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# The Impact of Agrochemicals on Heavy Metal Concentrations in Agricultural Soil

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## Abstract

Concentration of six heavy metals (Cu, Cr, Ni, Cd, Zn and Pb) were studied in the soils around Fadama area in Argungu Local Community, Kebbi State, Nigeria to assess heavy metals contamination distribution due to agricultural activities. Soil samples were collected at a depth of 0-15 cm in Fadama agricultural areas and the Fallow ground. The soil samples randomly obtained were subjected to wet digestion and the concentration of total metal was determined using the convectional Atomic Emission Spectroscopy (AES). Overall concentrations of Cd, Cr, Ni, Pb, Cu and Zn in the soil samples ranged from 0.01-0.06, 0.03-3.11, 0.69-2.40, 0.29-3.33,0.65-7.02 and 0.95-22.61 mg/kg respectively. The concentration of heavy metals in the soil display the following decreasing trend: Zn>Cu>Pb>Cr>Ni>Cd. The Pollution index revealed that Cu and Pb were classes as heavily contaminated in the Fadama areas, 23% of the samples in the Fadama areas are moderately contaminated, while 66% of the samples showed low contamination. Conversely, 100% of the samples collected from the fallow ground showed low contamination levels. Results of combined heavy metal concentration and heavy metal assessment indicated higher metals concentration in the Fadama areas, that could be as a consequence of agricultural activities. Indiscriminate used of agrochemicals in agricultural activities could have negative impacts on the environment, especially pollution loadings which can cause adverse effects in the food chain, natural ecosystems and decreased biodiversity. These indicate that heavy metal contamination especially Cu and Pb, should be taken into account during development strategies to protect the Fadama areas from long term pollution load.

**Keywords**: Agrochemicals, Contamination, Distribution, Ecosystem, Pollution index, Soil.

## Introduction

Environmental toxicity exceeding standard maximum residues limit (MRL) of pollutants have received heightened consideration from notable researchers worldwide [1,2]. Heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), and zinc (Zn) are notorious for causing vast network of environmental and health problems [3,4]. Heavy metals are natural component of the soil system, but activities such as industrial processes, mining, and agriculture could significantly increase their concentration in environmental matrices. Recently, the risk of heavy metals pollution in the environment has been increasing rapidly and creating serious challenge, especially in the agricultural sector, by accumulating in the soil and consequent uptake by plants [5]. The heavy metals contamination problem has become a menace, and the need for radical and practical solutions to reduce the hazards as much as possible has become very imperative.

Heavy metal accumulation has been described as an aggregation of metallic elements in the ecosystem. Plant roots are the essential point of contact for heavy metal ions which are transmitted from the soil. They tend to stabilize and concentrate the pollutants in the soil, therefore reducing their bioavailability. The mechanisms of heavy metals transmission to plants including the various phytoremediation processes are well documented. These metals especially in hyper-accumulator plants are directly transferred to human beings through the food chain causing an array of health issues [6,7].

Recently, due to the rapid advances made in technological breakthrough, the ecosystem and humans have been exposed to various types of chemical toxicants, in particular, pesticides and their residues in environmental matrices [8,9]. Scientists have often defined pesticides as synthesized chemical compounds used in many areas, including in the agricultural sector, to control pests of various kinds [10]. Therefore, pesticide applications are considered as efficient, economical, and effective weapons in integrated pest management systems (IPMs) [11]. The indiscriminate use of pesticides causes their residues to bioaccumulation in food chains and other environmental samples, causing high risk to mammals and other non-target organisms [12]. In addition, the direct or indirect effect of pesticide residues on non-target organisms leads to an imbalance of the surrounding ecosystem [13]. Moreover, the residues of the persistent pesticides especially the organochlorines remain in the plant parts, soil, air, and even penetrate into water [14]. Such residues are considered as one of the most destructive threats the ecosystem faces; these can exist in the environment for a long time, with carcinogenic effects [15].

The adverse health problems caused by toxicants are increasing worldwide due to their penetration and accumulation through the food chain, and their persistence in the ecosystem [16]. Such contaminants can cause a cocktail of acute and chronic diseases in the human body, such as lung cancer, renal dysfunction, osteoporosis, and cardiac failure [17]. Tong *et al*. [18], reported the degree of human health threats posed by heavy metals in China’s urban areas during the period 2003–2009. The results showed the adverse human health risk occasioned by the contamination of heavy metals. The accumulation of heavy metals in internal human tissues can affect the central nervous system, and act as a pseudo-co-factor or promotor of some health problems, such as seizures (epilepsy), headache, and coma. Heavy metal contamination is considered as a serious health threat to both adults and children [19]. Pesticides and their break down products are also hazardous to humans and other living organisms through contaminated food, water, or inhalation of contaminated air [20]. Exposure to pesticides even at low concentration is hazardous to the behaviour and physiology of humans [21].

Again, pesticides are seriously linked with a wide range of diseases, such as hypersensitivity, cancer, asthma, hormonal disturbances and in some cases congenital disabilities, reduce birth weight, and even death [22,23]. It has been reported that without the use of agrochemicals in agriculture more than 50% of agricultural yields will be lost and sustainable food sufficiency difficult to attain. But conversely, the use of these products has also impacted the soil and possibly the environment negatively. The determination of heavy metals in the soil around agricultural sites may give an indication of the extent of contamination and accumulation characteristics of these metals in the environment that will help in understanding the behaviour and fate of these persistent chemicals. This work, therefore, seeks to provide baseline information on the levels of heavy metals concentration in Fadama areas that have been intensively cultivated using agrochemicals which will assist in a scientific assessment of the impact of agrochemicals on public health, agriculture and the environment.

## Materials and Methods

### Sampling site

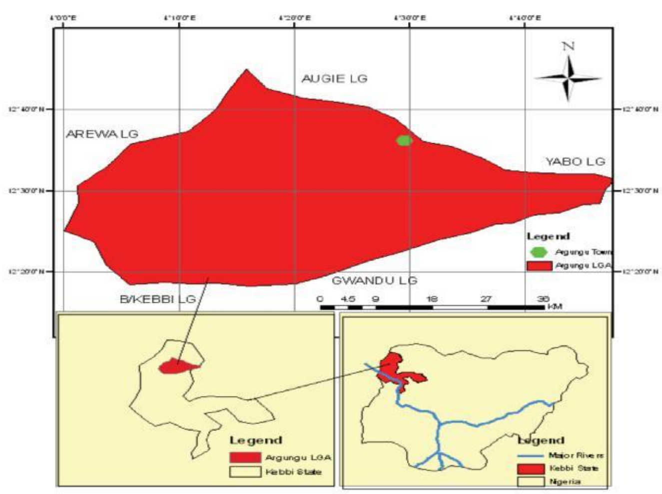


Fig.1 Map of the study area

### Samples Collection

Soil samples were collected in the study areas Fadama Area (Fd) in Argungu LGA, Kebbi State, Nigeria (where continuous agricultural activities are being carried out with the attendant intensive use of agrochemicals including fertilizers and pesticides to promote agricultural yield, and the adjourning fallow sites). A total of nine (9) soil samples were collected. Five from the Fadama site and four from the Fallow ground (FL). Each soil sample was a composite of 10 subsamples collected at each site using random sampling within an established grid Fig 2. The grid was established by identifying the approximate center of a field and dividing the field into 3 rows, 20 paces apart, with 3 core samples taken per row for a total of 10 cores [24]. Soil samples were collected from the 0-15 cm layer using a stainless-steel soil auger. The subsamples were placed into a 16-liter bucket, thoroughly mixed, and sifted through a No.5 (4 mm) brass soil sieve at the collection site. After each sample was collected, the auger, bucket, sieve and mixing tool were rinsed before next use. Five different soil samples were collected at the Fadama agricultural area and four samples collected from the fallow ground that was left uncultivated for period of time. Soil samples were then air dried and sieved through a No.20 (850 µm) brass soil sieve and stored in the laboratory prior to analysis using AES.

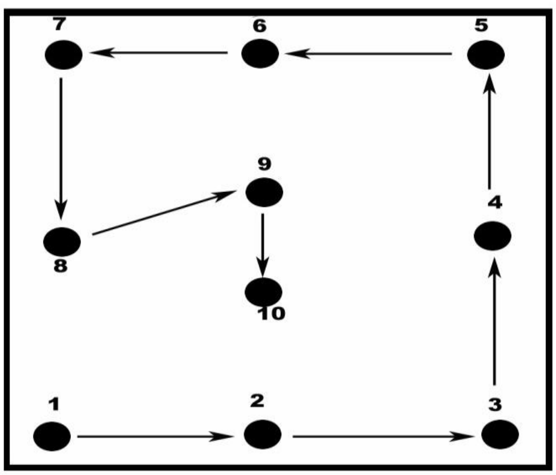


Fig.2 Diagram of composite sampling

**Sample digestion**

The method developed by Shriadah (1999) and modified by Udiba *et al*. [25], was used to extract metals from the soil samples. Soil samples from each plot were thoroughly mixed to obtain a representative sample, air dried, crushed and sieved with 2 mm mesh before wet digestion. One (1.0) g of a well-mixed sample from each sampling point was taken into a 250 $cm^3$ glass beaker and digested with 10 $cm^3$ of concentrated nitric acid, perchloric acid and hydrofluoric acid in the ratio 3:1:1 on a hot plate. After evaporating to near dryness, 10 $cm^3$ of 2% nitric acid was added, filtered through Whatman filter paper into a 50 mL-volumetric flask and then made up to mark with distilled deionized water.

**Heavy metal pollution assessment**

To assess contamination level of heavy metals, a pollution index (PI) of each metal was attributed to each metal using the equation below: [26].

PI = Cn/ Bn

where Cn (mg/kg) is the measured concentration of each heavy metal and Bn is background value for each metal.

The PI of each metal was categorized as PI <1 (low contamination), 1≤ PI <3 (moderate contamination), 3≤ PI <6 (considerable contamination) and PI ≥ 6 (very high contamination).

**Statistical analysis**

Sigma Plot version 11.0 (Systat Software Inc, USA) statistic software was used to analyse the statistical procedure. Shapiro-Wilk test and Levene test were applied to test the normal distribution of the data (p ≥ 0.05). One-way ANOVA (Kruskal-Wallis ANOVA on Ranks in case of non-normality), or two-sample T-test (Mann-Whitney U Test in case of non-normality) was run to find significant differences between groups.

**Results and Discussion**

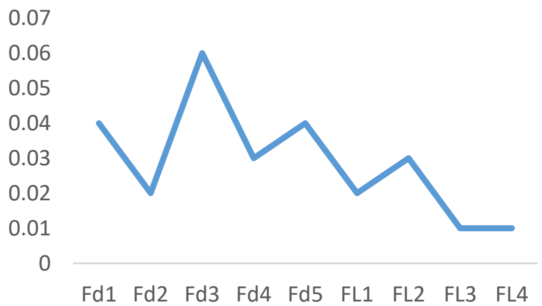


Fig. 3: Conc. of Cd in the Samples (Conc mg/kg)

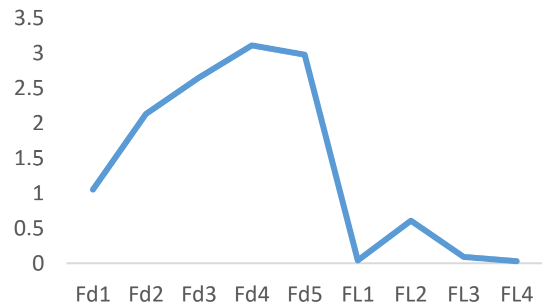


Fig. 4: Conc. of Cr in the Samples (Conc mg/kg)

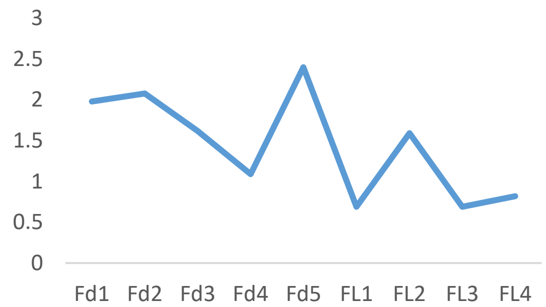


Fig. 5: Conc. of Ni in the Samples (Conc mg/kg)

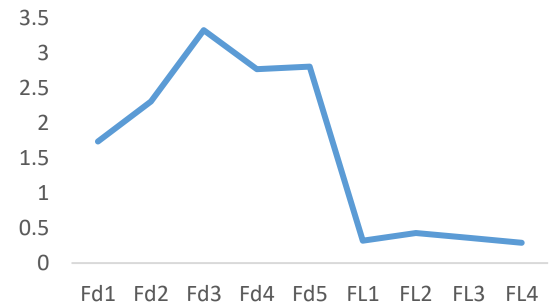


Fig. 6: Conc. of Pb in the Samples (Conc mg/kg)

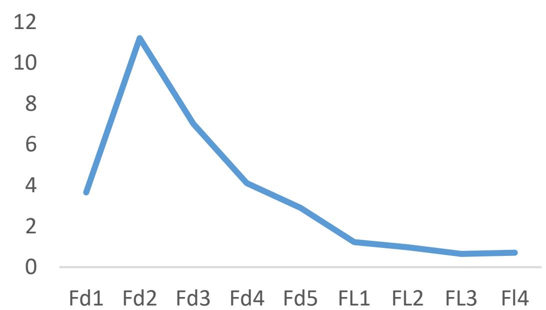


Fig. 7: Conc. of Cu in the Samples (Conc mg/kg)

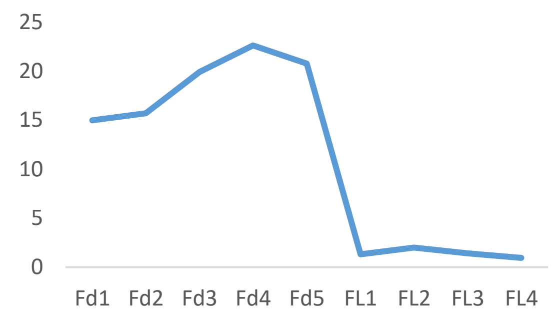


Fig. 8: Conc. of Zn in the Samples (Conc mg/kg)

**Discussion**

The concentration of heavy metals in the soil of Argungu Fadama area and environs are shown in figures 3-8. All the values were compared with the allowable limit as stipulated by FAO/WHO [27] also from Netherlands and China proposed by Wang *et al*. [28,29] since there are no local information available in Nigeria on soil background values for heavy metals concentration [30,29,28]. The maximum concentration of Pb (3.33 mg/kg) level was higher compared with the maximum allowable limit stipulated by FAO/WHO, the Netherlands and China. Thus, critical attention has to be taken in order to control the level of Pb since increased level of Pb may result to a dangerous effect in the future. Meanwhile, Cu, Cr, Cd and Ni are found to be relatively below the maximum limits especially in the fallow sites. Thus, we can summarize that, most of the Fadama area is still in safe level, except for the concentration of Pb which was found to be high within agricultural areas.

The results obtained showed that metals concentration in the Fadama areas were generally higher compared to the fallow sites. This obviously is due to the contributions from the intense agricultural activities going on continuously in these areas and the attendant indiscriminate use of agrochemicals. This result is in agreement with the elegant work reported by Yuan *et al*. [31] in China, who reported corresponding increase of heavy metals concentration in agricultural soil as a consequence of agrochemicals and other additives used in soil enrichment.

Zn generally has the highest values in both soils while Cd has the least and the order observed for this study is Zn>Cu>Pb>Cr>Ni>Cd. According to Hu *et al*. [32], the basic sources of metals polluting fertilizers containing phosphorus are phosphorites used as a source of phosphorus in combination with ground dolomite supplement. Thus, the elevated levels of cadmium, chromium and zinc observed in this study could be attributed to source impurities from fertilisers used to enhance crops productivities. Organometallic copper, lead and cadmium are often used as base in many pesticide formulations, these metals component are left as residues in the soil system when the pesticides eventually degrade.

Table 1: Heavy Metals Concentration (mg/Kg) Pollution Index PI of the Soil

| Samples | Cd | Cr | Ni | Pb | Cu | Zn |
|---|---|---|---|---|---|---|
| Fd1 | 0.10 | 0.05 | 0.81 | 1.78 | 2.13 | 0.22 |
| Fd2 | 0.05 | 0.10 | 0.86 | 2.36 | 6.52 | 0.23 |
| Fd3 | 0.15 | 0.12 | 0.67 | 3.40 | 4.08 | 0.30 |
| Fd4 | 0.08 | 0.15 | 0.45 | 2.83 | 2.39 | 0.34 |
| Fd5 | 0.10 | 0.13 | 0.99 | 2.87 | 1.69 | 0.31 |
| FL1 | 0.05 | 0.00 | 0.28 | 0.33 | 0.71 | 0.02 |
| FL2 | 0.08 | 0.03 | 0.65 | 0.44 | 0.57 | 0.02 |
| FL3 | 0.03 | 0.00 | 0.28 | 0.37 | 0.38 | 0.02 |
| FL4 | 0.03 | 0.00 | 0.34 | 0.30 | 0.41 | 0.01 |

NOTE: Fd = Fadama Site. FL = Fallow ground.

The concentration of heavy metals in soil in the study areas is influenced by various sources such as anthropogenic and natural. Thus, a pollution index (PI) was applied to the set of data to discover the possible sources that might influence the different distribution of elements around Argungu Fadama sites. The Pollution index calculated relative to the background values of heavy metals in the soils and the result as shown in Table 1.

Very high contamination PI values (greater than 6) was observed in one sample of Cu, one sample each of Pb and Cu have PI values between 3.4 and 4.08. (Table 1). These indicate that Pb and Cu pollution are considerably serious in the Fadama areas when compare with other elements. About 23% of the samples were found to be moderately contaminated with various metals in the Fadama areas. 66% of the analysed samples from the Fadama areas were found to have low contamination while 100% of the samples from the fallow ground revealed low contamination of the analysed metals. The PI values are generally higher in the Fadama areas than the fallow sites where there are continuous agricultural activities and the application of various farm inputs including fertilisers and pesticides of various grades to improve productivities and yields. This result is in complete agreement with the reports of. Yang *et al*. [31] and Wang *et al*. [28], who reported that agrochemicals used to enhance productivities are the major contaminants of agricultural soils releasing serious detrimental metals in the various environmental matrixes. Again Lu *et al*. [34], reported that farm lands are mostly polluted by anthropogenic emissions. The order of potential ecological harm degree of heavy metal was as follows: Cu > Pb > Ni > Zn > Cr > Cd.

Heavy metals correlation analysis (CA) can be used to determine the similarity of their sources. The correlation analysis results revealed that there is a positive correlation between the six heavy metals. It indicated that the pollution sources of these heavy metals were similar. The correlation coefficients of Cu and Pb ($r = 0.845$, $P < 0.01$), Cr and Ni ($r = 0.713$, $P < 0.01$) were greater than 0.70, which indicated that the pollution sources of Cu and Pb, Cr and Ni may be the same. The correlation coefficients of heavy metals were less than 0.30, like Cu and Ni ($r = 0.100$, $P < 0.01$), Zn and Cr ($r = 0.174$, $P < 0.01$), indicating that these elements were not homologous. Other heavy metals showed moderate correlation, like Cu and Zn ($r = 0.396$, $P < 0.01$), Cr and Cd ($r = 0.411$, $P < 0.01$) indicating that their sources were complex.

**Conclusion**

The analysis of soil samples collected from Argungu Fadama areas and environs showed varied concentration of heavy metals Cu, Cr, Ni, Cd, Zn and Pb. Cr, Ni and Cd concentrations in soil were lower than allowable limit, whereas Cu and Pb concentration exceeded their corresponding values. The results from this study showed that heavy metal concentrations in the soils from the Fadama areas were generally higher than the fallow ground indicating positive input of metals from the agrochemicals used intensively to enhanced productivities in these areas. The assessed pollution index (PI) in the areas showed that some soil samples from the Fadama areas were heavily contaminated by Pb and Cu consequent of fertilisers and pesticides input in farming activities. Consequently, it is imperative to continually assess and monitor the levels of heavy metals in the agricultural environment in order to mitigate the adverse effects of metals toxicity in the food chain and promote sustainable environment. A monitoring network should be established for long-term monitoring of dynamic changes in soil quality, which can provide accurate and up-to-date information for decision-making.

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