Global Journal of Researches in Engineering: J
General Engineering
Volume 14 Issue 3 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Trace Elements Distribution in Soil Columns as Affected by Cassava Effluents Application

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Keywords: soil type (iwo, apomu, egbeda), cassava effluents, trace elements (copper, manganese) and leachate.

GJRE-J Classification : FOR Code: 091599

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Strictly as per the compliance and regulations of :

Trace Elements Distribution in Soil Columns as Affected by Cassava Effluents Application

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I. Introduction

Cassava (*manihot esculenta crantz),* the major and the chief staple food in tropical Africa, is regarded as the most important among root and tuber crops. It can be processed into several products such as *gaari, fufu*, starch, flour, etc. It is the processing of those products that releases the waste water to the immediate environment and little effort is made to channel and collect the effluent for proper disposal. Cassava is one of the ancient foods that have helped to improve the rural life by reducing the nation's poverty rate and also serves as means of wealth generation. As the demand for cassava increases, so the amount of the waste water released into the environment increases which cause environmental pollution. Cassava consist of 60-70% water, processing it dry reduces the moisture content and convert it into a more durable and stable product with less volume, which makes it more transportable. Cassava, a plant originated from North-East Brazil, with the root as a good source of carbohydrate and the leaves provide an inexpensive and rich source of protein and minerals in the human diet (Adewusi and Akindahunsi, 1994). It is a traditional crop used by low-income people in the tropics and recommended for both consumption and starch production.

Soils are crucial to life on earth because to a large extent, the soil quality determines the nature of plant ecosystems and the capacity of land to support animal life and society (Brady and Weil, 1999). As human societies become increasingly urbanized, fewer people have inmate contact with the soil and individuals tend to lose sight of many ways in which depend on soils for their prosperity and survival. Therefore the rate to which man depend on the soil is likely to increase not decrease in the future. Of course, soils will continue to supply us with nearly all our food and much of our fibre, large percentage of our medicines and also biomass grown on soils which is likely to become an increasingly important source of energy and industrial feed stocks.

Cassava, which is processed into different products, has gone through various processes which include; peeling, washing, grating, dewatering, pulverizing and frying. The effluents are removed during the process of dewatering by applying pressure on the grated cassava mash using wood, stones, screw or hydraulic press and this process of pressing takes about 2-5 days. The waste water released during the processing, infiltrates into the soil as contaminant or pollutant, which produce various intermediate and final chemical products that can be environmentally damaging under normal physiological condition.

According to Brady and Weil (1999), the effluent infiltrating the soil is greatly influenced by the predominant type of soil due to the varying infiltration capacities of different soils which depends on the size and shape of grains. As part of these effluents infiltrate into the soil, the remaining parts that are left on the soil surface are easily washed away by run-off from heavy rainfall into a nearly stream or pond. These effluents contain cyanide in the form of hydrogen cyanide (HCN) which is very toxic to human life. The presence of

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hydrogen cyanide in cassava was established by Carmody and Francis (1979). The extent of damage to which waste water that infiltrates into the soil is imposing on the soil environment has not been properly quantified. The presence of this solute in the soil may affect the soil water quality and the chemical property of the soil both on long term and short term bases. The fate and the transport of these waste water constituents in the soil depend on various factors. The factors include the adsorption characteristics of the constituents to the soil particles; organic matter content of the soil; the soil solution pH and the loading rate of the constituent (Osunbitan, 2007).

Several developments over time have proved that there has been no much interest in the effects that cassava effluents can cause to the immediate environment. The major reason being that, most of the cassava products that release these effluents are being processed in the rural areas. The introduction of toxic and harmful waste into the environment will have adverse effect on human and animal life, agricultural productivity, soil and even the natural ecosystems. It is important then to know the distribution of these trace elements in the soil so as to mitigate the harmful effects they may have on the soil and/or groundwater environment. Thus, the objectives of this study are to evaluate the vertical distribution of trace elements from cassava waste water in the soil column and to determine the effects of the waste water on the flow rate of water through the soil column.

II. Materials and Method

The experiment was conducted using three different types of soils classified as *Iwo, Apomu and Egbeda* series. The three soils were collected from the Obafemi Awolowo University Teaching and Research Farm to the depth of 40 cm at 8 cm depth interval. The sites at which the samples were collected have no history of heavy metal application which could have occurred through fungicide, fertilizer or sewage effluent application. The soil samples were collected using shovels and packed into sacks and then transported to the laboratory for the column leaching experiment. Twelve 50 cm long and 15 cm diameter PVC pipes held the samples, four for each soil type.

Iwo series are geographically classified as *Iwo association*, soils derived from coarse-grained granites, coarse-grained granitic gneisses and pegmatite and form the most extensive group of soils in Western Nigeria, and taxonomically classified as *Ibadan fasc*. Soils of these series usually occupy level or gently sloping sites at high or intermediate levels in the topography. The sand fraction is usually coarse and small fragments of feldspar are often present. Furthermore, a presence of relatively un-weathered minerals at moderate depth suggests an ample reservoir of nutrients for deep rooted plants (Smith and Montgomery, 1962).

Apomu series are geographically classified as *Apomu association* and taxonomically classified as *Apomu fasc*. By definition, profiles of Apomu series are very sandy in texture to a depth of at least 50 cm and are free of stones and concretions to a similar depth. On account of the sandy nature of the soil, this soil has poor properties of moisture and nutrient retention and is considered unsuitable for cocoa, coffee, kola and citrus (Smith and Montgomery, 1962).

Egbeda series are geographically classified as *Egbeda association*, soils derived from fine-grained biotite gneisses and schists, and taxonomically classified as *Egbeda fasc*. By definition, they are clayey in texture, which is not sandier than very clayey sand in horizons between 25.4 cm and 30.5 cm from the surface. The sand fraction is usually very fine throughout the profile, but a well-marked gravel layer, including quartz gravel, quartz stones and fairly frequent small and spherical ironstone concretions, is present between depths of 25.4 cm and 50.8 cm. The mottled clays usually descend to depths greatly in excess of 305 cm and the only change normally displayed with depth is in the intensity and colouring of the mottling (Smith and Montgomery, 1962).

The effluent was collected as its being released when grated cassava mesh are placed under a screw press during garri production.

a) Method

The soil samples were collected and sun-dried to a moisture content of about 6% after which the soils were pulverised to remove plant stems and roots and then homogenized by sieving of the clumps and gravel using 2 mm sieves. Soil columns were then prepared using the collected soils for the mobility experiment. The PVC pipes mentioned earlier open at both ends were used. Twelve columns were packed with the dried soils to a bulk density of 1.50 g/cm^3 - four columns for each soil type. This required that about 10 kg (*mass*, m = *density*, $\rho \times$ *volume*, v) be packed into the column volume by volume (interval wise) for everything to fit in uniformly.

The experimental design is 3 × 4 factorial arrangement. The factors considered are soil type (Iwo, Egbeda, and Apomu soils) and cassava effluents volume of application (0 ml – for control experiment, 6 ml, 12 ml, and 18 ml). The cassava effluent application translates to: 2.74, 5.48, 8.22, 10.96 mg/l of copper; and 1.83, 3.66, 5.49, 7.32 mg/l of manganese for 0 ml, 6 ml, 12 ml, and 18 ml respectively. Table 3.1 shows the treatments chosen and their levels of application as used in this experiment.

The effluent samples were metered linearly into the saturated soil columns from the top and allowed to leach through the soil columns. Four volumes (0 ml, 6 ml, 12 ml, and 18 ml) were employed for the four columns with each soil type respectively. A funnel and a plastic beaker placed at the end of each column were used to collect leaching fluids from the columns as shown in Fig. 3.1. Rainfall was then simulated to model solute transport through the soil column. The leached samples through each of the columns were chilled immediately after collection until when required for analysis. The samples were later taken to the Central Science Laboratory, Obafemi Awolowo University, Ile-Ife for determination of Cu and Mn content using the Atomic Adsorption Spectrophotometer (AAS).

Table 1 : Treatment and Levels of Application

Experimental run	Soil types	Volume of Cassava Effluents (ml)
1	Iwo	0
2	Iwo	6
3	Iwo	12
4	Iwo	18
5	Apomu	0
6	Apomu	6
7	Apomu	12
8	Apomu	18
9	Egbeda	0
10	Egbeda	6
11	Egbeda	12
12	Egbeda	18

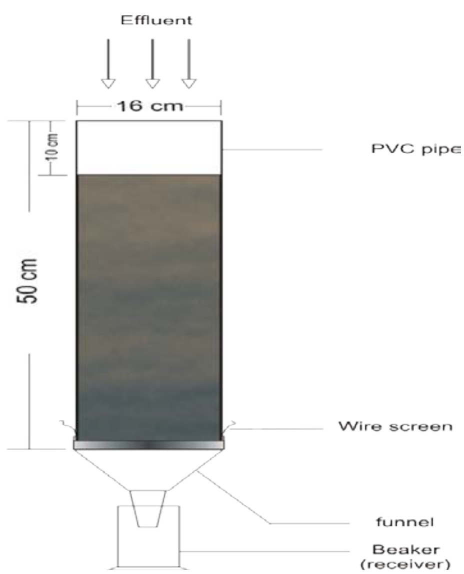

Fig. 1 : Soil column set-up with receiver in place

III. Results and Discussion

a) Leachate Analysis

The results obtained from the experiment are hereby presented. These were determined by the use of the Atomic Adsorption Spectrophotometer (AAS).

i. *Copper*

The concentration of copper in the leachate through the soil columns for seven days of the experimental run are given in Table 2. Figure 2 shows the daily leachate concentrations. There is an increase in total concentration leached – obtained by adding the daily leachate concentrations – with increasing effluent volume for Apomu and Egbeda soils while it remains unclear for Iwo soil. After about five days, the ions had almost completely leached in the Apomu soil. Iwo and Egbeda soils follow similar patterns and were not leached-out in the Seven days of the experiment.

ii. *Manganese*

Table 3 shows the prevalence of manganese, Mn, in the collected samples. It shows an increase in total concentration leached with increasing effluent volume for Apomu and the relationship between the total concentration leached and effluent volume remains indeterminate for the Iwo and Egbeda soils. Figure 3 shows the daily leachate concentrations for the three soil types. Apomu quickly dissipates much of the ions reaching a peak concentration on Day 3 or Day 4.

Table 2 : Concentration (in mg/l) of Cu in the leachate

Soil Type	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
			0 ml of effluents					
Iwo series	0	3.04	0.14	1.65	0	0.71	0	5.54
Apomu series	2.11	0.69	1.61	0	0.72	0	0	5.13
Egbeda series	0	2.14	0	4.81	0	0	2.67	9.2
			6 ml of effluents					
Iwo series	0.4	0	1.54	3.31	1.74	2.16	0.89	10.04
Apomu series	1.24	1.89	1.43	1.95	0	0	1	7.51
Egbeda series	0	0.83	2.78	2.91	2.05	1.17	0	9.74
			12 ml of effluents					
Iwo series	1.85	2.08	0	1.98	0	1.85	2.35	10.11
Apomu series	0	2.17	1.7	3.56	0	0	2.43	9.86
Egbeda series	0	2.74	0.54	1.4	3.06	1.7	2.32	11.76
			18 ml of effluents					
Iwo series	1.56	0	1.48	1.18	0	1.94	2.1	8.26
Apomu series	0	3.23	4.44	3.05	3.12	0.97	0	14.81
Egbeda series	1.71	0	4.57	0.66	3.86	2.49	2.11	15.31

Table 3 : Concentration (in mg/l) of Mn in the leachate

Soil Type	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
			0ml of effluents					
Iwo series	0	0	0.37	0	0.44	0	0	0.81
Apomu series	0.3	0.24	0.06	0	0.36	0.74	0	1.7
Egbeda series	0	0.09	0.08	11.2	0	0.62	0.04	12.03
			6ml of effluents					
Iwo series	0.83	0.27	0	2.45	3.46	2.01	0.31	9.33
Apomu series	0.41	4.21	1.04	6.33	0.35	0	0	12.34
Egbeda series	0.53	0.91	7.38	2.4	0.85	1.74	0.74	14.55
			12ml of effluents					
Iwo series	0.25	0	0	0.34	0	1.24	1.12	2.95
Apomu series	1.23	1.14	6.27	6.12	2.93	1.47	0.29	19.45
Egbeda series	0	0	2.14	1.31	3.3	2.07	2.12	10.94
			18ml of effluents					
Iwo series	1.47	1.97	7.51	0.99	0.72	8.93	5.77	27.93
Apomu series	0	4.12	11.2	8.29	8.63	2.02	0	34.26
Egbeda series	0.24	2.97	6.46	0	10.42	7.48	8.62	36.19

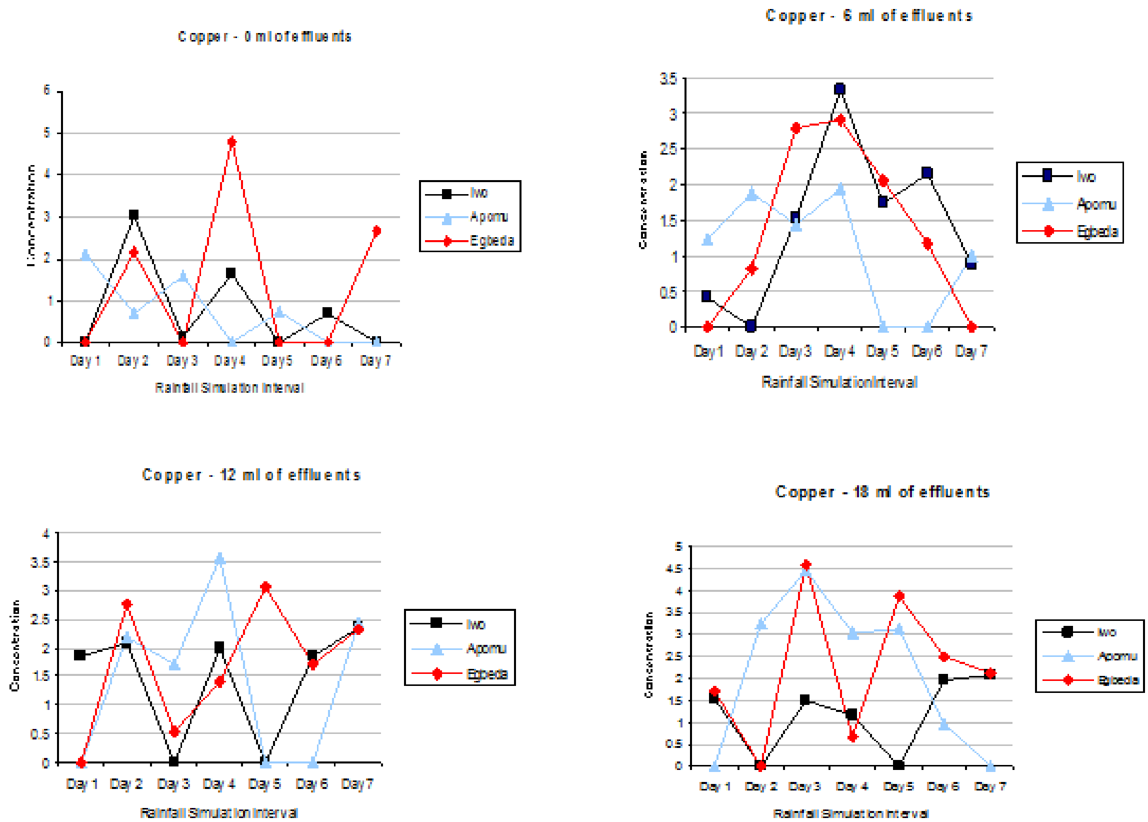

Figure 2 : Concentrations (in mg/l) of Copper with Rainfall Simulation Interval for different soil types

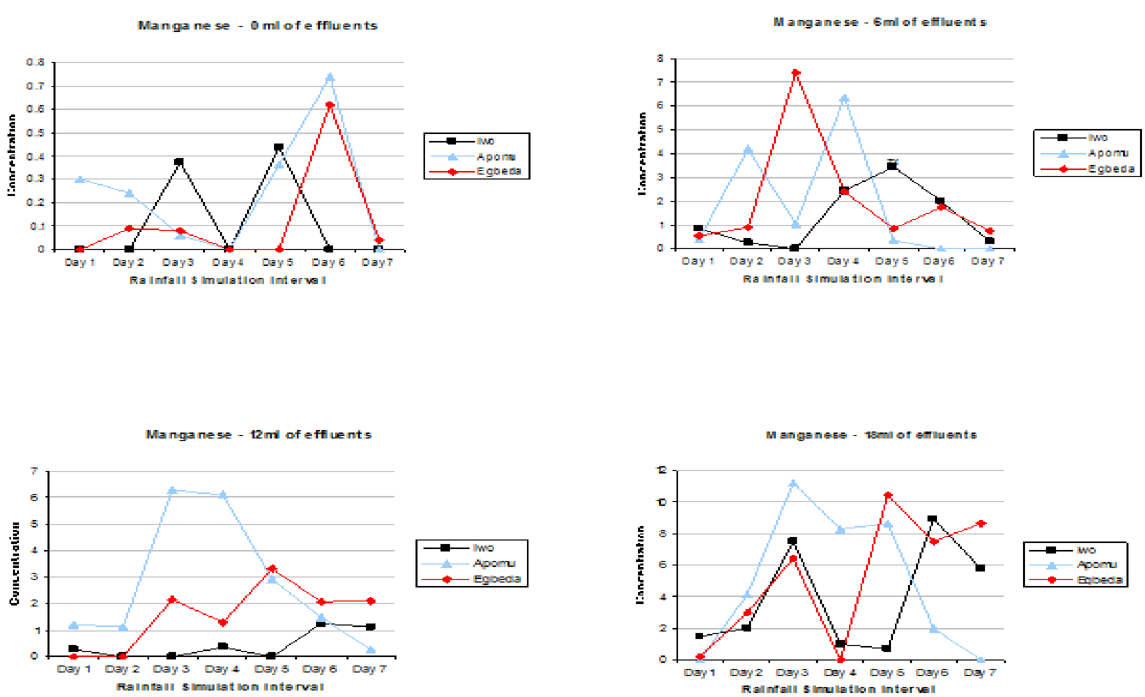

Figure 3 : Concentrations (in Mg/l) of Manganese with Rainfall Simulation Interval for different soil types

b) Effects of Varying Proportions of Effluents

The effect of varying concentration 0, 6, 12, 18 ml of effluent on the mobility of Cu and Mn through the soil columns is shown in Figure 4 and Figure 5 respectively.

The results for the three soils indicate the presence of Cu and Mn in the original soils without effluent addition. Increasing the concentration of Manganese leads to a corresponding increase in leachate concentration for Apomu soil. For Iwo soil, and more importantly for Egbeda soils, the structure (prominence of the soil micro- and macro- pores) and chemistry have a marked effect on the rate of leaching of Mn through the soil. The inability to convincingly determine the pattern for Iwo must be due primarily to its organic nature, and then to clayey proportion. The presence of soil micro-pores is the primary factor influencing flow through Egbeda soil.

c) Rate Analysis

When compared with the control experiment (Figure 6) and Figure 7 (Rate analysis for 12 ml effluent addition) shows that in soil columns to which the cassava effluent was added, the rate of infiltration by the simulated rainfall dropped for Iwo and Apomu soils and rose for the Egbeda soil. The effluent addition also caused the flow to reach its peak earlier than in the Control experiment. This is explained by the fact that due to the slightly starchy nature of the effluent, most the soil macro-pores must have been blocked which leads to a lower flow rate normally. However, the Egbeda soil having more micro-pores which are not blocked by the effluent quickly reaches its peak flow earlier than Iwo and the Apomu soils – a reversal of what occurs in the Control experiment.

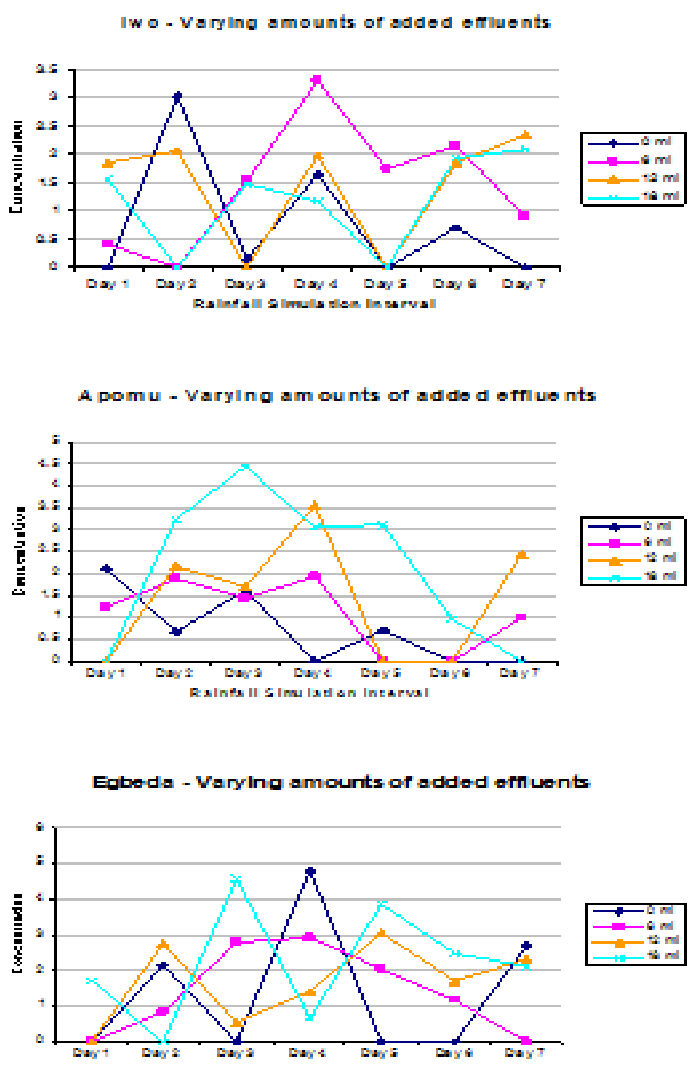

Figure 4 : Copper concentrations (mg/l) with Rainfall Simulation Interval for varying effluent proportions

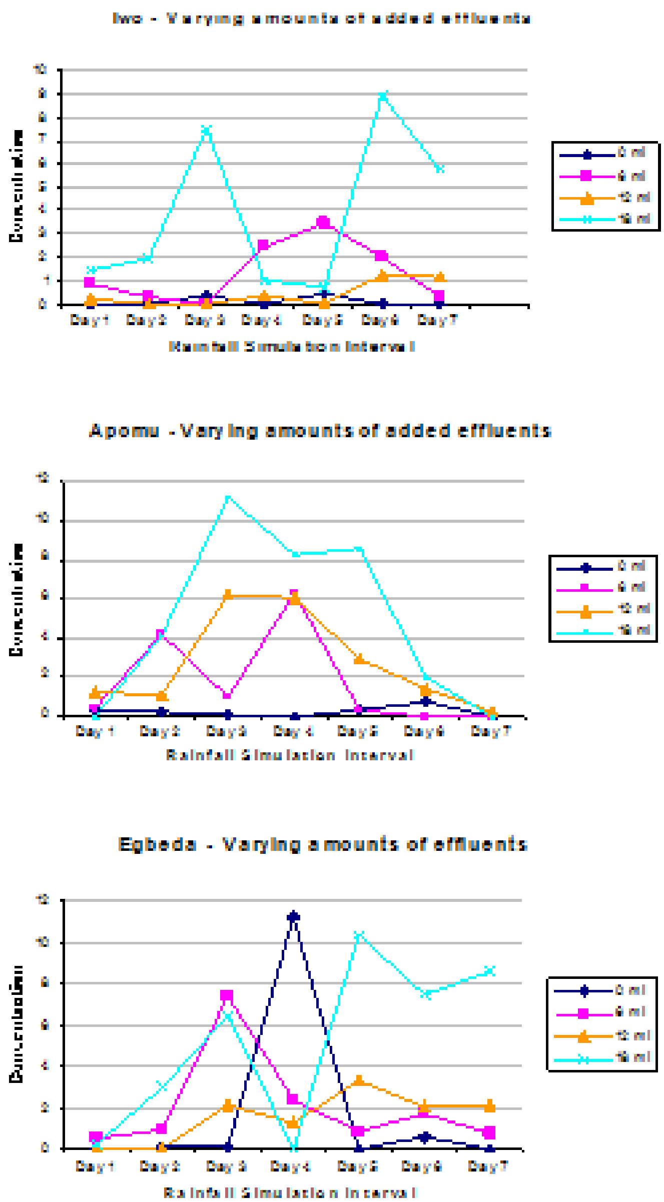

Figure 5 : Manganese concentrations with Rainfall Simulation Interval for varying effluent proportions

Table 4 : Rate of flow through soil columns

Duration (min)	Iwo (0ml)	Iwo (12ml)	Apomu (0ml)	Apomu (12ml)	Egbeda (0ml)	Egbeda (12ml)
2	20	21	52	43	24	34
4	51	40	81	75	40	64
6	51	46	82	77	64	107
8	44	40	75	69	71	74
10	38	34	50	50	64	48
12	33	36	35	34	45	28
14	27	30	27	24	30	22
16	23	22	22	18	23	16.5
18	20	19	18	14	19	13

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20	18	16	13.6	13.6	15	11
22	16	14	10.6	13.9	13	9.4
24	14	12.5	8.6	12.8	11	7.8
26	11	11	6.8	10.8	9.4	6.8
28	10.6	9.8	5.6	9	8	6
30	9	10.4	4.6	8	7.6	5.5
32	8.5	9.8	3.9	7	6.8	5.1
34	7.3	9.4	3.4	6.2	6	4.6
36	6.5	9	3	4.6	5.6	4.4
38	5.8	8	2.7	3.6	5.1	4
40	5.1	7.6	2.4	3.4	4.8	3.4
Total volume leached	418.8	405.5	507.2	496.9	472.3	474.5

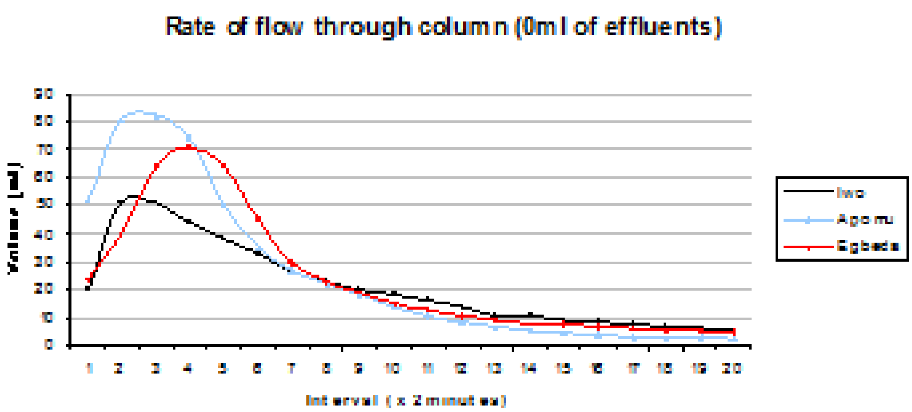

Figure 6 : Rate of flow for 0ml effluent addition (control experiment)

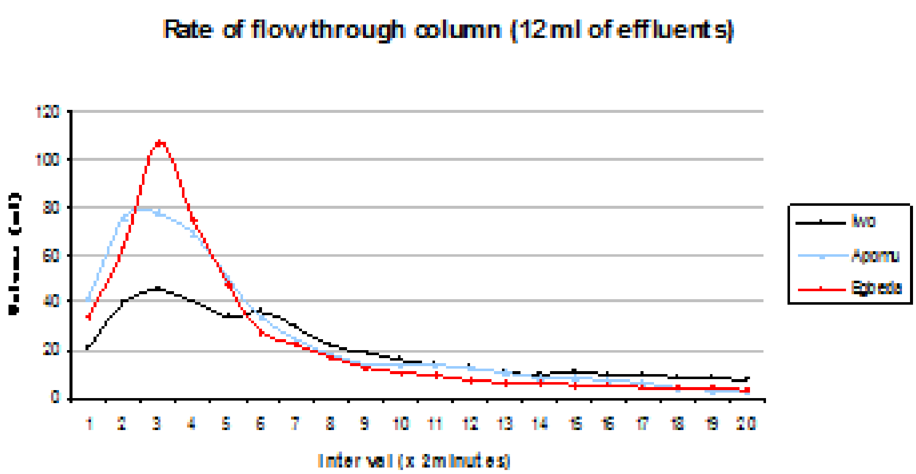

Figure 7 : Rate of flow for 12ml effluent addition.

IV. Conclusion

This experiment shows that distribution of heavy metals through soils is enhanced by porosity, and the organic content of the soil. Highly porous soils like Apomu displayed an unusually high mobility of these two ions under consideration. The more organic Iwo and clayey Egbeda displayed similar transport characteristics. At the end of the duration chosen for the experiment, leachate from the Apomu soil columns had no trace of the metals introduced. The effect of soil micro-structure and organic content is clearly evident and as observed serve as the key factors influencing the mobility of Copper, Cu, and Manganese, Mn, through the soils types studied. It has been shown by this experiment that these two metals will flow through the geological topsoil - surface to 40 cm depth - to lower layers and the rate decreases from Apomu to Iwo to Egbeda.

Thus, areas where cassava is being indiscriminately processed without any regard for wastewater treatment, with the Apomu soil type, will be at high risk of underground water contamination. For the Iwo and Egbeda soil types, it is observed that mobility was lesser than as it was for Apomu. The fairly average concentration was being released everyday and at the end of the seven day run, the concentration had hardly reduced. This implies that in such areas, with Iwo and Egbeda soil types, crops are at a higher exposure to re-absorption.

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