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Effects of Heavy Metal Content in the Fish Pond Soil Around Cassava Processing Area in Oja Oba, Igboora

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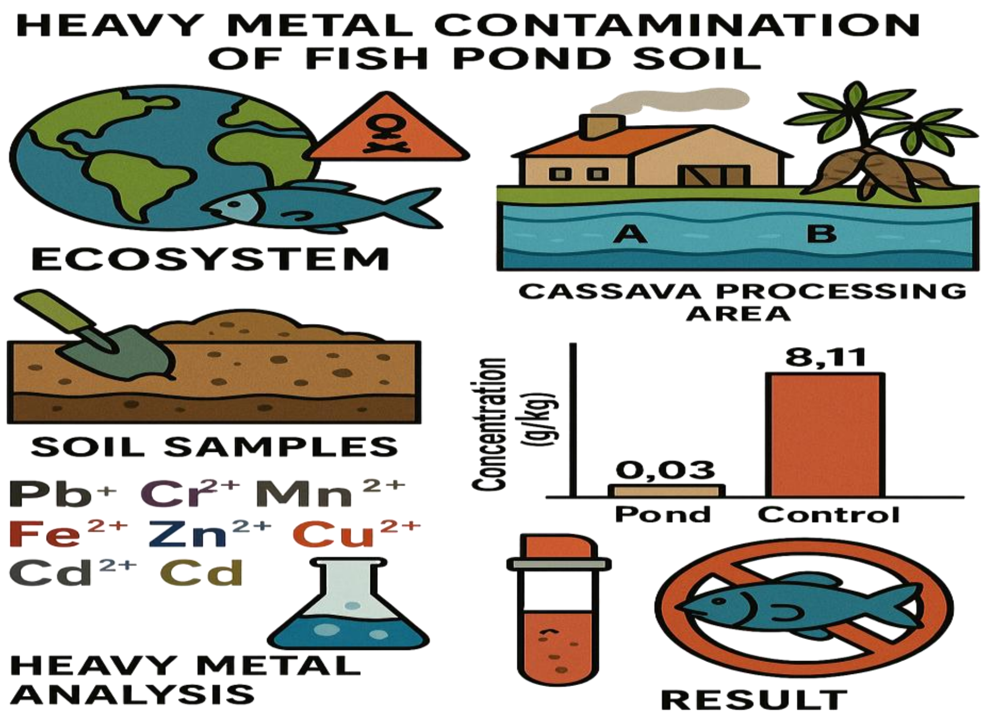
Abstract

Heavy metal contamination and bio-accumulation in ecosystem is of great concern to human existence on earth. As human population increases, knowledge in science and technology increases, these increase exposure of living organisms to adverse effects of pollution due to heavy metals. This research was designed to access heavy metal present in the fish pond soil within the cassava processing area in Oja Oba, Igboora. This research was carried out at Oja Oba cassava processing area in Igboora. Soil samples were taken at dry fish pond within the experimental site. The pond is 6m wide and has a shallow depth of 0.91m. The fish pond was partitioned into two (A, B), C is a sixty meter (60m) outside the pond which represented control area. Twenty-one soil samples taken were analyzed for heavy metal content in a recognized laboratory. Heavy metal analyzed were lead (Pb^{2+}), copper (Cu^{2+}), chromium (Cr^{3+}), iron (Fe^{2+}), manganese (Mn^{2+}), zinc (Zn^{2+}), cadmium (Cd^{2+}). Soil sample taken at side B of the pond at 4-6m range produced the highest significant lead (Pb^{3+}) concentration of 8.11g/kg. The control produced the lowest significant lead (Pb^{3+}) concentration 0.03g/kg. And due to high content of heavy metals in the pond, as recorded in the result of the soil analysis, it can be concluded that rearing of fish and consumption of fish reared in the pond is injurious to human being. Effluent treatment is also recommended for safety.

Keywords: *Contamination, Bio-accumulation, Heavy metals, Ecosystem, Processing*.

Graphical Abstract



1.0 INTRODUCTION

The word heavy metal can be classified as a group of metallic elements with high atomic weights and densities, which makes them dense and highly toxic [1]. Some of these heavy metals include lead, copper, cadmium, mercury, arsenic, chromium, and chromium [2]. They occur naturally in the earth [3]. Metals have wider usage in industrial and manufacturing processes, and human activities, such as agriculture, smelting, and mining [4]. These various human activities can lead to the release of heavy metals into the environment [5]. When heavy metals enter the ecosystem, they can accumulate in living organisms, including fish and other aquatic organisms, posing significant health risks to human and animal populations that consume them [6]. Heavy metals can have a range of toxic effects on human health, including damage to the nervous system, reproductive system, and kidneys, among others [7]. A continuous exposure to heavy metals can cause many obnoxious health challenges such as cancer, developmental problems in children and neurological disorders. Therefore, any potent means to assess and manage to reduce heavy metal contamination within the environment is considered critical for human health and environmental sustainability [8].

There are researches with convincing proofs that environmental physical, chemical, biological processes, and many anthropogenic activities that produce industrial and domestic effluents have devastated effect on aquatic environmental condition [9; 10]. The release of heavy metals are aided by weathering of rock and stone, distributed by running water and strong wind [11]. The spread of heavy metals are more rampant in the biosphere as a result of increase in human population that brings increased urbanization, industrial revolution, improved scientific and technological innovation. Much of these pollutants found their way into aquatic ecosystems and some into the atmosphere as particulate substances [9; 11]. These pollutants stay long in our environment, are non-biodegradable and pose a negative health impact to human beings. According to Pichhode et al. [10; 12], these heavy metals bio-accumulate rapidly in human body such as muscular tissue [6; 12]. Heavy metals are regularly washed into natural water and poison this aquatic environment [13]. As these pollutants increases in concentration in natural ecosystems, it alters the physical and chemical conditions of the ecosystem, until when it reaches a certain threshold level that causes death to the living component of the ecosystem [8; 13].

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Contaminants of this type disrupt a variety of physiological and biochemical pathways in fish and other aquatic animals [1; 14]. Every chemical substance at a lethal dose has ability to affect animals by causing damages at cellular or tissue level, and thereafter manifests itself in morphological or behavioral abnormalities [15]. Wastes generated from the bulk usage of agrochemicals by commercial farms, and proliferated industrial operations, found their way into natural freshwater sources, causing damages to soil and aquatic ecosystem [15]. It is imperative to effectively convert these harmful wastes to a more harmless and biodegradable wastes that will be naturally eco-friendly without any negative impact on living organisms [16]. Primary producers in aquatic environmental in form of phytoplankton and zooplankton serves as natural binders to heavy metals and eventually bio-accumulate in fish species and other aquatic creatures, that feed on them [13, 16]. Fish have structural capacity to accumulate heavy metals above the concentration of the surrounding environment [17]. The objective of this study is to provide a comprehensive assessment of heavy metal contamination in the fish pond soil around cassava processing area in Oja Oba, Igboora.

2.0 MATERIALS AND METHODS

2.1 Experimental Site.

The study was carried out at Oja Oba cassava processing area in Igboora. The town is located in Ibarapa area of Oyo State, Nigeria, West Africa.

2.2 Soil Sample Collection

Soil samples were taken at a dry fish pond within the experimental site. The pond is 6m wide and has a shallow depth of 0.91m. The soil samples containing decaying plants were collected at different points using soil auger, at 0-10cm deep. The fish pond was rectangular in shape. The two long length was marked as A, and B sides. Different soil samples were taken at interval of 0-2m, 2-4m, and 4-6m at both sides A and B of the pond. Eighteen soil samples were taken at both sides of the pond. The remaining three soil samples were taken at 60m away from the pond, as control. The soil samples collected were taken to the laboratory for heavy metal analysis. The observed flow limit area of effluent at the sampling site enabled the choice of 60 M for the control soil sample collection. This goes beyond the reach of cassava effluent flow.

Cassava plant has been reported by many Researchers as a good phyto-remediator for heavy metal polluted soil [1, 9, 13, 14]. This has prompted the choice of this cassava processing area for soil collection.

2.3 Soil samples analysis

Twenty-one soil samples taken were analyzed for heavy metal content in a recognized laboratory. The soil samples were grounded using mortar and pestle to powdery form. The powdered soil samples were thereafter digested for determination of heavy metal quantity. The digested soil samples were analyzed using atomic absorption spectrophotometer (AAS) (model ZA – 3300), for determination of the level of heavy metals present. Heavy metal analyzed were lead (Pb^{2+}), chromium (Cr^{3+}), manganese (Mn^{2+}), iron (Fe^{2+}), zinc (Zn^{2+}), copper (Cu^{2+}), and cadmium (Cd^{2+}).

2.3.1 Digestion of soil samples for heavy metal analysis

Each of the soil samples was oven dried at 45^0C for 5 hours and ground into powder using mortar and pestle. These three chemicals; HNO_3 at 70%, H_2SO_4 at 70%, and $HClO_4$ at 65% were mixed together in 5:1:1 respectively. A 15 mL of the mixture was poured into a beaker containing 1g of the powder soil sample. The beaker content was heated at a temperature of 80 °C until clear solution was formed. The solution was allowed to cool and filtered. Thereafter, diluted to a volume of 50 mL using deionized water. An inductively coupled plasma-optical emission spectrometer was used in order to determine the concentrations of several heavy metals (including Mn, Fe, Cu, Zn, Pb, and Cd) that were present in the digested samples.

2.4 Experimental Design

There were seven treatments, replicated three times. In this, soil samples were collected between 0-2m, 2-4m and 4-6m at both sides of the pond. Within each 2m division, three soil samples were collected at 60cm point apart at three different points. At side A of the pond, nine soil samples were collected. Also, at side B of the pond, nine soil samples were collected as well. Then, three soil samples were taken at point C which is the control (60m away from the pond). There were twenty-one soil samples collected from all. The treatments represented different distance range of 0-2m, 2-4m, 4-6m (each for pond bottom side A and B), and 60m for control soil collection. While, the replicates represented the 60cm distance points of soil collection within each treatment (samples taken at 3 points of 60cm apart).

2.5. Statistical analysis

All the values obtained were subjected to analysis of variance (one way, ANOVA), using Statistical package for social science and mean separated by Duncan multiple range test, with significant difference level of P = 0.05.

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3.0 RESULTS AND DISCUSSION

Table 1: Analysis of Lead, Chromium, Manganese, and Zinc in fish pond soil.

TREATMENT	LEAD (Pb) mg/kg	CHROMIUM (Cr) mg/kg	MANGANESE (Mn) mg/kg	ZINC (Zn) mg/kg
A (0-2M)	1.24c	1.55c	22.29d	16.63e
A (2-4M)	1.46c	1.47c	29.68c	27.79d
A (4-6M)	3.77b	10.21b	57.86b	134.04a
B (0-2M)	3.82b	10.52b	59.33b	121.51b
B (2-4M)	3.45b	11.27b	54.96b	133.56a
B (4-6M)	8.11a	14.83a	105.55a	133.91a
CONTROL	0.03d	0.34c	4.87e	42.51c

Means with the same letter are not significantly different using Duncan Multiple Range Test (DMRT) at 5% probability level.

Table 2: Result analysis of Iron, Copper, and Cadmium in fish pond soil

TREATMENT	IRON (Fe) mg/kg	COPPER (Cu) mg/kg	CADMIUM (Cd) mg/kg
A (0-2M)	22.63e	28.43b	0.34e
A (2-4M)	57.72d	21.53c	0.86d
A (4-6M)	157.79b	24.28c	1.25c
B (0-2M)	110.33c	31.28b	1.15c
B (2-4M)	145.73b	30.23b	1.42b
B (4-6M)	261.17a	55.72a	2.20a
CONTROL	26.41e	17.49d	0.88d

Means with the same letter are not significantly different using Duncan Multiple Range Test (DMRT) at 5% probability level.

Table 3: WHO and USEAP standard for heavy metals in fish pond grass

Heavy metals	WHO (2018)	USEPA (2019)
As(iii) As(v)	0.05	0.01
Pb	0.05	0.015
Cd	0.005	0.005
Cr	0.05	0.05
Hg	0.001	0.002
Zn	5.0	5.0
Cu	1.5	1.3
Co	0.01	_
Fe	0.03	0.3
Mn	0.3	0.05

3.1 Heavy metal content present in the fish pond soil

The control produced the lowest significant lead (Pb^{2+}) concentration 0.03mg/kg. However, soil sample taken at 4-6m range from side A and, 0-2M and 2-4m range from side B of the pond at 4-6m range produced the highest significant lead (Pb^{2+}) concentration of 8.11mg/kg. Also, side B produced 3.77mg/kg, 3.82mg/kg and 3.45mg/kg respectively. The control produced the lowest significant chromium (Cr^{3+}) concentration of 0.34mg/kg. Moreover, soil sample taken at 4-6m range from side B produced 10.21mg/kg, 10.52mg/kg and 11.27mg/kg respectively. Side B of the pond at 4-6m range produced the highest significant chromium concentration of 14.83mg/kg.

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While, the same side B of the pond at 4-6m range has the highest significant Manganese concentration of 105.55mg/kg. The control produced the lowest significant Manganese concentration of 4.87mg/kg. The highest mean level of Zinc (Zn^{2+}) was recorded as 134.04mg/kg. Whereas the sample taken at side A (0-2m) produced the lowest significant Zinc concentration of 16.63mg/kg.

However, chromium has highest concentration of 14.83mg/kg at 4-6M, lowest value of 0.34mg/kg at control area. Manganese has highest value of 105.mg/kg at 4-6M, lowest value of 4.87mg/kg at control. While, Zinc has highest value of 133.91 at 4-6M, and lowest value of 42.51mg/kg, at the control area as well.

3.2. Analysis of Iron (Fe^{2+}), Copper (Cu^{2+}), Cadmium (Cd^{2+})

Soil sample taken in side B of the pond at 4-6m range has the highest significant iron (Fe^{2+}) concentration of 261.17mg/kg. The side A of the pond at range 0 -2m has the lowest significant iron (Fe^{2+}) concentration of 22.63mg/kg. The highest means level of copper (Cu^{2+}) was recorded at side B (4-6m) with 55.72mg/kg. Control produced the lowest significant copper (Cu^{2+}) concentration of 17.49mg/kg. The concentration of cadmium at side A 0-2m produced the lowest significant. However, soil sample taken at side A (4-6m) and side B (0-2m) range produced 1.25mg/kg. While the side B (4-6m) of the pond produced 2.20mg/kg as the highest concentration of cadmium.

4.0. CONCLUSION

The pond soil samples analyzed for heavy metals, shown high contents of these metals, above the permissible levels in the soil (Cu2+, 55.72mg/kg; Fe^{2+}, 261.17mg/kg; Cd^{2+}, 2.20mg/kg; Pb^{2+}, 8.11mg/kg. There permissible level has recorded by WHO were 1.5mg/kg; 0.03mg/kg; 0.005mg/kg; and 0.05mg/kg respectively. This could be as a result of exposure of the land farmland to heavy metal pollution, where the cassava plants were raised. It may also come from the available water that was used for its processing. The different concentration of heavy metals recorded at different distance, might be as a result of undulating nature of the pond bottom surface that enabled unequal settling of effluent in the pond. This result shows that the products of this cassava are not safe for human consumption. There is likelihood of the finished products to have high content of this heavy metal ready to be transferred to its consumers. Any water run off during rainy season will carry these heavy metals contained in the cassava effluents into streams and rivers, to bio-accumulate in living organisms. The heavy metal contamination of the pond is higher than permissible recommendation by both WHO and USEAP. Bioremediation is therefore recommended for cleaning the area of heavy metal pollution. The cassava effluent must equally be treated before discharge into the environment.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research paper

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Authors' Contribution.

Johnson Oladele Popoola, the corresponding author, was responsible for the conceptualization and design of the research, in addition to the initial drafting and final review of the manuscript. Ayanwusi Kayode Akanji contributed to the study's methodology by supervising the field work and sample collection, and he also provided critical review and editing of the manuscript. Adewole Adedokun performed the essential laboratory analysis of the soil samples and helped with the data analysis and interpretation of the results. Lastly, Patrick Adeyemi Oyekan offered his expertise in soil and water engineering, assisting in the experimental design and contributing to the review of the final manuscript.

Authors' Declaration

The authors affirm that the content of this manuscript is original, has not been published elsewhere, and is not under consideration for publication in any other journal. The authors accept full responsibility for the integrity and accuracy of all data and interpretations presented herein.

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