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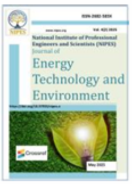
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Evaluation of Heavy Metal Pollution in Farm Soil and Irrigation Water in Yamaltu Deba Gombe State, Nigeria

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Abstract

Heavy metals concentration is worrisome because of its accumulation in the soil, water and food substances. It poses a great threat to human and animals such as lung cancer, liver damage and gastrointestinal distress. Therefore, this study was aimed at investigating the level of heavy metals in farm soil and irrigation water in Yamaltu Deba Gombe State. Samples were appropriately stored, preserved and treated before they were transported for laboratory analysis. Results obtained from the laboratory analysis were analyzed using Microsoft Excel 2013. The mean values were subjected to one-way analysis of variance (ANOVA) at 95% confidence level. The results of this study revealed that the accumulation of heavy metals in farm soil and irrigation water shows the concentration of cadmium, Chromium, Lead, Arsenic, Cobalt, Iron and Cupper were significantly below the WHO permissible limit except for Manganese that recorded highest value in all the sampling point. The results were above the permissible limit. Water samples were also analyzed to determine the accumulation of heavy metals concentrations. Cadmium, Chromium, Lead, Arsenic, Cobalt, Iron and Cupper was found to be in a range of 0.11 to 0.083. The high concentration was recorded at Kunji normal and the lowest in Kanawa control. Even though, they were below the permissible limit of 0.1. Cadmium was undetected in all samples obtained from Kwadom control, Poli normal as well as Poli control. Manganese has highest value above the WHO Permissible limit. In analyzed soil samples, the moisture content, pH, electrical conductivity, cation exchange capacity, and organic matter were found below the permissible limit, except electrical conductivity and organic matter were found to be above the limit. It can be recommended that soil in the study area is good for crop production, the water and vegetables are safe for drinking and consumption.

1. Introduction

Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from rapidly expanding industrial areas, mine tailings, disposal of high-metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, waste water irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition [1].

Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those most commonly found at contaminated sites are: lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni) [2]. Soils are the major sink for heavy metals released into the environment by aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation [3] and their total concentration in soils persists for a long time after their introduction [4]. Changes in their chemical forms (speciation) and bioavailability are, however, possible. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants [5].

Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phytotoxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems [6]. The adequate protection and restoration of soil ecosystems contaminated by heavy metals require their characterization and remediation. Contemporary legislation respecting environmental protection and public health, at both national and international levels, is based on data that characterize chemical properties of environmental phenomena, especially those that reside in our food chain [7]. While soil characterization would provide an insight into heavy metal speciation and bioavailability, an attempt at remediation of heavy metal contaminated soils would entail knowledge of the source of contamination, basic chemistry, and environmental-associated health effects (risks) of these heavy metals. Risk assessment is an effective scientific tool which enables decision makers to manage sites of contamination in a cost-effective manner, while preserving public and ecosystem health [8].

Immobilization, soil washing, and phytoremediation techniques are frequently listed among the best demonstrated technologies (BDATs) for remediation of heavy metal-contaminated sites. Despite their cost effectiveness and environmental friendliness, field applications of these technologies have only been reported in developed countries. In most developing countries, these are yet to become commercially available technologies, possibly due to the inadequate awareness of their inherent advantages and principles of operation. With greater awareness by the governments and the public of the implications of contaminated soils on human and animal health, there has been increasing interest amongst the scientific community in the development of technologies to remediate contaminated sites [9].

Heavy metal contamination of soil poses risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil- plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability), reduction in land usability for agricultural production causing food insecurity, and land tenure problems. Environmental contamination in developing countries is attributed to the negative effects of technological development, like- urbanization, industrialization, and poor planning in waste disposal and management [10]. Sources of contamination include: accidental spills, leaks of chemicals and human activities. Spills, runoff, or aerial deposition of chemicals used for agriculture or industry, materials stored or dumped on the site, contaminants in imported fill and demolition can also result in contamination of the soils and water at residential sites [11]. Activities of humans have added substances such as pesticides, fertilizers and other amendments to soils. Milling operations, together with grinding ores, provide a route for contamination in the surface environment [12]. Burning of fossil fuel, mining and metallurgy, industries, and transport sectors redistribute toxic heavy metals into the environment [13].

The distribution of contaminants released to soils by human activities is related to how and where they are added. Soil contaminants can leach from landfills or other garbage disposal sites, including petroleum products, solvents, pesticides, lead, and other heavy metals [14]. Additionally, electrical and electronic equipment waste contains substantial quantities of materials that can serve as potential environmental contaminants [15]. Certain pollutants are also bioavailable. Furthermore, human activities such as industrial production, mining, agriculture, and transportation release high amounts of heavy metals into surface and ground water, soils, and ultimately to the biosphere. The accumulation of heavy metals in crop plants is of great concern due to the probability of food contamination through the soil-root interface. Although heavy metals like Cd, Pb, and Ni are not essential for plant growth, they are readily taken up and accumulated by plants in toxic forms.

Ingestion of vegetables irrigated with wastewater and grown in soils contaminated with heavy metals poses a possible risk to human health and wildlife. Heavy metal concentration in the soil solution plays an important role in controlling metal bioavailability to plants.

Chemicals are the most important sources of heavy metals in soils [16]. The presence of heavy metals in soil can affect wildlife, plant growth, etc. [17]. These heavy metals may adversely affect soil ecology, agricultural production or product quality, and ground water quality, and will ultimately harm the health of living organisms through the food chain. These effects are closely related to the biological availability of heavy metals, which in turn are controlled by the metal ion speciation in the soil. Therefore, the determination of free metal ion concentrations in soil solution becomes important. The free metal ion concentration not only depends on the total metal content in soils, but also on the metal species that exist in the soil. In addition, some environmental conditions such as pH, concentration of complexing ligands in solution, and the soil colloid [18].

Pollution in the soil environment is a growing problem worldwide, and currently it has reached an alarming rate. There are various sources of heavy metals; some originate from anthropogenic activities like draining of sewage, dumping of hospital waste and recreational activities. Conversely, metals also occur in small amounts naturally and enter into aquatic system through leaching of rocks, airborne dust, forest fire and vegetation. As heavy metals cannot be degraded, they are continuously being deposited and incorporated into water and soil, thus causing heavy metal pollution in water bodies and the surface of the soil. The presence of heavy metals in the water may have a profound effect on the microalgae, which constitute the main food source for bivalve molluscs in all their growth stages, zooplankton (rotifers, copepods, and brine shrimps) and for larval stages of some crustacean and fish species. Moreover, bioconcentration and magnification could lead to high toxicity of these metals in organisms, even when the exposure level is low. Under such conditions, the toxicity of a moderately toxic metal could be enhanced by synergism and the fish population may decline. Apart from destabilizing the ecosystem, the accumulation of these toxic metals in the aquatic food web is a threat to public health and thus their potential long-term impact on ecosystem integrity cannot be ignored [19]. Pollution of fresh water bodies, especially the rivers, is no longer within safe limits for human consumption as well as aquatic fauna. This can be measured through the heavy metal analysis in fish.

Disposal of sewage wastes into a large volume of water could reduce the biological oxygen demand to such a great level that all the oxygen may be removed. This would cause the death of all aerobic species, including fish. The Kohat Nala, locally called Kohat Toi, originates from Hungo. During its flow, it gets contaminated with agricultural, industrial and domestic wastes. Thus, making it unfavourable for aquatic fauna, especially fish and also affecting the water quality and making it hazardous for human households as well as drinking purposes. Its water is stored and this stored water is mostly used for irrigation purposes.

Heavy metal contamination is becoming a serious issue of concern around the world as it has gained momentum due to the increase in the use and processing of heavy metals during various activities to meet the needs of the rapidly growing population. Soil and water are the major environmental compartments which are affected by heavy metal accumulation. Little is known about the susceptibility of accumulating these heavy metals in Yamaltu Deba, Gombe State. Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes. In the aquatic environment, heavy metals are highly persistent, toxic in trace amounts, and can potentially induce severe oxidative stress in the organism. This study aimed to investigate the heavy metals pollution in farm soil and irrigation water and to determine the concentration of heavy metals in the available vegetables found in Yamaltu Deba, Gombe state.

Heavy metals accumulation of farm soil and irrigation water are associated with the emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, waste water irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. The data obtained from this study will be used to help environmental professionals and hydrologist to determine the extent or the effect of heavy metals accumulation in farm soil and irrigation water, as well as the effects of heavy concentration and physicochemical parameters of farm soil and irrigation water to put in place strategies of reducing the high accumulation of heavy metals and too much concentration of physicochemical parameters in farm soil and irrigation water to reduce the effects of these chemicals in soil, crop and vegetables.

2. Materials and Methods

2.1. Study Area

Kwadom District is an area within the Yamaltu Deba Local Government Area of Gombe State. It lies between $10°00^1$, $10°30^1$ and on $11°11^1$E to 11°45E respectively. The study area is located about 7km away from the State Capital, along Gombe-Biu road Figure 3.1. The area under study is part of the extreme tropical continental type of climate. One of the basic characteristics of this climatic zone is its relatively short rainy season and the comparatively long dry season. The beginning and the end of the rainy season change from year to year. It usually begins in late April to early May and ends in late September or early October. The area has a rainfall distribution ranging from 970.7mm to 1.142mm annually, with a mean of 850mm and a mean maximum and mean minimum temperature of 32.8°C and 18.3°C, respectively. The Yamaltu Deba L.G.A occupies a land mass of 1,981km with a postal code of 781 003. The major tribes are Tera and a few minor tribes, such as Fulani, with a few diverse tribes: Kanuri, Hausa, Jara and Waja. Yamaltu Deba has a population of 255,726 (National Population Commission, 2007). Fig. 3.1

The relief of Yamaltu Deba L.G.A comprises part of the upper Benue trough of northern Nigeria. The plain has generally undulating characteristics, especially towards the northern part of Kwadom, where the height of the area is estimated to be 274m above sea level. The area is drained by Wango Stream through Kwadom, Zambuk, down to Dadin-Kowa which is a tributary to the River Gongola. The soils are shallow to deep loamy, sandy, clay, vertisols and cracking clay that have weathered and are very fertile and support intensive agriculture. The soil of the study area is developed on sandstone parent material (Gombe Sandstone). The vegetation of the area is Sudan Savannah; most of the forest cover in the area has been reduced to semi-desert shrubs. The inhabitants of Kwadom are predominantly farmers who depend on this activity for their livelihood, inherited from their forefathers. The geology of the study area is that of Gombe sandstone (Mbaya, 2012). The soil of the study area is typically of ferruginous type. The soil is dark grey colour with pit value ranging from 4 to 6, depending on the location.

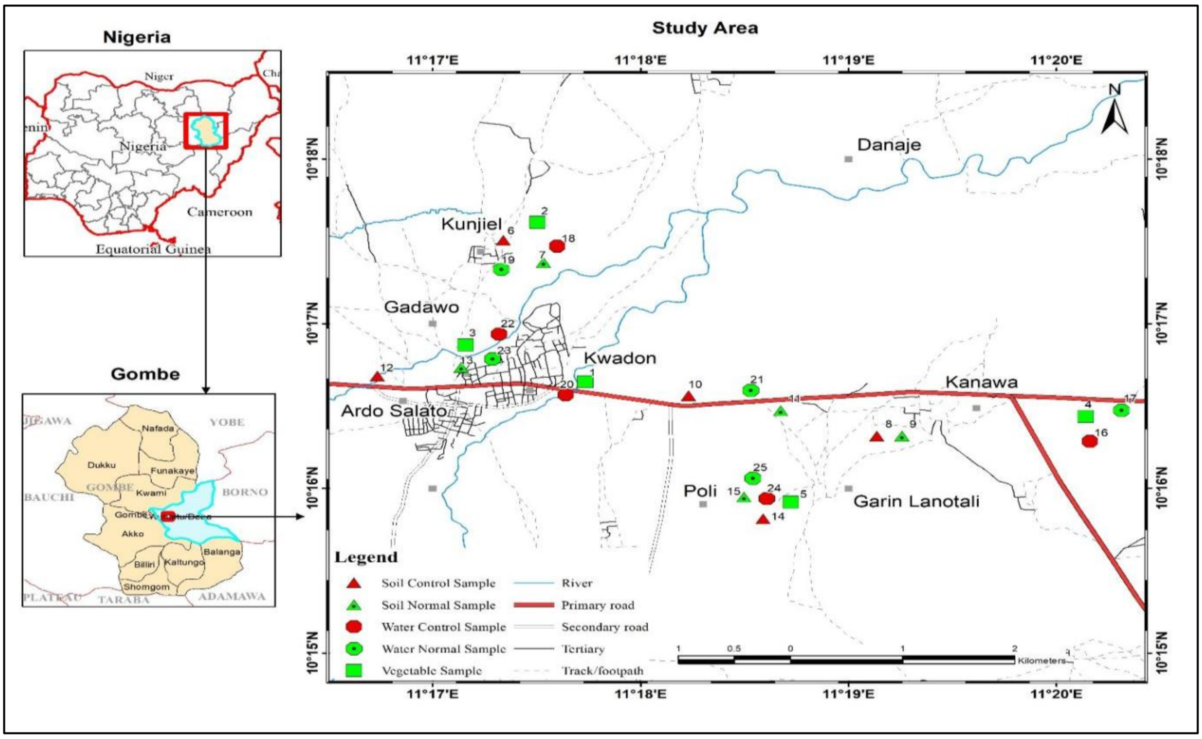

Figure 3.1: Map of the Study Showing Sampling Locations
Source: Department of Geography, Gombe State University, GIS unit. (2021)

2.2 Water Sample Collection

Water samples were collected from irrigation boreholes of five different communities, which include: Kunji, Gadawo, Poli, Kwadom and Kanawa, and 500m away from the irrigation boreholes, which served as control, whose depth varied from 20-35. The water was pumped for 2 minutes and collected into 120 ml sterile bottles. The water was acidified with 2ml of analytical grade nitric acid in all the samples used for heavy metal analysis to preserve metals and avoid precipitation as performed [20]. A total of ten (10) different samples were collected for the study. The water samples were chemically analysed using standard methods [21]. The water was labelled according to the source and region from which they were obtained. The water samples were stored at 5^0C temperature awaiting transportation to the laboratory for analysis.

2.3 Soil Sample Collection, Preservation and Pretreatment

The soil samples were collected from five (5) different farmlands in the communities, Kunji, Gadawo, Poli, Kwadom and Kanawa. At each sampling point, approximately 0.5 kg of soil was collected (0 – 20cm depth) at ten different spots with the help of a stainless-steel spoon and made into a composite sample. The soil samples were then placed into a nitric acid-treated polythene bag to prevent metals from adhering to the containers and then transported to the laboratory where they were air-dried for about 3 days then oven-dried to constant weight at 105^0C, disaggregated in a ceramic pestle and mortar, ground to powder and sieved [22].

2.4 Sample Treatment

The water samples were treated and concentrated into small volumes to increase the sensitivity of the method of determination.

2.4.1 Treatment of Water Samples for Heavy Metal Analysis

75 ml each of the water samples from different irrigation boreholes were measured into a digestion flask; and 25ml of concentrated HNO_3 acid was added to the flask and heated on a hot plate for 1 hour. The digested samples were cooled and thereafter quantitatively transferred to a 100 ml volumetric flask and the volume adjusted to 100 ml with deionized water [23].

2.4.2 Treatment of Soil Samples

1g of each prepared soil sample was placed into a 150 ml digestion flask, and a mixture of concentrated HNO_3:$HClO_4$: HF in the ratio 3:1:3 was added. The mixture was then placed on a hot plate and digested for three hours at 80^0C. The digests were then filtered into a 100 ml standard flask and made up to the mark with distilled water.

2.5 Measurement of physicochemical parameters

2.5.1 Soil Moisture Determination

10g of soil was weighed into a crucible and the weight of soil and crucible was taken as (W_1), the crucible was taken to the oven for drying at 105°C for 6 hours until a constant weight was attained on cooling (W_2).

$$Moistureperent \ = \frac{W_1 - W_2}{Weightofsoil} \text{ x } 100$$

2.5.2 Total Nitrogen Determination

1g of soil sample was weighed into a Kjeldahl flask, 0.7g of $CuSO_4$, 1.5g of K_2SO_4 and 30 ml of concentrated H_2SO_4 were added to the sample into the flask. The mixture was heated gently until frothing ceased and boiled briskly until the solution became clear. The digestion was continued for 30 minutes. The flask was removed from the heater and cooled. 50 ml of distilled water was added and transferred into a distillation flask. 30 ml of 35% NaOH was added to the mixture in the distillation flask. Heat was applied to distil the ammonia for about 30-40 minutes. A receiving flask containing boric acid was used to capture the ammonia gas released by distillation, to form an ammonium-borate complex. The ammonium-borate complex was titrated with the standard 0.25M H_2SO_4 solution. The percentage total nitrogen was calculated using the expression below:

$$\%\,Nitrogen = \frac{M \times v \times 14 \times 100 \times 100}{Weight\ of\ sample \times 1000 \times 10}$$

Where, M = Molarity of H_2SO_4
V = Volume of acid used
14 = Atomic weight of nitrogen.
100 = Total volume of digest.
100 = % conversion.
10 = Volume of the digest taken.
1000onversion to liters.

2.5.3 Available Potassium Determination

Potassium in soil was extracted with neutral ammonium acetate and estimated with a UV spectrophotometer. 5g of soil sample was shaken for 5 minutes with 25 ml of the ammonium acetate solution. The extract was filtered and read on the spectrophotometer.

2.5.4 Available Phosphorus Determination

50 ml of the Bray's Extractant No.1 (0.03M NH_4F in 0.025M HCl) was poured into a 100 ml conical flask containing 5g of soil sample. This was shaken for 5 minutes and filtered. A colour was developed on the addition of 5 ml of molybdate reagent to 5 ml of filtered soil extract and diluted to about 20 ml with distilled water, and shaken. This was then followed by the addition of 1 ml of the dilute $SnCl_2$ solution with a pipette. The solution volume was brought to the 25 ml mark and shaken thoroughly. The blue colour was read after 10 minutes using a UV spectrophotometer at 660nm.

2.5.5 Available Sulphur Determination

20g of soil sample was weighed into a 250ml conical flask, 100ml of the $CaHPO_4$ extracting solution (500 mg/s) was added and shaken for 1 hour, and filtered through No. 42 filter paper. 10 ml of the clear filtrate was placed in a 25ml volumetric flask. 2.5ml of 25 percent HNO_3 and 2ml of acetic-phosphoric acid were added and diluted to about 22ml, stoppered and shaken well. 0.5ml $BaSO_4$ seed suspension and 0.2 g of $BaCl_2$ crystals were also added, inverted 3 times and kept for 10 minutes, then inverted 10 times. After another 5 minutes, it was inverted 5 times and finally allowed to stand for 15 minutes. 1 ml of glacial acetic acid solution was then added. The volume was made up to 25ml, inverted 3 times and set aside for 90 minutes. After which it was measured spectrophotometrically at 440nm.

2.5.6 Determination of Heavy Metal Concentrations

Heavy metals (Cd, Cr, Mn, Pb, Fe, Ar, Co, Cu) were determined using an Atomic Absorption spectrophotometer (AAS), according to the standard methods of Dara (2004). The spectrophotometer was calibrated, standard solutions of all the parameters to be measured were run; blank samples (distilled water) were also passed between every three successful measurements to check for any eventual contamination or abnormal response of the equipment.

2.5.7 Data Analysis

All experiments were conducted in replicate measurements and presented as Mean ± SD. Data obtained were analysed using Microsoft Excel 2013. The mean values were subjected to one-way analysis of variance (ANOVA) at a 95% confidence level using GraphPad Prism Software (GraphPad Inc., San Diego, CA, USA) (*6*) at $p<0.05$.

3. Results and Discussion

Five different communities: Kunji, Gadawo, Poli, Kwadom and Kanawa of Yamaltu Deba LGA of Gombe State and were assessed for physicochemical parameters (pH, Temperature, Conductivity, Total Dissolved Solids (TDS), Salinity and Total Hardness), major anions (chloride, sulphate, nitrate and phosphate) and Water, soil and vegetable samples were obtained from farmlands and irrigation boreholes heavy metals contents (which included Cd, Cr, Mn, Pb, Fe, As, Co and Cu) respectively.

3.1 Heavy Metals Concentration of Soil Samples

The concentration of cadmium ranged between 0.019 mg/kg in Gadawo Control to 0.528 mg/kg in Kwadom Control, having the highest concentration. Cadmium concentration results obtained were below the permissible limits of 0.80 mg/kg; chromium concentration ranged between 0.011 and 0.090 mg/kg, and chromium concentrations obtained were significantly below the permissible limits of 0.10 mg/kg in Table 4.1 below.

Table 1: Heavy Metal Concentrations of Soil Samples from Farmlands in Yamaltu-Deba LGA of Gombe State

Samples	Heavy Metal Concentrations (mg/kg)							
	Cd	**Cr**	**Pb**	**As**	**Co**	**Fe**	**Cu**	**Mn**
KwadonNrml	0.418 ± 0.00^{d}	0.022 ± 0.00^{b}	0.066 ± 0.00^{a}	0.021 ± 0.00^{b}	0.147 ± 0.00^{b}	0.617 ± 0.00^{d}	0.138^{b}	500.450^{d}
KwadonCntrl	0.528 ± 0.00^{c}	0.013 ± 0.00^{a}	0.041 ± 0.00^{a}	0.016 ± 0.00^{b}	0.083 ± 0.00^{a}	0.223 ± 0.00^{b}	0.018^{a}	227.050^{b}
PoliNrml	0.079 ± 0.00^{a}	0.071 ± 0.00^{d}	0.000±0.00	0.051 ± 0.00^{d}	0.074 ± 0.00^{a}	0.051 ± 0.00^{a}	0.361^{d}	247.550^{b}
PoliCntrl	0.108 ± 0.01^{b}	0.011 ± 0.01^{a}	0.000±0.00	0.030 ± 0.00^{c}	0.067 ± 0.00^{a}	0.031 ± 0.00^{a}	0.196^{b}	341.700^{c}
KunjiNrml	0.397 ± 0.01^{d}	0.055 ± 0.01^{c}	0.240 ± 0.01^{c}	0.039 ± 0.00^{c}	0.034 ± 0.00^{a}	0.357 ± 0.00^{c}	0.077^{a}	159.200^{a}
KunjiCntrl	0.240 ± 0.00^{c}	0.050 ± 0.00^{c}	0.040 ± 0.00^{a}	0.028 ± 0.00^{b}	0.027 ± 0.00^{a}	0.253 ± 0.01^{b}	0.031^{a}	317.150^{c}
GadawoNrml	0.289 ± 0.00^{c}	0.029 ± 0.00^{b}	0.000±0.00	0.021 ± 0.01^{b}	0.179 ± 0.00^{b}	0.231 ± 0.00^{b}	0.242^{c}	445.050^{d}
GadawoCntrl	0.019 ± 0.00^{a}	0.025 ± 0.00^{b}	0.000±0.00	0.009 ± 0.00^{a}	0.228 ± 0.00^{c}	0.140 ± 0.00^{b}	0.111^{b}	652.500^{e}
KanawaNrml	0.186 ± 0.00^{b}	0.090 ± 0.00^{d}	0.125 ± 0.01^{b}	0.004 ± 0.00^{a}	0.130 ± 0.00^{b}	0.369 ± 0.00^{c}	0.229^{c}	616.100^{e}
KanawaCntrl	0.241 ± 0.01^{c}	0.078 ± 0.00^{d}	0.092 ± 0.00^{b}	0.003 ± 0.00^{a}	0.110 ± 0.00^{b}	0.340 ± 0.01^{c}	0.152^{b}	396.200^{e}
P/Limits WHO (1994)	0.80	0.10	0.10	0.02	0.05	50.00	36	2.00
P/Limits WHO (1994)	**0.80**	**0.10**	**0.10**	**0.02**	**0.05**	**50.00**	**36**	**2.00**

Key: Nrml = Normal, Cntrl = Control
Values are mean ± standard deviation. Same superscript along the column means no significance difference, while different superscripts along the same column show significant differences at 95% confidence level, $p < 0.05$

3.2 Heavy Metals in Water

Water samples were analysed to assess the level of heavy metal concentrations and the results are given in Table 4.2. Cadmium was found to be in a range of 0.11 to 0.083 (include the unit). The high concentration was recorded at Kunji normal and the lowest in Kanawa control. Even though they were below the permissible limit of 0.1 set by [24]. However, Cd was undetected in all samples obtained from Kwadom control, Poli normal, as well as Poli control, which may be attributed to the lack of anthropogenic activities in the areas. The result of chromium showed the highest concentration of 0.053 and the lowest range of 0.011mg/kg. The highest was recorded at Kunji normal, while the lowest was at Kwadom normal. Chromium concentration was found to be below the permissible limit of irrigation water set by WHO. Chromium plays a vital role in the metabolism of cholesterol, fat, and glucose. Its deficiency causes hyperglycemia, elevated body fat, and decreased sperm count, while at high concentrations. It is toxic and carcinogenic. Lead values found ranged from 0.030 to 0.002 mg/kg. The highest was recorded at Kunji normal and the lowest at Kanawa control. Lead levels from all the areas were below the permissible limit of 5.0mg/kg set by the FAO. At a very high level, Lead can cause convulsions, coma and death.

Arsenic concentration was not detected in some of the areas, the highest was found at Kunji normal, with a value of 0.014, while the lowest was recorded at Poli normal, with a range of 0.06mg/kg. Heavy metal was found to be lower than the accepted limit. Long-term exposure to high levels of arsenic in drinking water can cause human problems, which include cancer, thickening and discoloration of skin, high blood pressure, heart disease and even death in young adults. The concentration of cobalt ranged from 0.007 to 0.049. The maximum was recorded at Kanawa normal, while the minimum value was found at Kanawa control. Cobalt was found to be above the permissible limit of 0.05mg/kg set by the WHO standard at Kanawa, with a value of 0.049 mg/kg.

The accumulation of copper in water samples from irrigation was found to be within the range of 0.025 to 0.056 mg/kg. A high amount of Cu was determined in the water sample of Kanawa control and the lowest concentration level obtained from this study was determined at Kunji normal. Manganese was recorded in the highest amount compared to other heavy metals in analysed water samples. Its concentration in different water samples was varied from 7.690 to 58.970 mg/kg. In this study, the maximum concentration of Mn was recorded at the Gadawo control, while the Poli control had the lowest concentration. as indicated in Table 4.4. The concentration of heavy metals is found to be above the permissible limit in all the water sample areas set by (WHO/FAO (2011).

Table 2: Heavy Metal Concentrations of Water Samples from Irrigation Boreholes in Yamaltu-Deba LGA of Gombe State

Samples	Heavy Metal Concentrations (mg/L)							
	Cd	Cr	Pb	As	Co	Fe	Cu	Mn
KwadonNrml	0.033 ± 0.00^{b}	0.011 ± 0.00^{a}	0.019 ± 0.00^{b}	0.000 ± 0.00	0.020 ± 0.00^{b}	0.006 ± 0.00^{a}	0.035 ± 0.00^{b}	27.600 ± 0.53^{b}
KwadonCntrl	0.000 ± 0.00^{d}	0.023 ± 0.00^{b}	0.004 ± 0.00^{a}	0.000 ± 0.00	0.000 ± 0.00	0.002 ± 0.00^{a}	0.040 ± 0.00^{b}	16.545 ± 0.30^{a}
PoliNrml	0.000 ± 0.00^{b}	0.016 ± 0.00^{a}	0.000 ± 0.00	0.006 ± 0.00^{a}	0.000 ± 0.00	0.012 ± 0.00^{b}	0.000 ± 0.00	12.255 ± 0.14^{a}
PoliCntrl	0.000 ± 0.00	0.000 ± 0.00^{d}	0.000 ± 0.00	0.000 ± 0.00	0.000 ± 0.00	0.004 ± 0.00^{a}	0.000 ± 0.00	7.690 ± 0.31^{a}
KunjiNrml	0.083 ± 0.00	0.053 ± 0.00^{d}	0.030 ± 0.01^{c}	0.014 ± 0.00^{b}	0.000 ± 0.00	0.017 ± 0.00^{b}	0.025 ± 0.00^{a}	36.555 ± 0.16^{b}
KunjiCntrl	0.023 ± 0.00	0.018 ± 0.01^{a}	0.008 ± 0.00^{a}	0.004 ± 0.00^{a}	0.000 ± 0.00	0.000 ± 0.00	0.026 ± 0.00^{a}	11.495 ± 0.02^{a}
GadawoNrml	0.057 ± 0.01	0.024 ± 0.00^{b}	0.000 ± 0.00	0.000 ± 0.00	0.033 ± 0.00^{c}	0.000 ± 0.00	0.054 ± 0.00^{c}	43.130 ± 0.03^{b}
GadawoCntrl	0.027 ± 0.00^{c}	0.000 ± 0.00	0.000 ± 0.00	0.000 ± 0.00	0.014 ± 0.00^{b}	0.000 ± 0.00	0.037 ± 0.00^{b}	58.970 ± 0.25^{c}
KanawaNrml	0.059 ± 0.01^{b}	0.036 ± 0.00^{c}	0.015 ± 0.01^{b}	0.000 ± 0.00	0.049 ± 0.00^{d}	0.027 ± 0.00^{c}	0.042 ± 0.00^{b}	25.435 ± 0.08^{b}
KanawaCntrl	0.011 ± 0.00^{c}	0.020 ± 0.00^{b}	0.002 ± 0.00^{a}	0.000 ± 0.00	0.007 ± 0.00^{a}	0.023 ± 0.00^{c}	0.056 ± 0.00^{c}	45.130 ± 0.03^{b}
WHO	**0.1**	**0.2**	**5.0**	**0.10**	**0.05**	**5.00**	**0.2**	**0.2**

Key: Nrml = Normal, Cntrl = Control
Same superscript along the column means no significance difference, while different superscripts along the same column show significant differences at 95% confidence level, $p < 0.05$

3.3 Major Anions in Water Samples

Chloride values obtained from this study ranged between 261.09mg/L in Kunji normal, which is the highest due to anthropogenic, or human-caused, factors such as road salt, sewage contamination, and water softeners. While Gadawo control, Kunji control and Kanawa normal recorded 67.93, 72.72, and 45.70, respectively. The lowest was found in Poli normal with 14.60, the effect of low chloride can lead to sickness and dehydration. The lowest was found in Kanawa normal with 8.47mg/L. The high concentration of sulphate may be attributed to runoff from fertilized agricultural land. The nitrate values of 74.00,65.74, 39.08mg/L from Kunji normal, Kunji control and Gadawo normal were recorded, while Gadawo control, Kwadom normal, and Poli normal have the values of 26.75,21.73 and 14.23mg/L.

The lowest was recorded in Kwadom control with 7.85mg/L. Consuming too much nitrate can affect how blood carries oxygen and can cause methemoglobinemia, also known as blue baby syndrome.

The highest concentration of phosphate was recorded in Kunji normal with 30.74mg/L due to human activities as well as Animal waste dump within the irrigation water. 21.83, 19.73, 14.19 and 12.59mg/L were recorded from Kanawa normal, Kunji control, Kanawa control and Poli normal. The lowest was recorded in Kwadom control with 4.41mg/L and the high accumulation of phosphate can cause increased growth of algae and large aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. (Table 4.5)

3.4 Major Anions in Soil Samples

The major Anions of soil samples were studied. The results obtained in the analysis are recorded in Table 4.6. Sulphate values ranged from 61.74 to 168.25 mg/L, with the highest recorded at Kunji normal and the lowest at Gadawo normal. Nitrate was found to be highest at Gadawo control with a value of 80.55 and the lowest at 30.99 mg/L in Kunji control. The percentage of phosphate was varied from 22.48 to 65.94 mg/L. The highest concentration of phosphate was registered at Kunji normal soil sample, while the lowest concentration was obtained at Kwadom control. Total Nitrogen (%) was ranged from 0.68 to 1.66%. Gadawo recorded the highest, while the lowest was found in the Kanawa control. High concentration of nitrogen in the soil affects plants, which may look lush and green, but their ability to fruit and flower will be greatly reduced.

Table 3: Major Anions of Water Samples from Irrigation Boreholes in Yamaltu-Deba LGA of Gombe State

Samples	Major Anions			
	Chloride (mg/L)	Sulphate (mg/L)	Nitrate(mg/L)	Phosphate (mg/L)
Kwadon Nrml	32.95±1.66^b	19.32±0.04^b	21.73±0.68^c	6.76±0.04^a
Kwadon Cntrl	22.14±0.33^a	9.95±0.71^a	7.85±0.27^a	4.41±0.06^a
Poli Nrml	14.60±0.04^a	23.94±0.82^b	14.23±0.30^b	12.59±0.28^b
Poli Cntrl	20.03±0.71^a	13.09±0.18^a	11.42±0.04^b	9.72±0.42^b
Kunji Nrml	261.09±0.87^d	133.77±0.24^d	74.00±1.57^d	30.74±1.09^c
Kunji Cntrl	72.72±0.87^c	25.46±0.15^b	65.74±0.54^d	19.73±0.48^c
Gadawo Nrml	53.09±0.09^c	17.56±0.27^b	39.08±0.68^c	8.78±0.68^a
Gadawo Cntrl	67.93±0.28^c	31.16±0.61^c	26.75±0.60^b	9.43±0.32^b
Kanawa Nrml	45.70±0.31^b	8.47±0.15^a	15.21±0.13^a	21.83±0.23^c
Kanawa Cntrl	19.00±0.65^a	12.59±0.34^a	7.87±0.23^a	14.19±0.95^b

Key: Nrml = Normal, Cntrl = Control

Values are mean ± standard deviation. Same superscript along the column means no significance difference, while different superscript along the same column shows significant difference at 95% confidence level, $p < 0.05$.

Table 4: Major Anions of Soil Samples from Farmlands in Yamaltu-Deba LGA of Gombe State

Samples	Major Anions			
	Sulphate (mg/kg)	Nitrate (mg/L)	Phosphate (mg/L)	T. Nitrogen (%)
Kwadon Nrml	64.52±1.08^a	75.76±1.56^b	40.48±0.91^b	0.96±0.00^a
Kwadon Cntrl	88.80±0.56^b	60.99±1.38^b	22.48±1.28^a	0.75±0.03^a
Poli Nrml	133.45±1.75^c	53.89±1.58^a	60.83±0.45^c	0.87±0.02^a
Poli Cntrl	130.50±1.90^c	52.40±2.21^a	41.49±1.16^b	0.73±0.01^a

Kunji Nrml	168.25±1.75^{c}	37.55±0.80^{a}	65.94±0.45^{c}	1.50±0.02^{b}
Kunji Cntrl	158.00±3.30^{c}	30.93±0.46^{a}	57.16±1.46^{b}	1.42±0.05^{b}
Gadawo Nrml	61.74±1.09^{a}	92.14±1.60^{b}	39.54±1.37^{b}	1.66±0.03^{b}
Gadawo Cntrl	64.69±1.29^{a}	80.55±1.31^{b}	25.49±0.87^{a}	1.22±0.07^{b}
Kanawa Nrml	114.20±3.60^{b}	73.78±2.46^{b}	45.84±1.35^{b}	1.12±0.02^{b}
Kanawa Cntrl	91.79±2.43^{b}	48.05±2.25^{a}	38.14±1.43^{b}	0.68±0.05^{a}

Key: Nrml = Normal, Cntrl = Control

Values are mean ± standard deviation. Same superscript along the column means no significance difference, while different superscripts along the same column show significant differences at a 95% confidence level, $p < 0.05$

3.5 Heavy Metals in Vegetables

Cadmium values of heavy metals in vegetables Table 4.7 were 0.012, 0.021 and 0.029 mg/kg, respectively. The values obtained from Kunji and Gadawo were found to be above the detected limit of 0.02 as adopted by [25] (Table 4.7). Chromium showed that the mean concentration lies between 0.009 to 0.042 mg/kg. Among the analysed vegetable samples, Cr was detected in all the areas, but was found to be below the permissible limit of 1.30 mg/kg. The highest amount was found at Kunji and Kanawa, while the minimum concentration was recorded at Kwadom. The levels of lead in the vegetable sample considered in this study were found to be 0.025 in Kwadom, 0.011 in Kanawa and 0.056 in Kunji mg/kg.

The concentration found in all three areas was found to be below the permissible limit. Iron (Fe) was found ranging from 0.011 to 0.039 mg/kg. Kanawa recorded the highest value while Gadawo recorded the lowest value. All the detected heavy metals found in the sample areas were below the permissible limit of 0.3 mg/kg as adopted by [25]

The levels of Cu were found to be 0.04 to 0.080 mg/kg. The highest concentration was found in Kwadom, while the lowest was detected at Gadawo, though they are all below the recommended limit of 10 mg/kg. Manganese levels, on the other hand, were found to be 82.800 in Poli, 111.550 in Kunji, 199.250 in Kwadom, 156.900 in Gadawo, as well as 239.250 mg/kg in Kanawa. The levels of Mn obtained in this study were found to exceed the allowable limit value reported by [25]

Table 5: Heavy Metal Concentrations of Vegetable Samples from Farmlands in Yamaltu-Deba LGA of Gombe State

Samples	**Heavy Metal Concentrations (mg/kg)**							
	Cd	Cr	Pb	As	Co	Fe	Cu	Mn
Kwadon Veg.	0.012±0.00^{a}	0.009±0.00^{a}	0.025±0.00^{b}	0.000±0.000	0.039±0.00^{c}	0.027±0.00^{b}	0.080^{c}	199.250^{c}
Poli Veg.	0.000±0.00	0.014±0.00^{a}	0.000±0.00	0.009±0.00^{a}	0.000±0.00	0.015±0.00^{a}	0.020^{b}	82.800^{c}
Kunji Veg.	0.029±0.00^{b}	0.042±0.00^{b}	0.056±0.00^{c}	0.016±0.00^{b}	0.000±0.00	0.024±0.00^{b}	0.000	111.550^{b}
Gadawo Veg.	0.000±0.00	0.009±0.00^{a}	0.000±0.00	0.000±0.000	0.019±0.00^{b}	0.011±0.00^{a}	0.004^{a}	156.900^{b}
Kanawa Veg.	0.021±0.00^{b}	0.042±0.00^{b}	0.011±0.00^{a}	0.000±0.00	0.006±0.00^{a}	0.039±0.00^{b}	0.014^{b}	239.250^{c}
P/Limits	**0.02**	**1.30**	**2.0**	**0.5**	**40**	**0.3**	**10**	**50.16**

Adapted from Rowe and Abdel-Magid (1995)

Values are mean ± standard deviation. Same superscript along the column means no significance difference, while different superscripts along the same column show significant differences at a 95% confidence level, $p < 0.05$

3.6. Heavy Metal Concentrations of Soil Samples from Farmlands in Yamaltu-Deba LGA of Gombe State

The mean concentration ranged of element analyzed (Cd, Cr, Pb, As, Co, Fe, Cu and Mn) from the result from this study revealed that the accumulation of heavy metals in farm soil and irrigation water shows they were significantly below the permissible limits except for Mn which records the highest value of 159.2 and 652.5 mg/kg and Co which recorded 0.027 and 0.228mg/kg [26]. Statistical analysis between the samples showed no significant difference at $p<0.05$.

3.7.Heavy Metal Concentrations of Water Samples from Irrigation Boreholes in Yamaltu-Deba LGA of Gombe State

The concentration of [(Cd 0.00-0.059), (Cr 0.00-0.53), (Cu 0.00-0.054), Co 0.00-0.049), Mn 7.69-58.97] Mg/Kg. Shown from the study were above the permissible limits except for [(Pb 0.00-0.030), (As 0.00-0.014), (Fe 0.00-0.027)] Mg/Kg, which were below the permissible limit set by (FAO/WHO 2011)

3.8 Major Anions of Water Samples from Irrigation Boreholes in Yamaltu-Deba LGA of Gombe State

The major anions analysed included chloride, sulphate, nitrate and phosphate. Chloride concentration ranged between 14.60 mg/L in Poli Normal and 261.09 mg/L in Kunji Normal. Chloride is one of the major anions assessed in water; it is generally associated with sodium. High levels of chloride ions may result in an objectionable salty taste and high chloride concentration is attributable to corrosion of metals [24]. The sulphate contents obtained from the water samples in irrigation boreholes were 8.47 mg/L to 133.77 mg/L, which are all below the desired range of 400 mg/L. Nitrate is found naturally in the environment, thus giving it the potential to migrate to groundwater since they are very soluble and does not bind to soil, thereby making it an important plant nutrient. The nitrate level observed in this study shows that there is less exposure of water to inorganic constituents, and thus the results obtained pose no potential health risk [27]. The phosphate content obtained in this study ranged between 4.41 mg/L to 30.74 mg/L. This causes eutrophication or over-fertilization as it chokes up the waterways and uses up large amounts of oxygen [28]. There seems to be a positive correlation between all the physicochemical parameters assessed.

3.9 Major Anions of Soil Samples from Farmlands in Yamaltu-Deba LGA of Gombe State.

The major anions analysed included sulphate, nitrate, phosphate and total nitrogen. The sulphate content obtained for the soil samples from sampling sites ranged between 61.74 mg/L and -168.25 mg/kg. Sulphate is a very leachable anion, which indicates how much precipitation the soil received. Low sulphate levels indicate the soil is getting leached out and has to be supplemented through organic matter [29]. The nitrate content obtained in this study ranged between 30.93-92.14 mg/L. Nitrate is a very important nutrient in soil as it serves as a source of nitrogen (N) available for crops and, before its reduction and assimilation into amino acids, must enter the root cells and then move throughout the whole plant.

The available total nitrogen present in the soil samples varied from 0.68 % to 1.66 %. Nitrogen occurs in soil in both organic and inorganic forms and plays an important role in denitrification. Nitrogen is such an important key nutrient element for plants that it warrants careful management, and – if mismanaged – can lead to severe environmental problems [30]. The phosphate content obtained in this study ranged between 4.41 mg/L to 30.74 mg/L. Thus, phosphorus is an important nutrient necessary for the development of plants and animals, though higher values can be detrimental to the soil as it can enter freshwater bodies through surface runoff and can cause algal bloom [31].

3.10.Heavy Metal Concentrations of Vegetable Samples from Farmlands in Yamaltu-Deba LGA of Gombe State

The concentration of heavy metals analysed varied from one farm to the other and this might be due to differences of irrigation practices. The concentration of cadmium ranged between 0.012-0.029 mg/kg. Chromium concentration ranged between 0.009 and 0.042 mg/kg. Lead concentration ranged between 0.011 mg/kg to 0.056 mg/kg. Arsenic was only detected in vegetables having small amounts, 0.009 and 0.016 mg/kg, respectively. Cobalt was not detected in two study sites, while the other three study sites' vegetables had cobalt concentrations of 0.006, 0.019 and 0.039 mg/kg. Iron was found to be present in all sampled vegetables, having the highest concentration of 0.011 mg/kg - 0.039 mg/kg. Copper concentration ranged between 0.004 to 0.080 mg/kg. Manganese was found to be present in all the vegetable samples, ranging between 82.8-239.25 mg/kg. Statistical analysis between the samples showed no significant difference at $p<0.05$. A particular concern has been generated over the possibility of toxic elements, especially Pb and Cd, which cause more insidious problems for humans and animals due to their accumulation in food plants. Crops are one of the principal sinks for the accumulation of heavy metals, and these metals contaminated, edible portions act as poisons for human beings and other living organisms [32].

4. Conclusion

The results of this study revealed that the accumulation of heavy metals in farm soil and irrigation water shows the concentration of cadmium, Chromium, Lead, Arsenic, Cobalt, Iron and copper were significantly below the WHO permissible limit, except for Manganese, which recorded the highest value in all the sampling points. The results were above the permissible limit set by WHO, (2011). Water samples were also analysed to determine the accumulation of heavy metal concentrations. Cadmium, Chromium, Lead, Arsenic, Cobalt, Iron and Copper were found to be in a range of 0.11 to 0.083. The high concentration was recorded at Kunji normal and the lowest in Kanawa control. Even though they were below the permissible limit of 0.1 set by (WHO (2011). However, cadmium was undetected in all samples obtained from Kwadom control, Poli normal, as well as Poli control which may be attributed to lack of anthropogenic activities in the areas, while Manganese has highest value above the WHO Permissible limit. This could be attributed to high rate of wood combustion by the residents.

In analyzed soil samples, the moisture content, pH, electrical conductivity, cation exchange capacity, and organic matter were found below the permissible limit sets by FAO (2011), except electrical conductivity and organic matter were found to be above the limit. Therefore, the temperature, PH, electrical conductivity, total dissolved solutes, salinity and total hardness were found to be below the permissible limit set by WHO (2011), except electrical conductivity, TDS, and total hardness were found to be above the permissible limit, reason is due to many electrons energy level near the farming area.

The result of the heavy metals in vegetables according to farm sites shows that Chromium, Lead, Arsenic, Cobalt, Iron and Copper were found below the permissible limit by (FAO/WHO). While Cadmium in Kunji and Gadawo were found above the permissible limit. In Poli and Gadawo, Cadmium was not detected. While Manganese was found in all the sample sites above the permissible limit.

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