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Effects of Fertilizers on Copper and Nickel Accumulation and Human Health Risk Assessment of Vegetables and Food Crops

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EFFECTS OF FERTILIZERS ON COPPER AND NICKEL ACCUMULATION AND HUMAN HEALTH RISK ASSESSMENT OF VEGETABLES AND FOOD CROPS

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ABSTRACT

Despite the fact that fertilizers have been used for millennia for sustainable crop production, this high and considerable dependence on fertilizers heightens environmental concerns with the indirect human exposure due to accumulation of toxins in food chain via soil contamination. The purpose of this study is to evaluate the application of fertilizers to the soil and their effect on the accumulation of copper and nickel in spinach (*Spinacia oleracea*), garlic (*Allium sativum*), wheat (*Triticum aestivum*), maize (*Zea mays*), and barley (*Hordeum vulgare*); as well as potential health concerns associated with consuming vegetables cultivated on this contaminated land. Samples of available soil, food crops, and human blood were collected from three different Tehsils: Bhalwal, Sahiwal, and Silanwali and were regarded as site 1, site 2 and site 3 respectively. Urea, farmyard manure, and potassium chloride were delivered to Site 1; urea phosphate, manure, and ammonium sulphate were delivered to Site 2; and superphosphate, ammonium phosphate, and nitrate phosphate were delivered to Site 3. Data was subjected to statistical analysis for computing out ANOVA and correlation. Analysis revealed that minimum copper concentration was found in the soil of *T. aestivum* grown at Site-1 while the inhabitants of Site 3 had the highest concentration of Cu in their blood. The highest level of HIR was found in the human beings that ate the *S. oleracea* grown at Site 3. It is strongly advised that fertilizers be used sparingly, as their excessive use can cause human health risks.

Keywords: Ammonium phosphate, fertilizers, food crops, maximum permissible limit, pollution load index.

INTRODUCTION

Soil is the primary source of nutrition for agricultural products, and its stability can be severely compromised by the overuse of fertilizers (Rai et al., 2019). Many contaminants are found in fertilizers and can end up in the environment, whether it is the soil, the surface water, or the ground water. Some of these contaminants may thus threaten the natural environment and, by addendum, human health if they are ingested through food grown in contaminated soil or come into contact with humans through water.

Heavy metals are among those contaminates found in chemical fertilizers that are used in agricultural settings have been a major contributor to soil pollution in recent years, which has been a critical issue for the environment (Esmaeilzadeh et al., 2019). Several hazardous metals, such as cadmium (Cd), arsenic (As), chromium (Cr), lead (Pb), and zinc (Zn), can enter the food chain through contaminated soils and water. When these metals reach critical concentrations, they can cause harmful metabolites in the body and have negative effects on the living organisms they come into contact with.

The demands for soil nutrients for high yield have been increased and the manufacture and use of nitrogen, phosphorous and potassium fertilizers have also been increased (Jones et al., 2012). To increase the nutrients in soil fertilizers are intensively used both in developed and developing countries. Fertilizers play an important role to increase the crop yield and to feed the increasing urban population (Sanchez, 2006).

Environmental pollution due to heavy metals has been increased day by day and this rapidly rising metal concentrations in farmland and food products pose a threat to human health (Naz et al., 2022). Due to human activities the level of contaminants has been elevated and creates the food security problems globally. This situation is a big threat for human beings (Clarke et al., 2011; Samuel et al., 2012; Toth et al., 2016).

The accessibility of heavy metals like copper (Cu), nickel (Ni), lead (Pb) in soil is essentially connected to crop accumulation of metals (Zhang et al., 2018). The movement of toxic metals from soil to plant is direct relation with available metal concentration in soil (Adamoa et al., 2014).

In soil-plant human pathway (cycle), health of human beings could be adversely damaged by these toxic heavy metals. Therefore, heavy metals availability plays a significance part in the phytoremediation assessment method. Heavy metal accessibility in farming soil may be manipulated by many factors. Earlier research has described that a long-term plantation in greenhouse may increase the movement of heavy metals in soil (Ramos-Miras et al., 2011). The study's goal was to check out the consequence of contaminated food crops and propose future guidance to manage the feeding requirements. Objectives were to determine heavy metal concentrations in soil and food crops, to check the impact of heavy metals on human beings, to check out the amount of heavy metals in food crops as a result of fertilizer use.

MATERIALS AND METHODS

Location

Sargodha is a city in Pakistan's Punjab province. The city offers food as well as a cash crop market. And its market is connected by road to Lahore and Mianwli, as well as by rail to Faisalabad (formerly Lyallpur) and Lahore. Sargodha's industrial sector is dominated by textiles, socks, flour and oil-seed mills, cotton gins, and chemical and soap companies. Sargodha, the capital of the Lower Jhelum Canal Colony, was granted municipal status in 1914, but it was formed in 1903. It is one of Pakistan's well-planned cities, along with Faisalabad and Islamabad. The climate in Sargodha is semi-arid, subtropical, and continental. The main features of this climate are high summer temperatures, hot dry winds, and frequent sandstorms, as well as torrential showers and erratic monsoon rains later in the summer. Alluvial sediments deposited in the Jhelum River, as well as the Chenab River in the district's southwest, contribute to the formation of the district's soil. The majority of Pakistan's soil has been degraded as a result of continual agricultural production and insufficient supplies.

Wheat, rice, sugarcane, and fodder are among the principal crops grown in this area. Sargodha is home to one of the top citrus-producing regions in the world. Kinow, Orange, and Lemon, as well as fruits like Guava and Watermelon, are popular citric items in Sargodha. Peas, Spinach, Cauliflower, Coriander, Squash, Bitter gourd, Chillies, Radish, and Carrots are among the nutritious vegetables grown in this city.

Sampling Sites

In Pakistan's District Sargodha, samples of available soil, food crops, and human blood were collected from three different Tehsils: Bhalwal, Sahiwal, and Silanwali. Three replicates of each sample are obtained from each site. The sampling took place from August 2019 until May 2020 (Table No. 1).

Sampling of Soil and Food Crops and Blood

The research locations were dug up with a drill to a depth of thirteen to fifteen cm, and one kilograms of earth was obtained from all levels. A total of 45 samples were taken from five different food crops. Five duplicate specimen selections were made for each location. Along the side of a road, samples of spinach (*Spinacia oleracea*), garlic (*Allium sativum*), wheat (*Triticum aestivum*), maize (*Zea mays*), and barley (*Hordeum vulgare*) were taken. All food crop and soil samples were air dried before being roasted at 75 degrees Celsius for 45 hours. All of the oven dried samples were then placed in polythene bags and incubated for four days at 71 degrees Celsius. There were labels on all of the samples (Table No.2)

Mineral Investigation

Assessment of minerals comprise of following phases.

Phase1: Digestion
Phase 2: Dilution
Phase 3: Filtration
Phase4: Atomic absorption spectrophotometry

Apparatus and Chemical

Gloves, hotplate, four beakers of 100 ml and 250 ml volume, hydrogen peroxide (H_2O_2) 50%, filter paper, two digestion flasks of 100 ml, Sulphuric acid 2 ml, tripod stands, stirrer, freshly prepared distilled water, 50 ml measuring cylinder and small plastic bottles.

Process of Digestion Method

Wet digestion was used to breakdown all of the natural compounds in the samples of food crops and soil. Principally made to obtain:

- Complete biological ecosystem breakdown
- Avoidance from impurity
- A complete matrix solution

Weighting each Crucible

By using the weight balance each sample’s weight was noted before performing the process of dry digestion.

Food Crops

The Plant samples were oven dried at 100° C for 24 hours and blended to fineness for easy digestion with an electrical blender and then sieved through a 2 mm mesh sieve for easy digestion. 5

ml of 4:1 mixture of concentration HNO_3: $HClO_4$ was added to 1 g of weighed plant with an analytical weighing balance. It was heated at a temperature of 105° C for 1 hour to dryness. Then allowed to cool and made up to the mark of 50 ml volumetric flask with 1M HNO_3. The solution was centrifuged using a (HARRIER 15/80 model centrifuge) for 30 min then transferred into sampling bottles for analysis; all digested samples were analyzed using a Perk-Elmer Analyst AAS (Atomic Absorption Spectrophotometer).

Soil

Soil (5g) and 2ml of Sulfuric Acid were added in digestion chamber. The whole amount of toxic material in soil was determined after the process of digestion. The chemicals including 2.5ml of nitric acid, 0.5ml 30% hydrogen peroxide and 7.5 ml of hydrochloric acid were used.

Dilution and Filtration

All the samples were purified via the process of filtration. By using the distilled water all the samples that were digested had been diluted and made their volume up to 50 ml. After that, all of the samples were saved in plastic bottles and labeled them.

Statistical Study

Data was subjected to statistical analysis by using SPSS software version 25. Variation in level of metals was computed through two-way ANOVA while correlation was carried out to check the association of metal level with change in type of fertilizers.

Indices for Pollution Exposure Evaluation

i. Pollution load index (PLI)

The Pollution Load Index (PLI) measures how much soil sediment is linked to particular heavy metals that may have an impact on the micro flora and fauna of soil. Table 3 express Cu and Ni reference values (mg/kg) in soil.

Liu et al., (2005) reported PLI

$$\mathrm{PLI} = \frac{\text{Concentration of metal (mg/kg) in known soil}}{\text{Reference value of metal in soil}}$$

ii. Bioconcentration Factor (BCF):

Cui et al., (2004) suggested BCF by using the following formula

$$\mathbf{BCF} = \frac{\underline{\textbf{Metals value in food crops}}}{\textbf{Metals value in soil}}$$

iii. Enrichment Factor (EF)

Table 4 represents the Cu & Ni standard concentrations (mg/kg) in soil and food crops. To calculate EF following formula is used:

$$\mathbf{EF} = \frac{\dfrac{\text{Concentration of metal value in plant}}{\text{Metal value in soil}}}{\left(\dfrac{\text{Metal value in plant}}{\text{Metal value in soil}}\right)\text{standard}}$$

iv. Daily Intake of Metal (DIM)

Table 5 showed DIM for Ni and Cu and it is obtained by following formula:

DIM = C metal *F conversion factor * D food intake / B average weight of sheep

v. Health Risk Index (HRI)

The HRI (Health Risk Index) is a tool for determining the health risks associated with consuming polluted feed. Oral reference dose is shown in table 6 for Cu &Ni.

Health risk index = Daily intake of metal / R_f D

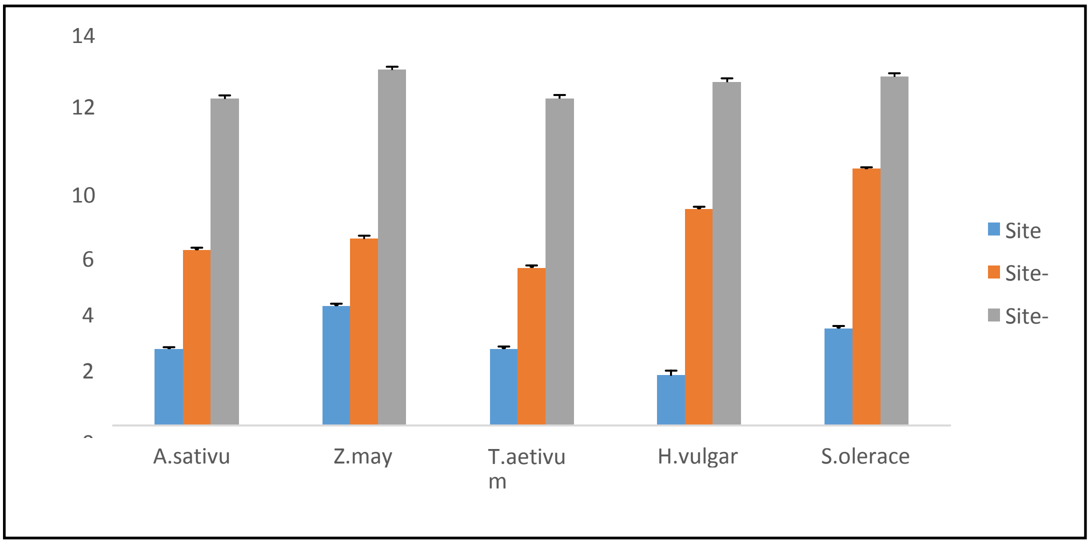

Figure 1: Fluctuation in the concentration of copper in soil treated with different types of fertilizers

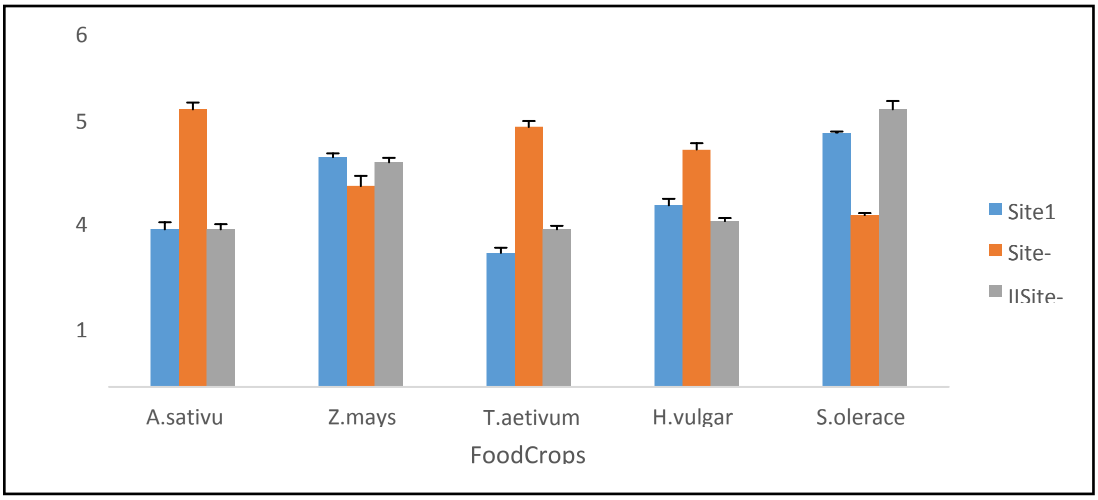

Figure 2 Fluctuating level of Nickel in food crops treated with different fertilizers

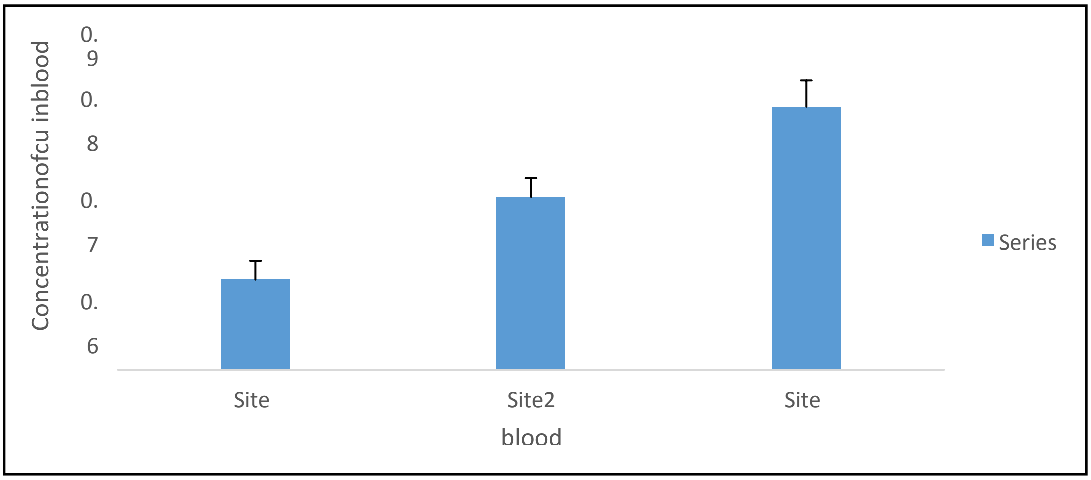

Figure 3 Fluctuation of copper in human blood samples

Table 1: List of studied areas

Sites	**Bhalwal**	**Sillanwali**	**Sahiwal**
Fertilizers	Urea	Urea phosphate	Super phposphate
Fertilizers	Farmyard manure	Manure	Ammonium phosphate
Fertilizers	Potassium Chloride	Ammonium Sulphate	Nitrate phosphate

Table 2: list of collected food crops samples

Sr. No	Common name	Scientific name
1	Spinach	*Spinacia oleracea*
2	Garlic	*Allium sativum*
3	Wheat	*Triticum aestivum*
4	Maize	*Zea mays*
5	Barley	*Hordeum vulgare*

Table 3: Metals reference values in soil

Heavy Metals	Reference Values ($mgkg^{-1}$)	References
Cu	8.39	(Singh et al., 2010)
Ni	9.06	(Singh et al., 2010)

Table 4: Standard concentration of metals (mg/kg)

Heavy metals	Standard values in Food crops (mg/kg)	Standard value in Soil (mg/kg)
Cu	10a	8.39b
Ni	1.5b	9.06a

*a*FAO/WHO(2007), b*FAO/WHO 2001*

Table 5: Daily intake of metal

Human	DIM	B average weight	Conversion factor
	0.345 mg/kg	55.9k	0.085 (Jan et al., 2010)

Table.6: Oral reference dose (mg/kg) for heavy metals

Heavy metals	Oral reference dose R_fD (mg/kg)	References
Cu	3	FAO/WHO (2007)
Ni	1.4	FAO/WHO (2007)

RESULTS

Analysis of variance revealed that there was significant difference regarding accumulation of copper in nickel among sites and food crops. Interactive effect of sites and varieties was also significant for metal accumulation (Table No.7).

Table No. 8 represents the summary of mean concentration of Cu in the soil samples. The mean values ranged from 10.2 to 15.8 mg/kg in soil. The minimum concentration was found in the soil of *T.aestivum* grown at Site-1 treated with urea, farmyard manure and potassium chloride. The highest level of heavy metal was observed in the soil *S.oleracea* that was collected from site-2 treated with urea phosphate, manure, ammonium sulphate fertilizers (Figure 1), and the results of current investigation was lesser than the permissible limit of Cu in soil 60 mg/kg FAO/WHO (1996).

Concentration of Copper and Nickel in Food Crops

Accumulation of copper significantly varied among food crops, sites as well as interactive effect of site and food crops was also significant (Table No. 9). The Table No. 10 showed the fluctuating values of copper concentration in the different food crops treated with many types of fertilizers. The mean Cu concentration ranged from 1.23 to 5.20 mg/kg. It can be observed that the *Z. mays* of the site-3 had the higher concentration of copper treated with superphosphate, ammonium phosphate and nitrate phosphate fertilizers while the *T. aestivum* plant that was grown at site-1 treated with urea, farmyard manure and potassium chloride fertilizers accumulate the lowest amount of Cu as compared to the plant of other sites (Figure 2). All the present study values are lower than the permissible limit of Cu 10 mg/kg given by WHO (1996).

The table No.11 showed the different concentrations of Cu in human blood. The mean values ranged from 2.68 to 3.74 mg/kg. It can be clearly observed that the inhabitants of site-3 had the maximum concentration of Cu in their blood. The residents of site-1 had lowest level of Cu in their blood (Figure 3).

Correlation

At site-1 there was a positive non-significant correlation and at site-2 and 3 negative significant correlations was observed for Cu between the soil and food crops. The results of correlation between food crops and blood showed the positive non-significant correlation at site-1 and negative non- significant correlation at site-2 and 3 (Table No.12)

Pollution Load Index

PLI value varies from 1.215 to 1.7189 mg/kg. According to the treatments of fertilizers the Site-1 has the following PLI order *H.vulgare> Z.mays> T. aestivum> A. sativum> S. oleracea.*This order was different at site-2 *T.aestivum> Z.mays> A.sativum> H.vulgare> S.oleracea.* The site-3 treated with superphosphate, ammonium phosphate and nitrate phosphate fertilizers represent the PLI order of *T.aestivum> Z.mays> A.sativum> A.sativum> S.oleracea> H.vulgare.* The largest value of PLI was found in *H.vulgare* at site-3 while the minimum PLI value was found in *S. oleracea* of site-1 (Table No.13).

Bio concentration Factor (BCF)

Bio concentration factor of three different sites represent the three different trends of BCF values.

Table 8: Copper and Nickel concentration in the soil samples (Mean± S.E)

Sites	Cu concentration in the soil samples			Ni concentration in the soil samples		
	Site1	**Site2**	**Site3**	**Site1**	**Site2**	**Site3**
T.aestivum	10.20±0.058	14.23±0.059	12.22±0.089	2.76±0.089	5.70±0.058	9.50±0.115
A.sativum	11.23±0.089	11.73±0.089	11.48±0.089	3.23±0.088	5.26±0.333	8.53±0.353
Z.mays	10.77±0.089	12.76±0.063	11.76±0.089	4.03±0.014	4.80±0.057	6.56±0.120
H.vulgare	11.50±0.058	11.73±0.058	11.61±0.058	2.40±0.058	5.26±0.088	7.73±0.088
S.oleracea	12.20±0.058	15.80±0.088	14.00±0.058	4.20±0.057	6.02±0.008	9.26±0.008

Table 9: Analysis of data variance of Copper and Nickel metal in food crops treated with different fertilizers

Variables	Degree of freedom	Mean Square value of Cu	Mean Square value of Ni
Site	1	32.240***	1.571***
Varieties	4	6.421***	2.240***
Site * Varieties	4	4.514***	.166***
Error	20	.018	.014

****=Significant (p<0.001)*

Table 10: The concentration of copper and nickel in food crops samples treated with different fertilizers (Mean± S.E)

Sites	Concentration of copper in food crops samples			Concentration of nickel in food crops samples		
	Site1	**Site2**	**Site3**	**Site1**	**Site2**	**Site3**
T.aestivum	1.23±0.032	1.65±0.087	2.56±0.13	0.66±0.088	1.04±0.006	1.12±0.009
A.sativum	2.37±0.086	2.70±0.070	3.28±0.088	0.90±0.042	1.30±0.153	1.16±0.008
Z.mays	3.74±0.09	4.02±0.005	5.20±00.058	0.70±0.078	1.02±0.008	1.73±0.120
H.vulgare	3.70±0.12	3.63±0.09	4.09±0.020	0.02±0.008	0.17±0.009	1.06±0.163
S.oleracea	2.71±0.09	3.73±0.19	4.05±0.023	1.63±0.012	1.74±0.119	2.06±0.153

Table 11: Concentration of copper and nickel metal in human blood

Sites	Site1	Site2	Site3	Site1	Site2	Site3
Mean conc. of Cu and Ni	2.68±0.07	3.22±0.06	3.74±0.07	1.68±0.08	1.58±0.12	2.22±0.05
Mean square		1.405ns			0.593***	

Table 12: Correlation for Copper and Nickel

Correlation for Cu Sites	**Soil-food crops**	**Food crops-blood**
Site-1	0.407^{ns}	0.307^{ns}
Site-2	-0.454^{ns}	0.447^{ns}
Site-3	-0.136^{ns}	-0.421^{ns}
	Correlation for Ni	
Site-1	0.779***	-0.581^{ns}
Site-2	0.475	0.052^{ns}
Site-3	-0.054^{ns}	0.693^{ns}

Table13: Pollution Load Index For Copper And Nickel

Sites	Pollution load index for Copper			Pollution load index for Nickel		
	Site1	Site2	Site3	Site1	Site2	Site3
T.aestivum	1.338895	1.39849	1.368693	0.305372	0.629139	1.048565
A.sativum	1.283274	1.521653	1.402463	0.35688	0.58131	0.941869
Z.mays	1.370679	1.39849	1.384585	0.44518	0.529801	0.724798
H.vulgare	1.454112	1.668653	1.71789	0.264901	0.58131	0.853569
S.oleracea	1.215733	1.696464	1.456099	0.463576	0.664827	1.022811

Table 14: Bio Concentration Factor for copper and nickel

Sites	Bio concentration Factor for copper			Bio concentration Factor for nickel		
	Site1	Site2	Site3	Site1	Site2	Site3
T.aestivum	0.121242	0.116393	0.20955	0.240964	0.182456	0.118597
A.sativum	0.211573	0.230114	0.286212	0.279381	0.246835	0.136328
Z.mays	0.347368	0.314882	0.441926	0.17438	0.213889	0.263959
H.vulgare	0.321739	0.309659	0.352367	0.009722	0.032911	0.137931
S.oleracea	0.222678	0.236287	0.289524	0.388095	0.289983	0.222302

Table 15: Enrichment Factor for copper and nickel

Sites	Enrichment Factor for Cu			Enrichment Factor for Ni		
	Site1	Site2	Site3	Site1	Site2	Site3
T.aestivum	0.10172192	0.097654	0.175812	1.45542224	1.102035	0.716323
A.sativum	0.17750953	0.193065	0.240132	1.68746347	1.490886	0.823422
Z.mays	0.2914421	0.264186	0.370776	1.05325579	1.291889	1.594314
H.vulgare	0.26993913	0.259804	0.295636	0.05872138	0.198784	0.833104
S.oleracea	0.18682653	0.198245	0.24291	2.34409524	1.7515	1.342705

Table 16: Daily Intake of Copper and Nickel

Sites	Daily Intake of Cu			Daily Intake of Ni		
	Site1	Site2	Site3	Site1	Site2	Site3
T.aestivum	0.10172192	0.097654	0.175812	0.535307	1.343825	1.57304
A.sativum	0.17750953	0.193065	0.240132	0.300298	1.633476	2.98842
Z.mays	0.2914421	0.264186	0.370776	0.611712	1.868484	1.76452
H.vulgare	0.26993913	0.259804	0.295636	0.934242	1.633476	1.677
S.oleracea	0.18682653	0.198245	0.24291	0.884924	1.873854	2.9055

Table 17: Health Risk Index for copper and nickel

Sites	Health Risk Index for Cu			Health Risk Index for Ni		
	Site1	Site2	Site3	Site1	Site2	Site3
T.aestivum	0.000649	0.000869	0.001343	0.002395	0.0674161	0.124
A.sativum	0.001247	0.001416	0.001724	0.007859	0.0166769	0.917
Z.mays	0.001962	0.002109	0.002728	0.007226	0.0620346	0.889
H.vulgare	0.001941	0.001906	0.002147	0.008101	0.0166769	0.055
S.oleracea	0.001425	0.001958	0.002126	0.009178	0.0052753	0.850

The site three had the order of BCF *T. aestivum> A. sativum> S. oleracea> H. vulgare> Z.mays while the site-2* supplied with urea phosphate, manure, ammonium sulphate fertilizers showed the following order of *T.aestivum> A.sativum> S.oleracea> H.vulgare> Z.mays, and* the Site-3 revealed the following order of BCF values *T.aestivum> A.sativum > S.oleracea> H.vulgare> Z.mays* (Table No. 14).

Enrichment Factor (EF)

EF values in accordance with the food crops treated with the fertilizers (urea, farmyard manure and potassium chloride) were *T.aestivum> A.sativum>*

S.oleracea> *H.vulgare*> *Z.mays.*The EF of the food crops grown at the site supplied with urea phosphate, manure, ammonium sulphate showed that the *T.asetivum*> *A.sativum*> *S.oleracea*> *H.vulgare*> *Z.mays.*The food crops of site- 3 represent the following order of EF *T.aestivum*> *A.sativum*> *S.oleracea*> *H.vulgare*> *Z.mays* (Table No.15).

Daily Intake of Copper

The table No.16 showed the daily intake of copper of the residents of three different sites. The DIM values ranged from 0.000649 to 0.0027 mg/kg. It was found that the inhabitants of site three ingested the *Z. mays* had the maximum concentration of Copper in their blood as compared to the residents of two other sites.

Health Risk Index

Highest level of HIR was found in the human beings that ate the *S.oleracea* grown at site-3 treated with superphosphate, ammonium phosphate and nitrate phosphate. It revealed that the site-3 was more contaminated than the other two sites (Table No.17).

DISCUSSION

As compared to the range of 22.26–25.43 mg/kg for Cu concentration in agricultural soil reported by Leogrande et al. (2019), the level of copper observed in the current study is lower. In contrast, Hamid *et al.* (2017) found low levels of Cu metal in soil, with concentrations ranging from 1.3 to 4.8 mg/kg, in an agricultural area near drains in Lahore. This is lower than the concentrations found in the current study, which ranged from 10.2 to 15.8 mg/kg. There is more Cu in the soil assessed in this study than khan et al. (2013) did their analysis (1.16 to 5.42 mg/kg).

Copper (Cu) levels in the current study were found to be between 52.1 and 77.3 mg/kg higher than in the previous study by Addis et al. (2017). In our case, the result was under the FAO/WHO (1996) recommended limit of 60 mg/kg for Cu. According to the current study's findings, the average concentration of Cu found by Ahmad et al. (2016) was between 2.79 and 4.13 mg/kg, which is lower than the current study's concentration.

Cu concentrations in crops from three locations ranged from 1.23 to 5.20 mg/kg, exceeding the 10 mg/kg WHO (1996) threshold. Previous research by Zhuang et al. (2009). had found that there was a higher mean value of Cu in the rice and vegetables, at 6.34 and 10.40 mg/kg, respectively. By comparing the results of the current study with those of a previous one by Ahmad et al. (2016), it was found that the current study had a lower Cu concentration in vegetables (ranging from 10.43 to 15.65 mg/kg. Adeel & Riffat, (2013) also found a lower copper concentration in vegetables (1.3-1.85 mg/kg) than what was found in the current study of food crops. Since copper's Health Risk Index in this analysis was less than 1, there was no evidence that it posed a threat to public health. Previous research found levels to be between 0.02 and 0.05 mg/kg (Adeel & Riffat, 2013), indicating that the food crops in the region under study were safe for human consumption. The present study found lower copper concentrations than the work of Ahmad et al. (2016). The previous research indicated that the food crops or vegetables had an unsafe concentration of copper metal because the HRI values for Cu were greater than one.

Ni concentrations in soil were measured at 2.40–9.50 mg/kg, which is higher than found in the work of Leogrande et al. (2019). Less Ni was detected in soil samples collected by Khan *et al.* (2016). Presently, we have measured concentrations lower than those reported by Suzuki et al. (2009) and significantly higher than those reported by Mayland et al. (2001). Ni concentrations below the (EU, 2002) maximum allowable of 75 mg/kg in soil were found. This study found lower Ni concentrations in soil samples when compared to a previous study by Oladeji (2017), which also used samples from Kaduna State, Nigeria. Ni levels in the crops tested ranged from 0.02 to 2.06 mg/kg, well below the WHO (1996) recommended maximum of 10mg/kg for Ni in food crops. Food crops Ni concentrations in Oladeji (2017), previous study ranged from 6.97 to 18.79 mg/kg, which is also higher than the present study. Ni concentrations recorded by Ahmad et al. (2016) ranged from 6.17 to 7.91 mg/kg, while those found in the currently investigated food crops were lower. Compared to present-day values, the 1.8 to 5.05 mg/kg Ni concentrations measured by Latif et al. (2018) are much higher. Values less than one indicate that food crops are not accumulating a significant amount of Ni, meaning that there is no risk to human health from consuming these crops. The Ni concentration in humans was found to be higher than in the current study by Latif et al. (2018), but still lower than in the reference value of 1. Assessing the potential risk to human health from toxic substances in staples is done with the help of HRI. Ahmad et al. (2016) found HRI values that ranged from 1.77 to 2.27 mg/kg, which is higher than the current values and also above one, i.e. could pose a serious risk to human health.

CONCLUSION

Excessive use of various fertilizers resulted in the accumulation of heavy metals in soil and food crops, according to the current study. Heavy metal concentrations in food crops (Cu and Ni) were within EU and USEPA acceptable limits. Humans eat food crops as their primary source of nutrition. However, due to a scarcity of food as a result of rising population, farmers are being obliged to use excessive amounts of fertilizers to improve crop output for agricultural purposes. Although these fertilizers include critical nutrients, they also contain a large number of pollutants. Humans that consume polluted food crops accumulate a variety of dangerous metals in their bodily organs and blood. It is now necessary to raise public awareness about the health concerns linked with consuming tainted foods.

AUTHORS CONTRIBUTION

All authors have equal contribution in this article.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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