# Health Risk Assessment and Nickel Content in Soils, Rice (*Oryza Sativa* L.) and Wheat (*Triticum Aestivum* L.) Grown in Damietta Governorate, Egypt

S. H. Badawy<sup>1</sup>, R. A. El-Motaium<sup>2</sup>, M. F. Hossain<sup>3</sup>, H. M. Abdel-Lattif<sup>4</sup>, H. M. Ghorab<sup>5</sup> & M. A. El-Sayed<sup>1</sup>

<sup>1</sup> Soil Science Department, Faculty of Agriculture, Cairo University, Egypt

<sup>2</sup> Plant Researches Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Egypt

<sup>3</sup> American International University - Bangladesh, Kuratoli Road, Kuril, Dhaka 1229, Bangladesh

<sup>4</sup> Agronomy Department, Faculty of Agriculture, Cairo University, Egypt

<sup>5</sup> Health Affairs Directorate, Damietta, Ministry of Health, Egypt

Correspondence: S. H. Badawy, Soil Science Department, Faculty of Agriculture, Cairo University, Egypt. E-mail: shbadawy60@agr.cu.edu.eg

Received: February 7, 2022	Accepted: April 5, 2022	Online Published: April 6, 2022
doi:10.5539/ep.v11n2p1	URL: https://doi	.org/10.5539/ep.v11n2p1

# Abstract

Nickel (Ni) concentration in soils is highly depended on the parent materials and the types of pollutant sources that plays a beneficial role in plant growth however; at high concentration it may cause toxicity for plants and creating hazards to animals and human. Therefore, this study aimed to estimate the levels of Ni in soils, straw and grain of rice and wheat plants grown in the soils contaminated with Ni and evaluate its effect on human health. In the surface soil layers the total  $(31.4 \pm 8.02 \text{ mg kg}^{-1})$  and available Ni concentration  $(3.10 \pm 0.91 \text{ mg kg}^{-1})$  are slightly higher by  $1.25 \pm 0.14$  and  $1.24 \pm 0.25$  fold respectively, than the subsurface layers. Available Ni increased linearly with increasing Ni in soil (r = 0.91). A significant positive correlation was found between available Ni and soil OM content (r = 0.89), while a significant negative correlation was observed for soil CaCO<sub>3</sub> percent (r = -0.72) and soil pH (r = -0.90). Rice Ni content of the straw (2.1  $\pm 0.32$  mg kg<sup>-1</sup>) and grains (0.44  $\pm 0.07$  mg kg<sup>-1</sup>) were significantly correlated with soil total Ni (r = 0.89 and 0.86) and available Ni (r = 0.84 and 0.74), respectively. Wheat Ni content of straw  $(1.68 \pm 0.28 \text{ mg kg}^{-1})$  and grains  $(0.28 \pm 0.04 \text{ mg kg}^{-1})$  were significantly correlated with soil total Ni (r = 0.87 and 0.81) and available Ni (r = 0.84 and 0.85), respectively. By increasing straw Ni content grains increased (r = 0.89 for rice and r = 0.95 for wheat). Grains of rice and wheat exhibited lower Ni concentration than that of the straw (20.9%  $\pm$  1.64 and 16.7%  $\pm$  1.04, respectively). According to FAO/WHO rice and wheat grains contain normal Ni concentration and no evidence of possible potential human health risk with grains consumption.

Keywords: Nickel, rice (Oryza sativa L.), wheat (Triticum aestivum L.), grains, Egypt

## 1. Introduction

Nickel, is a heavy metal and also an essential micronutrient for plant growth and development (Eskew et al., 1983) and even humans (Anke et al., 1995), and Ni deficiency can cause problems, such as the limitation of agricultural production (Freitas et al., 2018). Nickel status in soils is highly depended on the Ni content of the parent materials that reflects on soil forming process and pollution (Ali et al., 2009). Nickel contamination in soil has become a severe environmental issue and health risk because there are many anthropogenic sources of Ni in the environment (e.g. coal combustion, burning of fuel, the ignition of waste and sewage, Ni–Cd batteries, electroplating, metal industry and catalysts used in the food and chemical industry), which increase Ni in soil to become a pollutant (Wuana and Okieimen, 2011; Wang et al., 2015; Wang et al., 2017).

Numerous studies reported soils Ni content, however, in general, naturally occurring concentration of Ni in soil is lower than 100 mg kg<sup>-1</sup> (McGrath 1995) and recorded up to 26.4 mg kg<sup>-1</sup> in some soils (Zwolsman and Van Bokhoven, 2007 and Chen et al., 2009). McIlveen and Negusanti (1994); Kabata-Pendias and Pendias (2000) reported that Ni content for the world soils ranged from 0.2 and 450 mg kg<sup>-1</sup>, while the grand mean is calculated to be 22 mg kg<sup>-1</sup>. Chau et al. (1995) also, reported an average concentration of 86 mg kg<sup>-1</sup> for the natural nickel

content in the earth's crust. Values representing the pollution level of nickel in rural soils of the world for various countries have been reported by Yousra et al., (2019) as follows: Australia (60 mg kg<sup>-1</sup>), Canada (150 mg kg<sup>-1</sup>), China (20 mg kg<sup>-1</sup>), France (50 mg kg<sup>-1</sup>), Germany (200 mg kg<sup>-1</sup>), Japan (100 mg kg<sup>-1</sup>) The Netherland (210 mg kg<sup>-1</sup>), South Africa (15 mg kg<sup>-1</sup>), United Kingdom (60 mg kg<sup>-1</sup>), and USA (420 mg kg<sup>-1</sup>).

Total concentration of Ni in the soil is not a good indication for the availability of Ni in soil. Moreover, the mobility and availability of Ni in soils depend upon the type of soil, soil texture, soil structure, thickness of soil layers, soil pH, soil contents of CaCO<sub>3</sub>, clay and organic matter (Kabata-Pendias and Pendias, 2000; Rooney et al.2007; Soares et al., 2011; Shahid et al., 2014). The increased soil CaCO<sub>3</sub> content and soil pH value decreased Ni bioavailability, which promoted the precipitation reaction, thereby reducing the impact on the environment (Xian et al., 2010; Xiang et al., 2020).

Nickel is readily taken up by plants from soils, and up to certain Ni concentrations in plant tissues, this positively correlated with the soil Ni content (Kabata-Pendias and Pendias, 2000). The accumulation of Ni in crop grains is mainly controlled by the soil pH (Wang et al., 2020). However, soils polluted with Ni can cause toxicity to rice and decreased Fe uptake by rice plants (Ramzani et. al., 2016). The normal concentration range of nickel in most plant tissue is between 0.1 to 1.0 mg kg<sup>-1</sup> (Marscher, 1995). However, Brown et al. (1987); Bryson et al. (2014); Fabiano et al. (2015) reported that the normal range of nickel concentration in most plant tissues from 0.05 to 5 mg kg<sup>-1</sup> wet weight, and a concentration above this range induces toxicity to plants (Yusuf et al., 2011). Due to its low requirements, it is found in sufficient levels as a contaminant in the soil, water and fertilizers. High concentration of Ni is toxic for both plants and animals including humans (Amen et al., 2019). The toxicity index of Ni is different insensitive and tolerant crop species, i.e., >10 mg kg<sup>-1</sup> in sensitive crop species and > 50 mg kg<sup>-1</sup> in tolerant crop species (Seregin and Kozhevnikova, 2006; Yusuf et al., 2011; Marschner, 2012). Food is the major source of nickel exposure, with an average intake for adults estimated to be approximately 100 to 300 µg day-1 based on a 60 kg body weight (1.6 to 5 µg kg<sup>-1</sup> body weight; WHO, 1997 and EPA, 2000). However, agriculture is one of the main activities of Damietta governorate, Egypt; rice and wheat relatively represent the major cultivated crops. Therefore, this study aimed to quantify the concentration of Ni in soils and crops cultivated in study area and evaluate the possible human health risk caused by the daily intake through contaminated rice and wheat grain using standard tolerable daily intake.

### 2. Materials and Methods

### 2.1 Study Area

The study was conducted in Damietta governorate (Egypt), located at the Mediterranean Sea to the northeast of the Nile-Delta (Figure 1). It is lies between these coordinates 31° 28' 29" to 32° 03'32" E and 31° 09' 28" to 31° 31' 45" N. It covers an area of about1029 km<sup>2</sup> and representing 4.7% of the Delta-region and about 1.22% of Egypt total area (Elnaggar et al., 2017). Soil classification order was Entisols (El-Gammal et al., 2014), with three sub orders: Typic torrifluvents; Typic torripsamments and Typic psamaquents according to soil survey staff (1975). Agricultural land constitutes the majority of Damietta area which covered approximately 50,000 hectares (ha), which encompasses 4 districts; El-Zarqa (5,500 ha), Faraskur (9,500 ha), Kafr Saad (26,000 ha), and Damietta (9,000 ha). Wheat, maize, cotton, rice, potatoes, lemons, grapes, and tomatoes are famous for growing (CAPMAS, 2011). According to the Central Laboratory of Agricultural Climate (www.clac.edu.eg) of the Ministry of Agriculture, climate of Damietta is generally Mediterranean, where dry summer predominates with mild dry winter. Annual winter temperatures fall to 13 °C in January and rise to 26 °C in August with a mean annual temperature of 20 °C. Precipitation (P) is generally low and does not exceed 125 mm y<sup>-1</sup>. Due to its occurrence close to the Mediterranean Sea, the humidity is generally high with maximum value during summer months (up to 76%). The main irrigation source of study area is Damietta Nile branch. In addition to the quantity of agricultural drainage water, industrial wastewater and treatment of domestic wastewater, which suffered from intensive pollution, flowing back into the Nile River and becoming available again as mixed polluted water (Abdel Wahaab and Badawy 2004; Abdelrazek, 2019; EL-Bady, 2019).



Figure 1. Location map of Damietta. Governorate, Egypt

#### 2.2 Soil Sampling and Analysis

The total one hundred forty-two composite soil samples (12 subsamples one kg each) were taken; seventy-one samples from surface (0-30 cm) and seventy-one samples subsurface (30-60 cm) to represent agricultural area of four districts (10 surface and 10 subsurface for El-Zarqa, 17 surface and 17 subsurface Faraskur, 29 surface and 29 subsurface Kafr Saad, and 15 surface and 15 subsurface Damietta). Locations of the studied sites were identified using a "GPS" (Model German) as shown in Figure 2. Soil samples were air-dried, grounded using wooden mortar, passed through a 2 mm sieve before use and prepared for analyses. The particle size distribution (sand, silt and clay), soil texture was performed using the pipette method (Claydon, 1989), pH, EC, total CaCO<sub>3</sub>, organic matter (OM), according to standard methods outlined by Jackson (1973) and Diethylene Triamine Penta Acetate (DTPA) extractable Ni according to method of Lindsay and Norvell (1978). Total Ni was measured using Aqua regia extraction methods (Cottenie et al., 1982) and Ni concentrations in extractions were measured by Graphite Furnace-Atomic Absorption Spectrophotometer (GF-AAS), Shimadzu 6800, Japan. Physical and chemical characteristics of the investigated soils are presented (Table 1).



Figure 2. Location map of Damietta governorate showing the sampling points

## 2.3 Irrigation Water Sampling and Analysis

Twenty irrigation water samples were collected from the irrigation canal sources of study area to represent 4 districts; El-Zarqa (4), Faraskur (4), Kafr Saad (7) and Damietta (5). Locations of the irrigation water samples sites were identified using a "GPS" (Model German) as shown in Figure 3. From each location 10 liters of water samples were collected in clean polyethylene bottles and stored at 4 <sup>o</sup>C until analyses. Water pH, electrical conductivity (EC), soluble cations and anions were measured according to standard methods (Keeney and Nelson, 1982). Soluble Ni in water samples were directly determined after the filtration. The total Ni concentrations was done by adding 2 ml of concentrated HNO<sub>3</sub> and 5 ml of concentrated HCl to a 100 ml aliquot of collected water sample. The solution was covered with a watch glass and heated at 95 <sup>o</sup>C till volume reduced to 15 ml before being allowed to cool. Thereafter, the final volume was adjusted to 25 ml with reagent water and replicates were processed on a routine basis to determine precision. The concentrations of Ni in the filtrate of water were estimated using the GF-AAS. The results for the collected irrigation water are presented in Table 2.



Figure 3. Location map of Damietta governorate showing the irrigation water sampling points

### 2.4 Plant Sampling and Analysis

A composite sample of rice and wheat plants (50 plants each) was carefully harvest from the same locations where soil samples were taken at maturity stage by hand (Figure 2). Samples were washed with tap water and deionized water three times to remove any adhered soil particles, dried at 80  $^{\circ}$ C for 3 days to a constant weight and grounded before analysis. Samples were separated to straw and grains. The oven-dried plant materials were ground using stainless steel mill and kept for chemical analysis. The ground oven dried plant was subjected to digestion using mixture of acids (HNO<sub>3</sub>-H<sub>2</sub>SO<sub>4</sub>-HCLO<sub>4</sub>) as described by Jackson (1973). Concentrations of Ni were measured in the digest solution by GF-AAS.

## 2.5 Health Risk Index (HRI)

Nickel HRI assessment in grains of rice and wheat is calculated by dividing daily intake of Ni as mentioned by Farrag et al. (2016); in reference to oral dose (5  $\mu$ g Ni kg<sup>-1</sup> body weight day<sup>-1</sup>; WHO, 1997 and EPA, 2000). This index represents the amount harmful to people which consume food contaminated with Ni. If the value of HRI is less than 1, people will be safe to eat those kinds of food (Cui et al., 2005).

## 2.6 Statistical Analyses

Statistical analyses of variance were carried out on the obtained results for all the studied parameters according to the procedure described by Snedecor and Cochron (1981). Factorial experiment arranged in randomized complete block design with two factors (soil depths and locations) were used for analysis of all data with unequal numbers of composite samples for each location for Al Zarqa, Faraskur, Kafr Saad and Damietta, respectively by used SAS 9.4 program. Duncan's new multiple range test (DMRT) was applied to detect the significant differences between tested treatments means (Duncan, 1955). The relationship among different traits, simple correlation coefficient measures the strength and directions of association between two variables are calculated and the statistical significance of correlations is preceded according to Gomez and Gomez (1984).

	Sail donth	Soil properties							
Locations*	(cm)	Particles size distribution (%)							
	(cm)	C. Sand	F. Sand	Silt	Clay	Texture**			
•	0-30	2.13±0.67	11.4±1.25	38.0±3.62	49.2±4.48	C.			
A	30-60	2.15±0.14	$4.62 \pm 2.00$	45.0±4.19	51.7±2.10	Si. C.			
D	0-30	2.34±1.34	7.41±1.34	38.6±1.40	53.2±1.61	C.			
В	30-60	4.71±0.52	11.3±1.41	35.6±2.30	49.8±3.32	C.			
	0-30	21.9±29.2	14.7±5.80	23.5±12.6	37.4±21.0	C.L			
C	30-60	24.5±40.1	12.4±6.98	22.1±14.9	41.9±32.4	Si.C.			
	0-30	23.7±26.9	15.5±2.50	23.9±12.6	40.2±23.0	C.			
D	30-60	28.2±29.1	13.9±4.15	22.2±14.9	36.3±21.9	C.L.			
		Chemical properties							
		OM	pН	CaCO <sub>3</sub>	EC(dS/m)				
		(%)	(1:2.5)	(%)	EC (dS/m)				
•	0-30	1.80±0.65	8.06±0.15	2.77±0.59	2.13±0.46				
A	30-60	$1.05\pm0.37$	8.18±0.21	2.54±1.05	2.47±0.76				
D	0-30	2.00±0.23	8.23±0.16	1.96±0.69	3.00±1.47				
В	30-60	1.39±0.19	8.23±0.16	1.96±0.69	3.37±1.40				
C	0-30	2.23±0.64	8.10±0.25	2.58±1.19	3.26±1.90				
L	30-60	2.24±0.73	8.27±0.19	2.68±1.28	3.04±1.45				
	0-30	1.72±0.18	7.90±0.14	1.86±1.26	3.17±2.67				
D	30-60	1.14±0.32	8.00±0.18	1.88±1.35	3.40±2.78				

Table 1. Mean levels, and standard deviation of soil physical and chemical properties in the different districts

\*A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

\*\* Si. C. = silty clay; C. L. = clay loam; C. = clay.

Table 2. Electrical conductivity (EC), pH and Ni concentration of collected irrigation water from different districts

Locations*	EC	aII	Ni concentration (µg l <sup>-1</sup> )		
	(dS/m)	рп	soluble	total	
А	$0.49 \pm 0.07$	7.63±0.28	n.d.	15±1.8	
В	B 0.71±0.28		11±3.2	12±2.1	
С	0.73±0.33	7.75±0.14	18±8.2	22±6.5	
D 1.79±2.08		7.72±0.15	23±3.6	37±4.3	
***Allowed Limits in	< 0.7	( 5 9 4	200		
irrigation water	< 0.7	0.3 - 8.4	200	200	

\*A = Al Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

\*\*n.d. = not detected,

\*\*\* FAO, 2017; Ayers and Westcot, (1985)

#### 3. Results and Discussion

## 3.1 Nickel in Soils

#### 3.1.1 Soil Total Ni Content

The ranges and mean values of Ni concentration in the surface and subsurface soil samples collected from the different districts of Damietta governorate, Egypt are presented in Figure 4 and Table 3. In general, soil total Ni contents varied widely from district to another. The total Ni contents ranged from low for uncontaminated soil to high for soils received historically large quantities of Ni through agricultural or industrial activities. The Ni concentrations for all the studied soil samples ranged from 14.2 to 48.3 mg kg<sup>-1</sup> with an average of  $31.4 \pm 8.02$  mg kg<sup>-1</sup> in the surface layer and from 9.5 to 45.5 mg kg<sup>-1</sup> with an average 27.5  $\pm$ 7.15 mg kg<sup>-1</sup> in the subsurface layers. The average Ni concentration of all the studied soils showed that the surface layers accumulated 1.06 to 1.50 with an average  $1.25 \pm 0.14$ -fold than the subsurface layers. The increases in surface layer Ni are due to crop residues and the different anthropogenic sources such as sewage effluent and industrial waste. Our results agree with Okoli et al. (2020) and Wang et al. (2015) who reported that the Ni in soil surface layers was higher than the subsurface layers due to the organic matter content, soil pH and parent materials. The average Ni concentrations in the surface soil layers are lowest (26.8  $\pm$ 3.77 mg kg<sup>-1</sup>) in Faraskor districts followed by El-Zarga district (29.7  $\pm$ 2.54 mg kg<sup>-1</sup>) <sup>1</sup>), while the highest values were found in both Kafr Sad district  $(31.7 \pm 8.80 \text{ mg kg}^{-1})$  and Damietta districts (36  $\pm 7.50$  mg kg<sup>-1</sup>). The high values in Damietta district may be attributed to irrigation with sewage effluent, industrial effluent or mixed water (Nile water + sewage effluent). The frequency distributions of total Ni in the studied soils shows that 60% of the studied soils contained less than 30 mg kg<sup>-1</sup>, while 36% of the studied soils contained from 30-45 mg kg<sup>-1</sup> (Figure 5). Soils that contain relatively high levels of Ni (>45 mg kg<sup>-1</sup>) represented only 4% of the studied soils which were mainly located in Kafr Sad and Damietta districts.

An assessment and evaluation of total Ni status in Damietta governorate soils with respect to soil pollution was carried out and results were compared with the international limits as reported by numerous studies (Figure 4 and Table 3). It could be stated that the concentrations of total Ni in all the studied soils are within the normal concentration's limits. However, there is evidence of Ni accumulation in some districts particularly in soil irrigated with mixed water.



Figure 4. Minimum, maximum and average of soil total nickel concentrations in the different districts



Figure 5. Frequency distribution of the total Ni concentration in the studied soils of the different districts

#### 3.1.2 Soil DTPA Extractable-Ni

Results shows that the concentrations of soil DTPA extractable Ni varied from district to another (Figure 6 and Table 3). The concentrations range of the soils Ni under this study is from 0.85 to 4.0 mg kg<sup>-1</sup> with an average of  $2.42 \pm 0.91$  mg kg<sup>-1</sup> in the surface layers. While the concentrations range is from 0.77 to 3.08 with an average 1.93  $\pm$  0.78 mg kg<sup>-1</sup> in the subsurface layers. These results agree with another study, who reported that the values of DTPA extractable Ni in Egyptian soils varied widely among the different soils, being from 0.55 to 4.0 mg kg<sup>-1</sup> with an average of  $2.27 \pm 0.08$  mg kg<sup>-1</sup> (Badawy, 1992).

The concentrations of DTPA extractable Ni of the surface soil layers (0 to 30 cm) is higher than the subsurface layers (30 to 60 cm) by 1.10 to 1.30-fold with an average of 1.20 ±0.25 fold (Table 3). This may be due to the organic matter and the pH values of the soil surface layers. Under such conditions the solubility of Ni in the surface soil layers increases. In general, the DTPA extractable Ni is lower than the total Ni in all the studied soils and correlated (r = 0.91) with the total Ni concentration. The DTPA extractable Ni represents a small fraction (approximately 10% as an average) of the total Ni accumulated in the soils. The highest percentages that exist in Damietta and Kafr Sad districts may be attributed to the relatively high OM contents (which resulted from the application of sewage sludge and sewage effluent) and the lower soil pH. The district average concentration of surface soil Ni is lowest in Faraskor district ( $1.79 \pm 0.57 \text{ mg kg}^{-1}$ ) followed by the El-Zarqa district ( $2.96 \pm 0.43 \text{ mg kg}^{-1}$ ), while the highest values was found in both Damietta district ( $3.10 \pm 0.91 \text{ mg kg}^{-1}$ ) and Kafr Sad district ( $2.38 \pm 0.90 \text{ mg kg}^{-1}$ ). The high values in Damietta and Kafr Sad districts may be attributed to the irrigation practices with sewage effluent or mixed water (Nile water + sewage effluent) or industrial water.

The frequency distribution of DTPA extractable-Ni in the studied soils (Figure 7) showed that 43% of the studied soils contained less than 2.0 mg kg<sup>-1</sup> of available Ni, while 27% of the studied soils contained from 2 to 3 mg kg<sup>-1</sup>. Soils contain relatively high levels of Ni from 3 to 4 mg kg<sup>-1</sup> represented 30% of the studied soils which mainly located in Kafr Sad and Damietta districts. A significant positive correlation was found between DTPA extractable Ni and soil clay (r = 0.84) and organic matter (r = 0.89), while negative correlation was found for CaCO<sub>3</sub> (r = -0.72) and pH (r = -0.90) and agree with Bencko (1983) and Cempel and Nikel (2005). They reported that nickel become a problem at low soil pH, which was result from no liming of agricultural soils and thus high Ni mobilization. Soil pH is the major factor controlling nickel solubility, mobility and sorption, while clay content, iron-manganese mineral and soil organic matter being of secondary importance (Anderson and Christensen, 1988; Ge et al., 2000; Suavé et al., 2000; Tye et al., 2004).



Figure 6. Minimum, maximum and average of soil DTPA extractable nickel concentrations in the different districts



Figure 7. Frequency distribution of DTPA extractable-Ni in the studied soils of the different districts

The mean performance showed significant differences at the 5% level of probability between the two depths for total and DTPA extractable Ni Table 3. The results also revealed that, surface layer (0 to 30 cm) gave the highest values of total and DTPA extractable Ni (31.4 and 2.49 mg kg<sup>-1</sup>, respectively). The locations effect on the total and DTPA extractable Ni across the depths had a significant difference. Damietta (location D) was observed the highest mean values for total Ni, on the other hand, Faraskur (location B) was recorded the lowest mean values. However, Al Zarqa and Damietta (location A&D) was obtained the highest mean values for DTPA extractable-Ni. Results showed significant effect for the interaction between depths and locations for total and DTPA extractable Ni. The highest Ni means under surface layer (0 to 30 cm) were achieved by Damietta (location D), for total (36.8 mg kg<sup>-1</sup>). On the other hand, Al Zarqa and Kafr Saad (location A and C) had the lowest mean Ni values for subsurface layer (30 to 60 cm). Al Zarqa and Damietta (location A&D) under 0-30 cm was observed the highest mean values for DTPA extractable Ni (2.96 and 3.10 mg kg<sup>-1</sup>, respectively). On the other hand, Faraskur (location B) under both depths was recorded the lowest mean values for DTPA extractable Ni (1.79 and 1.48 mg kg<sup>-1</sup>, respectively).

Depth (cm)		Soil Ni concentration** (mg kg <sup>-1</sup> )						
	Location*		Total	DTPA extractable				
	-	Mean **	±SD	CV%	Mean	±SD	CV%	
0 - 30		31.4 a	8.02	25.6	2.49 a	0.89	36.1	
30 - 60		25.1 b	7.15	7.15 28.5		0.76	39.2	
	А	27.4 b	3.38	12.4	2.73 a	0.42	15.4	
	В	23.3 c	4.58	19.6	1.63 c	0.53	32.1	
	С	28.9 b	8.89	30.8	2.09 b	0.88	42.1	
	D	32.9 a	9.41	28.6	2.78 a	0.90	32.2	
0 - 30	А	29.6 cb	2.537	8.6	2.96 a	0.435	14.7	
	В	26.8 ed	3.767	14.1	1.79 c	0.567	31.6	
	С	31.7 b	8.796	27.8	2.38 b	0.877	36.6	
	D	36.8 a	9.136	24.6	3.10 a	0.892	28.5	
	А	25.1 e	2.493	9.9	2.49 b	0.245	9.8	
30 - 60	В	19.9 f	1.899	9.6	1.48 d	0.44	29.8	
	С	26.2 e	8.255	31.5	1.81 c	0.788	44.1	
	D	28.1 cd	7.872	27.5	2.51 b	0.775	31.9	

Table 3. Mean, standard deviation (±SD) and coefficient of variation (CV%) of two depths evaluated fewer than four locations for total and DTPA extractable Ni of the different districts

\*A = El Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

\*\* Means followed by the same letter within the row for Ni were not significant based on the least significant difference test at P < 0.05

#### 3.2 Nickel in Plants

### 3.2.1 Nickel in Rice Plant

Results of Ni content in straw and grain of rice plant grown on the same soils where soil samples were collected are presented in Figure 8 and Table 4. Nickel concentration in the rice straw of all the collected samples ranged from 1.33 to 2.58 with an average of  $2.12 \pm 0.28$  mg kg<sup>-1</sup>, and from 0.26 to 0.58 with an average 0.44  $\pm 0.06$  mg kg<sup>-1</sup> <sup>1</sup> in rice grains. Results show that nickel content in rice plants are within the normal range as stated by several researchers (Brown et al., 1987; Bryson et al., 2014; Fabiano et al., 2015). They reported that the normal range for Ni in most plant tissue is from 0.05 to 5 mg kg<sup>-1</sup>. Nickel concentration of all the studied samples showed that rice grain contains lower Ni than the straw. It represents from 19.6% to 22.5% with an average 20.7±1.69% from that of the straw. The narrow ratio of Ni in the straw and grain may be due to the fact that Ni is fairly mobile in plant after their uptake thus considerable amounts of Ni are transferred to the seeds and fruits (Mitchell et al., 1978 and Badawy et al., 1992). A significant positive correlation (r = 0.89) between rice grains and straw Ni content, i.e. by increasing straw Ni concentration grain Ni concentration increased. Data showed that 31% of the rice straw samples contained from 1.0 to 2.0 mg kg<sup>-1</sup> Ni and 69% of the samples contain from 2.0 to 3.0 mg kg<sup>-1</sup> Ni (Figure 9). However, about 32% of the rice grain samples contain between 0.2 to 0.4 mg kg<sup>-1</sup> Ni and 68% of the samples contain from 0.4 to 0.6 mg kg<sup>-1</sup> Ni. Results showed that the lowest average of Ni concentrations 2.03  $\pm$ 0.30 mg kg<sup>-1</sup> in rice straw and  $0.45 \pm 0.07$  mg kg<sup>-1</sup> rice grains in Faraskur district. However, the highest average  $2.19 \pm 0.18$ mg kg<sup>-1</sup> in rice straw and 0.45  $\pm 0.06$  mg kg<sup>-1</sup> rice grains was found in Damietta district. This is attributed to the soil DTPA extractable Ni (Figure 10), which showed a significant correlation (r = 0.91 and 0.86 with rice straw and grains Ni contents, respectively). In another word, as the soil DTPA extractable Ni increased the straw and grain Ni concentrations. Our results indicate that Ni is readily and rapidly taken up by plants from the soils and the concentration in rice plant is positively correlated with the available Ni in the soils.



Figure 9. Minimum, maximum and average of rice parts nickel concentrations in the different districts



Figure 10. Frequency distribution of Ni content in rice straw and grain of soils of the different districts



Figure 11. Correlation between soil DTPA extractable Ni and rice straw and grains Ni concentrations

#### 3.2.2 Nickel in Wheat Plant

Nickel content in wheat straw ranged from 1.06 to 2.22 mg kg<sup>-1</sup> with an average of  $1.69 \pm 0.27$  mg kg<sup>-1</sup>, and from 0.19 to 0.35 mg kg<sup>-1</sup> with an average 0.28  $\pm$ 0.04 mg kg<sup>-1</sup> in wheat grain (Figure 11 and Table 4). Results also showed that Ni concentration in wheat plants is within the normal range (Brown et al., 1987; Bryson et al., 2014; Fabiano et al., 2015). They reported that the normal range of Ni concentration in most plant tissues is between 0.05 to 5.0 mg kg<sup>-1</sup> (FAO, 2017). However, Ni concentration in all the studied samples showed that wheat grains exhibited lower values than that of the straw. The grain Ni concentration represents from 15.8% to 17.9% with an average 16.6±1.06% from that of the straw. Following Ni uptake considerable amounts of Ni are transferred to the seeds and fruits (Mitchell et al., 1978; Badawy et al., 1992). A positive significant correlation (r = 0.96) is shown between grain Ni concentration and that of the straw. It is clear that as the straw Ni concentration increases, the grain Ni concentration follow the same trend. Figure 12 shows that 83% of the wheat straw samples contained from 1.0 to 2.0 mg kg<sup>-1</sup>Ni and 17% of the samples contain from 2.0 to 3.0 mg kg<sup>-1</sup>Ni. However, about 1% of the wheat grain samples contain from 0 to 0.2 4 mg kg<sup>-1</sup> Ni and 99% of the samples contain from 0.2 to 0.4 mg kg<sup>-1</sup> Ni. Results showed that the lowest average of Ni concentrations  $(1.59 \pm 0.28 \text{ in wheat straw and } 0.25 \pm 0.03 \text{ mg kg}^{-1}$ <sup>1</sup> in wheat grain) was found in Damietta district. However, the highest average  $(1.84 \pm 0.24 \text{ mg kg}^{-1})$  in wheat straw and  $0.30 \pm 0.03$  mg kg<sup>-1</sup> in wheat grain) was found in Faraskor district. This relationship is related to the soil DTPA extractable-Ni (Fig 13), which represent a significant positive correlation (r = 0.84 and 0.85, respectively) with wheat straw and grain Ni concentration. The positive correlation between soil available Ni and the straw and grain Ni concentration indicates that Ni is readily taken up by plants. Results in Figure 14 showed that the mean values of Ni in rice grain  $(0.44 \pm 0.06 \text{ mg kg}^{-1})$  is higher than that of wheat grain  $(0.28 \pm 0.04 \text{ mg kg}^{-1})$  that could be related to biological and/or genetic factors. In spite of the differences between rice and wheat Ni concentration it still within the normal range.



Figure 11. Minimum, maximum and average of wheat parts nickel concentrations in the different districts



Figure 12. Frequency distribution of Ni concentration in wheat straw and grain of the studied soil of the different districts



Figure 13. Correlation between soil DTPA extractable-Ni and wheat straw and grains Ni concentrations



Figure 14. Correlation between Ni content in grains and straw of rice and wheat plants

In general, there was a significant increase in all studied traits (straw, grain and straw/grain) for both crops (Table 4). For straw, grain and grain/straw, it could be concluded from the obtained results that the rice plant recorded the greatest values (2.12, 0.44 mg kg<sup>-1</sup> and 20.7%, respectively). While in locations showed a significant difference for grain/straw only, El Zarqa and Faraskur recorded the highest values of grain/straw (19.3 and 19.2%, respectively). However, results showed significant effect for the interaction between crops and locations at the 5% level of probability. Results also indicated that the interaction between rice and all locations given the highest Ni values of straw (2.13, 2.03, 2.13 and 2.19 mg kg<sup>-1</sup>, respectively). However, results in Table 4 indicates that the interaction between rice and all locations except Kafr Saad (locations C) gives the highest values of grain and grain/straw.

		Plant Ni concentrations mean** (mg kg <sup>-1</sup> )								
Crops Location*		Straw			Grains		Grains /Straw			
		Mean	$\pm SD$	CV%	Mean	$\pm SD$	CV%	%	$\pm SD$	CV%
Wheat		1.69 b	0.27	15.7	0.28 b	0.04	12.1	16.6 b	1.06	6.40
Rice		2.12 a	0.28	13.2	0.44 a	0.06	14.6	20.7 a	1.69	8.10
	А	1.88 a	0.38	20.2	0.37 a	0.11	28.6	19.3 a	2.70	14.0
	В	1.94 a	0.29	14.7	0.37 a	0.09	24.9	19.2 a	3.15	16.4
	С	1.90 a	0.36	18.7	0.35 a	0.08	23.3	18.3 b	1.55	8.50
	D	1.89 a	0.38	20.2	0.35 a	0.12	32.6	18.3 b	2.93	16.0
	А	1.62 c	0.28	17.4	0.28 dc	0.03	10.5	17.1 d	1.53	8.90
Wheet	В	1.84 b	0.24	13.3	0.30 c	0.03	10.1	16.2 de	0.67	4.10
wheat	С	1.68 c	0.23	14.2	0.28 dc	0.03	10.3	17.0 d	0.77	4.50
	D	1.59 c	0.28	17.6	0.25 d	0.03	13.4	15.9 e	1.12	7.10
Rice	А	2.13 a	0.28	13.4	0.46 a	0.06	13.5	21.5 ab	1.57	7.30
	В	2.03 a	0.30	14.7	0.45 ab	0.07	15.3	22.1 a	1.28	5.80
	С	2.13 a	0.31	14.7	0.42 b	0.06	14.1	19.7 c	0.82	4.20
	D	2.19 a	0.18	8.10	0.45 a	0.06	14.2	20.7 b	2.07	10.0

Table 4. Mean, standard deviation and coefficient of variation (CV%) of two crops evaluated fewer than four locations for straw and grins Ni concentrations of the different districts

\*A = El Zarqa, B = Faraskur, C = Kafr Saad, D = Damietta

\*\* Means followed by the same letter within the row for Ni were not significant based on the least significant difference test at P < 0.05

#### 3.3 Human Health Risk

Results of the present study indicates that Ni content in dry weight of rice grains ranges from 260 to 580 mg kg<sup>-1</sup> with an average 440  $\mu$ g kg<sup>-1</sup>, whereas wheat grain ranges from 190 to 350 mg kg<sup>-1</sup> with an average 280  $\mu$ g kg<sup>-1</sup>. Thus, compared with the above-mentioned figures the tolerable intake of Ni (1.6 to 5  $\mu$ g kg<sup>-1</sup> body weight day<sup>-1</sup>; FAO, 2017) can be reached, as an average, when a person (60 Kg body weight) consumes from 0.52 to 1.15 kg rice grins and 0.86 to 1.58 kg wheat grain per day. Thus, the high levels of Ni in grains growing with polluted soils will decrease its suitability for human consumption. The present study data cleared that both rice and wheat grains are still safe for human consumptions compared with world maximum consumptions of wheat grains (0.445 kg; Trethowan and van Ginkel, 2009) and rice grains (0. 278 kg per capita per day; WHO, 2003). Furthermore, the calculated Health Risk Index (HRI) value was less than 1 which indicates that Ni in rice and wheat grains have no potential human health risk for now but may be in future.

## 4. Conclusion

The concentrations of total and available Ni are higher in the soil surface than the subsurface layers in all the studied districts of Damietta governorate. Nickel concentrations in the straw and grain of rice and wheat plants are correlated with total and available Ni in the soil. Rice and wheat straw exhibited higher Ni concentrations than the grain. Nickel concentration in rice straw and grain is much higher than the wheat. This could be due to genetic variation of the two species which result in different Ni uptake requirements. The grain of rice and wheat plants grown in Damietta governorate contains Ni concentration in the normal range. Thus, the consumption of such grain is safe for human health.

#### References

- Ali, B., Hayat, S., Fariduddin, Q., & Ahmad, A. (2009). *Nickel: essentiality, toxicity and tolerance in plants*. Nickel in relation to plants. Narosa Publishing House, New Delhi, India.
- Ameen, N., Amjad, M., Murtaza, B., Abbas, G., Shahid, M., Imran, M., Naeem, M. A., & Niazi, N. K. (2019). Biogeochemical behavior of nickel under different abiotic stresses: toxicity and detoxification mechanisms

in plants. *Environmental Science and Pollution Research, 26*(11), 10496-10514. https://doi.org/10.1007/s11356-019-04540-4

- Anderson, P. R., & Christensen, T. H. (1988). Distribution coefficients of Cd, Co, Ni, and Zn in soils. *Journal of soil science*, 39(1), 15-22. https://doi.org/10.1111/j.1365-2389.1988.tb01190.x
- Anke, M., Angelow, L., Glei, M., Müller, M., & Illing, H. (1995). The biological importance of nickel in the food chain. *Fresenius' journal of analytical chemistry*, 352(1-2), 92-96. https://doi.org/10.1007/BF00322304
- APHA (American Public Health Association). (2012). *Standard Methods for the Examination of Water and Wastewater* (2nd ed.). APHA, Washington, DC.
- Ayers R. S., & Westcot, D. W. (1985). "Water Quality for Agriculture," FAO Irrigation and Drainage Paper No. 29, Rome.
- Badawy, S. H. (1992). Studies on some heavy metals in soils of Egypt and plant grown thereon. Ph.D. Thesis, Fac. of Agric., Cairo Univ., Egypt.
- Bencko, V. (1983). Nickel: a review of its occupational and environmental toxicology. *Journal of hygiene*, epidemiology, microbiology, and immunology, 27, 237-247.
- Brown, P. H., Welch, R. M., & Cary, E. E. (1987). Nickel: A micronutrient essential for higher plants. *Plant physiology*, 85(3), 801-803. https://doi.org/10.1104/pp.85.3.801
- Bryson, J. F., Herrero-Albillos, J., Kronast, F., Ghidini, M., Redfern, S. A., van der Laan, G., & Harrison, R. J. (2014). Nanopaleomagnetism of meteoritic Fe–Ni studied using X-ray photoemission electron microscopy. *Earth and Planetary Science Letters*, 396, 125-133. https://doi.org/10.1016/j.epsl.2014.04.016
- Cempel, M., & Nikel, G. J. (2006). Nickel: A review of its sources and environmental toxicology. *Polish Journal* of Environmental Studies, 15(3), 375-382.
- Chau, Y. K., & Kulikovsky-Cordeiro, O. T. R. (1995). Occurrence of nickel in the Canadian environment. *Environmental Reviews*, 3(1), 95-120. https://doi.org/10.1139/a95-004
- Chen, C., Huang, D., & Liu, J. (2009). Functions and toxicity of nickel in plants: recent advances and future prospects. *CLEAN–Soil, Air, Water, 37*(4-5), 304-313. https://doi.org/10.1002/clen.200800199
- Claydon, J. J. (1989). *Determination of particle size distribution in fine-grained soil: Pipette method*. Lower Hutt, New Zealand: Department of Scientific and Industrial Research
- Cottenie, A., Verloo, M., Kiekens, L., Velghe, G., & Camerlynck, R. (1982). Chemical analysis of plants and soils. *Lab. Agroch. State Univ. Gent, Belgium*, 63.
- Cui, Y., Zhu, Y. G., Zhai, R., Huang, Y., Qiu, Y., & Liang, J. (2005). Exposure to metal mixtures and human health impacts in a contaminated area in Nanning, China. *Environment international*, 31(6), 784-790. https://doi.org/10.1016/j.envint.2005.05.025
- Duncan, D. B. (1955). Multiple range and multiple F tests. *Biometrics*, 11(1), 1-42. https://doi.org/10.2307/3001478
- El-Gammal, M. I., Ali, R. R., & Abou Samra, R. M. (2014). Assessing heavy metal pollution in soils of Damietta governorate, Egypt. Int. Conf. Adv. in Agricultural, Biological & Environmental Sciences (AABES-2014) Oct 15-16, 2014 Dubai (UAE).
- Elnaggar, A. A., El-Hamdi, Kh. H., & Daibes, T. Y. (2017). Fertility evaluation of some soils in Damietta governorate, Egypt using GIS. J.Soil Sci. and Agric. Eng., Mansoura University 8(2), 58-92. https://doi.org/10.21608/jssae.2017.37093
- EPA. (2000). *Nickel Compounds Hazard Summary*. Retrieved from http://www.epa.gov/airtoxics/hlthef/nickel.html
- Eskew, D. L., Welch, R. M., & Cary, E. E. (1983). Nickel: an essential micronutrient for legumes and possibly all higher plants. *Science*, 222(4624), 621-623. https://doi.org/10.1126/science.222.4624.621
- Fabiano, C., Tezotto, T., Favarin, J. L., Polacco, J. C., & Mazzafera, P. (2015). Essentiality of nickel in plants: a role in plant stresses. *Frontiers in Plant Science*, *6*, 754. https://doi.org/10.3389/fpls.2015.00754
- FAO. (2017). *Wastewater Treatment and Use in Agriculture*. Retrieved April 30, 2017, from http://www.fao.org/docrep/T0551E/ T0551E00.htm
- Farrag, K., Elbastamy, E., & Ramadan, A. (2016). Health risk assessment of heavy metals in irrigated agricultural

crops, EL - Saff wastewater canal, Egypt. CLEAN-Soil, Air, Water, 44(9), 1174-1183. https://doi.org/10.1002/clen.201500715

- Freitas, S. D., Wurr Rodak, B., Rodrigues dos Reis, A., de Barros Reis, F., Soares de Carvalho, T., Schulze, J., Carbone Carneiro, M. A., & Guimaraes Guilherme, L. R. (2018). Hidden nickel deficiency? Nickel fertilization via soil improves nitrogen metabolism and grain yield in soybean genotypes. *Frontiers in Plant Science*, 9, 614. https://doi.org/10.3389/fpls.2018.00614
- Ge, Y., Murray, P., & Hendershot, W. H. (2000). Trace metal speciation and bioavailability in urban soils. *Environmental Pollution*, 107(1), 137-144. https://doi.org/10.1016/S0269-7491(99)00119-0
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons., Inc. New York.
- Jackson, M. L. (1973). Soil chemical analysis prentice Hell of India Private Limited, New Delhi.
- Kabata-Pendias, A., & Pendias, H. (2000). Trace elements in soils and plants. CRC Press, Boca Raton. https://doi.org/10.1201/9781420039900
- Keeney, D. R., & Nelson, D. W. (1982). Nitrogen. Inorganic forms. In A. L. Page (Ed.), *Methods of Soil Analysis*. *Part 2. Chemical and Microbiological Properties*. Soil Science of América, Madison, USA.
- Lindsay, W. L., & Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal, 42*(3), 421-428. https://doi.org/10.2136/sssaj1978.03615995004200030009x
- Marschner, H. (1995). Mineral nutrition of higher plants (2nd ed.). London, UK, Academic Press.
- Marschner, H. (2012). Marschner's mineral nutrition of higher plants (3rd ed.). Elsevier.
- McGrath, S. P., Chaudri, A. M., & Giller, K. E. (1995). Long-term effects of metals in sewage sludge on soils, microorganisms and plants. *J Ind Microbiol Biotechnol, 14*, 94–104. https://doi.org/10.1007/BF01569890
- McIlveen, W., & Negusanti, J. (1994). Nickel in the terrestrial environment. *Sci Total Environ, 148*, 109–138. https://doi.org/10.1016/0048-9697(94)90390-5
- Mitchell, G. A., Bingham, F. T., & Page, A. L. (1978). Yield and metal composition of lettuce and wheat grown on soils amended with sewage sludge enriched with cadmium, copper, nickel, and zinc. *Journal of Environmental Quality*, 7(2), 165-171. https://doi.org/10.2134/jeq1978.00472425000700020002x
- Okoli, N., Uzoho, B., Ahukaemere, C., Egboka, N., & Irokwe, I. (2020). Chemical fractionation and mobility of nickel in soils in relation to parent materials. *Archives of Agronomy and Soil Science*. https://doi.org/10.1080/03650340.2020.1776265
- Ramzani, P. M. A., Iqbal, M., Kausar, S., Ali, S., Rizwan, M., & Virk, Z. A. (2016). Effect of different amendments on rice (Oryza sativa L.) growth, yield, nutrient uptake and grain quality in Ni-contaminated soil. *Environmental Science and Pollution Research*, 23(18), 18585-18595. https://doi.org/10.1007/s11356-016-7038-x
- Rooney, C. P., Zhao, F.-J., & McGrath, S. P. (2007). Phytotoxicity of nickel in arange of European soils: influence of soil properties, Ni solubilityand speciation. *Environ Pollut*, 145, 596–605. https://doi.org/10.1016/j.envpol.2006.04.008
- SAS Institute Inc. (2014). SAS/STAT 9.4 user's guide. SAS Institute Inc. Cary.
- Seregin, I. V., & Kozhevnikova, A. D. (2006). Physiological role of nickeland its toxic effects on higher plants. *Russ J Plant Physiol*, 53(2), 57-277. https://doi.org/10.1134/S1021443706020178
- Shahid, M., Sabir, M., Arif Ali, M., & Ghafoor, A. (2014). Effect of organicamendments on phytoavailability of nickel and growth of berseem (Trifolium alexandrinum) under nickel contaminated soil condi-tions. *Chem Speciat Bioavailab, 26*, 37–42. https://doi.org/10.3184/095422914X13886890590610
- Snedecor, G. W., & Cochron, W. G. (1981). Statistical Methods (7th ed.). Iowa State Univ., Press, Ames, Iowa.
- Soares, M. R., Casagrande, J. C., & Mouta, E. R. (2011). Nickel adsorption by variable charge soils: effect of pH and ionic strength. *Braz Arch Biol Technol*, 54, 207–220. https://doi.org/10.1590/S1516-89132011000100025
- Soil Survey Staff. (1975). *Web Soil Survey*. USDA Natural Resources Conservation Service. Retrieved from http://websoilsurvey.nrcs.usda.gov.
- Suavé, S., Hendershot, W., & Allen, H. E. (2000). Solid-solution partitioning of metals in contaminated soils:

Dependence on pH, total metal burden, and organic matter. *Environ. Sci. Technol.*, 34(7), 1125–1131. https://doi.org/10.1021/es9907764

- Trethowan, R. M., & van Ginkel, M. (2009). *Synthetic wheat–an emerging genetic resource*. Wheat Sci. Trade. Ed. B. Carver. Wiley-Blackwell, Ames, IA.
- Tye, A. M., Young, S., Crout, N. M. J., Zhang, H., Preston, S., Zhao, F. J., & Mcgrath, S. P. (2004). Speciation and solubility of Cu, Ni and Pb in contaminated soils. *Eur. J. Soil Sci.*, 55, 579-590. https://doi.org/10.1111/j.1365-2389.2004.00627.x
- Wang, G., Xia, X., Yang, J., Tariq, M., Zhao, J., Zhang, M., Huang, K., Lin, K., & Zhang, W. (2020). Exploring the bioavailability of nickel in a soil system: Physiological and histopathological toxicity study to the earthworms (Eisenia fetida). *Journal of hazardous materials*, 383, 121169. https://doi.org/10.1016/j.jhazmat.2019.121169
- Wang, S., Wu, W., & Liu, F. (2017). Accumulation of heavy metals in soil-crop systems: a review for wheat and corn. *Environ Sci Pollut Res*, 24, 15209–15225. https://doi.org/10.1007/s11356-017-8909-5
- Wang, X., Qu, R., Huang, Q., Wei, Z., & Wang, Z. (2015). Hepatic oxidative stress and catalyst metals accumulation in goldfish exposed to carbon nanotubes under different pH levels. *Aquat Toxicol*, 160, 142-150. https://doi.org/10.1016/j.aquatox.2015.01.015
- WHO (World Health Organization). (1997). *Guideline for drinking water quality* (2nd ed., Vol. 1). Recommendations.
- Wuana, R. A., & Okieimen, F. E. (2011). Heavy metals in contaminated soils: areview of sources, chemistry, risks and best available strategies for remediation. https://doi.org/10.5402/2011/402647
- Xian, X., Homma, S., & Kuno, K. (2010). Relationship between concentration of heavy metals in soil and contents of that absorbed by mulberry plant. J. Sericult. Sci. Jpn., 57, 481-488.
- Xiang, Z. L., Gao, H. F., Yan, H., Li, Y. L., Diao, Z. L., Zhang, E. Z., Li, C., & Cao, Y. C. (2020). Study on the Treatment of Nickel-Contaminated Soil Using Calcium Oxide. *Water, Air, & Soil Pollution, 231*, 1-7. https://doi.org/10.1007/s11270-020-04569-z
- Yousra, M., Mahmood-ul-Hassan, M., Sarwar, S., & Naeem, S. (2019). Adsorption of Lead, Cadmium, and Nickel on Benchmark Soils of Pakistan. *Eurasian Soil Science*, 52(9), 1063-1074. https://doi.org/10.1134/S1064229319090126
- Yusuf, M., Fariduddin, Q., Hayat, S., & Ahmad, A. (2011). Nickel: an over view of uptake, essentiality and toxicity in plants. *Bull Environ Contam Toxicol*, 86, 1–17. https://doi.org/10.1007/s00128-010-0171-1
- Zwolsman, J., & Van Bokhoven, A. (2007). Impact of summer droughts onwater quality of the Rhine River. a preview of climate change? *Water Sci. Technol, 564*, 5. https://doi.org/10.2166/wst.2007.535

## Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).