heavy metals. The decaying activities in addition to the nutrients released, consequently leads to the production of unpleasant odour and heating effect to the environment. The occurrence is usually natural but also due to anthropogenic activities via burning, waste from factories, releasing and washing of garbage materials containing various types of refuses [1]. Generally, solid phase soil organic matter (*SOM*) is associated with retention, decreased mobility and reduced bioavailability of trace metals [2]. Soil organic matter (*SOM*) refers to the non-living organic material in the soil, which makes up by far the major portion of the total organic components [3]. Land rich in organic matter actively retains metallic elements [4]. The amount of available soil organic matter significantly influences metal bioavailability since it is considered as the most important soil constituent that retains heavy metals. Generally, fulvic-metal complexes are soluble, while humic-metal complexes are insoluble [5]. Heavy metals can be found to either strongly adhere within the interstitial matrices of under-water sediments where they can become chelated to organic matter or adsorb superficially on the surface of sediment colloids where they can be readily redistributed within the water column in the event of environmental disturbances [6]. Due to various anthropogenic activities, potentially toxic metals are accumulated in soils, with a risk of water and biota contamination [7]. In soils where the vegetation changes from C_3 to C_4 (or vice versa), the variations in the natural abundance of ^{13}C ($^{13}\text{C}/^{12}\text{C}$ ratio) in *SOM* over time can be used to identify organic carbon sources in the soil [8]. Problems of settling matter and sediment is known to occur in some parts of the world. In China, agricultural soils have been shown to be extensively polluted with heavy metal. Rice paddies, mostly distributed in South China, are particularly affected by heavy metal pollution, causing a decline in grain yield and accumulation of toxic metals such as Cd, Pb and/or As in rice grains [9]. Settling particulate matter and sediments along the Swedish River System contain high concentrations of polychlorinated biphenyls (*PCB's*), polychlorinated dibenzo-*P*-Dioxin/Furan and polychlorinated hydrocarbons [10]. The sediments by the stream near a gold mining area in Southern Columbia has levels of heavy metals such as Ni, Cr, Pb, Zn, Hg, Cd, As [11]. The concentration, size class, and organic carbon content of particulates plays a major role in how much dissolved metal will complex to solid material [12]. In addition to particulate fraction both dissolved and particulate organic carbon may be important. It has been shown that metals and metal compounds have affinity for particulate organic carbon such that the higher the organic carbon content of the suspended particulates, the higher the total concentration of metals or metal

compounds—all other factors being equal [13]. The flow of carbon containing wastes (waste wood, fibers, sludge from treatment plants, etc.) from production process of industries to landfills was estimated to be 0.2 TgCyr^{-1} in 1990 [14]. Among the various reactive soil constituents, soil organic matter (*SOM*) has a large sorption capacity towards metals [15]. Metals participate and/or affect biogeochemical cycles in soils and influence the soil biota [16]. Cationic metals that would ordinarily precipitate at the pH values of most soils are sometimes maintained in solution through complexation with soluble organics [17]. The design of pertinent soil criteria for environment protection and remediation relies on an understanding of the mechanisms controlling metal behaviour [18] [19]. The decomposition of soil organic carbon (*SOC*) is related to soil available substrate, microbial community and activities, as well as climate and soil properties, such as moisture, temperature status, and soil texture [20]. Soil moisture strongly affects *SOC* decomposition through soil aeration, substrate supply, and microbial activity [21].

Settling particulate matter and sediments can express deposition in some part of Sierra Leone; as in Freetown the capital city notably Wellington Industrial Estate (*WIE*) flood plains. This study location by several human activities not limited to agriculture, felling of trees for charcoal production among others lead to deposition of organic carbon. The wastes of from factories, garages are usually washed into the Wellington industrial estate flood plain; undergo chemical decomposition and consequently the deposition of chemical substances both organic and inorganic consisting of metallic and non-metallic substances existing in forms particulates and sediments. These settling particulate matter and sediment may exhibit high levels of soil organic matter (organic carbon) as part of the particulate matter and sediment deposited at varying depths in different locations; in addition organic carbon in the particulates and sediments will complex with metals to form solid materials that will be deposited from one location to another. This research was conducted to determine the levels of organic matter content which is a path way by which metal are been incorporated into settling particulate matter and sediment that may be hazardous to the environment in the Wellington Industrial Estate flood plains in Wellington; the under mentioned are indicative of the research objectives:

- To determine the moisture content, moisture correction factor of the samples at varying depths.
- To determine the organic matter content of the soil samples at varying depths.

2. Materials and Method

2.1. Description of Study Area

Wellington is located in the East end of the capital city, Freetown, Sierra Leone (**Figure 1**). This place is an important commercial, industrial estate which provides the city and its whole country infrastructural needs. It is facing northwards by the Sierra Leone River; which to a large extent provides domestic, industrial,

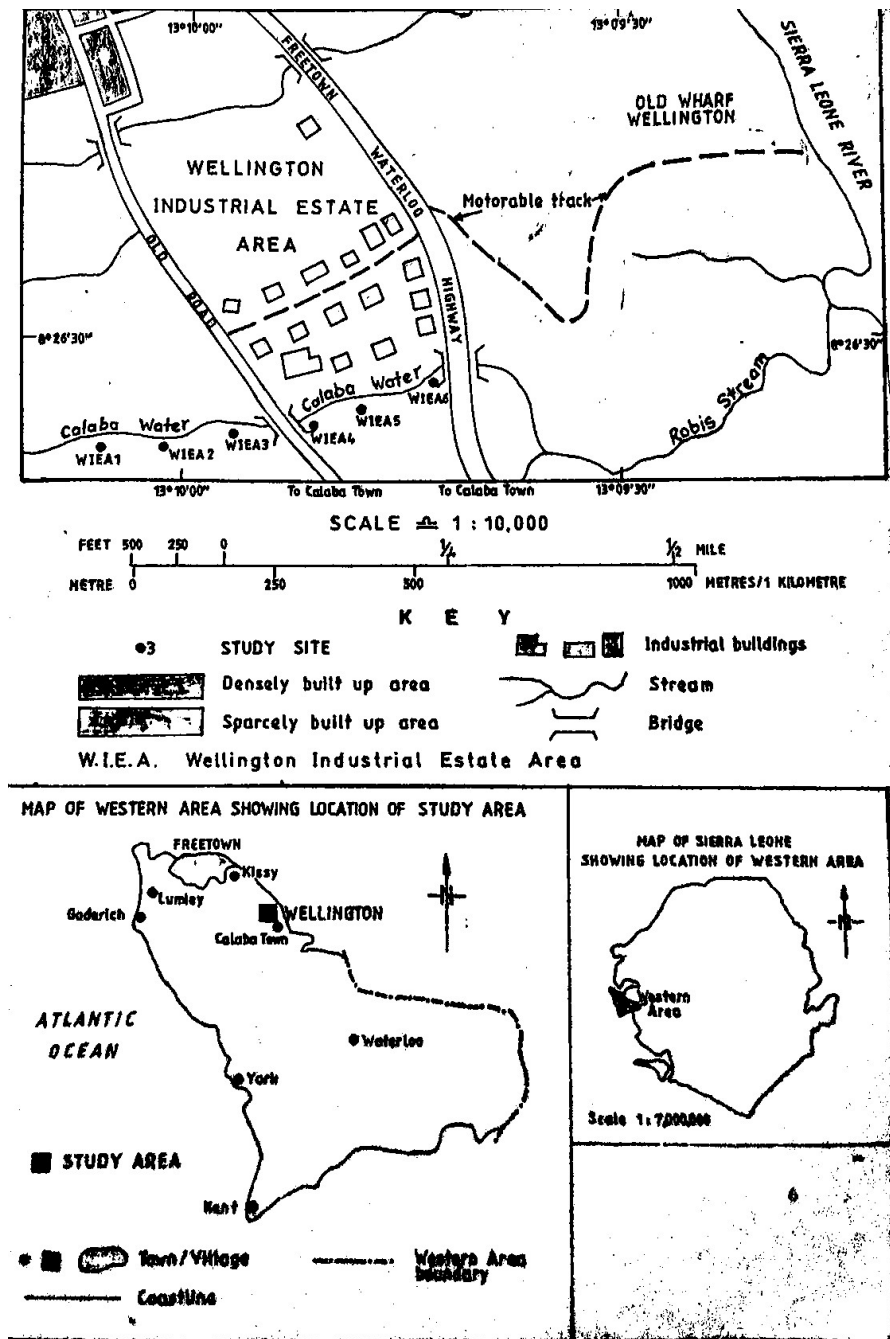


Figure 1. Map of study area (part of Wellington).

transportation and trading facilities for the area. Westwards is the 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 cooking and bathing.

From the east and north stretches a fertile plain which extends about a few kilometers towards the south. This area is good for agricultural activities; 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 between mid-February and mid-March 2020 by which time low precipitation is experienced and such enhanced the sample collection process required—along the Calaba water, 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: 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. Moisture Content Determination

For the moisture content determination, it was done in accordance with the principle of the model outlined. Approximately 5 g of fine earth was transferred to tared moisture tin and weighed with 0.01 g accuracy. The samples in the tare-tin were transferred into an oven with lead removed and dried over night of 105°C, After drying the tin was removed from the oven and then closed with lid, cooled on desiccators and weighed. The drying process in the oven was repeated until a constant weight was obtained. The moisture content in weight percent (*Wt. %*) was obtained by the formula [22].

$$Wt.\% = \frac{A - B}{B - tare\ tin} \times 100\% \quad (1)$$

where *A* = Weight of the soil used.

B = Weight of the oven dry soil.

The corresponding moisture correction factor (*mcf*) can be calculated using the relation below

$$\text{Moisture correction factor (mcf)} = \frac{100 + \% \text{ moist}}{100} \quad (2)$$

2.5. Organic Carbon

Preparation of Reagents

Potassium Dichromate

49.04 g of 105°C dried potassium dichromate was dissolved in 1 litre distilled water

Ferrous Sulphate

140 g of ferrous sulphate was dissolved in water. 15 ml concentrated sulphuric acid was added, cooled and diluted to 1 litre. This was standardized by titrating with 10 ml of 1 M potassium dichromate solution.

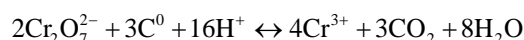
Diphenylamine Indicator

0.5 g diphenylamine was dissolved in 100 ml concentrated sulphuric acid and this was added to 20 ml water and stored in a brown bottle.

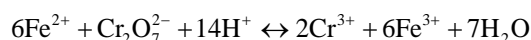
2.6. Method (Walkley-Black Method)

Principle:

The determination of soil organic carbon is based on the Walkley & Black chromic acid wet oxidation method. Oxidizable organic carbon in the soil is oxidized by 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution in concentrated sulphuric acid. The heat of reaction raises the temperature which is sufficient to induce substantial oxidation. Chemical reaction is as follows:



The $Cr_2O_7^{2-}$ reduced during the reaction with soil is proportional to the oxidizable organic carbon present in the sample. The organic carbon can then be estimated by measuring the remaining unreduced dichromate by back-titrating with ferrous sulphate or ammonium ferrous sulphate using diphenylamine or o-phenanthroline-ferrous complex as an indicator [23].



Calculation of Carbon

$$\% \text{ Organic Carbon} = M \times \frac{V_1 - V_2}{S} \times 0.39 \times mcf \quad (3)$$

where: M = molarity of ferrous sulphate solution (from blank solution)

V_1 = ml of ferrous solution required for blank

V_2 = ml of ferrous sulphate required for sample

S = Weight of air-dry sample in gram

0.39 = $3 \times 10^{-3} \times 100\% \times 1.3$ (3 = equivalent weight of carbon)

mcf = moisture correction factor.

3. Results and Discussion

Tables 1-3 are indicative of the quantitative determinations of organic matter

Table 1. Determination of organic carbon content.

Station (WIEA)	Depth (cm)	Mass of Soil (g)	Volume of 0.49M FeSO ₄ Solution (cm ³)			mcf	Percentage Carbon	Organic Matter Content %	Classification of Organic Matter Content
			1 st Trial	2 nd Trial	Mean ± 0.05				
1	0 - 5	0.20	13.10	13.10	13.10	1.004	6.91	13.82	Rich
1	5 - 10	0.20	13.50	13.60	13.55	1.003	6.48	12.96	Rich
2	0 - 5	0.20	9.20	9.30	9.25	1.003	10.60	21.20	Rich
2	5 - 10	0.20	10.10	10.20	10.15	1.003	9.73	19.46	Rich
3	0 - 5	0.20	6.10	6.00	6.05	1.005	13.68	27.36	Rich
3	5 - 10	0.20	6.20	6.10	6.15	1.004	13.57	27.15	Rich
4	0 - 5	0.20	12.70	12.70	12.70	1.004	7.29	14.58	Rich
4	5 - 10	0.30	12.80	12.70	12.75	1.003	4.82	9.64	Rich
5	0 - 5	0.50	10.20	10.20	10.20	1.007	3.89	7.78	Medium
5	5 - 10	0.50	10.30	10.40	10.35	1.003	3.81	7.62	Medium
6	0 - 5	1.00	13.30	13.20	13.25	1.006	1.36	2.72	Low
6	5 - 10	1.00	13.20	13.30	13.25	1.004	1.35	2.70	Low
Blank	-	-	20.30	20.30	20.30	-	-	-	

Table 2. Moisture content and moisture correction factor.

Station (WIEA)	Depth (cm)	Mass of Tare-Tin (g)	Mass of Tare-Tin and Moisture (g)	Mass of Tare-Tin and Dry Soil (g)	Percentage Moisture Content	Moisture Correction Factor
1	0 - 5	4.54	24.54	18.83	0.40	1.004
1	5 - 10	4.54	24.54	19.92	0.30	1.003
2	0 - 5	4.34	25.30	20.46	0.30	1.003
2	5 - 10	4.60	24.70	20.06	0.30	1.003
3	0 - 5	4.52	24.52	17.85	0.50	1.005
3	5 - 10	4.60	24.60	18.89	0.40	1.004
4	0 - 5	4.33	24.33	18.62	0.40	1.004
4	5 - 10	4.40	24.30	19.71	0.30	1.003
5	0 - 5	4.54	24.55	16.31	0.70	1.007
5	5 - 10	4.33	24.33	19.72	0.30	1.003
6	0 - 5	4.42	24.53	17.03	0.60	1.006
6	5 - 10	4.43	24.45	18.73	0.40	1.004

content, the moisture content with moisture correction factor (*mcf*) of samples at each depth of study area, and the classification of organic matter content respectively.

When the data in **Table 1** is compared to Brooks' [24] classification in **Table 3**,

Table 3. Classification of organic matter content.

% organic matter	Classification
<2	Very low
2 - 4	Low
4 - 8	Medium
>8	Rich

Source: Brooks (1983).

organic matter content in most of the soil samples collected are rich or high, except samples collected from station 5 and 6. The organic matter content decreases with depth. The high levels of organic matter during this time (dries) can also be attributed to the increased microbial during this season. The organic carbon content plays a major role in how much dissolved metals complex with solid materials. This gives an indication that soils high in organic matter content as those found in most of the samples have high levels of metal, which in some cases can be hazardous to the environment because of their toxic effect [12]. The medium and low levels of organic matter content in stations 5 and 6 respectively can be attributed to the disproportionate amounts of soil organic content (*SOC*) as a primary component in soil organic matter (*SOM*). In addition to this low levels of organic matter content in stations 5 and 6; it can be seen primordially again in relation to their moisture content indicated in **Table 2** as it also plays a major role in organic carbon decomposition which is in accordance with some studies that reported thus; the decomposition of soil organic carbon (*SOC*) is related to soil available substrate, microbial community and activities, as well as climate and soil properties, such as moisture, temperature status, and soil texture [20]. Soil moisture strongly affects *SOC* decomposition through soil aeration, substrate supply, and microbial activity [21].

High organic carbon content indicates high level of microbial activities; these activities can also release nutrients to the environment. It is therefore expressed that areas with high organic matter content have high levels of nitrogen, potassium, phosphorus, and some other nutrients.

4. Conclusions

Settling particulate matter and sediment occur on flood plains where the flow of water is not as rapid as that of slopes; materials transported by the flowing water are deposited. This deposition depends on the gravity of the materials being transported and the materials consist of both organic and inorganic substances. The organic matter content in the samples were high, but decreases with depth in all stations. The organic carbon content plays a major role in how much dissolved metals complex with solid materials [12]. This in is indicative of the samples containing high levels of both metal and microbial activities that can lead to the release of toxic metals and other nutrients to the environment.

It is highly recommended for industrial effluents to be readily and regularly detoxified as a function of treatment, closely monitored, and biomonitors be introduced to give an indication of the presence of toxic metals. This is in compliance with the statement “the flow of carbon containing wastes (waste wood, fibers, sludge from treatment plants, etc.) from production process of industries to landfills was estimated to be 0.2 TgCyr⁻¹ in 1990” [10]. Also it is recommended that the soil organic matter (*SOM*) from industrial effluents containing soil organic carbon (*SOC*); a primordial component of soil organic matter (*SOM*) which attracts and releases toxic metals to the environment should be closely checked; this is in accordance with the statement “among the various reactive soil constituents; soil organic matter (*SOM*) has a large sorption capacity towards metals” [15].

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Conflicts of Interest

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

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