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RESEARCH ARTICLE

Urinary outputs of nickel in association with their concentration levels in water, soil, and selected foods among farmers in the industrial estate of district swabi

Ijaz Ahmad[1], Niamat Ullah[1*], Zia-ud-Din[1]

[1]Department of Human Nutrition, The University of Agriculture Peshawar Pakistan

Corresponding Author: Niamat Ullah, niamatullah@aup.edu.pk
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Abstract
Diet is the main route of exposure to trace metals, so the assessment risk of these elements to human via dietary intake is important. The non-carcinogenic health risk of Nickel (Ni) to the farmers via dietary intake in the Gadoon Amazai Industrial Estate (GAIE) Swabi of Kyber Pakhtunkwa was assessed. A cross sectional study was carried out in the GAIE to estimate the concentration of Nickel in all types of vegetables, grains, drinking water, irrigation water, soil and in urine of the farmers. A total of 22 farmers, living within the 2km distance in all four directions were selected and enrolled in the study after signing consent form. Atomic absorption spectrophotometer was used for the Ni analysis in the collected samples of water (both drinking and irrigation water), soil, foods and in urine of farmers. Results shows that the mean age of the farmers using tube well water and wastewater for irrigation purposes was 43.5±21.01 and 44.75±16.44 years, height was 167.6±3.7 and 165.75±6.02 cm, weight was 61±12.52 and 64.75±9.63 kg and BMI was 21.65±3.73 and 23.7±4.4 respectively. The concentration of the Ni in the wastewater irrigated field was significantly higher than the tube well irrigated field. The mean concentration of Ni in the soil irrigated with wastewater was 123.50±54.74 mg/kg respectively and in the tube-well irrigated field was 54.25±10.14 mg/kg. The Ni concentration in the wastewater irrigated garlic, fodder grass, potato, wheat and maize were 9.15±0.50 mg/kg, 8.82±1.30mg/kg, 7.70±1.04mg/kg and 7.56±1.24mg/kg respectively compared to tube-well irrigated land i.e., 0.97±0.25 mg/kg, 0.64±0.42 mg/kg, 1.08±0.35 mg/kg, 1.05±0.013 mg/kg and 1.02±0.39 mg/kg. A positive correlation was observed between the water, soil, and all crops grown in the GAIE . The bio-accumulation factor was higher for Ni in both the site. The Hazzard Quotient (HQ) for Ni exceeded the 1 for crops irrigated with industrial wastewater compared with tube-well irrigated crops and thus pose adverse health affect to farmers health. This study concluded that a strong association was evident between the Ni concentration in crops and cereals and waste-water irrigation.

Keywords: Dietary intake; Health risk; Hazzard Quotient (HQ); Farmer's health; Nickel; Industrial Wastewater

Introduction

Heavy metals are found on the earth crust naturally and their exposure to the environment occurs through both human and natural activities. Metals have crucial biological effects to both plants and animals but they became toxic after exceeding a certain limits, when enter to body these heavy metals combine with biomolecule of body (such as proteins and enzymes) form stable bio-toxic compounds (Mahurpawar, 2015).

Heavy metals are not degradable in nature and possess to accumulate in different parts, due to no proper mechanism to eliminate from the body these heavy metals even at low concentration damage the health of both humans and animals (Arora, Kiran, Rani, Rani, Kaur, & Mittal, 2008). Each metals possess specific toxicity signs and their effect may be acute, chronic, or sub-chronic (Hossain, Ahmed, Abdullah, Akbor, & Ahsan, 2015).

Diet is essential component for human body, fruits and vegetables provide nutrients (CHO, Protein, minerals and vitamins) to body, therefore contamination of fruits and vegetables by metals cannot be underestimated (Itanna, 2002). The heavy metals enter to food chain by the consumption of vegetables (Wang, Shan, Zhang, & Wen, 2004). Consumption of unsafe contaminated heavy metals for long time through foodstuff results deposition of metals in the kidney and liver, which causing disturbance in various processes and leads to some kind of diseases like nervous, cardiovascular, kidney and bone (Järup, 2003). Some nutrients are depleted by the intake of contaminated food which causes intrauterine growth retardation, lower immunological defenses, impaired psycho-social behaviour and the gastrointestinal cancer (Arora, Kiran, Rani, Rani, Kaur, & Mittal, 2008). The nature of effect can be neurotoxic, mutagenic, carcinogenic, or teratogenic (Duruibe, Ogwuegbu, & Egwurugwu, 2007).

In the economy of any nation good health and productive agriculture is important especially in the poverty. Pakistan is an agriculture country, and the farmers are considered to be the backbone of Pakistan economy. Agriculture system can be affected by health of producer's (farmers). The poor health of farmers decreases the work capacity and ability to explore various farming practices and also result in loss of workdays, decrease innovation ability. The agriculture production process and its output effected by both good and poor health of the farmers as well as in the society (Corinna & Ruel, 2006)

Due to the adverse health effects, heavy metals became an important concern in the agricultural products. Heavy metals even at very low concentrations are significantly very toxic due to its cumulative nature. The heavy metals accumulated at toxic level in the crop by the long term application of wastewater to irrigated field (Juste & Solda). Enormous volumes of wastewater is released by rapid urbanization and industrialization, which is used as a source for irrigation practices. The wastewater irrigation are creating problems and opportunities for agriculture production, as this wastewater contains considerable amount of toxic heavy metals and plants nutrients respectively (Singh, Mohan, Sinha, & Dalwani, 2004). The wastewater treatment does not remove the heavy metals and thus causes risk to food chain by heavy metals contamination by soil (Fytianos, Katsianis, Triantafyllou, & Zachariadis, 2001).

Vegetables are grown on small scale as compared with commercial main crops like, maize, wheat, and rice, but the productivity of vegetable totally depends on the good quality water availability for irrigation purposes. However, because of recently increase in the exportation of vegetables to other countries, in Pakistan the area of vegetables cultivation is increasing by the time. Like, vegetables were cultivated during 2007 and 2008 at about 253,800ha (M. Abbas, Parveen, Iqbal, Riazuddin, Iqbal, Ahmed, et al., 2010). However, the most commonly consumed vegetables are grown in the areas of peri-urban where formers using polluted waste-water for irrigation purpose coming from sewage with no proper filtration. Thus, it is expected that from the peri-urban locations of have polluted irrigation water, all the grown vegetables accumulate a considerable amount of heavy metals (Firdaus-e & Tahira, 2011). A variety of heavy metals are present in wastewater, by extensive uses of contaminated waste-water as source of irrigation for cereals and vegetables accumulate toxic metals (Adhikari, Manna, Singh, & Wanjari, 2004). These heavy metals easily enter the food chain, because the removal of these toxic metals from the water and soil is very difficult (Wilson & Pyatt, 2007).

Several approaches have been proposed to estimate the potential health risks of contaminants, distinguished mainly by carcinogenic and non-carcinogenic effects. United States Environmental Protection Agency (USEPA) current methods of assessing non-cancer risk and cancer risks are very different. The standard cancer risk assessment methods can be used to quantify the magnitude of risk, while similar methods are not available for quantifying the non-cancer risks (U. EPA, 1989). The non-cancer risk assessment is based on the use of hazards quotient (HQ), which is a ratio of the estimated dose of a contaminant to the Reference Dose (reference dose or RfD is the level below which there will not be any appreciable risk of the contaminant). If the estimated dose for an exposed population is equal to or greater than the RfD, then the population is at risk of contracting the adverse effect associated with the contaminant (U. EPA, 1989; USEPA). To assess the overall potential risk of more than one contaminant for non-carcinogenic effects, a Hazard Index (HI) approach has been developed based on the United States Environmental Protection Agency (Urban & Cook, 1986) Guidelines for Health Risk Assessment of Chemical Mixtures. The HI represent the total non-cancer hazard for all exposure pathways presented. The HI is equal to the sum of all the hazard quotients in USEPA-1989 (A. EPA, 1989). When the hazard index exceeds unity, there may be concern for potential health effects. Any single contaminants with exposure level greater than toxicity value will cause the hazard index to exceed unity, the hazard index can also be exceeded for multiple chemicals even if no single chemical exceed its RfD (A. EPA, 1989). We have carried out this study to estimate the concentration of Nickel (Ni), and to assess the hazard quotient and target hazard quotient of the Ni via the foodstuff for the local farmers in the Industrial Estate of District Swabi. A variety of heavy metals are present in wastewater, by extensive uses of contaminated wastewater as source of irrigation for cereals and vegetables accumulate toxic metals (Adhikari, Manna, Singh, & Wanjari, 2004). These heavy metals easily enter the food chain because the removal of these toxic metals from the water and soil is very difficult (Wilson & Pyatt, 2007). The target hazard quotients (THQs) and hazard index (HI) were calculated to assess non-carcinogenic health effects from individual and combined heavy metals because of daily foodstuff consumption.

Material and Methods

Study site

The Gadoon Amazai Industrial Estate (GAIE) is in district Swabi, Khyber Pakhtunkhwa, and is 325 meters elevated above the sea level, bounded north, east, west and south by Baisak, Maini, Gandaf, and Topi. GAIE contains a total of 330 active units and was established in 1986-1987(Khan, Ahmad, Shah, Rehman, & Khaliq, 2009). The main active units in the industrial state are steel, marble, textiles, chemicals, soap and soap, plastic, and ghee and cooking oil (Khan, Ahmad, Shah, Rehman, & Khaliq, 2009).

Inclusion Criteria and sample size

All those farmers having farms within 2 kilometers from industrial estate were orientated about the study. A total of 22 farmers were randomly selected and data were collected from the agreed farmers.

Anthropometric Assessment:

Farmer’s body weight and height were assessed through WHO standard methods. Weight was measured through digital scale, while weighing, the farmers were asked to remover heavy clothes, shoes and all un-necessary things. The height of farmers were measured through studio-meter. BMI was calculated through the height and weight data.

Sampling and pre-treatment

The study area was divided into 4 directions (North, South, West and East) from the mid-point. The samples of water, soil, crops, vegetables (Potato, Garlic) Milk, and Urine were selected for the study. Water of both the irrigation and drinking purpose were collected, for drinking purpose water from different sources (Tube-well, hand-pump, Open-well and tape water) were used in the Industrial estate. The farmers use two types of water for irrigation of fields 1) Industrial wastewater and 2) Tube-well water. The water samples and milk of animals were directly collected in polythene bottles, all the bottles were washed with acidify water and dried, the morning urine samples were collected with the addition of 2 drops of HCL to reduce the decomposition of urine by bringing its PH to below 4. The crops samples which were grown in the industrial area were collected in polythene bags, labelled, and brought in ice-cold boxes to the Department of Human Nutrition, The University of Agriculture Peshawar for further analysis. In the laboratory the vegetable samples were thoroughly washed firstly by ordinary tape water followed by distilled water to eliminate soil and air burn pollutant. Edible portion of vegetables samples were cut into pieces and placed in oven for 48 hours at 80^0 C to completely dry. After the heating the samples were kept overnight to cool down to room temperature. Each sample was ground to fine powder and stored for further chemical treatment.

Digestion and treatment

All the required glassware was first washed with standard detergent followed by tap water, soaked in an acid bath (10% HCL) and placed in oven to dry. I gm of sample was taken into the digestive tube, 12 ml concentrated nitric acid was added to the tubes and kept overnight. The next day 4 ml of perchloric acid was added and placed in heat-block, gradually increased the temperature from 80^0 C until a white fume started AOAC, 2000 (Cuniff, 2003). After heating the solution was cooled down at room temperature filtered in 50 ml volumetric flask, diluted by distilled water up to the mark (50 ml). The powdered soil was treated with solutions of HNo_3, perchloric acid and sulphuric acid with a 4:1:1, samples were filtered using Whatman No.42 filter paper to eliminate suspended substances. Prepared samples were stored in the clean bottle prior analysis (Shakya & Khwaounjoo, 2013). Atomic absorption spectrophotometer was used as standard method of AOAC 2000(Cuniff, 2003) for the determination of nickel in the samples.

Health Risk Assessment:

The health risk from the consumption of contaminated food was calculated by the following quotient hazards equation (Huang, Zhou, Sun, & Zhao, 2008) (Muhammad, Ullah, & Jadoon, 2019).

$$HQ = \frac{CDI}{RfDo}$$

$$CDI = \frac{CF \times IR \times EF \times ED}{BW \times AT}$$

Where CDI is the chronic daily intake of metal from food expressed in mg kg^{-1} day^{-1}, RfDo is the oral reference dose (in mg kg^{-1} day^{-1}). CF is the concentration of metal in plants, IR is the ingestion rate, EF is the exposure frequency (365 days per year), ED is the exposure duration, BW is the body weight and AT is the averaging exposure time(364×ED). The RfDo values for Ni was 0.02 mg/kg according to US-EPA. If the HQ values exceed the unity, there will be potential effect to the body.

Daily Intake of Metal:

The daily intake of metals (DIM) from the food sources was calculated by the following equation (Bi, Zhou, Chen, Jia, & Bao, 2018) (Orisakwe, Nduka, Amadi, Dike, & Bede, 2012).

$$DIM = \frac{C\text{fveg} \times \text{Wveg}}{BW}$$

Where Cveg is the concentration of metal in in vegetables or food (mg/kg), Wveg (mg/day) is the ingestion rate of food contaminated by particular metal and BW is the Body weight (kg)

Bio-accumulation Factor:

The bio-accumulation factor also known as transfer factor, which is the transfer of heavy metals from the soil to the crops grown in an area. The bio accumulation factors is an index reflecting the ability of a plant species to accumulate a particular metal regards to its concentration in the soil (Galal & Shehata, 2015; Ghosh & Singh, 2005) It is calculated as the metal concentration in the plants (dried weight basis) divided by the concentration of that particular metal in the soil on which it grows (Cui, Zhu, Zhai, Chen, Huang, Qiu, et al., 2004; Liu, Zhao, Ouyang, Söderlund, & Liu, 2005), (Ahmad, Khan, Ashfaq, Ashraf, & Yasmin, 2014), (Muhammad, Ullah, & Jadoon, 2019).

$$TF = \frac{CP}{CS}$$

Where CP is the concentration of metal in plants and CS is the concentration of metal in the soil. The bio-accumulation shows the bio-availability of metals and nutrients to the plants.

Health Risk Assessment:

The health risk from the consumption of contaminated food was calculated by the following quotient hazards equation (Huang, Zhou, Sun, & Zhao, 2008) (Muhammad, Ullah, & Jadoon, 2019).

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Results and discussion

The body mass index (BMI) gives the best gauge for estimate of the nutritional status of the farmers, As the farmers characterize an occupational group which required heavy amount of physical activity for their field work in farm. Because of this heavy workload the farmers might tend to decrease risk for development of overnutrition. The farmers use tube well water for irrigation purposes had BMI within normal range (18.5-24.9 kg/m^2) as compared to farmers uses wastewater for irrigation as shown in table 1. Different studies reported different obesity status of farmers in different countries like in Australia only 15.2% of the farmers reported to overweight (Dorner, Leitner, Stadlmann, Fischer, Neidhart, Lawrence, et al., 2004) and in Greece 86.1% of the farmers reported to overweight (Vardavas, Linardakis, Hatzis, Saris, & Kafatos, 2009).

Table 1. Anthropometric, Socio-demographic features of the farmers

Variables		Tube Well Mean±SD/Frequency (%)	Wastewater Mean±SD/Frequency (%)
Age (Years)		43.50±21.01	44.75±16.44
Weight (kg)		61±12.5	64.75±9.63
Height (cm)		167.5±3.9	165.8±6.02
BMI (kg/m$^{2)}$		21.61±3.73	23.7±4.4
Household size		8.25±1.3	7.25±1.5
Area of Farming (kanals)		62.5±28.7	42.00±33.9
Living since (Years)		8.25±6.0	11.25±6.1
Educational Level	Illiterate	70%	50%
	Literate	30%	50%

The farmers living in the study location were not of permanent resident that's why the mean time of residency for both the categories of farmers were 8.25±6.0 and 11.25±6.1 years. Education is positively related to the production of farmers the literacy rate of farmers in the study location was very low. Because of poverty and workload in the field, the farmers are unable to enroll their children for education. The literacy rate of farmers in underdeveloped and developing countries remain the lowest as reported in Odisha (Das & Sahoo, 2012). In south Nigeria about 33.8% of the farmers were reported uneducated (Fabunmi, Aba, & Odunaiya, 2005).

The industries effluents were fallen directly to nearest small canal of water, theses small canals were then used for the irrigation purposes, so the waste from the industries were transferred through canals water to the farming land. The study area was divided in to four directions (North, East, West and South) from the mid-point to estimate the Ni in all the industries effluents in irrigation water.

Figure 1 shows the Nickel concentration in the irrigation water sources in the GAIE. The wastewater used for irrigation purposes had significantly high concentration of nickel compared to the tube-well irrigated water. The highest mean of 3.87 ppm nickel was present in the North side followed by East 3.57 ppm, West 2.19 ppm and South 1.87 ppm in the wastewater sources for irrigation. No nickel was found in the East site in tube-well irrigation source. The nickel concentration in the waste-water irrigation crossed the permissible limit of 0.2 ppm set by the US Irrigation Water Quality standards, while in the tube-well irrigation water were in the safe limit for irrigation.

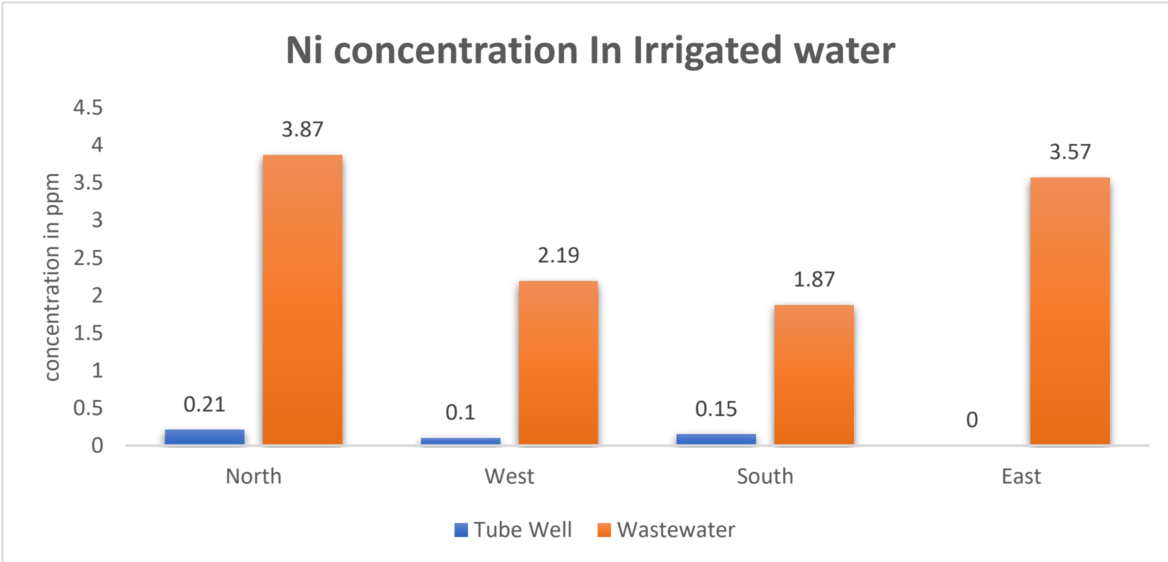

Figure 1. Nickel concentration in the irrigated water

This high amount of nickel was due to the nickel-cadmium batteries, steel and ghee and oil, kitchen appliances, surgical instruments and steel alloys industries in GAIE (Tariq, Ali, & Shah, 2006). These industries released a vast amount of nickel to the environment. Industrial activities such as mining, electroplating, and manufacturing of essential commodities produce a huge volume of wastewater as effluents containing heavy metals and other toxicants, which deteriorate the quality of aquatic system (S. Abbas, Sarfraz, Mehdi, & Hassan, 2007), (Bose & Bhattacharyya, 2008). In the study area, drinking water was consumed from the four types of sources, from tube-well, tape water hand pump and well-water in the home.

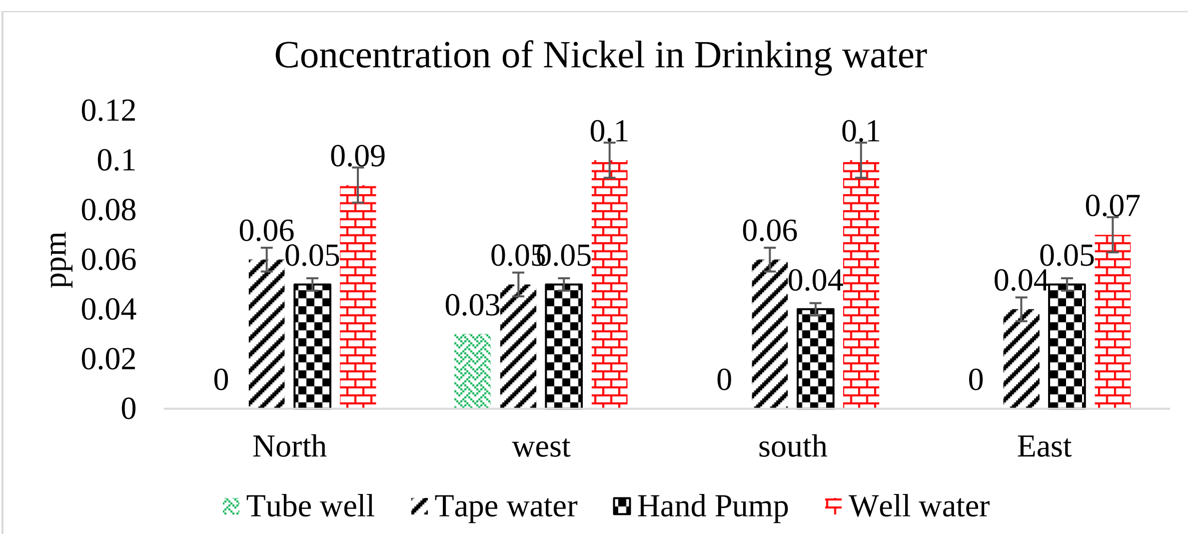

Figure 2. Nickel concentration in the Drinking water

Figure 2 shows the concentration of nickel in the drinking water sources used in the Industrial zone of GAIE. The results showed the Ni concentrations was significantly higher in the open well-water used for drinking. The Ni concentration in tube-well and hand pump drinking sources was found within the safe limit of 0.05 ppm set by the Pakistan National Standard for Drinking water (NSDWQ-Pak). The highest concentration of Ni contamination was found in the Well-water in West and South site of 0.1 ppm, while 0.09 ppm and 0.07 ppm in North and East site. No nickel was detected in the tube-water in the East, South and North regions (detection limit for nickel is 0.02). The highest concentration in the tap-water was recorded in the North and South region of 0.06 ppm followed by West and East of 0.05 ppm and 0.05 ppm respectively. Compared with concentration of Ni of 0.037 ppm in Karachi (Karim, 2011) the current concentration was higher.
Table 2 illustrate the nickel concertation in the soil, wheat, maize, potato, garlic and fodder grass gown in the industrial estate by the waste-water irrigation. The mean concentration of nickel in all the vegetables, soil and milk samples in waste-water irrigation was significantly higher than in the tube-well irrigation. The nickel concentration in soil samples irrigated by tube-well and wastewater was measured as 54.25±10.14 mg/kg and 123.50±54.74 mg/kg. In the tube-well irrigated wheat the Ni concentration was in range from 0.93 to 1.2 mg with a mean of 1.05±0.13 mg compared to the wastewater irrigated wheat of range from 6.14 mg to 8.93 mg. Whereas the mean concentration of Ni in the maize was recorded as 1.02±0.39 mg in the tube-well irrigated compared with the wastewater irritated of 6.31±0.76mg.

Table 2. Concentration of Nickel in Food, grown in the industrial estate irrigated through Tube Well and Industries-wastewater

Variables	Tube Well Source	Wastewater Source	p-value
Soil	54.25±10.14	123.50±54.74	.047
Wheat	1.05±0.13	7.56±1.24	.001*
Maize	1.02±0.39	6.31±0.76	.004*
Potato	1.08±0.35	7.70±1.04	.002*
Garlic	0.97±0.25	9.15±0.50	.003*
Fodder	0.64±0.42	8.82±1.30	0.00**

*Significant difference observed at $p < 0.05$ ** Significant difference observed at $p < 0.01$

Among all the food sources in the waste-water irrigation, the highest mean value of Ni was recorded in the garlic 9.15±0.50mg, while in the tube-well sources was recorded in the potato samples of 1.08±0.35mg. The Ni mean concentration in the wastewater irrigated potato was 7.70±1.04 mg while in the tube-well irrigated was 1.08±0.35 mg. The average value in the fodder grass was recorded as 8.82±1.30 mg in the water-water irrigation compared to tube-well irrigation of 0.64±0.42 mg.
The results of this study is resembles with the finding of (Hussain, Khattak, Shah, & Ali, 2015) who studies the contamination of soils by the industrial effluents, and resulted that the mean concentration of nickel in the waste-water soil was 119.8mg. compared with the reference or tube-well irrigated soil which was 58.8mg. The highest concentration in the industrial waste-water was due to the stainless steel, alloys industries, which direct expelled their waste to the environment without any treatment. A study (Al-Othman, Ali, Al-Othman, Ali, & Habila, 2016) reported that the mean nickel concentration in the wheat grains grown by tube-well water in district Swabi was 0.087mg lower than the finding of this study. The average concentration of Ni in the wheat and maize irrigated with un-polluted water was 0.04±0.01mg and 0.11±0.01mg, significantly lower than that of the crops grown with

the polluted water which was 0.1±0.01 mg in wheat and o.10±0.01mg in maize. The soil contamination with toxic metals and pathogens was due to the long term irrigation with waste-water (Farahat & Linderholm, 2013). The extractable concentration of nickel in the present study was lower than the soil irrigated by canal water and waste-water of Hyderabad city in southern Pakistan (Jamali, Kazi, Arain, Afridi, Jalbani, & Memon, 2007). Nickel is utilized in certain industrial applications and can be a potential contaminant in food products. Ni is also an essential element for human health but may become toxic above certain levels. There is currently no published permissible limit of Ni in milk; however, researchers still maintain a focus on Ni contamination in milk due to its potential for negative health impacts (Ismail, Riaz, Akhtar, Goodwill, & Sun, 2019) and the concentration of nickel in milk was found in the range of 0.0070-2.631mg/l.

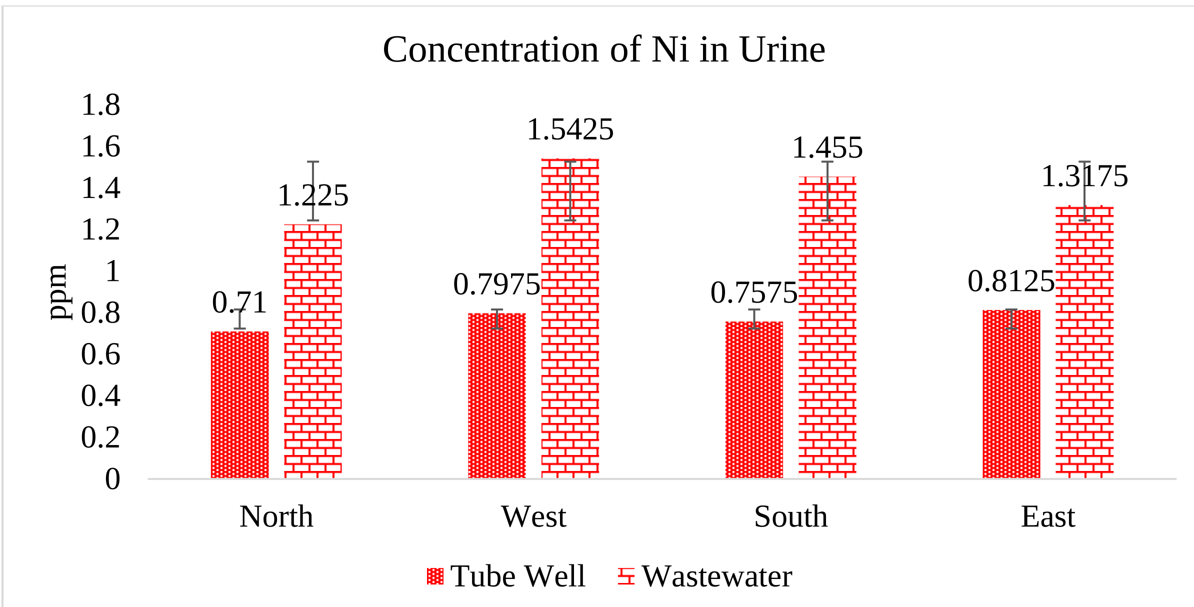

Figure 3. Nickel Concentration in Urine

Figure 3 shows the Ni concentration in the urine of farmers using food from wastewater irrigated land and tube-well irrigated land. The waste-water farmers urine showed significantly high concentration of nickel compared to the farmers urine using tube-well water for irrigation. The highest concentration of 1.5 ppm was observed in the farmers urine of West side to industries, while the lowest was recorded in the North side farmers, who were using wastewater for the irrigation purposes. While in the farmers who was using tube-well water for irrigation, the highest mean concentration 0.81 ppm of nickel was recorded in the farmers urine to the East side to industries, followed by the West, South and North. According to the Korea National survey for environmental pollutants in the human body 2018, and heavy metals in the blood and urine of the Korean population (Lee, Lee, Moon, Choi, Lee, Yi, et al., 2012) reported that the high level of heavy metals in the urine and blood was due to the high intake of contaminated foods, the level of toxic metals in urine was strongly related to its oral intake.

The bio-accumulation and transfer factor is used to estimate the plants potential to attract the particular metal or nutrients from the soil through roots (Farahat & Linderholm, 2015) (Galal & Farahat, 2015). Table 4.3 shows the bio-concentrations factors of Ni for crop-soil system. The crops grown on Wastewater possess higher accumulation factors compared with crops grown on tube-well water.

Table 3. Nickel content for tube well and wastewater for different crops

Crops	Nickel	
	Tube well	Wastewater
Wheat	0.021±0.006	0.050±0.014
Maize	0.021±0.012	0.042±0.012
Potato	0.022±0.011	0.051±0.013
Garlic	0.020±0.008	0.033±0.011
Fodder grass	0.014±0.011	0.057±0.10

Table 4. Correlation between Soil and Crops

Soil crops	Ni
Soil-Wheat	.807*
Soil-maize	.771*
Soil-potato	.813*
Soil-garlic	.725*
Soil-Fodder	.802*
Fodder-Milk	.987**

* Correlation is significant at the 0.05 * Correlation is significant at the 0.01

Table 4 shows the Pearson correlation among the soil and crops, soil and fodder and fodder to milk was determined to check the route of the nickel from soil to crop, fodder and from fodder to milk. It was found that a strong correlation (significant at 0.05) was found for nickel.

Health risk is defined as the quotient between the estimated to daily metal intake from the soil through food chain and oral reference dose for each metal. An index under the value 1 assumed as safe. The hazard quotient from nickel is presented in figure 4.

The HQ value for nickel exceed the unity in the food grown by waste-water irrigation water and pose adverse health effect to farmers health as shown in figure 4.4. All the foods grow with tube-well water pose no health effect from nickel.

The present study resemble with the study (Qin, Zou, & Qiu, 2008) stated that the health risk of chromium was less compared to nickel because of the high RfDo value of 1.5mg/day. They calculated the health risk of the heavy metals to the general public of Guangzhou China. There result showed the HQ value for chromium in the safe limit of below the unity.

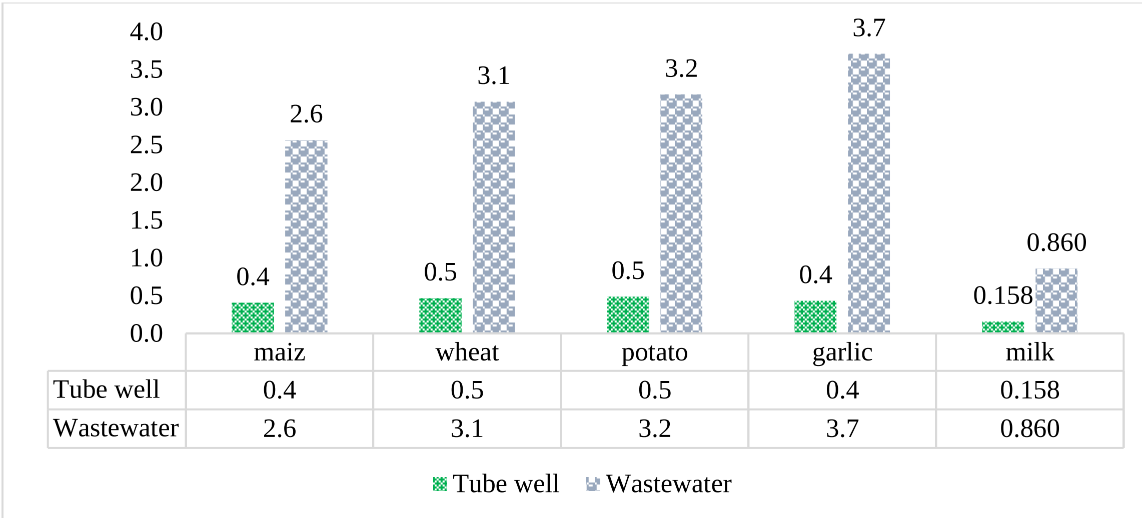

Figure 4 . Hazard Quotient for Nickel

Conclusion

The wastewater from the industries in the Gadoon Amazai Industrial Estate (GAIE) contained significant amount of nickel. Soil, vegetables, cereals and fodder for cattle from the agriculture land irrigated through wastewater from GAIE contained significant amount of nickel. Food consumption had been identified as the major pathway of human exposure to heavy metals. Farmers of GAIE area shows significant amount of nickel in their Urine. The health risk assessment indicates that the farmers of GAIE were at high risk of nickel toxicity.

Declaration

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Authors contribution: N/A

Data availability: From the authors

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