Heavy Metals Suitability in Irrigation Water Sources of Bauchi Suburb, Bauchi State, Nigeria

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***Abstract*: - This study determined the concentrations of copper, chromium, lead, nickel, zinc, manganese, iron, cadmium and cobalt in the irrigation water samples collected within Bauchi metropolis using Atomic Absorption Spectrophotometry. Water samples were collected from Federal Secretariat, Murtala Muhammad Way, Ran Road and Fadamar Mada. The concentrations of all the metals varied with locations. The results revealed that concentrations of chromium (0.05 to 0.15 mg/dm^3), lead (0.10 to 0.38 mg/dm^3), nickel (0.05 to 0.10 mg/dm^3) and cobalt (below detectable limit to 0.02 mg/dm^3) are within the permissible limits of WHO, 2001, while that of copper (5.48 to 22.32 mg/dm^3), zinc (0.90 to 8.02 mg/dm^3) and cadmium (0.05 to 0.10 mg/dm^3) are above the permissible limits of WHO, 2001. The levels of iron (2.67 to 6.33 mg/dm^3) and manganese (0.10 to 0.88 mg/dm^3), in water samples collected from Federal Secretariat Road and Ran Road are within the permissible limits, while those from Murtala Muhammad Way and Fadamar Mada are above the maximum limits of WHO. The results obtained in the water samples were subjected to One- Way Analysis of Variance (ANOVA) and Least Significant Difference (LSD) test. The differences in the levels of chromium, nickel, manganese, cadmium and cobalt were found to be significantly the same, while the differences in the concentrations of copper, lead, iron and zinc were significantly different ($p \leq 0.05$). Based on the high concentrations of copper, zinc, cadmium, manganese and iron in some irrigation water samples found in the different sources of the irrigation water sampled, this means there is contamination in the irrigation water samples which may affect the plant(s) grown in those areas and this may also in turn pose a health threat(s) to the consumers of the agricultural products.**

***Keywords:* Heavy metals, Irrigation water, permissible limit, One-Way Analysis of Variance (ANOVA) and Least Significant Difference (LSD).**

I. INTRODUCTION

Food security is one of the major problems of the world [1]. When agricultural lands are exposed to polluted water for a long time, toxic metals can build up to high unacceptable concentrations [2]. Among all the contaminants that affect water supplies, heavy metals need a special attention because of their high toxicity even at low levels [3]. The volume and availability of water is one of the factors limiting irrigation. Considering the gradual decrease of water resources in recent times, the proper use of available water sources is one of the most important responsibilities of human kind. Unless precautions are put in place for effective water purification, the ground and surface water as well as soil may lose their characteristics gradually. In many regions of the world, agricultural activities have been mainly maintained on riversides. The contaminations from industrialization, agricultural activities and urbanization may combine with river water and all these may result in serious metal accumulation in vegetables [2].

Irrigation may be defined as the practice of supplying water to an area of land through pipes or channels so that crops will grow [4]. There are four methods of irrigation namely: Surface, Sprinkler, Drip/trickle and Subsurface [5].

Water pollution is one of the most important environmental problems. Heavy metals in the water are in colloidal, particulate and dissolved forms. Sources of heavy metals in water comprises of natural sources and these include eroded minerals within sediments, leaching of ore deposits and volcanic materials as well as anthropogenic sources such as solid waste disposals, industrial or municipal effluents and wharf channel dredging [3].Waste water is an important source for enriching the poor soils of arid and semi-arid areas [2]. Due to increase in urbanization and industrializa-tion, there are various contaminative matters mixing into water. In view of the use of such matters in agricultural areas, several problems may arise. The waste water sources that are beneficial to vegetables can cause soil pollution and degradation of food quality because of the contaminative factor mixing into water [2].

The term heavy metals are chiefly associated with pollutants discharged into parts of the environment namely: air, water and soil. Many heavy metals have considerable toxicity, others are considered not to possess significant toxic properties and several of these elements such as zinc, iron, copper, chromium and cobalt are largely necessary for metabolic functions for a large class of organisms [6]. Metals can occur in sand, dust and even in variety of organic and inorganic compounds. Some of these heavy metals are essential micronutrients for animals, plants and many micro-organisms depending on the route and dose. All heavy metals demonstrate toxic effects on living organisms via metabolic interferences and mutagenesis [6].

Heavy metals enter the human body mainly through inhalation or ingestion and dermal contact [7]. The intake of heavy metals through vegetable consumption is a problem that has been reported globally. It is receiving increasing attention not only from Governments, but also from the public, who are becoming increasingly concerned about the possible health risks associated with the higher concentrations of heavy metals found in human food chain. It is estimated that nearly half of the average intake of heavy metals is of plant origin. Bioaccumulation of heavy metals in vegetables and fruits could pose a direct threat to human health [8].

At higher concentrations, heavy metals can lead to poisoning. Heavy metals poisoning could result from drinking water contamination from lead pipes, high ambient concentration near emission sources or intake via food chain. Heavy metals are dangerous because they tend to bio-accumulate (increase in the concentration of a chemical in a biological organism over time, compared to the chemical concentration in the environment). Heavy metals contamination threatens agriculture and other food sources for human population as well as poor vegetation growth and lower plant resistance against forests pests, there by having impact on the quality of food, groundwater, microorganisms and plant growth [9]. This research work is aimed at assessing heavy metals suitability irrigation water sources of Bauchi suburb, Bauchi State, Nigeria.

II. MATERIALS AND METHODS

2.1 Materials

In the preparation of all the solutions, chemicals of analytical reagent grade purity and distilled water were used. A solution of 5.00 % (v/v) trioxonitrate (V) acid was used to wash all the glass and plastic wares to eliminate any metal which may interfere with the results and finally the apparatus were repeatedly rinsed with water and the/ solutions used in them [10].

2.2 Methods

2.2.1 Sampling of Irrigation Water

Irrigation water samples were collected randomly from four different sources "up and down" the stream and also from well and were kept in polyethylene transparent gallons. The irrigation water samples were preserved by adding 1.00 cm^3 of concentrated trioxonitrate (V) acid (HNO_3) to 1.00 $dm^3$of irrigation water and stored at 4 ^oC for the determination of the heavy metals of interest [11]. The four (4) sites from which the water samples were collected are within Bauchi metropolis/suburb (Murtala Muhammad Way, Federal Secretariat Road, Fadamar Mada and Ran Road respectively).

2.3 Sample Pre-treatment and Determinations

2.3.1 Digestion of Different Sources of Irrigation Water

Irrigation water sample (50.00 cm^3) was measured into a 500 cm^3 beaker and 10.00 cm^3 of concentrated trioxonitrate (V) acid was added. The beaker and its content was moderately heated on a hot plate at 80 ^oC for two (2) hours until brown fumes of trioxonitrate (V) acid was observed. Heating continued until the content reduced to about 10.00 cm^3 volume. On cooling, the content was quantitatively transferred into a 50 cm^3 volumetric flask and water was added to volume. The sample solution was transferred into screw- capped polyethylene bottles and labeled appropriately. The same procedure was repeated for all the irrigation water samples [12].

2.3.2 Determination of Heavy Metals

The concentrations of heavy metals (Cd, Pb, Cr, Co, Ni, Cu, Fe, Mn and Zn) in the various digests were determined using Buck Scientific Atomic Absorption Spectrophoto-meter Model VGP 210 at their individual wavelengths.

III. RESULTS AND DISCUSSION

3.1 Results

The levels of heavy metals (copper, chromium, lead, nickel, zinc, manganese, iron, cadmium and cobalt) determined in irrigation water samples collected within Bauchi metropolis are shown in Table 1.

Table 1: Levels of Heavy Metals (mg/dm^3) in Various Irrigation Water samples

	Sampling Locations			
Metals	**FSR**	**MMW**	**FM**	**RR**
Cu	$5.48^c \pm 0.78$	$9.25^c \pm 0.45$	$22.32^a \pm 1.88$	$17.33^b \pm 1.32$
Cr	$0.05^a \pm 0.00$	$0.05^a \pm 0.00$	$0.10^a \pm 0.00$	$0.15^a \pm 0.00$
Pb	$0.10^d \pm 0.00$	$0.22^c \pm 0.33$	$0.25^b \pm 0.00$	$0.38^a \pm 0.02$
Ni	$0.05^a \pm 0.00$	$0.07^a \pm 0.02$	$0.10^a \pm 0.00$	$0.08^a \pm 0.02$
Zn	$0.90^c \pm 0.06$	$2.92^b \pm 0.17$	$7.73^a \pm 0.24$	$8.02^a \pm 0.02$
Mn	$0.13^a \pm 0.02$	$0.88^a \pm 0.02$	$0.35^a \pm 0.00$	$0.10^a \pm 0.00$
Fe	$2.67^c \pm 0.17$	$5.83^a \pm 0.17$	$6.33^a \pm 0.33$	$3.50^b \pm 0.00$
Cd	$0.05^a \pm 0.00$	$0.10^a \pm 0.00$	$0.05^a \pm 0.00$	$0.10^a \pm 0.00$
Co	$0.01^a \pm 0.00$	$0.02^a \pm 0.00$	BDL	$0.01^a \pm 0.00$

Values are mean ± standard error of the mean (n = 3). FSR = Federal Secretariat Road, MMW= Murtala Muhammad Way, FM= Fadamar Mada and RR= Ran Road. BDL= Below Detection Limit. Values on the same row with the same superscript letters are significantly the same ($p \leq 0.05$) as revealed by one-way between groups ANOVA, while those on the same row with different superscript letters are significantly different ($p \leq 0.05$) as revealed by same one- way between groups ANOVA and Least Significant Difference tests ($p \leq 0.05$).

3.2 Discussion

Table 1 shows the levels of heavy metals (mg/dm^3) in four different irrigation water samples within Bauchi Metropolis, Bauchi State, Nigeria.

The concentrations of copper determined (mg/dm^3) in the irrigation water samples studied ranged from 5.48 (Federal Secretariat Road) to 22.32 (Fadamar Mada) with 9.25 (Murtala Muhammad Way) and 17.33 (Ran Road) falling in between the two extreme concentrations of the metal determined. The high concentration of copper in Fadamar Mada irrigation water may be as a result of the anthropogenic activities taking place in the area, since surface water collects most of the aerial pollution. It may also be due to the disposal of various domestic wastes and organic matter containing copper. The observed copper values of 5.48 to 22.32 mg/dm^3 are higher than their corresponding reported literature values of 0.06 ± 0.01 to 0.07 ± 0.03 mg/dm^3 [13]. The experimental values are all far above the maximum permissible limit of copper (0.20 mg/dm^3) in water samples [14]. The high levels of observed copper may be because it occurs in rocks, soil, air, water, plants and animals [15]. It may also be due to its occurrence in the earth's crust in a proportion of approximately 50 ppm [16]. Copper is an essential micronutrient required in the growth of both plants and animals as it is a key constituent of the respiratory enzyme. It helps in the production of blood haemoglobin while in plants it is used in seed production, disease resistance and regulation of water [15]. High levels of copper can cause anaemia, kidney and liver damage, stomach and intestinal irritation, neurological complications and hyper-tension. It is said to be a toxic waste and therefore unpalatable for consumption [15].

The levels of chromium determined (mg/dm^3) ranged from 0.05 (Federal Secretariat Road and Murtala Muhammad Way) to 0.15 (Ran Road) with 0.10 (Fadamar Mada) falling in-between the two extreme levels of chromium determined. The concentration of 0.15 mg/dm^3 chromium in the water sample from Ran Road was found to be the highest. This may be due to contamination from geological origin, since the water from Ran Road was sourced from well water, which draws variety of salts from the underground deposits. The variations in the concentrations of chromium determined in the irrigation water samples studied may be due to nature, sources of the water, the type of waste discharged into the water sources, effluents, leaching and runoff. The level of chromium assayed in the irrigation water samples are all within the maximum permissible limit of 0.10 mg/dm^3 [14] with the exception of that from Ran Road (0.15 mg/dm^3). Chromium (VI) rarely occurs naturally, but is usually produced from anthropogenic sources. Sources of chromium contamination could be disposal of waste (s) that contains chromium [15]. The observed values (0.05 to 0.15 mg/dm^3) are higher than reported literature chromium values [13] but relatively similar to the chromium values of 0.01 to 1.414 mg/dm^3 [17]. In humans and animals, chromium (III) is an essential nutrient that plays a role in glucose, fat and protein metabolism by potentiating the action of insulin [18].It also contributes in maintaining a normal glucose tolerance factor [15]. Exposure to chromium can lead to allergic dermatitis in humans, bleeding of the gastrointestinal tract, cancer of the respiratory tract and ulcers of the skin. This can also cause damage to the mucus membrane, liver and kidney [15].

The concentrations of lead obtained (mg/dm^3) ranged from 0.10 (Federal Secretariat Road) to 0.38 (Ran Road) with 0.22 (Murtala Muhammad Way) and 0.25 (Fadamar Mada) falling in between the two levels of the observed lead. The variations in the levels of lead determined may be due to the disposal of various domestic wastes and organic matter containing lead. Incineration of wastes can also contribute to a greater amount of lead available in urban areas. Other sources of lead in the environment include automobile exhaust, industrial wastewater, wastewater sludge and pesticides [19]. The concentrations of lead found in the various irrigation water samples were generally low when compared with the maximum permissible limit of 5.00 mg/dm^3 lead in water [14]. The observed values (0.10 to 0.38 mg/dm$^{3)}$ are higher than reported literature values of 0.08 ± 0.04 to 0.12 ± 0.017 mg/dm^3 [13].The presence of lead may affect the gastrointestinal tract, kidney and the central nervous system [15]. Decreased growth and yield have also been observed in plants grown in lead contaminated soils. Balba *et al*. (1991) showed a significant decrease in plant biomass yield with increasing lead treatments that varied with soil type [19].

The levels of nickel found in the irrigation water samples (mg/dm^3) ranged from 0.05 (Federal Secretariat Road) to 0.10 (Fadamar Mada). The observed values of 0.07 mg/dm^3 in Murtala Muhammad Way and 0.08 mg/dm^3 in Ran Road fell in between the range of the values determined in the irrigation water samples. The high concentration of nickel (0.10 mg/dm^3) in Fadamar Mada water sample may be attributed to the combustion of fossil fuels from cars moving around in the area [15] and may also be attributed to the fact that nickel present in the water might come from municipal sewage or organic and synthetic manures applied to the soil in the irrigation site. All the values obtained are below the maximum acceptable limit of 0.20 mg/dm^{3}of nickel [14]. The observed concentrations of nickel (0.05 to 0.10 mg/dm^3) are relatively similar to the minimum and maximum values of 0.06 ± 0.03 to 0.13 ± 0.009 mg/dm^3 [13]. Nickel is used in the manufacture of stainless steel, coins, nickel for armor plates, burglarproof vaults, vegetable oils, ceramics and Ni-Cd batteries [15]. Nickel can cause liver, lung and kidney damage. In high amount, it is responsible for allergies, eczema, dermatitis, respiratory failure, cancer, birth defects, heart and nervous system failure [15]. Nickel is not an accumulative poison, but higher doses or chronic inhalation exposure may be toxic, even carcinogenic and constitute an occupational hazard [20].

The levels of zinc found ranged from 0.90 (Federal Secretariat Road) to 8.02 mg/dm^3 (Ran Road) with Murtala

Muhammad Way (2.92 mg/dm^3) and Fadamar Mada (7.73 mg/dm^3) falling in between the two levels of zinc determined. The differences in the concentrations of zinc may be as a result of the differences in agricultural products used on the irrigation sites. The source of irrigation water from Ran road is a well water sample indicating that the high level of zinc in the water may be due to geological strata. Zinc occurs naturally in soil, but the concentrations are rising due to anthropogenic additions. The use of liquid manure, composted materials, fertilizers and pesticides in agriculture can also increase the level of zinc in soil and water [21]. The observed values are above the maximum tolerable limit of 2.00 mg/dm^3 of zinc [14] except for water sample from Federal Secretariat Road which is below the tolerable limit. The determined values (0.90 to 8.02 mg/dm^3) are comparatively higher than the values (0.13 ± 0.108 to 0.14 ± 0.05) determined in water sample obtained from Ghana, Accra [13]. Zinc is an essential element in human diet because it is required to maintain proper functions of immune system, important for normal brain activity and it is fundamental in the growth and development of fetus [22]. Zinc is also used in electroplating, smelting and ore processing [23]. If doses of 10-15 times higher than the RDA value are taken over a long period, anemia and damage to the pancreas and kidney can develop. Vomiting, diarrhea, abdominal cramping and in some cases, intestinal hemorrhage can occur from long-term exposure to high doses of zinc [23].

The concentrations of observed manganese (mg/dm^3) ranged from 0.10 (Ran Road) to 0.88(Murtala Muhammad Way). The levels as found in Federal Secretariat Road (0.13 mg/dm^3) and Fadamar Mada (0.35 mg/dm^3) fell in between the extreme concentrations of manganese determined. The values obtained from Federal Secretariat Road and Ran Road are within the maximum acceptable limit of 0.20 mg/dm^3 manganese in water [14], while irrigation water samples from Murtala Muhammad Way (0.88 mg/dm^3) and Fadamar Mada (0.35 mg/dm^3) are above the maximum acceptable limit. The concentrations range of manganese (0.10 to 0.88 mg/dm^3) are relatively similar to 0.31 ± 0.001 to 0.78 ± 0.73 mg/dm^3 [13].The main source of manganese is its salt found underground [24]. Manganese of geological origin may be responsible for the high concentration of manganese in water. It may also be due to domestic activities taking place in the area. Manganese is a required trace mineral for all known living organisms, but it also acts as a neurotoxin in larger amounts. When inhaled, it can cause manganism, a neurological disorder charact-erized by Parkinsonism-like extra-pyramidal syndrome and mood changes in mammals resulting in neurological damage that is sometimes irreversible [25] [26].

The concentrations of iron as determined in the irrigation water samples (mg/dm^3) ranged from 2.67 (Federal Secretariat Road) to 6.33 (Fadamar Mada) with Ran Road (3.50) and Murtala Muhammad Way (5.83) falling in between the two extreme concentrations of the observed metal concentration. The maximum tolerable limit of iron is 5.00 mg/dm^3 [14]. This research revealed that irrigation water samples from Federal Secretariat and Ran Road are within the tolerable limit, while samples from Murtala Muhammad way and Fadamar Mada are slightly higher than the tolerable limit. The variations in the levels of the metal determined may be as a result of the different domestic activities in the areas, disposal of various domestic wastes and organic matter containing iron. The concentrations range of iron obtained (2.67 to 6.33 mg/dm^3) are relatively higher than 0.67 ± 0.09 to 1.00 ± 0.023 mg/dm^3 [13]. High level of iron can cause a disease known as hemochromatosis. Hemochroma-tosis is estimated to be the cause of 0.30 to 0.80 % of all metabolic diseases of Caucasians [27]. Iron can damage cells in the heart, liver, causing adverse effects that include coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, long-term organ damage and even death [28].

The levels of cadmium determined (mg/dm^3) ranged from 0.05 (Federal Secretariat Road and Fadamar Mada) to 0.10 (Ran Road and Murtala Muhammad Way). The concentrations of cadmium found in the irrigation water samples are generally higher than the maximum allowable limit of 0.01 mg/dm^3 cadmium [14]. The elevated levels of cadmium may be because cadmium is a naturally occurring element and it is generally associated with oxygen, chlorides, sulfates and sulfides. It is also a byproduct of the extraction of lead, zinc and copper from their respective ores. Volcanism is the largest natural source of cadmium [29]. The experimental values (0.05 to 0.10 mg/dm^3) are relatively higher than the cadmium values of 0.010 to 0.063 mg/dm^3 [30]. Cadmium is used in Ni/Cd batteries, pigments, stabilizers for polyvinyl chloride (PVC), in alloys, electronic compounds, barriers to control nuclear fission, phosphors in the production of televisions, anticorrosive coatings for metals, amalgam in dentistry and worm treatments for swine and poultry [15]. Cadmium exposure can lead to situations such as neurotoxin, hypertension, carcino-genic, teratogenic, respiratory difficulties, cramps and loss of consciousness [15].

The concentration of cobalt ranged from below detection limit (Fadamar Mada) to 0.02 mg/dm^3 (Murtala Muhammad Way) with 0.01 mg/dm^3 (Federal Secretariat Road and Ran Road) falling in between the concentrations of the cobalt determined in the irrigation water samples. These values are all lower than the maximum permissible limit of 0.05 mg/dm^3 [14]. The observed values (below detection limit to 0.02 mg/dm^3) are higher than reported literature value of 0.00 mg/dm^3 [13]. The low concentrations of cobalt found may be because small amounts of cobalt compound are found in most soils, rocks, plants and animals [31].Cobalt is important to humans because it is part of vitamin B12, which is an essential vitamin and component for human health [21]. Inorganic form of cobalt is a micronutrient for bacteria, algae and fungi [32]. It is used in the treatment of anaemia in pregnancy as it stimulates the production of red blood cells [33]. Inhalation and dermal exposure to cobalt in humans can lead to bronchial asthma, interstitial lung disease, lung cancer, pneumonia, heart problems, thyroid damage, nausea, vomiting and diarrhea [34].

Statistical Analyses

One-Way Between Groups Anova

The results of heavy metals obtained in the irrigation water samples were subjected to- One- Way Analysis of Variance (ANOVA) and Least Significant Difference (LSD) test. The levels of chromium, nickel, manganese, cadmium and cobalt were found to be significantly the same (ANOVA), while the concentrations of copper, lead, iron and zinc are significantly different as revealed by the same ANOVA ($p \leq 0.05$) and LSD ($p \leq 0.05$).

The Least Significant Difference (LSD) Test

The least significance difference test ($p \leq 0.05$) was further carried out in order to corroborate the extents of the significant differences (Table 1). Significant differences were found to exist in the mean results of copper, lead, iron and zinc in all the irrigation water samples within Bauchi metropolis.

IV. CONCLUSION

The results of this study indicated high levels of copper, zinc, cadmium, manganese and iron in most of the irrigation water samples studied. Based on the present study, it is therefore evident that prolong use of the irrigation water can affect the plants/ vegetables grown in those areas and this can in turn pose some health challenges to the consumers of the plants/vegetables grown in the study area.

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