

DISTRIBUTION, MOBILITY AND TOXICITY OF NICKEL IN SALT-AFFECTED SOILS AND SOME CROPS

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ABSTRACT

Distribution, mobility, and toxicity of nickel is of great importance especially in soil under reuse of drainage water for irrigation. South Port Said plain, about 200,000 feddans, is considered one of the national projects that depend on the reuse of the drainage water for irrigation after mixing with Nile water. To define the natural and anthropogenic origins of nickel, sequential extraction protocol has been used in this study.

The obtained results indicated that the chemical speciation of nickel fractions in the soil can be arranged in the following order: F₁- soluble (So-) < F₂-exchangeable (Ex-) < F₅-bound to organic matter (OM-) < F₃- bound to carbonate (Car-) < F₄-bound to Fe-Mn oxyhydroxides (Fe-Mn-) and < F₆-residual (Res-).

The total Ni concentration in the studied soils was 20.74 and 103.00 mg/kg. However, almost all the total content of nickel in soil was lower than the pollution level of nickel in soil (i.e., 300 mg/kg) and in sewage sludge (i.e., 420 mg/kg). The calculated values of geo-accumulation index (I_{geo}) for all samples were in class '0'. This means that the studied area is considered within the uncontaminated category. In addition, the contamination factor (CF) values are less than 1. So, it indicated that CF for Ni is under low degree of contamination. Moreover, the highest bioaccumulation (BAC) which is 3.04 occurred in roots of Sugar beets (*beta vulgaris*) at location 5 and its lowest value (1.007) occurred in the leaves of Wheat (*Tritium Vulgare*) at location 9.

Key Words: Nickel; Fractionation; Mobility, Toxicity; Geo-accumulation index; Contamination factor; Bioaccumulation; Sugar beets (*beta vulgaris*); Wheat (*Tritium Vulgare*).

INTRODUCTION

Environmental pollution, increasing human population and increased salinization of soil and water and reduction in land available for cultivation are the threats for agricultural sustainability (Shahbaz and Ashraf, 2013). Hammam and Mohamed (2020) found that soil salinization is one of the most serious problems facing soil fertility, crop productivity and sustainable agricultural development especially in Egypt. The risk of salinization is considered serious when it leads to toxicity. The evaluation of soil salinization at East of Nile Delta to enhance management strategy program has been achieved in the last decades.

Globally, about 75 countries (mostly locating in arid and semi-arid regions) have been recognized as having vast areas (nearly 831 million hectares) of salt-affected lands (Martinez-Beltran, 2005; Gaber and Fattouh, 2021).

Noteworthy to state that many salt affected waste lands have been previously productive (Qadir *et al.*, 2000). Worldwide, around 23% of the arable lands, are vulnerable to salinity extension in addition to 10% are saline-sodic ones, while 340 million hectares of lands suffer from sodicity (Szabolcs, 1994; NLWRA, 2001). Moreover, there are about 95 million hectares under primary salinization inherited from the prevailing aridity that

is dominated by high atmospheric temperature and low rainfall accompanied by gradual salt efflorescence and accumulation on land surface due to the net upward water movement and evaporation. On the other hand, secondary salinization due the negative and irrational human impact as well as the ever rising of ground water effect on around 77 million hectares (Metternicht and Zink, 2003). Salinity problem managing to attenuate environmental impacts could also be a prerequisite for sustainable irrigated agriculture (Zewdu *et al.*, 2017; Sallam *et al.*, 2020).

Economically, extension of salt-affected soils induces about US\$ 12 billion annual global income loss. In Egypt, while the cultivated area is only 7.2 million feddans, the area of salt –affected soils is almost 1.9 million feddans, mostly in the northern and eastern fringes of the Nile Delta (Abdel-Fattah *et al.*, 2015).

One of 13.2 billion hectares of cultivated areas on Earth, like about 7.5% of the world is roofed with saline and sodic soils, also between 25 to 30% of cultivated areas are salt-affected and commercially unproductive (DRI, 2001). Many cultivated areas suffering from the raising of groundwater table and salinity of soil in the Middle East. The explanation for this can be due to the required irrigation practices, increase evaporation rates, and a rise in groundwater salinity (Shahid, 2013). In Egypt, about million ha of the entire irrigated cultivable lands along the Nile are salt-affected (Abdel-Fattah *et al.*, 2015).

Concerning the amendments applied to the saline-sodic soils such as El-Tina Plain, many are given particular consideration, i.e; gypsum, inorganic polymers, and agricultural wastes. Gypsum is the most common substance in this concern as it helps in decreasing values of pH, EC, ESP and bulk density while increasing the hydraulic conductivity infiltration rate of soil. In addition, gypsum is easily handled with rather low cost.

The salt-affected soils contain excessive concentrations of either soluble salts or exchangeable sodium or both due to inadequate leaching of base forming cations. The major soluble mineral salts are the cations like sodium, calcium, magnesium, potassium and the anions like chloride, sulfate, bicarbonate, carbonate, and nitrate. Hyper-saline soil water may also contain boron (B), selenium (Se), strontium (Sr), silica (Si), lithium (Li), fluorine (F), molybdenum (Mo), manganese (Mn), barium (Ba), and aluminum (Al), some of which can be toxic to plants and animals (Tanji, 1990). The average extent of nickel content at the surface levels of various soils is from 4-50 mg kg⁻¹; lower concentrations occur on light sandy soil and are on average 15 mg kg⁻¹ greater concentrations (approximately 30 mg kg⁻¹) occur in clay soils. Nickel is an essential nutrient for animals and a beneficial element for plants. It is thought to play a significant role in enzyme-catalyzed metabolic processes of higher plants as a cofactor of urease and hydrogenase. Although, excessive Ni concentrations in higher plants can decrease photosynthesis and cause chlorosis of the plants when phytotoxicity occurs (Phipps *et al.*, 2003; Thakali

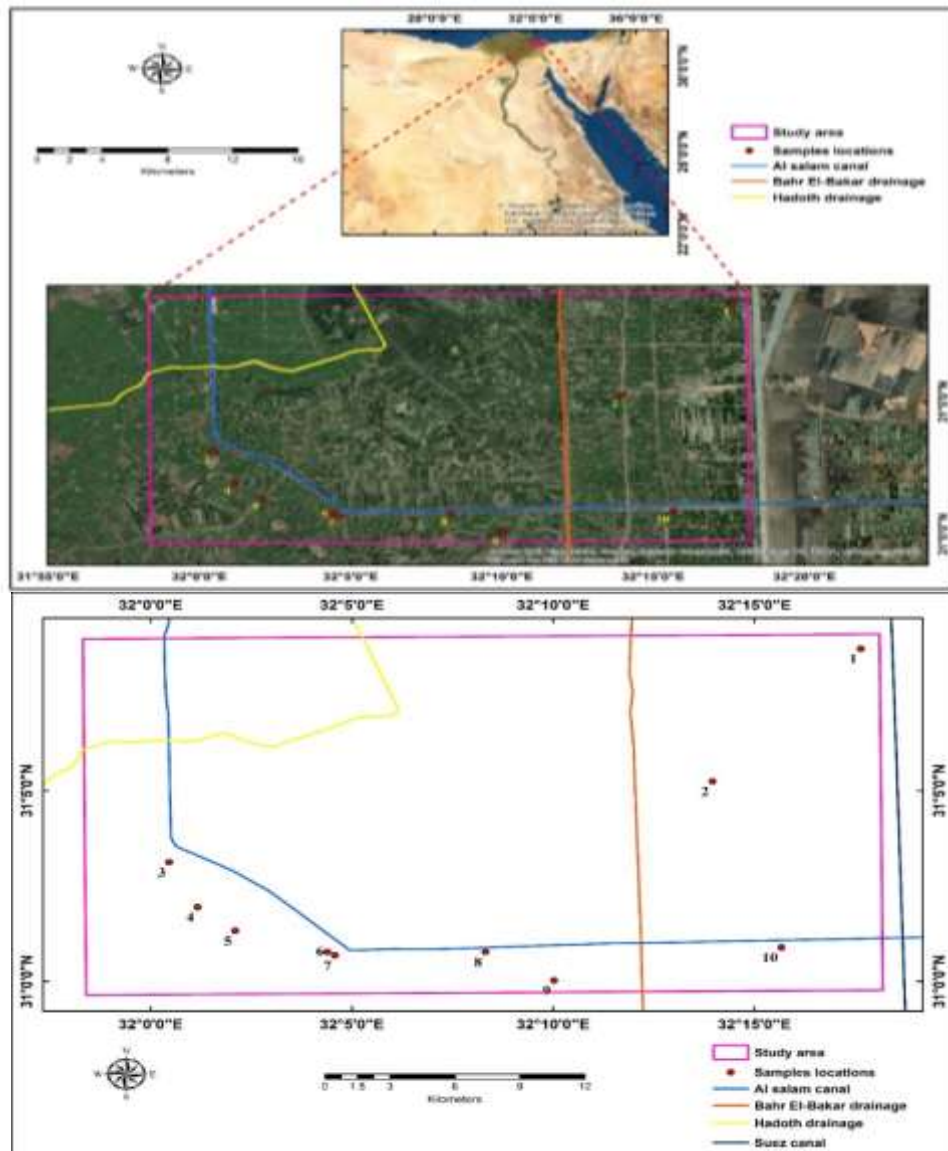
et al., 2006). The major sources of Ni to agricultural soils are atmospheric deposition, livestock manures, and phosphate fertilizers. Large amounts of anthropogenic Ni are released to the atmosphere by human activities, especially from burning of fossil fuel and residual oils, followed by Ni mining and smelting (Ma and Hooda, 2010). Other factors, such as organic manures and sewage sludge to soil also influence the fate and behavior of Ni in soils (Uren, 1992). The most important factor affecting the behavior of Ni in soils appears to be pH, while attributes such as clay content and Fe and Mn oxides in soils are of secondary importance. For instance, the mobility of Ni in soils increases as the pH and cation exchange capacity (CEC) decrease (Ma and Hooda, 2010).

Key soil properties are known to moderate the toxic effects of Ni on soil microbial activities, largely through their influence on metal retention–release processes. In this concern, Oorts *et al.* (2006) found that the toxicity of added Ni to three soil microbial activities (nitrification potential, glucose-induced respiration, and C-mineralization of plant residues) varied considerably across a wide range of soils. Pollution of soils by heavy metals, which includes nickel has elevated dramatically during the last years all over the world. That is due to mobilization via human actions, such as mining, smelting, industry, use of agricultural fertilizers, insecticides, municipal wastes, traffic exhausts and industrial effluents and chemicals (Chibuike and Obiora, 2014).

MATERIALS AND METHODS

Study area: The selected area in this study is located between Long. 32° 00` and 32° 29`E and Lat. 31° 00` and 31° 15` N. It includes in the salt-affected soils at south Port Said plain.

Soil sampling: Nineteen surface and subsurface soil samples have been collected from 10 locations in the salt-affected soils at the south Port Said plain. The sampling sites have been selected depending on a particular combination of soil characteristics and that were approximately distributed over the entire study area with a total of nineteen samples (Map 1). Moreover, eighteen plant samples of cultivated Alfalfa (*Medicago Sativa*), Sugar beets (*beta vulgaris*) and Wheat (*Tritium Vulgare*) have been collected from the ten locations, representing different fractions of grown plants in the study area during the period from October 2020 to April 2021.



Map (1): Locations and the samples sites in the study area.

Soil analyses: Determination of some physical and chemical properties for 19 soil samples collected from 0-30 cm depth and 30-60 cm depth was performed according to the following procedures:

- Mechanical analysis of finer textured soil samples was carried out by the international pipette method described by Kilmer and Alexander (1949) in which sodium hexametaphosphate is used as a dispersing agent and, for coarse textured samples the dry sieving method was applied according to Piper (1950).
- Organic matter content was determined by the method of Walkley and Black as mentioned by Jackson (1973).
- Soil reaction (pH) was determined electrometrically in the soil paste using bench type Beckman glass electrode pH-meter.
- Total soluble salts were determined conductimetrically as EC in the soil paste according to the method described by Jackson (1973).
- Total carbonates content were determined using Collin's calcimeter.
- Cation exchange capacity was determined according to the methods described by Jackson (1973).
- Sodium adsorption ratio (SAR) was estimated using the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Where the ionic concentration of the saturation extracts is expressed in meq/l.

- The exchangeable sodium percentage (ESP) was estimated using the following equation:

$$ESP = \frac{100(-0.0126 + 0.01475SAR)}{1 + (-0.0126 + 0.01475SAR)}$$

The physical and chemical properties of the studied samples are shown in Table (1).

- Nickel fractionation in soil samples was carried out by the sequential extraction described by Tessier *et al.* (1979) and Yang *et al.* (2012a). Each extraction step was performed in triplicate, starting with 1 g of the original soil material.

Nickel concentration in all extracts of the sequential extraction scheme was determined by the Inductivity Coupled Plasma (ICAP). Additionally, blanks of the different extractants were performed in triplicate and subtracted from the soil samples. The accuracy of the sequential chemical extraction scheme was determined by comparing the sum of the concentrations obtained at the different steps of the extraction scheme with total nickel content. The obtained results of Ni fractionation are presented in Table (2).

Plant analysis: The plant samples (aerial parts and roots) were collected and thoroughly washed and hence oven dried at 70° C. Plant samples were wet – digested by H₂O₂ and H₂SO₄ (Nicholson, 1984), and their nickel contents

were determined by Inductivity Coupled Plasma (ICAP). Some trace metal risk indices have been estimated as follow:

- **Geo-accumulation index (I_{geo}):** Another index to assess the contamination levels of metals is the geo-accumulation index (I_{geo}). This method estimates the degree of metal pollution in terms of seven enrichment classes based on the increasing numerical values of the index and could be calculated according to Muller (1969) & Rudnick and Gao (2004) as follow:

$$I_{geo} = \text{Log}_2(C_x / 1.5b_x) \quad (2)$$

Where:

C_x is the content of the element in the enriched samples, and b_x is the background value of the element. The I_{geo} classes of contamination levels are shown in Table (3). On the other hand, the obtained results of I_{geo} for the studied samples are given in Table (5).

- **Contamination factor (CF):** Contamination factor (CF) is the ratio of metal concentration in soil sample to its concentration in the background. The CF was calculated according to the following equation described by Hakanson, (1980):

$$CF = C_x / C_r \quad (3)$$

Where:

C_x and C_r are the mean concentration of the metal contaminant in the soil samples and background reference material, respectively, as described by

Chen *et al.* (2015). The classes describing the accumulation factor (FC) are shown in Table (4). And the obtained results of the studied samples are given in Table (5).

- **Metals bioaccumulation in plant:** The biological absorption coefficient (BAC) was used to characterize the degree of elements uptake by plants from soil system. Nagaraju and Karimulla (2002) have defined the BAC as the ratio of concentration of an element in plant ash to the total metal concentration in soils.

RESULTS AND DISCUSSION

The present work deals with the distribution, mobility and toxicity of nickel in salt affected soils, South Port Said plain. Consequently, it is important to throw light on the relevant physical and chemical properties of the investigated soils.

The main physical and chemical properties of the investigated soil samples are summarized in table (1). Soil pH ranged from 7.75 to 8.54, indicating neutral to alkaline soil reaction. The investigated soils are non-saline to saline, as indicated by EC values which ranged widely from 1.19 to 8.15 dS/m except the location (10) in South Port Said plain which is extremely saline. ESP values ranged widely from 3.94 to 31.57% that detected soils are non- saline to saline – sodic soils. Organic matter content is generally <1.85 % except for location (1) only (3.60%). CaCO₃ content

ranged widely from 3.70 to 17.05%. CEC ranged from 21.30 to 46.20, that indicating the soil texture is clay.

Table (1): Some physical and chemical properties of soil samples

Sample No.	Loc.	Depth (cm)	pH	EC (ds/m)	Ca ²⁺ (meq/l)	Mg ²⁺ (meq/l)	Na ⁺ (meq/l)	K ⁺ (meq/l)	CO ₃ ²⁻ (meq/l)	HCO ₃ ⁻ (meq/l)	Cl ⁻ (meq/l)	SO ₄ ²⁻ (meq/l)	SAR	ESP (%)	CaCO ₃ (%)	OM (%)	CEC
1	1	0-30	7.96	1.283	1.76	1.85	9.02	0.52	0.00	6.16	5.48	1.02	6.90	9.81	17.05	3.68	33.59
2	2	0-30	8.16	1.873	2.11	2.88	14.12	0.45	0.00	3.64	8.90	6.02	9.76	13.26	16.68	1.89	33.37
3		30-60	8.12	2.48	2.65	2.92	18.00	0.47	0.00	3.68	13.01	8.67	11.32	15.59	16.06	1.51	36.09
4	3	0-30	7.93	3.56	4.21	7.83	24.09	0.35	0.00	4.48	21.92	9.12	10.16	13.86	8.22	0.33	48.11
5		30-60	8.09	4.67	3.22	5.30	37.68	0.54	0.00	2.52	33.56	10.56	18.26	25.92	8.87	0.75	34.78
6	4	0-30	7.94	2.75	3.15	2.44	21.75	0.27	0.00	5.88	16.44	5.02	13.01	18.11	11.50	1.42	48.76
7		30-60	8.20	4.47	2.83	3.18	38.21	0.58	0.00	4.20	32.19	8.23	22.04	31.57	12.98	1.84	21.50
8	5	0-30	8.35	2.1	1.25	1.91	17.78	0.16	0.00	5.88	8.22	6.89	14.16	19.82	8.22	0.92	23.37
9		30-60	8.54	3.68	17.47	6.86	12.18	0.45	0.00	1.86	7.53	27.23	3.50	3.84	8.50	0.56	49.00
10	6	0-30	7.75	1.3	1.63	1.15	10.16	0.16	0.00	5.32	5.48	2.12	8.62	11.57	8.17	1.89	28.48
11		30-60	7.82	5.9	20.90	14.00	23.30	0.73	0.00	1.68	18.49	38.78	5.58	7.04	6.95	0.33	25.43
12	7	0-30	8.17	1.19	2.87	1.83	7.02	0.31	0.00	2.24	6.16	3.35	4.58	5.54	6.94	0.67	39.75
13		30-60	8.04	1.56	3.43	2.23	8.66	0.57	0.00	3.68	6.16	6.24	5.74	7.28	5.34	0.59	25.22
14	8	0-30	8.26	1.55	1.66	2.65	10.78	0.48	0.00	3.92	5.48	6.01	7.34	9.67	7.11	1.34	48.11
15		30-60	8.02	4.91	24.76	4.11	18.47	0.91	0.00	1.68	6.16	41.13	5.32	6.36	3.70	0.25	46.20
16	9	0-30	8.24	3.35	3.44	5.67	23.99	0.45	0.00	4.48	21.92	7.01	11.24	15.47	10.27	1.34	32.17
17		30-60	8.25	7.73	7.33	17.90	63.13	1.05	0.00	2.80	55.35	31.08	17.77	25.21	8.83	0.59	28.80
18	10	0-30	8.14	8.18	20.21	20.14	56.82	2.04	0.00	3.36	3.42	92.23	12.65	17.57	8.96	1.51	41.74
19		30-60	8.14	1.4	2.22	2.16	9.31	0.38	0.00	4.76	4.79	4.34	6.29	8.10	9.57	1.17	32.83

The obtained results indicated that Ni content in the individual fractions of the studied soils depends relatively on the different location and the total concentration of Ni. Total Ni content ranged between 20.74 and 103.00 mg/kg. The high nickel value was detected in soil samples collected from location 9. This may be due to human activities in using mineral fertilization in this location. In this concern, Yang *et al.* (2012b) declared that accumulation of heavy metals in the environment has considerably increased in recent decades owing to anthropogenic activities.

The determined nickel content in the six fractions following the sequential extraction procedure and its total content is shown in Table (2).

An internal check was performed on the results of the sequential extraction by comparing the total amount of nickel removed in the procedure with the total results of the full digestion (Table 2) where:

$$\text{Recovery \%} = [\text{total Ni} / \text{total Ni}] \times 100$$

This recovery% ranged between 67.49 and 194.38% in all samples.

Almost all the total content of nickel in soil was lower than the pollution level of nickel in soil (i.e., 300 mg/kg) according to Barańkiewicz and Siepak (1999). And more than the reference value of 30 mg/kg except in soil sample number 9 which was collected from location (5).

Table (2): Total content of Ni and its fractions in the studied soils

Sample No.	Loc.	Depth (cm)	F1	F2	F3	F4	F5	F6	Sum	Total Ni*	recovery	MF
1	1	0-30	3.45	1.98	11.43	12.37	14.13	22.93	66.29	62.32	106.38	25.44
2	2	0-30	1.82	1.98	17.32	17.36	4.08	29.32	71.87	74.48	96.50	29.38
3	3	0-30	1.08	1.29	11.80	20.42	8.13	24.30	67.01	85.95	77.97	21.15
4	4	0-30	0.76	2.04	7.53	13.93	6.17	27.18	57.60	64.41	89.43	17.93
5	5	0-30	2.31	8.29	8.49	21.16	7.64	32.97	80.85	58.15	139.04	23.61
6	6	0-30	1.92	1.99	3.84	14.91	7.15	29.29	59.09	44.25	133.54	13.11
7	7	0-30	2.35	2.52	3.96	12.33	14.01	33.27	68.44	35.21	194.38	12.90
8	8	0-30	0.29	7.37	3.72	16.99	11.43	25.72	65.52	97.07	67.49	17.36
9	9	0-30	0.10	3.51	4.25	16.99	1.02	28.10	53.97	65.10	82.91	14.57
10	10	0-30	0.53	5.17	11.80	21.04	6.29	33.58	78.40	58.50	134.02	22.32

Fractions: F1- soluble fraction; F2-exchangeable fraction; F3- carbonate fraction; F4- Fe and Mn oxide bound fraction (reducible fraction); F5- organic matter bound fraction (oxidizable fraction); F6- soil matrix bound fraction (residual fraction); total Ni = $\Sigma[F1+F2+F3+F4+F5+F6]$; *total Ni = Soil Ni content which resulting from full digestion.

The knowledge of mobility and bioavailability of nickel depends on the total concentration and on its chemical form. Hence, the more soluble metal compounds mean more mobile and more toxic. The soluble, exchangeable, and bonded to carbonates fractions are generally called bio-available of mobility factor as they exhibit mobility relative to the environment and are potentially available for plants. The mobility index of nickel was calculated as the mobility factor (MF) based on the following equation described by Kabala and Singh (2001):

$$MF = (F1+F2+F3) / (F1+F2+F3+F4+F5+F6) \times 100$$

Obtained results showed that the amount of Ni in bio-available form ranged between 12.90 and 29.38% in the soil. Some fractions of a metal in soil are highly mobile whereas, others are in immobile fraction. The mobile fraction of the elements in soil usually represents the potential bioavailability. Basically, there are four major fractions of metals in soils namely, acid-soluble, reducible, oxidisable and residual. The first three fractions are considered as mobile (Tokalioglu and Kartal, 2005).

Regarding the fraction bound to Fe-Mn oxides, results indicated high amount of nickel bound to Fe-Mn oxides as ranged between 18.02 and 31.48% in the soil. Whereas the fractions bound to organic matter showed low amount of nickel bound to organic matter as ranged between 1.88 and 21.31 % in the soil. This is because organic matter content in almost profiles was generally below 1%.

Regardless of the physical and chemical properties of the studied soils, the average percentage contribution of nickel in the fractions sequential extraction can be arranged in the following order: F1- soluble (So-) < F2- exchangeable (Ex-) < F5-bound to organic matter (OM-) < F3- bound to carbonate (Car-) < F4-bound to Fe-Mn oxyhydroxides (Fe-Mn-) and < F6- residual (Res-). The major fraction of Ni was the residual, and it's accounted for 34.58 to 52.06% of the total soil Ni.

Table (3): Index of geoaccumulation (I_{geo}) for contamination levels in soil (Rudnick and Gao, 2004).

I_{geo}	Class I_{geo} Value	Contamination Level
0	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated/moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately/strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly/extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

The CF values is less than 1, So, it indicated that CF for Ni is low contamination as in Table (4).

Table (4): The terminology used to describe the contamination factor (CF) Hakanson (1980).

CF	Description
CF<1	Low degree of contamination
1<CF<3	Moderate degree of contamination
3<CF<6	Considerable degree of contamination
CF>6	Very high degree of contamination

Nickel risk indices: The values of I_{geo} for all samples have been calculated and presented in table (5). Its value in all samples remains in class '0', so the category of studied area is considered uncontaminated.

Table (5): Some nickel risk indices

Sample No.	Profile No.	Depth (cm)	I_{geo}	CF
1	1	0-30	-1.59	0.50
2	2	0-30	-1.33	0.60
3		30-60	-1.44	0.55
4	3	0-30	-1.13	0.69
5		30-60	-1.40	0.57
6	4	0-30	-1.54	0.52
7		30-60	-2.07	0.36
8	5	0-30	-1.69	0.47
9		30-60	-3.18	0.17
10	6	0-30	-2.08	0.35
11		30-60	-2.49	0.27
12	7	0-30	-2.41	0.28
13		30-60	-1.78	0.44
14	8	0-30	-0.95	0.78
15		30-60	-1.22	0.65
16	9	0-30	-1.53	0.52
17		30-60	-0.86	0.82
18	10	0-30	-1.68	0.47
19		30-60	-1.44	0.55

Assessment of the trace metal contamination in plants: According to Nagaraju and Karimulla (2002), bioaccumulation of trace metal (BAC) such as Ni by plants has a wide range (0.001 to 100) which could be classified into five groups as follow: Very weak absorption 0.001–0.01; weak absorption 0.01–0.1; intermediate absorption 0.1–1; strong absorption 1–10; intensive absorption 10 – 100. The BAC of nickel in study area was calculated and the results were shown in Table (6), the classification of BAC could be strong absorption (100%). Furthermore, the highest BAC (3.04) occurred in Sugar beets roots (*beta vulgaris*) at location 5 and the lowest BAC (1.007) occurred in Wheat leaves (*Tritium Vulgare*).

Table (6): Nickel content in plants and calculated BAC in study area

Sample No.	Loc.	Weighted mean of Ni in soil ppm	Ni in plant ppm	plant fractions	BAC	Classification of BAC
1	1	62.32	188.63	Alfalfa (<i>Medicago Sativa</i>)	3.027	Strong absorption
2	2	71.7	137.53	Sugar beets roots (<i>beta vulgaris</i>)	1.918	Strong absorption
3			139.33	Sugar beets leaves (<i>beta vulgaris</i>)	1.943	Strong absorption
4	3	78.48	120.68	Sugar beets roots (<i>beta vulgaris</i>)	1.538	Strong absorption
5			106.25	Sugar beets leaves (<i>beta vulgaris</i>)	1.354	Strong absorption
6	4	54.505	90.03	Alfalfa (<i>Medicago Sativa</i>)	1.652	Strong absorption
7	5	39.445	120.08	Sugar beets roots (<i>beta vulgaris</i>)	3.044	Strong absorption
8			119.48	Sugar beets leaves (<i>beta vulgaris</i>)	3.029	Strong absorption
9	6	38.865	104.45	Wheat seeds (<i>Tritium Vulgare</i>)	2.688	Strong absorption
10			96.63	Wheat leaves (<i>Tritium Vulgare</i>)	2.486	Strong absorption
11	7	44.945	112.88	Wheat seeds (<i>Tritium Vulgare</i>)	2.511	Strong absorption
12			124.30	Wheat leaves (<i>Tritium Vulgare</i>)	2.766	Strong absorption
13	8	88.905	108.05	Wheat seeds (<i>Tritium Vulgare</i>)	1.215	Strong absorption
14			138.13	Wheat leaves (<i>Tritium Vulgare</i>)	1.554	Strong absorption
15	9	84.05	120.08	Wheat seeds (<i>Tritium Vulgare</i>)	1.429	Strong absorption
16			84.60	Wheat leaves (<i>Tritium Vulgare</i>)	1.007	Strong absorption
17	10	63.71	119.48	Wheat seeds (<i>Tritium Vulgare</i>)	1.875	Strong absorption
18			144.13	Wheat leaves (<i>Tritium Vulgare</i>)	2.262	Strong absorption

CONCLUSION

The study of distribution, mobility, and toxicity of nickel in the salt affected soil located at south Port Said plain declared that almost all the total content of nickel in soil was lower than its pollution level (i.e., 300 mg/kg). In addition, the calculated values of geo-accumulation index (I_{geo}) for all samples have been remain in class '0', which means that the studied area is considered in the uncontaminated category. Moreover, the contamination factor (CF) values were less than 1, So, it also indicat that CF for Ni is low contamination. Regardless of the physical and chemical properties of the studied soils, the average percentage contribution of nickel in the fractions sequential extraction can be arranged in the following order: F1- soluble (So-) < F2-exchangeable (Ex-) < F5-bound to organic matter (OM-) < F3- bound to carbonate (Car-) < F4-bound to Fe-Mn oxyhydroxides (Fe-Mn-) and < F6-residual (Res-). The major fractions of Ni was the residual, and it's accounted for about 34.58 to 52.06% of the total soil Ni. The highest biological absorption coefficient (BAC) (i.e., 3.04) occurred in Sugar beets roots (*beta vulgaris*) at location 5 and the lowest BAC (1.007) occurred in Wheat leaves (*Tritium Vulgare*).

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توزيع وحركة وسمية النيكل في الأراضي المتأثرة بالأملاح وبعض المحاصيل

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المستخلص

يهدف هذا العمل إلى دراسة توزيع وحركة وسمية النيكل في التربة المتأثرة بالأملاح. ويعتبر سهل جنوب بورسعيد، الذي تبلغ مساحته نحو ٢٠٠ ألف فدان، أحد المشروعات القومية التي تعتمد على إعادة استخدام مياه الصرف للري بعد خلطها بمياه النيل. ولتحديد الأصول الطبيعية والبشرية للنيلك استخدم بروتوكول استخلاص متسلسل. وتشير النتائج إلى أن التحليل الكيميائي للنيلك في التربة يمكن ترتيبه على النحو التالي:

F₁- soluble (So-) < F₂-exchangeable (Ex-) < F₅-bound to organic matter (OM-) < F₃- bound to carbonate (Car-) < F₄-bound to Fe-Mn oxyhydroxides (Fe-Mn-) and < F₆-residual (Res-).

أوضحت النتائج أن التركيز الكلي للنيلك في التربة المدروسة هو (٢٠,٧٤ و ١٠٣,٠٠ ملجم/كج). وكان المحتوى الكلي من النيكل في التربة أقل من مستوى التلوث من النيكل في التربة (٣٠٠ ملجم/كج) وفي حمأة مياه الصرف الصحي (٤٢٠ ملجم/كج) في معظم العينات. وكانت قيمة مؤشر التلوث (I_{geo}) التي تم حسابها لجميع العينات في الفئة '0'، وعلى ذلك فإن المنطقة المدروسة تعتبر فئة غير ملوثة. وكانت قيمة معامل التلوث CF أقل من ١، وبذلك يعتبر CF بالنسبة لعنصر النيكل منخفض التلوث. وكانت أعلى قيمة لـ BAC 3.04 وجدت في جذور البنجر السكر وأقل قيمة وجدت في أوراق القمح.

الكلمات المفتاحية: النيكل - تجزئة - حركة - سمية - مؤشر التراكم الجغرافي - عامل التلوث البيولوجي التراكمي. بنجر السكر - القمح.