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Effect of Pharmaceutical Effluent on the Growth of Crops in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author DTO designed the study and wrote the protocol. Author AAO wrote the first draft of the manuscript, performed the statistical analysis and managed the literature searches. Author COO managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Environmental pollution constitutes a great health hazard to human, animals and plants with local, regional and global implications. Pollution has adverse effects on land, water and its biotic and abiotic components. Effluents from industries are normally considered as the main industrial pollutants containing organic and inorganic compounds.

This experiment was conducted under laboratory condition to investigate the effect of different heavy metals in pharmaceutical effluent on germination and growth of okro (*Abelmoschus esculentus*) and tomato (*Lycopersicon esculentum*) seed. The effect of these effluents was compared with control water. The soil on which the plants were grown was analysed. A control sample watered with de-ionised water was also analysed. The plant

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samples were divided into stem, root and leaf prior to digestion and analysed. The soil and plant samples were digested by wet-oxidation technique and analysed for heavy metals by atomic absorption spectrophotometer (AAS). Lead, Cadmium, Chromium, Zinc, Copper, Nickel and Iron concentrations were found in tomato (*Lycopersicon esculentum*) and okro (*Abelmoschus esculentus*) plants watered with different concentrations of pharmaceutical effluent. The results stated that the industrial effluents significantly affect germination; root, stem and shoot elongation of the investigated crops with the highest concentration found in the root of the investigated plants when compared to the stem and leaf. Hence, it can be concluded that effluents from pharmaceutical companies is toxic to life.

Keywords: Pollution; effluent; Okro; tomato; heavy metals.

1. INTRODUCTION

Pollution of the biosphere by heavy metals due to industrial, agricultural and domestic activities has be considered to be a global problem owing to its serious effects on all forms of life and exposed materials [1,2]. Pollution of the land occurs from various degradable and non-degradable materials. These materials may be solid waste, trash or chemicals. Heavy metal pollution serves as a great threat to the biosphere due to the fact that they cannot be degraded, rather they persist and are accumulated, hence pose severe effects on humans, animals and plants. They can cause adverse toxic effects on the plants growing in the affected area leading to a decrease in agricultural productivity. Moreover, due to high cost and scarcity of chemical fertilisers, the land disposal of agricultural, municipal and industrial waste is widely practiced as a major and economic source of nutrients and organic matter for growing cereal crops by poor farmers in Pakistan [3,4]. The use of waste water in irrigation system definitely provide some nutrients to enhance the fertility of soil, it also deposits toxicants that change soil properties in the long run. This necessitates a detailed scientific study before any specific waste can be used for irrigation for a particular crop and environmental conditions. Different crop species may have different tolerance to various pollutants. Seed germination and plant growth bioassays are the most common techniques used to evaluate phytotoxicity [5]. The present study was designed to assess the impact of heavy metals in pharmaceutical effluent on germination and growth of okra (*Abelmoschus esculentus*) and tomato (*Lycopersicon esculentum*).

2. MATERIALS AND METHODS

The soil on which the studied plant was grown was taken from egbejila village, airport road, Ilorin with co-ordinates latitude 08º25.535' N and longitude 004º29.885'. The soil samples were air dried to remove moisture content. After drying, the samples were crushed with a clean, dry mortar and pestle then sieved through a 2-mm sieve to fineness. Three (replicates) of tomato, okra and pepper were small buckets and watered with ordinary water for 5 weeks before wetting with different concentration (0%, 1%, 5%, 10%, 20%, 30%, 40%) of untreated effluent gotten from a pharmaceutical company. The vegetables were planted between December, 2014 and March, 2015. The different plant samples were harvested and sliced into chips using knife rinsed with nitric acid and air dried for 3-4 days. The samples were ground and sieved with a 2 mm sieve prior to digestion [6].

2.1 Digestion of Soil and Plant Samples

1 g of sieved soil samples were weighed into digestion flask. 10 ml of 1:1 HNO_3 was added to the digest. The sample was heated to 95°C ± 5°C and refluxed for 10-15 minutes without boiling. The sample was allowed to cool and 5mL of concentrated HNO_3 was added and refluxed for another 30 minutes. The step was repeated by addition of 5ml of conc. HNO_3. The solution was evaporated to approximately 5 ml without boiling by heating for two hours, the sample was cooled, 2 ml of water and 3 ml of 30% H_2O_2 were added. The vessel was covered with a watch glass and the peroxide reaction was initiated. 1-ml of 30% H_2O_2 was continuously added with warming until the effervescence was minimal. The sample was covered with a ribbed watch

glass device and the acid peroxide digestate continued until the volume was reduced to approximately 5 ml. After cooling, the digestate was diluted to 100 ml with water. 10 ml conc. HCl was added to the sample digest and covered with a watch glass. The sample was placed on the heating source and refluxed at 95°C ± 5°C for 15 minutes. The digestate was filtered through Whatman No. 41 filter paper and the filtrate collected in a 100-ml volumetric flask, made to the volume before analysing by FLAA [7].

3. RESULTS AND DISCUSSION

The mean concentrations of heavy metals (chromium, cadmium, iron, copper, nickel, lead and zinc) in *Abelmoschus esculentus* stem, leaf and root are presented in tables 1 to 3. The samples gave a range concentration value of the 7 elements. The concentrations of the heavy metals in the various samples from the sites were detected using Atomic Absorption Spectrophotometer.

Generally, it is observed that the concentration of all the metals was increasing with increasing concentration of untreated pharmaceutical effluent (Tables 1-3). Considering the control plant (Table 4), the concentration of heavy metals was significantly low.

The use of many plants for food is often limited by the composition of heavy metals in them as they pose dangerous effects in both man and animals [8]. Heavy metals are environmental pollutants, and their toxicity is a problem of increasing significance for ecological, nutritional, evolutionary, and environmental reasons. The term “heavy metal” refers to any metallic element which has a relatively high specific gravity (typically five times heavier than water) and is often toxic or poisonous even at low concentrations. This group of heavy metals includes lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), zinc (Zn), chromium (Cr), arsenic (As), silver (Ag), and the platinum group elements [9]. Some of the heavy metals (Fe, Cu, and Zn) are known to be essential for plants and animals [10]. Other heavy metals such as Cu, Zn, Fe, Mn, Mo, Ni, and Co are essential micronutrients [11], excess uptake of which by plants results in toxic effects [12,13].

Cu is an essential micronutrient, exposure to excess Cu has a detrimental effect on plant growth. In the table above, the concentration of Cu was high in the root compared to the stem and leaf of *Abelmoschus esculentus*. Marschner [14] reported that Cu tends to accumulate in the root tissue of plants and simultaneously translocate to the shoots. The concentration of Cu in the root tissue of *Abelmoschus esculentus* ranges between 120.5 to 492.75 mg/kg which is far above the range of 80-100 mg/kg suggested by Marschner [14] as a general critical concentration for Cu toxicity. The effect of Cu toxicity on root morphology is similar to that of chromium toxicity [15]. Both affect root proliferation and reduce root hair formation and hence, affect nodulation. Similarly, iron is an essential micronutrient and the third most limiting nutrient for plant growth and metabolism, primarily due to the low solubility of the oxidised ferric form in aerobic environments [16, 17]. The concentration of iron in *Abelmoschus esculentus* was generally high in the root compared to the stem and leaf and consequently above optimal level [18]. Iron toxicity promotes the formation of reactive oxygen-based radicals, which are able to damage vital cellular constituents (e.g., membranes) by lipid peroxidation which are often characterised by bronzing (coalesced tissue necrosis), acidity, and/or blackening of the roots [19].

Tables 5 to 7 presents the mean concentrations of heavy metals (chromium, cadmium, iron, copper, nickel, lead and zinc) in *Lycopersicon esculentum* stem, leaf and root.

From the Tables (5-7) above, it is observed that the concentration of the metals increased with increasing concentration of the effluents in the entire samples (stem, leaf and root) with the root being highest. All the investigated heavy metals are significantly higher than the tolerable values for plants [18].

Lead is a major environmental pollutant of world-wide concern that accumulates in soils [20]. It is known to exert its toxic effect on plants by causing a rapid inhibition of root growth, probably due to the inhibition of cell division in the root tip [21]. It has been reported to have similar mechanism in several plants species, including *Triticum aestivum* [22,23], *Z. mays* L. [24], *Pisum sativum* [25]. This effect on root growth has been shown to be similar to that of nickel toxicity [26,27].

Table 1. Mean Concentration of heavy metals in *Abelmoschus esculentus* Stem

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% OS	16.50±0.13	26.25±0.25	201.00±0.04	3.33±0.31	11.00±0.31	7.50±0.13	2.88±0.13
10% OS	32.88±0.34	54.50±0.34	319.50±0.34	8.00±0.13	10.75±0.55	9.25±0.13	3.63±0.34
20% OS	52.88±14.33	76.38±0.34	393.50±0.21	8.63±0.13	13.02±0.34	11.25±0.25	3.88±0.34
30% OS	69.38±0.125	84.38±0.125	578.88±0.13	10.38±0.34	14.50±0.13	12.63±0.13	5.00±0.13

Table 2. Mean Concentration of heavy metals in *Abelmoschus esculentus* Leaf

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% OL	105.75±0.34	133.25±0.21	325.63±0.13	3.88±0.33	13.75±0.44	11.50±0.21	6.38±0.13
10% OL	163±0.45	138.75±0.13	477.63±0.13	8.50±0.13	14.75±0.34	12.75±0.34	7.87±0.45
20% OL	238.50±0.45	254.25±0.74	545.25±0.31	8.77±0.13	15.75±0.34	13±0.25	8.58±0.15
30% OL	376.75±0.21	355.00±0.76	851.75±0.25	9.13±0.34	26.25±0.25	13.75±0.13	9.13±0.34

Table 3. Mean Concentration of heavy metal in *Abelmoschus esculentus* Root

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% OR	112.63±0.13	120.50±0.12	314.75±0.10	4.13±0.21	15.21±1.55	12.25±0.25	7.75±0.34
10% OR	162.75±0.34	205.5±0.13	343.25±0.13	8.5±0.21	15±0.25	13±0.34	8.5±0.21
20% OR	251.38±0.13	196±0.13	701.25±0.13	9.5±0.13	16±0.13	13.75±0.13	8.875±0.34
30% OR	451.25±0.21	492.75±0.13	917.75±0.21	10.25±0.26	17±0.26	14.458±0.26	9.75±0.25

Table 4. Mean Concentration of heavy metal in control plant

Sample	Concentration(Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
0%BR	16.25±0.13	23.50±0.13	182.88±0.13	2.63±0.13	10.75±0.25	2.63±0.21	2.25±0.13

Table 5. Mean Concentration of heavy metal in *Lycopersicon esculentum* stem

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% TS	8.50±0.13	21.75±0.13	175.13±0.21	2.25±0.25	9.75±0.13	8.38±0.13	2.38±0.13
10% TS	67.13±0.21	46±0.13	279.50±0.25	5.25±0.21	12.92±0.53	10.13±0.13	2.63±0.13
20% TS	35.25±0.21	63.88±0.13	367.50±0.13	6.00±0.21	13.63±0.21	11.88±0.33	3.63±0.13
30% TS	39.25±0.50	70.25±0.13	455.96±0.38	7.00±0.34	14±0.25	13.29±0.26	3.88±0.21

Table 6. Mean Concentration of heavy metal in *Lycopersicon esculentum* leaf

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% TL	112.63±0.13	101.38±0.19	147.75±0.21	3.75±0.13	12.50±0.25	12.25±0.13	5.25±0.34
10% TL	155.38±0.19	127.63±0.21	251.25±0.13	4.88±0.45	13.88±0.13	12.88±0.34	6±0.13
20% TL	225.5±0.21	81±0.13	362.63±64.84	5.25±0.25	14.25±0.21	12.75±0.34	7.75±0.21
30% TL	360.25±0.03	298.25±0.21	418.25±0.13	6.63±0.65	14.88±0.13	13.88±0.13	8.25±0.13

Table 7. Mean Concentration of heavy metal in *Lycopersicon esculentum* root

Sample	Concentration (Mean±SD)						
	Zn(mg/kg)	Cu(mg/kg)	Fe(mg/kg)	Cr(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	Cd(mg/kg)
5% TR	113.13±0.21	102.00±0.13	148.50±0.21	3.88±0.13	12.63±0.21	12.63±0.13	5.38±0.13
10% TR	157.88±0.13	129.50±0.21	262.63±0.13	4.75±0.25	14.25±0.44	14.58±0.19	6.13±0.34
20% TR	220.25±0.38	251.75±0.58	252.42±0.26	5.63±0.13	14.75±0.13	14.38±0.21	7±0.13
30% TR	363.75±0.34	298.25±0.13	455.50±0.13	7.25±0.21	15.13±4.30	14.75±0.25	8.63±0.13

4. CONCLUSION

From the present study it could be concluded that the effluent from pharmaceutical companies are toxic to life and consequently affect the growth of plants. All the studied metals are significantly higher in concentration compared to the control group and as well higher than the permissible limit by world health organisation. The increase in the concentrations of these elements from the control might be as a result of their presence in soil and pharmaceutical effluent as well as the plant itself.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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