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ARTICLE

Effects of Electroplating Effluents on Growth, Heavy Metals Accumulation and Concentrations in *Amaranthus viridis* Lin.

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ABSTRACT

Pollution in recent times has become prevalent due to industrial expansion, hence, releasing pollutants into the environment. Thus, this study aimed at investigating the effects of effluents from electroplating companies on growth, heavy metals accumulation and concentrations in *Amaranthus viridis*. Seeds of *A. viridis* were obtained from the National Institute of Horticulture, Ibadan. Loam soils were collected from Lagos State University and two samples of electroplating effluents were obtained from Oregun, Lagos. Seeds were sown, nursed, and transplanted in a uniform bucket filled with 5 kg loam soil and transplanted seedlings were treated with Effluent A (5 and 10% conc.) and Effluent B (5 and 10% conc.) and control respectively. Growth parameters such as plant height and so on were measured and plant samples harvested were analyzed for heavy metal concentrations using Atomic Absorption Spectrophotometer. Data collected were subjected to a one-way analysis of variance. Results revealed that Effluents A and B are highly acidic and above discharge limits. Also, the result revealed that 5% conc. of Effluents A and B had more effects on growth ($p < 0.05$) of *A. viridis* across the harvests than 10% conc. in relation to control. This result showed that the effluent samples affect the growth rhythms of plants. Results further revealed vigorous accumulation of the heavy metals: Zn (241.66 µg kg^{-1} ± 0.10 at third harvest in Effluent A: 10%), Cu (68.25 µg kg^{-1} ± 0.23 at first harvest in Effluent B: 5%), Cr (500 µg kg^{-1} ± 0.90 in harvests at all concentrations.) and Ni (500 µg kg^{-1} ± 0.90 at third harvest in Effluent B: 5%) and all these metals are far above the control and permissible limits of WHO/FAO recommendations. From this study, it could be concluded that electroplating effluents had adverse effects on growth and increased metals' bioaccumulation in *A. viridis*. Therefore, the treatment of effluents to enhance an eco-friendly environment should be done.

Keywords: Electroplating; Effluent; Pollution; Heavy metals; Discharge; Vegetable; *Amaranthus viridis*

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1. Introduction

Industrial pollution has become prevalent, especially in developing nations like Nigeria. However, in recent times, concerns about the environment are widely being expressed by environmentalists and health organizations. Effluents from industries are among the major wastes causing environmental pollution [1,2].

Industries in particular make prodigious use of water as an ingredient with other raw materials to create finished products. It is also used as a transporting medium, a cleansing agent, a coolant and a source of steam for heating and power generation. The main problem, however, is that water that goes out of these industries is discharged into the waterways in a relatively polluted condition depending on its use and treatment, if at all it receives any before discharge [3-5].

The discharge of industrial, agricultural, and domestic wastes or effluents have led to the degradation of water bodies due to high concentration of heavy metals and other pollutants. Whatmuff [6] and McBride [7] reported that increased concentrations of heavy metals in soil often lead to increased crop uptake of these heavy metals. Nriagu [8] observed that we may be experiencing what he termed a silent epidemic of environmental and metal poisoning from ever-increasing amounts of metals dumped or washed into the biosphere and hydrosphere. Sources of heavy metal deposition include metalliferous mining, electroplating, galvanizing and agricultural materials such as fertilizers, pesticides, fungicides, sewage sludge, compost manure, corrosion of metal objects and domestic wastes [9,10].

The main environmental agency in Nigeria-Federal Environmental Protection Agency (FEPA) and other world-recognized agencies have drawn attention to the effluents being discharged into the wetlands and farmland near the industries and possible attendant problems on crops and vegetables being produced by small-scale farmers [11-14].

Amaranthus viridis L. is a green vegetable belonging to the family Amaranthaceae. It occurs mainly in tropical and sub-tropical countries as a semi-wild protected plant that is grown when land is cleared or weeded [15]. It is a robust annual herb with erect stem. The seeds are small and dark brown to black with shining testa. It is a popular plant known for its nutritive value containing various essential amino-acids, and little amount of crude fibre or carbohydrate [16,17].

In view of the above, the study investigates the effects of effluents from an electroplating company on *Amaranthus viridis*, a popular nutritious vegetable in West Africa. This study, thus, reports the effects of two effluent samples on the growth, accumulation, and concentration levels of heavy metals such as zinc, nickel, chromium, and copper in the plant parts (leaf, stem and root) of *Amaranthus viridis*.

2. Materials and methods

2.1 Collection of materials

Amaranthus viridis seeds were obtained from the National Institute of Horticulture (NIHORT), Ibadan, Oyo State, Nigeria. The loam soil was collected from the Botanical Garden of the Lagos State University, Ojo in Nigeria. Two different samples of electroplating effluents tagged: Sample A and B were obtained from Grizzi Nigeria Limited situated at Plot 2, Adewumi Estate, Kudirat Abiola Road, Oregun in Ikeja, Lagos State (**Figure 1**), Nigeria, manufacturer of wooden and metal electroplating or coating substances. Effluents were collected in clean containers and transported to laboratory for analysis and usage.

2.2 Soil preparation and nursery

Matured seeds of *Amaranthus viridis* were sun-dried and sown in seed trays (30 cm in width and 10 cm in depth) filled with loam soil and watered moderately. The seeds emerged after the third day. After 14 days of emergence, the seedlings were ready for transplant.

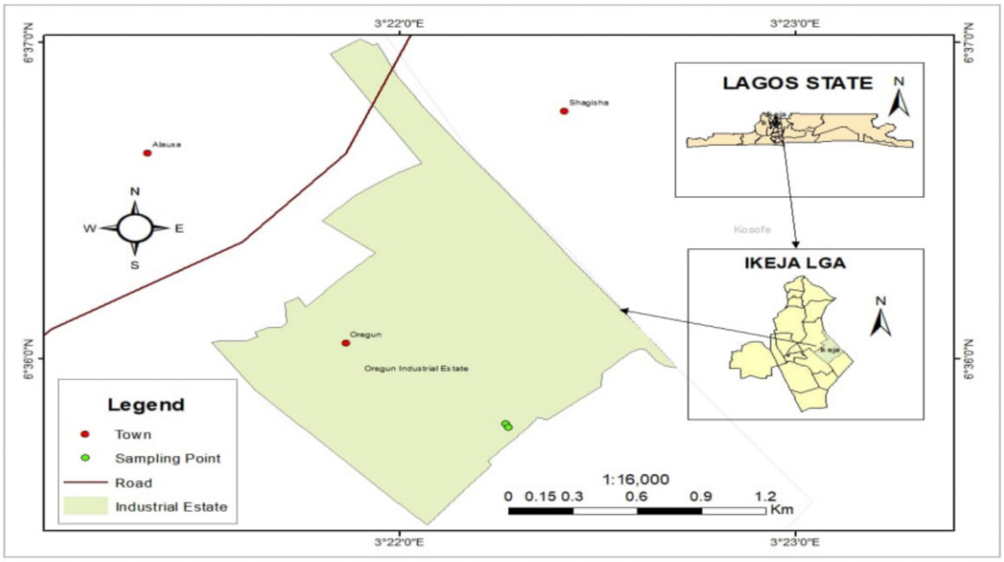

Figure 1. Map of Ikeja LGA, Lagos State showing sampling point.

2.3 Seedling transplant and growth experimental design

One hundred (100) equally perforated plastic buckets were used. Each bucket was filled with 5 kg of loam soil respectively and uniform seedlings of *Amaranthus viridis* were transplanted respectively. The seedlings were watered twice daily. After two weeks of establishment, the established seedlings were divided into five groups, namely Control, Sample A_1 Plants, Sample A_2 Plants, Sample B_1 Plants and Sample B_2 Plants respectively. Control was watered with distilled water, Sample A_1 Plants were watered with a 5% concentration of Effluent A mixed with 95% distilled water, Sample A_2 Plants were watered with a 10% concentration of Effluent A mixed with 90% distilled water, Sample B_1 Plants were watered with 5% concentration of Effluent B mixed with 95% distilled water while Sample B_2 Plants were watered with 10% concentration of Effluent B mixed 90% distilled water.

2.4 Analysis of effluent samples

Sample A contained a chromium-plating effluent which was golden yellow while Sample B contained a nickel-plating effluent which had a greenish blue colour collected separately and differently as these two metals are the major electroplates used. The samples were collected in sterilized containers and filtered out of the debris. The analysis of the effluents was carried out using standard methods for the examination of water and wastewater as reported by Rice and Bridgewater [18]. Thus, the physico-chemical analysis carried out includes pH, turbidity, acidity, total dissolved solids, suspended solids, and heavy metal content.

pH: The pH of the samples was determined using a standardized buffer solution and a pH meter model 22409 (United Kingdom).

Turbidity: The turbidities of these effluents were measured by H193703 portable microprocessor turbidity meter and readings were taken in the Formzin Turbidity unit (TU).

Acidity: This was determined using 0.02M NaOH and 0.02M KHP prepared with distilled water. The 0.02M NaOH was standardized against 0.02M KHP. The standardized NaOH was then titrated with 2 mL of each of the effluents using phenolphale as an indicator. The acidity was calculated using the formula:

$$\text{Acidity} = \frac{\text{Molarity of Base-Titre value} \times 500}{\text{Volume of effluent used}}$$

Total solids: This was determined by mixing the samples thoroughly and heating 20 mL of each of the samples to complete dryness in Petri dishes in ovens at 105 °C. The solids were calculated using the formula:

$$\text{Total solids (mg/L)} = \frac{(A-B)\times 1000}{\text{Volume of the Sample}}$$

where: A is the weight of dried residue + Petri-dish; B is the weight of empty Petri-dish.

Total Dissolved Solids (TDS): This was determined using 20 mL of filtered samples and heating to complete dryness. Total dissolved solids were calculated using the formula:

$$\text{TDS} = \frac{(A-B)\times 1000}{\text{Volume of the Sample}}$$

where A represents the weight of dried residue + Petri-dish while B represents the weight of an empty petri-dish.

2.5 Harvesting and data collection

Leaves from each group [Sample A_1, Sample A_2, Sample B_1 and Sample B_2] in three replicates were harvested every two weeks for six weeks. These plants were harvested using the traditional destructive method outlined by Oluwole et al. [19]. The plants were carefully uprooted, and the root parts were rinsed with clean water. The weights of the plants were determined before separating into parts namely leaves, stems, and roots. Fresh weights of the parts were determined, thereafter the plant parts were oven dried at 80 °C for 48 hours, cooled and their dry weights were determined using electric balance. Growth analysis was carried out using a completely randomized design. Data collected were used to determine the following growth parameters—mean total dry weight (TDW), leaf weight ratio (LWR), stem weight ratio (SWR), root weight ratio (RWR) and shoot-root ratio (S: R). The plant part dry weight is calculated as a percentage of total dry weight.

2.6 Digestion of plant samples and heavy metal analysis

One gram (1 g) of dried finely grounded plant sample was weighed into Kjedahl flask and 20 mL of nitric acid was then added to it. The Kjedahl flask was placed on a hot plate for approximately 2 hours. The hot plate was then placed in the fume cupboard to avoid choking from the fumes released from the nitric acid. After the 2 hours, the digested sample was poured out into a 25 mL flask, distilled water was then added to make up to the 25 mL mark, cooled for some minutes and the digested samples of each plant part were filtered into clean plastic (60 mL) bottles and then taken for chemical analysis using Atomic Absorption Spectrophotometer (AAS) model 1233 (England).

2.7 Statistical analysis

The data obtained from the study for various plant parameters were subjected to single univariate summary statistics such as the mean and standard deviation. The analysis of variance (ANOVA) was then used to compare the variability in the selected parameters with the aid of the software SPSS 2007 version 20. Significant means were separated by the Least Significance Difference test (LSD) at the 95% probability level using Duncan Multiple Range Test.

3. Results and discussion

3.1 Physicochemical analysis of electroplating effluent samples

Table 1 shows the result of the chemical analysis of the two Effluents A and B collected. The result showed that samples A and B have high heavy metal content far above the effluent discharge limits by Federal Environmental Protection Agency [14]. However, apart from the heavy metal concentrations, the effluent samples were highly acidic (**Table 1**). The heavy metals present in sample A are nickel, chromium, zinc and copper with concentrations of 65.43 $\mu g\ L^{-1}$, 388.20 $\mu g\ L^{-1}$, 12.32 $\mu g\ L^{-1}$ and 50.17 $\mu g\ L^{-1}$ respectively with Sample B having the same metals as in Effluent A (**Table 1**) but in varying concentrations. The concentration of chromium (388.20 $\mu g\ L^{-1}$) was about six times greater than the concentration of nickel and copper, and about twenty-five times greater than the concentration of zinc. This is in no doubt responsible for the deep-golden yellow colour of this sample. Effluent B also had the highest concentration of nickel, about six times greater than the concentration of chromium and copper and about sixty times greater than the concentration of zinc. The high concentration of nickel in Effluent B is also responsible for the greenish blue colour of this sample. This was supported by Yasser et al. [2] and Monica et al. [5], when they reported that wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals.

3.2 Effects of electroplating effluents on the growth of *Amaranthus viridis*

Effects of two electroplating effluents of Samples A and B collected on the growth of *A. viridis* is shown in **Table 2**. The results showed that control, Effluent A (5 and 10% conc.) and Effluent B (5% conc.) had ascending increases in mean plant fresh and dry weights of *A. viridis,* while Effluent B (10% conc.) showed descending increase in mean plant fresh and dry weights (**Table 2**). The mean plant heights of seedlings subjected to treatments showed ascending increase in plant heights, the seedlings in control had the best plant heights while those subjected to both Effluent A (5 and 10%) and Effluent B (5 and 10%) had similar poor heights. However, fresh, and dry weights and plant heights in Control ($p < 0.05$) were significantly higher than others (**Table 2**). This result showed that the height of the seedlings of *A. viridis* watered with effluent samples was hindered (**Table 2**). The leaf weight ratios of seedlings of *A. viridis* in Control, Effluent A (5% conc.) and Effluent B (10% conc.) showed ascending increase, while Effluent A (10% conc.) and Effluent B (5% conc.) revealed descending increase in mean leaf weight ratios (**Table 2**). More so, the stem weight ratios, root weight ratios and shoot-root ratios showed that seedlings in control and Effluent A (5% conc.) had a positive increase, while those in Effluent A (10% conc.) and Effluent B (5 and 10% conc.) showed a significant decrease (**Table 2**). However, leaf weight ratios and stem weight ratios at the third harvest in Control and Effluent A (10% conc.) at the first harvest were significantly higher ($p < 0.05$) than others. It was observed that the leaves of seedlings of *A. viridis* treated with Effluent A had some yellow patches on them, which were later glaring on the seedlings subjected to Effluent A (10% conc.). However, this result was supported by the work of Bahemuka and Mubofu [20] and Ikeda et al. [21] when they reported that intake of toxic metals at a chronic level through soil had adverse impacts on plants and the associated harmful effects become apparent after days of exposure. Oluwole et al. [22] also reported that bioaccumulation of several factors is responsible for the effective and efficient growth of plants. Some of the factors itemized include soil water, soil mineralization, organic and inorganic components such as metallic concentrations within the soil. Oluwole et al. [19,23] further reported that variation in the growth parameters of seedlings under different treatments is a function of both biotic and abiotic factors.

3.3 Effects of electroplating effluents on heavy metal concentrations in *Amaranthus viridis*

Effects of electroplating effluents on heavy metal concentrations in *Amaranthus viridis* is shown in **Table 3**. The results revealed that the chromium (Cr) metal was significantly ($p < 0.05$) accumulated by the vegetable from the first to the third harvests. Also, Cr concentrations were above the standard permissible limits of WHO/FAO for chromium which is 2.3 $\mu g\ kg^{-1}$ (**Table 3**). Thus, the consumption of such vegetables with high concentrations of Cr is toxic. This result was against the findings of Tasrina et al. [24] which reported lower concentrations of Cr in some vegetables contaminated with heavy metals. However, Romic and Romic [3] reported that toxicity of Cr in the body causes skin ulceration, damage to the liver, kidney, and nerve tissues. They further reported that Cr contamination is usually from the wearing down of asbestos lining, tobacco smoke and so on. Also, from the results, nickel (Ni) was not detected at all during the first harvest until the second harvest in the roots of *A. viridis* watered with Effluent A (5%

conc.) while significantly ($p < 0.05$) higher concentrations were also found in those treated with Effluent B (5 and 10% conc.) by third harvest (**Table 3**). The concentration of Ni estimated in the vegetable was above the WHO/FAO permissible limits, which invariably poses a danger to the consumers. This study was supported by Ibrahim [25], which reported the accumulation of nickel in some plants; he said nickel is disastrous to both animal and human health. He also reported that automobile exhausts are the major source of atmospheric nickel.

The results further showed that the concentrations of both zinc and copper taken by *A. viridis* treated with Effluent samples A and B. The results revealed that concentrations of Cu and Zn increased arithmetically throughout the three harvests (**Table 3**). These concentrations are more than permissible limits recommended by WHO/FAO (**Table 3**). Similar findings to the current study were also reported by Landsberger and Iskander [26] and Oluwole et al. [27] where higher and lower concentrations of zinc in vegetables cultivated along the roadsides were reported respectively. However, zinc has been reported to be an essential element in the human diet as it helps in maintaining the functioning of the immune system but its excess or toxicity could be detrimental to human health [28]. While copper toxicity has been reported to cause anaemia, changes in ossification and Wilson's disease. However, copper has been described as an important element for plants and animals [29].

More so, it could be observed from the results (**Table 3**) that there were metallic uptakes and accumulations by the plant compared to the control and excessive accumulation of these metals in the plant is evident in its growth from the first harvest to the third harvest in the study. This is an indication that effluents should be properly treated before being disposed of into the environment (land or water).

Table 1. Physicochemical analysis of electroplating effluent samples.

Parameters	**Effluents**		**Discharge limit [14]**
	A	B	
pH	4.14	4.87	6.00-9.00
Acidity (as μg L^{-1} $CaCO_3$)	25000	52000	
Alkalinity (as μg L^{-1} $CaCO_3$)	*	*	45
Turbidity NTU	0.86	4.0	
Total Dissolved Solid (mg/w)	17.82	71.67	2000
Total Solid (mg/w)	24.24	100.75	2300
Nickel (μg L^{-1})	65.43	75.70	1.00
Chromium (μg L^{-1})	388.20	10.53	1.00
Zinc (μg L^{-1})	12.32	1.40	1.00
Copper (μg L^{-1})	50.17	11.03	1.00

(*) means Not Found.

Table 2. Effects of electroplating effluent on the growth of *Amaranthus viridis.*

Treatment/Growth parameter	PFW (g)	PDW (g)	pH (cm)	LWR (% total dry weight)	SWR (% total dry weight)	RWR (% total dry weight)	SRR
Control							
Mean ± S.D 1st Harvest	9.01 ± 0.05^{a}	1.08 ± 0.10^{a}	19.50 ± 0.90^{a}	30.73 ± 1.04^{a}	32.78 ± 0.10^{a}	15.41 ± 0.17^{a}	3.78 ± 0.70^{cd}
2nd Harvest	11.77 ± 1.80^{b}	2.00 ± 0.40^{bc}	25.40 ± 0.40^{bc}	45.66 ± 0.29^{c}	35.79 ± 0.30^{ab}	18.54 ± 0.05^{a}	4.40 ± 0.20^{d}
3rd Harvest	14.65 ± 0.22^{d}	2.46 ± 0.12^{d}	30.90 ± 1.10^{d}	51.81 ± 0.11^{d}	48.33 ± 0.81^{d}	20.94 ± 0.30^{ab}	5.40 ± 0.18^{d}
Effluent A (5% Conc.)							
Mean ± S.D 1st Harvest	9.93 ± 0.50a	1.09 ± 0.03^{a}	18.30 ± 0.10^{a}	26.47 ± 0.01^{a}	25.69 ± 0.02^{a}	31.61 ± 0.12^{b}	1.37 ± 0.08^{a}
2nd Harvest	12.03 ± 1.00^{b}	1.58 ± 0.03^{b}	21.15 ± 0.70^{ab}	34.60 ± 0.08^{ab}	31.27 ± 0.08^{ab}	35.24 ± 0.02^{c}	1.84 ± 0.01^{ab}
3rd Harvest	12.06 ± 0.80^{b}	1.69 ± 0.08^{bc}	22.50 ± 1.00^{b}	39.07 ± 0.20^{b}	33.79 ± 0.16^{b}	42.26 ± 0.15^{d}	2.16 ± 0.10^{b}
Effluent A (10% Conc.)							
Mean ± S.D 1st Harvest	7.47 ± 1.80^{a}	1.38 ± 0.05^{a}	18.95 ± 0.10^{a}	36.71 ± 0.13^{a}	48.07 ± 0.24^{d}	36.04 ± 0.10^{c}	3.98 ± 0.70^{cd}
2nd Harvest	8.68 ± 0.30^{a}	1.31 ± 0.10^{a}	20.76 ± 0.40^{ab}	35.23 ± 0.03^{ab}	35.58 ± 0.05^{b}	32.72 ± 0.14^{bc}	2.06 ± 0.07^{b}
3rd Harvest	$10.\ 67 \pm 0.60^{b}$	1.06 ± 0.20^{a}	23.30 ± 0.80^{bc}	28.36 ± 0.05^{a}	30.56 ± 0.02^{a}	16.70 ± 0.01^{a}	1.77 ± 0.30^{ab}
Effluent B (5% Conc.)							
Mean ± S.D 1st Harvest	9.41 ± 0.23^{a}	1.23 ± 0.10^{a}	18.65 ± 0.50^{a}	47.28 ± 0.05^{b}	40.10 ± 0.09^{bc}	33.01 ± 0.02^{b}	3.92 ± 0.66^{cd}
2nd Harvest	11.53 ± 0.16^{b}	1.73 ± 0.03^{b}	21.25 ± 0.45^{ab}	42.62 ± 0.23^{c}	35.99 ± 0.10^{ab}	18.38 ± 0.05^{a}	3.40 ± 0.20^{b}
3rd Harvest	$12.\ 66 \pm 1.30^{c}$	1.75 ± 0.10^{b}	24.40 ± 0.20^{bc}	35.38 ± 0.08^{a}	$31.60 \pm 0.\ 02^{a}$	12.62 ± 0.11^{a}	2.03 ± 0.04^{a}
Effluent B (10% Conc.)							
Mean ± S.D 1st Harvest	11.15 ± 0.40^{b}	1.28 ± 0.08^{a}	18.80 ± 0.01^{a}	$28.\ 31 \pm 0.07^{a}$	43.43 ± 0.29^{c}	32.15 ± 0.001^{b}	3.76 ± 0.16^{cd}
2nd Harvest	9.30 ± 1.00^{a}	1.25 ± 0.20^{a}	21.10 ± 0.20^{ab}	43.30 ± 0.07^{c}	28.26 ± 0.12^{a}	28.25 ± 0.19^{ab}	2.54 ± 0.50^{c}
3rd Harvest	9.67 ± 0.16^{a}	1.20 ± 0.05^{a}	23.95 ± 0.15^{bc}	50.69 ± 0.16^{d}	24.54 ± 0.01^{a}	21.04 ± 0.09^{ab}	2.11 ± 0.66^{ab}

Means ± S.D in the same column that do not have similar letters are significantly different at $P < 0.05$ according to one-way Analysis of Variance (ANOVA-1); PFW = Plant Fresh Weight; PDW = Plant Dry Weight; PH = Plant Height; LWR = Leaf Weight Ratio; SWR = Stem Weight Ratio; RWR = Root Weight Ratio; SRR = Shoot-Root Ratio.

Table 3. Effects of electroplating effluents on heavy metal concentrations in *Amaranthus viridis*.

	1st Harvest				2nd Harvest				3rd Harvest			
Samples	**Zn** µg kg^{-1}	**Ni** µg kg^{-1}	**Cr** µg kg^{-1}	**Cu** µg kg^{-1}	**Zn** µg kg^{-1}	**Ni** µg kg^{-1}	**Cr** µg kg^{-1}	**Cu** µg kg^{-1}	**Zn** µg kg^{-1}	**Ni** µg kg^{-1}	**Cr** µg kg^{-1}	**Cu** µg kg^{-1}
Control												
Leaves	41.65 ± 0.01^{a}	*	1.00 ± 0.90^{a}	30.55 ± 0.05^{a}	55.65 ± 0.10^{b}	*	1.00 ± 0.70^{a}	34.55 ± 0.05^{a}	56.65 ± 0.10^{a}	1.00 ± 0.01^{a}	1.20 ± 0.04^{a}	35.39 ± 0.10^{a}
Stems	38.88 ± 0.01^{a}	*	1.10 ± 0.40^{a}	31.73 ± 0.29^{a}	50.00 ± 0.30^{b}	*	1.10 ± 0.20^{a}	30.90 ± 0.80$_{a}$	52.78 ± 0.40^{a}	*	1.15 ± 0.29^{a}	31.37 ± 0.30^{a}
Roots	36.10 ± 0.01^{a}	*	1.10 ± 1.10^{a}	29.73 ± 0.11^{a}	38.88 ± 0.81^{a}	*	1.15 ± 0.18^{a}	24.10 ± 0.22^{a}	44.42 ± 0.12^{a}	*	1.15 ± 0.29^{a}	30.73 ± 0.01^{a}
Effluent A-5%												
Leaves	91.65 ± 0.50^{bd}	*	500.00 ± 0.10^{b}	34.10 ± 0.01^{a}	88.88 ± 0.02^{c}	*	357.15 ± 0.01^{b}	42.90 ± 0.05$_{b}$	130.55 ± 0.10^{c}	357.15 ± 0.90^{c}	357.15 ± 0.04^{bc}	47.73 ± 0.10^{b}
Stems	72.20 ± 0.22^{bc}	*	485.70 ± 0.70^{b}	54.55 ± 0.08^{b}	50.00 ± 0.08^{b}	*	357.15 ± 0.01^{b}	41.90 ± 0.05$_{b}$	136.10 ± 0.40^{c}	*	428.57 ± 0.29^{c}	34.10 ± 0.30^{c}
Roots	66.65 ± 0.80^{b}	*	357.00 ± 0.03^{b}	40.90 ± 0.20^{c}	41.65 ± 0.16^{a}	168.58 ± 0.01^{a}	428.57 ± 0.10^{bc}	54.55 ± 0.22$_{c}$	86.10 ± 0.12^{b}	*	428.57 ± 0.29^{c}	47.73 ± 0.10^{a}
Effluent A-10%												
Leaves	47.20 ± 0.80^{a}	*	500.00 ± 0.10^{b}	68.18 ± 0.13^{d}	230.55 ± 0.2^{d}	*	214.30 ± 0.70^{bd}	47.30 ± 0.05$_{bc}$	241.66 ± 0.10^{d}	357.15 ± 0.90^{c}	357.15 ± 0.11^{bc}	40.90 ± 0.10^{ab}
Stems	36.10 ± 0.30^{a}	*	485.57 ± 0.40^{b}	61.37 ± 0.03^{d}	69.43 ± 0.05^{bc}	*	357.15 ± 0.07^{b}	40.90 ± 0.40$_{b}$	55.55 ± 0.40^{a}	142.85 ± 0.40^{b}	347.15 ± 0.29^{bc}	40.90 ± 0.10^{ab}
Roots	36.10 ± 0.60^{a}	*	500.00 ± 0.80^{b}	68.18 ± 0.05^{d}	61.10 ± 0.02^{b}	*	357.15 ± 0.07^{b}	34.10 ± 0.22$_{a}$	47.20 ± 0.12^{a}	*	357.15 ± 0.11^{bc}	37.90 ± 0.21^{a}
Effluent B-5%												
Leaves	55.55 ± 0.23^{cd}	*	500.00 ± 0.50^{b}	47.73 ± 0.05^{c}	33.32 ± 0.09^{a}	178.58 ± 0.02^{a}	428.57 ± 0.02^{b}	54.55 ± 0.05^{c}	133.30 ± 0.10^{d}	500.00 ± 0.90^{d}	357.15 ± 0.04^{bc}	61.37 ± 0.10^{d}
Stems	44.42 ± 0.16^{ac}	*	214.30 ± 0.45^{c}	68.25 ± 0.23^{d}	38.88 ± 0.10^{a}	*	258.70 ± 0.20^{d}	47.73 ± 1.80^{bc}	113.87 ± 0.40^{d}	250.00 ± 0.40^{bc}	214.31 ± 0.29^{d}	54.55 ± 0.30^{bc}
Roots	36.10 ± 1.30^{a}	*	500.00 ± 0.20^{b}	34.10 ± 0.08^{a}	36.10 ± 0. 02^{a}	214.30 ± 0.11^{ab}	258.70 ± 0.04^{d}	40.90 ± 0.22^{b}	61.10 ± 0.12^{b}	71.43 ± 0.10^{b}	357.15 ± 0.04^{bc}	61.37 ± 0.10^{d}
Effluent B-10%												
Leaves	47.20 ± 0.40^{ac}	*	500.00 ± 0.01^{b}	54.55 ± 0.07^{b}	91.65 ± 0.29^{c}	107.15 ± 0.01^{c}	158.70 ± 0.16^{d}	47.73 ± 0.22^{bc}	83.32 ± 0.10^{b}	285.70 ± 0.90^{bc}	357.15 ± 0.04^{bc}	54.55 ± 0.10^{bc}
Stems	30.55 ± 0.50^{a}	*	258.70 ± 0.20^{c}	47.73 ± 0.07^{c}	75.00 ± 0.12^{c}	178.58 ± 0.19^{a}	158.70 ± 0.16^{d}	47.73 ± 0.22^{bc}	61.10 ± 0.12^{a}	*	357.15 ± 0.04^{bc}	61.37 ± 0.30^{d}
Roots	27.78 ± 0.16^{a}	*	258.70 ± 0.15^{c}	47.73 ± 0.16^{c}	38.88 ± 0.01^{a}	178.58 ± 0.19^{a}	148.70 ± 0.06^{d}	47.73 ± 0.22^{bc}	61.10 ± 0.12^{a}	142.85 ± 1.10^{b}	357.15 ± 0.04^{bc}	47.73 ± 0.01^{a}
Standard Permissible Limits	60[1]	1.50[1]	2.32	40[3]	60[1]	1.50[1]	2.32	40[3]	60[1]	1.50[1]	2.32	40[3]

(*) means Metal Not Detected; [1]WHO/FAO (Codex Alimentarius Commission. Joint FAO/WHO [30]; [2]WHO (Codex Alimentarius Commission, Joint FAO/WHO [31] and codex alimentarius commission [28]; [3]WHO/FAO (FAO/WHO, codex general standard for contamination and toxin in foods [32]); Means ± S.D (µg kg^{-1}) in the same column that do not have similar letters are significantly different at $P < 0.05$ according to one-way Analysis of Variance (ANOVA-1).

4. Conclusions and recommendation

This research has shown that there were great effects of electroplating effluents on the growth and heavy metals' accumulations and concentrations in *A. viridis*. The results revealed that the effluent affects the growth rhythms of the plant. Also, it showed that plants do take up metals from the soil and surrounding media. Furthermore, it revealed that most of the effluents are either acidic or alkaline in nature, which is toxic to plants. Thus, from all indications, *A. viridis* and many other leafy vegetables may take up heavy metals from the soil through their roots to the stem and then to the leaves. This, therefore, poses a great risk to the consumers of vegetables especially those grown around discharge areas of industrial effluents. However, waste from industries especially those from electroplating companies should be treated and all heavy metals removed or reduced to the required discharge limits before they are released into the environment.

Author Contributions

Oluwole S.O. and Ogun M.L. conceived the idea, Ogun M.L., Tope-Akinyetun, R.O., Asokere S.Y., Ewekeye T.S. and Usamot Q., designed it, Ogun M.L., Asokere S.Y., and Usamot Q., executed it, Oluwole S.O, Asokere S.Y., Ewekeye T.S and Ogun M.L. interpreted the data and Ogun M.L., Ewekeye T.S., Asokere S.Y. and Tope-Akinyetun, R.O. wrote the manuscript.

Conflict of Interest

All Authors declare no conflict of interest.

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