ALEXANDRIA
SCIENCE EXCHANGE JOURNAL

VOL. 46 JANUARY- MARCH 2025

Assessment of Selenium in Agrosystem of the Northwest Delta, Egypt

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ABSTRACT

Selenium (Se) is an essential element for saving living organisms. Plants are vital sources of organic Se to avoid living organism deficiency problem and brought good health. The results showed that the average total selenium (Se) concentrations in soils were slightly low (0.431, 0.339 and 0.365 ppm) in Burj Al Arab, Abu El Matamir and Nubariya areas, respectively. The results did not show any significant correlation with the examined soil characteristics. It might be related to the cultivation intensity near the Delta and soil parent material. The average selenium concentration in clover (0.72 mg/kg) is below the required range of 0.03-0.1 mg/kg for cattle, indicating a potential risk of selenium deficiency in livestock grazing on these soils. Quality of soils and Se content in all areas of the Northwest Delta should be regularly recorded to prevent metal toxicity or deficiency of Se-enriched plants.

Key-words: Total Selenium, available Selenium, Selenium uptake, clover plant.

INTRODUCTION

Among various micronutrients, selenium (Se) is essential in small amounts for the life cycle of organisms, including crops. Selenium has the potential to improve soil health, leading to the improvement of productivity and crop quality. However, Se possesses an immense encouraging phenomenon when supplied within the threshold limit, also having wide variations (Moulick *et al.,* 2024).

There is sufficient data on soil selenium status in countries like the USA, Canada, Europe, Australia, New Zealand, Japan, and China (Gissel-Nielson, 1984 and Frankenberger & Engberg, 1998), information of many other countries is lacking (Abdelrazek *et al.,* 2022).

Selenium behavior in soils and plants

Different regions around the world can be classified as selenium deficient, selenium adequate, or selenium toxic based on appropriate dietary intake limits for livestock (Maksimovic *et al.,* 1995). The primary source of selenium in human food and animal fodder is the soil-plant system (Abdelrazek and Fayed, 2018).

Selenium is a mineral found in soil and many soils in Egypt are suffer from selenium deficiency. Selenium becomes harmful to plants when absorbed in excess. The recommended dietary allowance (RDA) encompasses the total selenium intake from both natural sources and any dietary supplements.

Selenium can accumulate in soils up to 50 ppm in Celtic soils. The accumulation of selenium in plants is influenced by their genetic makeup (Amara *et al.,* 2011 and Cai *et al.,* 2021).

A model suggests that increasing the Se concentration in irrigation water by 100 milligrams per liter within a leaching fraction range of 0.2 to 0.3 will not exceed the maximum permissible soil solution Se concentration for clover when irrigated with sulfate-rich waters. Consequently, the recommended maximum Se concentration in irrigation water for alfalfa cultivated in the study area is 100 milligrams per liter. Clover, a plant exceptionally sensitive to selenium (Se) accumulation, can tolerate an average soil solution Se concentration of 250 milligrams per liter without surpassing the critical threshold of four milligrams of Se per kilogram of dry forage. This limit is established to safeguard bovine animals from Se toxicity. The plant has the ability to metabolize selenium, as some plants can tolerate a high concentration of selenium, more than 50 milligrams, and it accumulates in some plants like wheat (Cao, 2017).

Selenium availability, soil salinity and pH

The presence of high levels of selenium in soils and waters is often linked to high salinity levels, as stated by Li *et al.* (2012). An experiment conducted with alfalfa grown in sand culture showed that both salinity (0.5 and 5.0 dS/m as sodium and calcium sulfate) and selenium treatments (0, 0.25, 0.5, and 1.0 me Se (VI)/L) significantly reduced yields. However, boron (0.5 and 3.0 mg/L) did not have the same effect. Plant selenium levels dropped from 620 mg/kg to less than 7 mg/kg in the presence of sulfate. Li *et al.* (2012) also investigated the impact of increasing salinity using Cl^- or SO_4^{--} salts. They discovered that biomass production of shoots and

DOI: 10.21608/asejaiqjsae.2025.403214
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.Received December 05, 2024, Accepted, January 01, 2024.

roots decreased with selenium and each of the anions. When selenium was present, the reduction in yield was more pronounced with Cl^- salinity compared to SO_4^{--} salinity. Therefore, the existence of high SO_4^{--} levels in seleniferous soils and waters must be taken into account when assessing selenium availability and toxicity in drinking water and forage for animal consumption.

The availability of selenium in soil is greatly influenced by the redox potential and soil pH. In well-aerated alkaline soil, selenite is the predominant form of selenium. However, it tends to be adsorbed to clays and hydrous Fe oxides, making it generally inaccessible for plant uptake. While it can still be taken up by plant roots, selenite does not remain readily available when added to soil at low concentrations, having minimal impact on selenium uptake and plant growth (Hoogmoed and Stroosnijder, 1984). Productivity has been shown to increase in the presence of selenium (Adams *et al.*, 2002). This observed response is likely a result of the diminished adsorption capacity of clays and Fe oxides due to the higher pH and exchange of hydroxyl ions for SeO^{--} (Sakizadeh *et al.*, 2016).

Selenium and health of living organism

Selenium is an essential micronutrient necessary for the growth and survival of mammals, birds, fish, and many bacteria (Stadtman, 1979 and Burau, 1985). Selenium works on the regulation of food metabolism, the regulation of the glands, and the regulation of the muscular. Muscles of the heart (Rosenfeld and Beath, 2022). It is anti-oxidizing to the oils found in the skin under normal conditions for storage and storage of mineral elements or fatty acids (Watkinson, 2023). The deficiency of selenium in humans and animals has been linked to various health issues such as heart failure (Ge *et al.*, 2020 and Fleming *et al.*, 2022), muscle pain (Van Rij *et al.*, 1981), cancer inhibition (Ip & Ganther, 1994 and Cech *et al.*, 2022), and other diseases (Ip and Ganther, 2021). Although, trace amounts of selenium are essential for optimal human and animal health, the permissible concentration range is narrow. Excessive or deficient selenium intake can lead to health problems. Regions prone to salinity often exhibit elevated Se levels in soil and irrigation water, posing potential health risks.

MATERIAL AND METHODS

Study area description

1- Borg El Arab area

The studied area is a part of the eastern section of the north-western coastal region of Egypt. It was selected in the north and south Borg El Arab area, 48 kilometers west of Alexandria on the Marsa Matruh Road. It lies approximately between latitudes 30▫ 45 and 30▫ 55 N and longitudes 29▫ 30 and 29▫ 50 E. The study area covers 2,023.43 hectares acres of land and has differences in elevation and relief. The elevation varies between zero and more than 40 m above sea level as shown in Fig. (1).

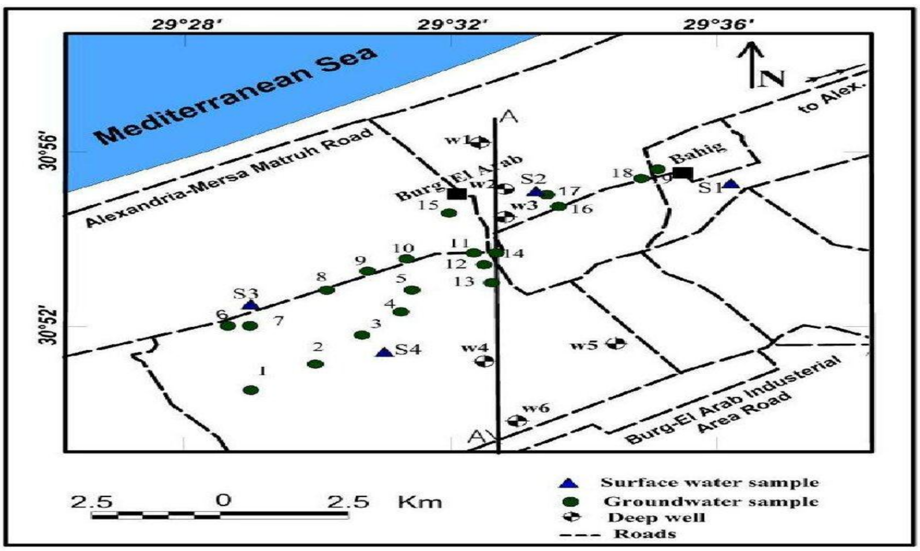

Fig. 1. Burg El Arab map

2- Abu al-Matamir

Abu al-Matamir region is situated in the North West of the Nile Delta, positioned to the east of the primary Cairo-Alexandria desert road between km 156/72 and km 160/68. It encompasses sections of the West Behera Settlement Project (WBSP) and is bordered by the Cairo-Alexandria desert road to the West, the WBSP project to the East and North, and the extended areas of Dalla and Ragab farms to the South (Fig. 1). Its coordinates range from latitudes 300 47` 38`` North to 300 47 00 South `, and longitudes 290 58` 03`` West to 290 59`27`` East. The area under scrutiny spans about 1,470 hectares (Abdelrazek, 2007a) as shown in Fig. (2).

3-Nubariya

The current research encompasses an area of approximately 1,825 km^2 in the West Nile Delta region. The Abu al-Matamir depression predominantly covers the southwestern part of this area. El-Nubariya is the primary city within the study area, situated about 100 miles north of Cairo, Nubariya, in Egypt. This town is well-connected to Cairo, Alexandria, the northwestern coastal zone, and the central part of the Nile Delta through a reliable network of roads and railways. The study area depicted in Fig. (1) is positioned to the west of the Nile Delta, flanking both sides of the Cairo-Alexandria desert road, within the latitudes 30 170 and 30 420N and longitudes 30 000and 30 300 as shown in Fig. (2).

4- Soil samples distribution in studied areas

Locations of soil samples from agricultural lands at Northwest Delta, Egypt, included Burj Al Arab, Abu Al-Matamir, and Nubariya areas as shown in Fig. (3).

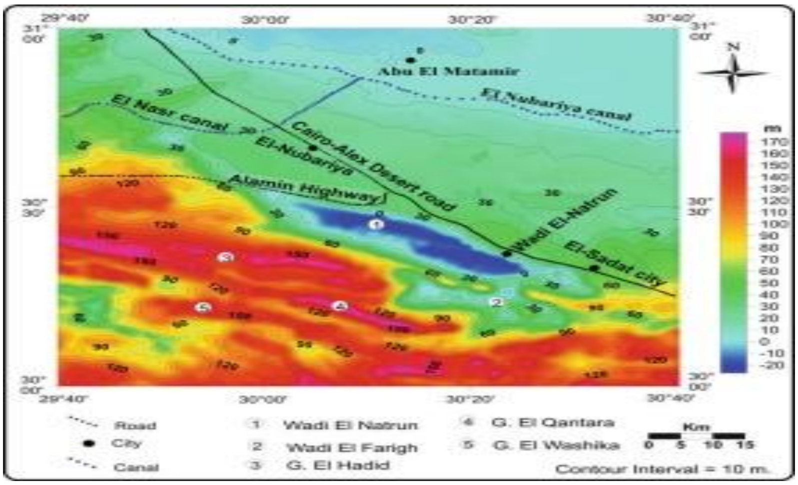

Fig. 2. Abu El Matamer and El- Nubaria areas

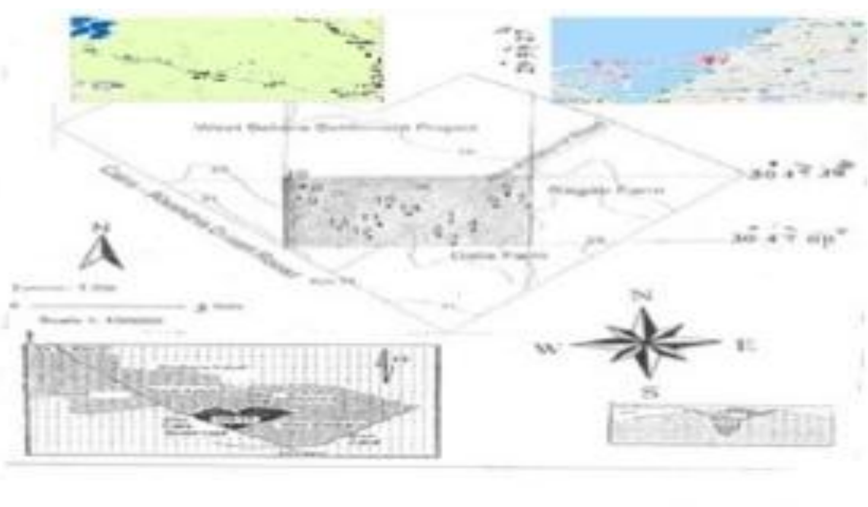

Fig. 3. Locations of soil samples in studied areas

Climate

The climate is arid, with a mean temperature of 21.8°C and average temperatures ranging from 13.6°C in January to 28.4°C in July. The average rainfall is less than 10 mm per year. Relative humidity varies from 43% in May to 62% in January. Evapotranspiration varies between 2.5 mm/day (December) and 8.6 mm/day (June).

Geology and geomorphology:

The geological history of the studied area has been investigated by many workers (Ball, 1939; Said, 1962; El-Shazly, 1964 and FAO, 1964). According to Said (1962), the area under study is covered by Holocene and Pleistocene formations.

The gradual rising of the land surface with the end of the Miocene resulted in the formation of table land provinces (Abdelrazek, 2019). The regressive phases of the Mediterranean shoreline in the Quaternary Era were accompanied by the formation of successive series of limestone ridges interspersed with lagoons. Also, hydrographic patterns took place due to the prevailing wet climatic conditions and are best illustrated in filling the successive depressions with calcareous deposits (El-Shazly, 1964 and Fayed *et al.,* 2005).

The coastal zone west of Alexandria shows a succession of limestone ridges at varying distances from each other, but all parallel to the present coast line. Alam El-Marga Bridge, which lies at the North of the study area, is probably the highest and most southern of these ridges (FAO, 1993).

Water resources

1- Bahig and El Nasr canal

Bahig canal is the branch of El Nubaria canal. It receives its water directly from the Nile and serve north Burg El Arab. El Nasr canal provides water to south Borg El Arab areas beside north Borg El Arab.

2- Behera Canal and artesian water wells

The main sources of irrigation in the study area at Abu Al-Matamir are the Behera Canal and its branches, as well as artesian water wells. The Behera Canal originates from the Nubaria Canal and carries Nile water through a branched system of canals and pumping stations to different parts of the area. The supply canal is 17.53 km long and has three pumping stations, which raise the water to 24.2 meters. According to the FAO (1980), the used Nile water could be classified as (C2-S1), which indicates a medium salinity hazard and a low sodium or alkali hazard (pH = 7.8, EC = 0.5 dS/m). Also, it has been estimated that the annual gross water requirement for the present cropping pattern is 120 Mm^3, while the actual deliveries constitute only 78 Mm.

3- El Nubaria canal

El Nubaria canal provides the irrigation water. It receives its water directly from the Nile. El Nasr Canal is a concrete-lined branch from the Nubaria Canal that provides water to the El Nubaria Sugar Beet, El-Bostan, and Borg El Arab areas. Surface irrigation is applied in most of the Borg El Arab area, and water delivery to the farm is by gravity.

Soil samples preparation

Soil samples were gathered from the agricultural fields using a technique known as coning, which was facilitated by an auger sampler. These samples were subsequently dried in an oven at a temperature of 60 ºC before being thoroughly mixed. Each sample was then ground into a fine powder using an agate mortar and pestle to achieve a particle size of 200 mesh. Approximately 0.5 to 1 gram of this powdered soil was utilized for analysis, following the method outlined by as follows.

Determination of Selenium

1- Selenium in soil

a) selenium stock solution preparation

A standard selenium solution was established with a concentration of 100 mg/L by dissolving 0.1 g of selenium metal in concentrated nitric acid and evaporating to dryness; this process was repeated twice. The resulting residue was dissolved in 6 M hydrochloric acid and diluted to 1 L with the same acid. Subsequent dilutions were carried out as needed.

b) Selenium concentration (ppm)

5 ml of concentrated HNO_3 and 10 ml of HF were added to 0.5 g of soil in a Teflon beaker. Subsequently, HNO_3 was added again and evaporated until dry. The resulting residue was dissolved in 6 M HCl, then transferred to a 25 ml glass vessel and topped up to 25 ml with 6 M HCl. The solution was then moved to a sealed plastic bottle (50 ml) and heated to 808 ºC for 30 min to convert Se (VI) to Se (IV). In cases where soil samples were high in organic matter after post-initial digestion, the residues were dark black. In such instances, 5–10 ml of H_2O_2 (30%) and 1-2 ml of concentrated HNO_3 were added and heated on a steam bath to break down the organic matter (Abdelrazek, 2007b).

c) Extractable Selenium (ppm)

Water-soluble $CaCl_2$ and extractable Se were determined by the method described by Hamdy and Gissel-Nic1sen (1976) with slight modifications. Twenty grams of air-dried soil were frequently shaken with 1 ml of distilled water for 24 hours and 1 ml of 0 mM $CaCl_2$ for 5 minutes. Fifty ml of the filtrate were reduced to 10 ml by evaporation in a low-pressure evaporator at 50°, transferred to a microkjeldahl flask, and wet digested after adding 3 ml of concentrated $HN0_3$ and 1 ml of concentrated $HClO_4$. Selenium was determined as mentioned above. Sodium bicarbonate extractable Se was determined by shaking 20 g of soil with 100 ml of 0.5 M $NaHCO_3$ (pH 8.5) for 30 min. Ten ml of the filtrate were digested, and Se determination was carried out fluorometrically.

d) Total Selenium concentration in Soil

Soils samples were collected from the agricultural fields before sowing at a depth of up to 15 cm from the north areas of Burj Al Arab and the and the southern areas of Burj Al Arab Abu Al-Matamir, and the sixteen selected locations were analyzed for some physical and chemical properties sing standard methods. Soil types are varied between calcareous and sandy; soil pH was 7·4–8.5. $CaCO_3$ content ranged between 26 and 59%, and organic matter was located between 0.83 and 1.3%. Total Se in soil and plant samples was determined by digesting two grams of soil and 05 g of plant material using HNO_3 and $HClO_4$. Selenium determination was carried out on the digest according to the method outlined by Lokeshwari and Chandrappa (2006). The fluorescence readings were made on a photoelectric fluorometer Turner III model (Maksimovic *et al.*, 1995).

In our research, we utilized 6 M HCl to analyze selenium levels in soil samples, following the method proposed by previous studies (Welz & Schubert-Jacobs, 1986 and Abdelrazek, 2017). Soil samples were examined using atomic absorption spectrophotometry and inductively coupled Plasma-Optical Emission Spectroscopy.

Instruments

A PC-based atomic absorption spectrophotometer, model ECIL4129, equipped with a hydride generator accessory (HG-AAS) and a selenium cathode lamp, was employed for the analysis of selenium content in soil samples. An oxidizing air-acetylene flame was utilized, and a wavelength of 196 nanometers was selected for light absorption measurements. To corroborate the findings, the selenium levels in the collected samples were also quantified using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES), model ICP-AES LABTAM 8440. A comparative analysis of the results obtained from both techniques was conducted.

Chemical properties of soil and water

The electrical conductivity (EC) of the saturated soil extracts and water samples was measured using a conductometer, as described by Jackson (1958). pH was measured using a Beckman pH meter on a saturated soil paste, following the methodology outlined by Jackson (1958). Cation exchange capacity was calculated using the sodium acetate method, as detailed by Richards (1954). Total carbonate content was estimated volumetrically through the use of a Collins calcimeter, following the procedure outlined by Williams (1948). Organic matter content was determined using the Walkley-Black method, as described by Jackson (1973). Soluble calcium, magnesium, bicarbonates, Sulfate and chloride were determined using the method of Page *et al.* (1982). Sodium and potassium were measured using a flame photometer. The Sodium Adsorption Ratio (SAR) was calculated using Donahue *et al.* (1990) formula as follows:

$$SAR = Na^{+}/\sqrt{(Ca^{++}+Mg^{++})/2}$$

Where Na^+, Ca^{++} and Mg^{++} refer to their concentrations in eq/l

Physical properties of soil

The soil samples were allowed to air-dry before being ground into smaller particles. These particles were then passed through a two-millimeter plastic sieve and subsequently stored for analysis. The physical properties of the soil were determined through a series of analyses. Particle size distribution was analyzed using the pipette method as described by the Food and Agriculture Organization (FAO) in 1970. Sodium hexametaphosphate and sodium carbonate were employed as dispersing agents during this process. Soil texture was categorized by plotting the data on a texture triangle diagram, a method outlined by the Soil Survey Staff in 1998.

RESULTS AND DISCUSSION

Water resources in studied area

1- Irrigation water in Abu Al-Matamir

The results depicted in Table (1) provides a chemical analysis of well water in Abu Al-Matamir. The pH of the water was slightly alkaline (8.52). The EC_w value was relatively low 1.33 dS/m, which suggests that the TDS concentration in the well water is also relatively low. The concentrations of major cations (Mg^{++}, Ca^{++}, Na^+, and K^+) and anions (Cl^-, HCO_3^-, and SO_4^{--}) are all within a typical range for groundwater. The concentration of selenium (Se) in the water is 0.16 mg/L.

Table 1. Chemical analysis of well's water in Abu Al-Matamir

EC dS/m	pH	Cations (meq/L)				Anions (meq/L)					Selenium* (mg/L
		Mg++	Ca++	K+	Na+	Cl^-	HCO_3^-	SO_4^{--}	CO_3^{--}	SAR	
1.33	8.52	1.88	1.90	0.15	7.10	3.82	5.10	2.42	1.90	5.02	0.16

The sample take from level of groundwater; the upper surface of the well

2- Irrigation water in Bahig canal irrigation water in Burg Al Arab

The results recorded in Table (2) showed a chemical analysis of Bahig canal irrigation water in BurgAl Arab. EC value was (0.69 dS/m) indicated that the water was relatively low in dissolved salts. This is suitable for irrigation cultivated crops. The pH of 7.5 suggests that the water is slightly alkaline. While slightly alkaline water is generally suitable for most crops, extremely high pH levels can lead to nutrient deficiencies. Na^+ and HCO_3^- were the dominant cation and anion, respectively. This combination can contribute to the formation of sodium-based soil problems if not managed properly. The selenium concentration of 0.18 mg/L indicates that the water is essentially free of selenium. While selenium is an essential micronutrient, excessive levels can be toxic to plants and animals. The SAR value of 0.948 suggests a moderate sodium hazard. A higher SAR value indicates a greater risk of soil sodicity. Therefore, we can conclude that the Bahig Canal irrigation water appeared to be of relatively good quality for irrigation purposes. However, continuous monitoring of soil salinity and crop performance is recommended to assess the long-term impact of using this water. While the SAR is moderate, long-term irrigation with this water could potentially lead to soil sodicity. Regular soil testing and appropriate management practices are essential. The dominance of sodium and bicarbonate ions might influence the availability of other nutrients in the soil. Regular soil fertility testing and fertilization based on crop needs are recommended. The suitability of this water for specific crops should be considered, as some crops are more sensitive to salinity and sodium than others. Proper irrigation practices, such as leaching and drainage, can help mitigate potential salinity and sodicity issues.

3- Irrigation water in El Nasr canal irrigation water in Nubariya

Table (3) showed the water quality of El Nasr canal irrigation water in Nubariya. The conductivity EC value was 0.63 dS/m indicated that the water has a moderate salinity level. This salinity level may not be suitable for all crops, and long-term use of this water on some soils could lead to salinization. The pH of 7.2 suggested that the water is slightly alkaline. While slightly alkaline water is generally suitable for most crops, extremely high pH levels can lead to nutrient deficiencies. Sodium (Na+) is the dominant cation, while bicarbonate (HCO_3^-) is the dominant anion. This combination can contribute to the formation of sodium-based soil problems if not managed properly. The selenium concentration of 0.31 mg/L exceeds the guideline value of 0.05 mg/L for irrigation water set by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (DEHP Qld 2000 and EPA Victoria, 2004). This indicates a potential risk of selenium toxicity in crops irrigated with this water. The SAR value of 0.944 suggests a moderate sodium hazard. A higher SAR value indicates a greater risk of soil sodicity. Therefore, El Nasr Camal irrigation water has a moderate salinity level and a slightly alkaline pH. These parameters may not be suitable for all crops, and long-term use could lead to salinization. Additionally, the selenium concentration significantly exceeds the recommended guideline value 0.05 mg/L, posing a potential risk of selenium toxicity in crops.

Table 2. Chemical analysis of Bahig canal irrigation water in Burj Al Arab

EC, dS/m	pH	Cations (meq/L)				Anions (meq/L)					Selenium, mg/L
		Mg++	Ca++	K+	Na+	Cl^-	HCO_3^-	SO_4^{--}	CO_3^{--}	SAR	**0.18**
0.69	7.5	1.6	1.82	0.29	1.24	1.91	2.62	1.04	0.00	0.948	

Table 3. Chemical analysis of El Nasr canal irrigation water in Nubariya

EC, dS/m	pH	Cations (meq/L)				Anions (meq/L)				SAR	Selenium, * mg/L
		Mg++	Ca++	K^+	Na+	Cl^-	HCO_3^-	SO_4^{--}	CO_3^{--}		
0.63	7.2	1.2	1.09	0.21	1.01	1.67	1.53	0.31	0.00	0.944	0.31

* Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Guideline value in irrigation water 0.05 mg/L (EPA Victoria ,2004; DEHP Qld 20 20).

It must select crops with higher tolerance to salinity and selenium for irrigation with this water, regularly monitor soil salinity and selenium levels to assess the long-term impact of irrigation with this water, and implement proper drainage practices to prevent salinization and leaching of excess selenium from the root zone.

Soil properties in studied area

Chemical properties of the soil in studied areas

Table (4) presents a detailed chemical analysis of soils from different locations and depths in Northern Egypt. North Burj Al Arab: Low to moderate salinity levels based on EC values. South Burj Al Arab: High salinity levels, particularly at the surface, indicating potential salinity issues. Abu Al-Matamir and Nubariya: Moderate salinity levels overall. pH: Generally alkaline conditions across all locations and depths, with slightly higher pH values in Abu Al-Matamir: Cation and Anion Composition: Sodium (Na+) is the dominant cation in most cases, indicating potential sodicity issues. Bicarbonate (HCO_3-) is the dominant anion in most cases. Chloride (Cl-) concentrations are relatively high in some cases, particularly in South Burj Al Arab. Sodium Adsorption Ratio (SAR): High SAR values in South Burj Al Arab indicate a severe sodium hazard. Moderate SAR values in North Burj Al Arab and Abu Al-Matamir suggest a potential sodium hazard. Lower SAR values in Nubariya indicate a lower risk of sodicity.

Implications: -

Salinity and Sodicity: The high levels in South Burj Al Arab pose significant challenges for agriculture. Soil reclamation and salt-tolerant crop varieties may be necessary.

Nutrient Imbalance: The dominance of sodium and bicarbonate ions can affect nutrient availability and plant growth.

Crop Suitability: Crop selection should consider the specific soil conditions of each location. Salt-tolerant and sodicity-tolerant crops may be suitable for some areas.

Irrigation Water Quality: The quality of irrigation water used in these areas should be carefully evaluated to avoid exacerbating salinity and sodicity problems.

Table 4. Chemical analysis in the soil Northern areas of Egypt

Location	Soil depth (cm)	E. C (dS/m)	pH	Cations (meq/L)				Anions (meq/L)			
				Mg++	Ca++	K+	Na+	Cl-	SO_4^{--}	HCO_3^-	SAR
North area of Burj Al Arab	0	0.98	7.91	1.2	2.1	0.5	4.3	3.2	2.5	2. 4	3.346
	25	1.21	8.32	5.3	3.1	0.2	5.3	4.3	3.2	2.3	1.261
	50	1.92	8.16	2.6	5.9	0.2	5.1	2.6	6.0	2.1	1.2
	75	1.23	8.29	0.2	2.6	1..9	7.5	1.6	5.2	3.4	5.357
	Mean	1.31	8.17								2.79
south area of Burj Al Arab	0	4.91	7.28	9.2	22.5	0.5	9.7	28.4	9.6	3.8	9.7
	25	4.91	7.82	4.9	16.8	0.3	13.9	23.5	9.7	2.7	0.877
	50	4.91	7.46	3.3	16.1	0.3	16.2	21.7	9.7	4.5	1.670
	75	3.89	7.95	4.5	15.5	0.5	12.9	22.4	8.3	2.7	1.32
	Mean	4.66	7.63								3.39
Abu Al-Matamir	0	1.52	8.68	1.50	2.74	0.58	13.68	12.31	4.08	2.10	9.37
	25	1.55	8.64	1.10	2.79	0.36	13.95	12.56	3.45	2.20	9.84
	50	1.52	8.74	0.65	2.74	0.17	13.68	12.31	2.62	2.30	10.52
	75	1.92	8.82	1.10	3.46	0.44	17.28	15.55	4.32	2.40	11.44
	Mean	1.63	8.72								10.29
Nubariya	0	1.42	8.40	1.40	3.32	0.12	9.10	6.90	3.89	3.15	5.91
	25	1.45	8.30	2.60	4.13	0.10	9.80	6.98	2.63	3.25	5.341
	50	1.42	8.50	1.90	5.87	0.9	9.05	7.98	4.29	5.45	4.592
	75	1.72	8.65	0.80	1.45	0.61	12.98	9.66	3. 90	3.40	12.24
	Mean	1.50	8.46	1.68	3.69	0.433	10.23	9.68	3.68	3.81	7.02

Physical and chemical analysis in soils in the study area

Table (5) presents a comprehensive analysis of soil properties across different locations and depths in Northwest Delta of Egypt. Abu Al-Matamir: Primarily loamy sand, characterized by a high sand content, suggesting low water-holding capacity and potential nutrient deficiency. Nubariya: Predominantly sandy soils, with low clay and silt content, indicating poor water-holding capacity and fertility. North and South Burj Al Arab: Relatively high CEC values, especially at the surface, suggesting good nutrient retention capacity. Abu Al-Matamir and Nubariya: Lower CEC values, indicating limited nutrient retention capacity. North and South Burj Al Arab: Moderate to high CaCO3 content, which can influence soil pH and nutrient availability. Abu Al-Matamir and Nubariya: Lower $CaCO_3$ content compared to Burj Al Arab. Generally low OM content across all locations and depths, suggesting potential limitations in soil fertility and structure.

The measure soil fertility

Soil fertility is assessed through a combination of chemical and physical properties.

Measuring soil nutrient levels: such as nitrogen, phosphorus, and potassium.

Determining soil pH: Soil pH is a measure of the acidity or alkalinity of the soil. It affects the availability of nutrients to plants and the activity of soil microbes.

Assessing organic matter content: Organic matter is decomposed plant and animal material that helps to improve soil fertility by improving soil structure, water holding capacity, and nutrient retention.

Evaluating soil texture: Proportions of sand, silt, and clay in the soil. It affects drainage, aeration, and nutrient adsorption.

Analyzing cation exchange capacity (CEC): CEC is a measure of the soil's ability to hold and exchange cations (positively charged ions). A higher CEC indicates a greater capacity to hold nutrients for plant uptake.

Implications: -

Soil Fertility: Soils in the North and South Burj Al Arab areas have a higher potential for fertility due to higher CEC and clay content compared to Abu Al-Matamir and Nubariya. Water Retention: Soils in Burj Al Arab have better water-holding capacity compared to Abu Al-Matamir and Nubariya, which are dominated by sandy textures. Nutrient Management: Due to low OM content across all locations, regular organic matter amendments are recommended to improve soil fertility and structure. Crop Selection: Crop selection should consider soil texture and fertility. For example, sandy soils in Abu Al-Matamir and Nubariya may be more suitable for drought-tolerant crops.

Table 5. Some physical and chemical properties in studied areas

Location	Soil depth (cm)	**CEC, * cmol /kg**	**$CaCo_3$ %**	**O.M %**	**Clay %**	**Silt (%)**	**Sand (%)**	Soil texture
North area of Burj Al Arab	0	13	47.12	0.28	27	23	50	Silt Clay Loam
	25	9	37.18	0.48	25	23	52	Silt Clay Loam
	50	12	32.64	0.62	24	14	62	Silt Loam
	75	8	39.65	0.34	23	12	65	Silt Loam
south area of Burj Al Arab	0	15	40.38	0.83	35	26	39	Silt Clay Loam
	25	10	24.98	0.69	4	53	43	Silt Loam
	50	14	47.36	0.76	33	22	45	Silt Loam
	75	9	47.28	0.48	32	42	26	Silt Loam
Abu Al-Matamir	0	10	10.30	0.75	12.8	0.7	86.5	Loamy sand
	25	8	11.05	0.25	12.0	1.4	86.6	Loamy sand
	50	9	10.50	0.20	12.9	1.2	85.9	Loamy sand
	75	8	9.45	0.15	13.0	1.1	85.9	Loamy sand
Nubariya	0	10.20	13.95	0.56	11.20	10.30	78.50	sand
	25	9.70	12.24	0.42	10.48	9.37	80.15	sand
	50	9.10	12.15	0.35	11.15	8.60	80.25	sand
	75	8.95	11.84	0.28	10.44	8.51	81.05	sand

* C.E.C Cation exchange capacity

Interaction between selenium and soil chemical properties

Table (6) illustrates a generally strong relationship between both total and extractable soil selenium and plant selenium content. Studies conducted in these regions have revealed lower selenium levels. Selenium from lower soils dissolves and moves to the surface. This selenium transport and uptake is pertinent to reclamation management problems. Geographical regions showing similarities in their results also demonstrated lower selenium levels. Factors such as lower clay content (%), lower Cation Exchange Capacity (CEC cmol/kg), and lower Organic Matter (% OM) are significant.

Selenium availability to vegetation is influenced by several factors, including soil pH, mode of occurrence, soil weathering, physiography, and climate. Mobile selenium is defined here as the forms of selenium that are transported by water under toxic soil conditions and are available for plant uptake. Although selenium can exist in four oxidation states, selenium-VI (as selenate, SeO^{2-}) and selenium-IV (as selenite, SeO^{2-}) are the predominant mobile forms, whereas selenides (Se^{2-}) and elemental selenium (Se^{2-}) are insoluble. Selenite is the primary selenium species encountered in solution in arid and semi-arid regions (Száková *et al.*, 2015).

Selenium competes with other anions, such as phosphate, sulfate, oxalate, and molybdate, for adsorption sites. Selenium is adsorbed more strongly than sulfate onto clays but not as strongly as phosphate (Bitterli *et al.*, 2010). This adsorption decreases with increasing pH, and this decrease is most marked for selenate in low ionic strength sodium systems. The sorption of selenite by soil shows some analogies with the sorption of phosphate, whereas the sorption of selenate is closer to that of sulfate (Pinheiro *et al.*, 2004).

Johnson *et al.* (2000) found that selenium mobility, as opposed to adsorption, is higher under alkaline pH, high selenium concentrations, oxidizing conditions, and high concentrations of strongly adsorbed anions. Selenium anions have been adsorbed by clay (%) (Di Gregorio, 2008). They found that between pH 4 and 8, selenium solubility is governed by adsorption. The hydroxyl ions are more effective in modifying the selenium ion's adsorption capacity than in competing with selenium for common adsorption sites.

Selenium sorption on calcite is also significant in calcareous soils. It is pH-dependent, increasing from pH 6 to 8, peaking between pH 8 and 9, and decreasing above pH 9. Using a variety of semi-arid soil types, Navarro-Alarcon and Cabrera-Vique (2008) showed that selenium was adsorbed in varying amounts according to the general soil sequence: high organic carbon > calcareous > saline > alkali. Adsorption is positively influenced by organic carbon, clay content, $CaCO_3$, and cation-exchange capacity (CEC) and negatively by high salt, alkalinity, and pH (Dumont *et al.*, 2006).

Effect of salinity on selenium availability

Selenium, a trace element typically found in soils at concentrations around 200 milligrams per kilogram, (Rosenfeld and Beath, 2022), exhibits elevated levels in the studied regions of South Burj Al Arab (0.092 mg/kg), Abu Al-Matamir (0.208 mg/kg), and North Burj Al Arab (0.331 mg/kg). These elevated selenium occurrences often coincide with increased salinity, as documented in previous research, (Broadley *et al.*, 2006).

Within soils, selenium predominantly resides in organic matter, bound to molecules such as proteins, peptides, and amino acids. A specific selenium-containing polypeptide with a molecular weight of 3200 electron volts per mole has been identified (Nazemi *et al.*, 2012). The distribution and chemical form of selenium in the soil environment are dynamic, influenced by factors including plant uptake and ongoing biological and geochemical processes (Smedley and Kinniburgh, 2002).

Table 6. Relationship between the selenium and some soil properties

Location sites	pH	E. C (dS/m)	$CaCo_3$ %	OM %	CEC cmolLkg	Clay %	SAR	Selenium (Se) in clover plant (mg/g)	Selenium (Se) in water mg/L
North area of Burj Al Arab	0.053	0.331	0.11	1.001	0.042	0.017	0.155	0.557	0.369
south area of Burj Al Arab	0.056	0.092	9.33	2.071	0.036	0.036	0.137	0.493	0.419
Abu Al-Matamir	0.039	0.208	0.033	0.251	0.039	0.017	0.033	0. 464	0. 915
Nubariya	0.043	0.243	0.011	0.227	0.038	0.034	0.052	0. 760	0.849

The geochemical behavior of selenium in a soil

Understanding these geochemical processes is crucial for predicting selenium availability and potential environmental impacts (Kazemi and Mehdizadeh, 2003).

Selenium levels in the soils

Table (7) presents data on selenium levels in soils from different locations and depths in Northern Egypt. The table includes information on total selenium concentration, soil pH, extractable selenium, selenium in clover plants, and extraction methods used (water, calcium chloride, and sodium bicarbonate). There is significant variation in total selenium concentration across different locations and depths. The highest levels were found in the 0-25 cm depth of North and South Burj Al Arab. Soil pH ranges from slightly acidic to alkaline, with most values falling within the neutral to slightly alkaline range. The amount of selenium extracted varies depending on the extraction solution. Generally, sodium bicarbonate extracted the highest amounts of selenium. Selenium concentrations in clover plants are relatively low, suggesting limited selenium uptake.

Implications

Selenium Status: The data suggests that selenium status varies across the study area, with some locations potentially having sufficient selenium levels for plant uptake, while others may be deficient.

Selenium Availability: The differences in selenium extracted by different solutions indicate that selenium forms in the soil may vary, affecting its availability to plants.

Risk of Selenium Deficiency: The low selenium concentration in clover plants suggests a potential risk of selenium deficiency in livestock grazing on these soils.

Table 7. Selenium levels in the soils of studied areas (Selenium stock solution)

Location	Soil depth (cm)	TOTAL (Se) Selenium conc. in Soil (mg/kg)	Soil pH	Extractable Se (mg/g)			Selenium *(Se) in clover plant (mg/g)
				Water	Ca CI2	$NaHCO_3$	
North area of Burj Al Arab	0	0.208	7.37	3.1	3.9	8.9	0.79
	25	0.539	8.44	5.2	4.8	9.7	0.68
	50	0.538	8.61	6.3	5.7	10.6	0.77
	75	0.446	8.30	7.4	6.7	11.5	0.88
	Mean	0.433	8.18	5.5	5.3	10.2	0.78
south area of Burj Al Arab	0	0.207	8.25	3.6	3.9	7.9	0.88
	25	0.537	7.62	5.4	4.8	5.7	0.86
	50	0.547	6.98	6.5	5.7	9.6	0.84
	75	0.427	8.73	7.5	6.8	11.5	0.89
	Mean	0.429	7.90	5.8	5.3	8.7	0.87
Abu Al Matamir	0	0.563	7.61	2.8	4.1	6.8	0.62
	25	0.517	7.87	2.5	3.9	5.6	0.74
	50	0.269	8.92	5.6	4.9	7.6	0.72
	75	0.276	8.42	7.8	8.9	9.7	0.82
	Mean	0.339	8.21	4.7	5.5	1.9	0.73
Nubariya	0	0.433	8.62	13.70	7.5	43.9	0.52
	25	0.489	7.52	14.50	8.2	45.8	0.47
	50	0.254	8.83	14.92	9.6	47.5	0.46
	75	0.283	8.54	14.12	8.5	46.6	0.45
	Mean	0.365	8. 38	14.31	8.5	45. 9	0.48
Over all means of selenium (se)	0	0.353	8.00	5.8	4.9	16.9	0.70
	25	0.521	7.86	6.9	5.4	16.7	0.73
	50	0.402	8.34	8.3	6.5	18.6	0.69
	75	0.358	8.50	8.31	7.7	19.8	0.76
	Mean	0.409	8.18	7.33	6.1	18.0	0.72

* Cattle require selenium concentrations of 0.03–0.1 mg/kg in forage to prevent deficiency (Wood *et al.*, 2018)

The study areas are characterized by arid conditions and limited irrigation water availability. Soil selenium concentrations were determined to be 0.339, 0.365, 0.429, and 0.433 milligrams per kilogram in Abu Al-Matamir, Nubariya, South Burj Al Arab, and North Burj Al Arab, respectively. The observed variations in selenium content among these regions are attributed to differing parent materials. Notably, selenium levels in the study areas exceed those found in the sandy soils of Northern Burj Al Arab, which exhibit lower selenium concentrations. Similar to the southern part of Burj Al Arab, these areas also experience reduced rainfall.

While the essentiality of selenium as a micronutrient for clover growth remains speculative, it is established that plants can absorb selenium from both soil and air (Roca-Perez *et al.*, 2010). Some plant species exhibit a remarkable capacity to accumulate selenium, reaching concentrations of hundreds or even thousands of milligrams per kilogram (Gupta and Gupta, 2000). However, no signs of selenium toxicity were observed in the clover plants examined in this study.

Selenium concentration in soil samples

Fig. (4) illustrates the varying selenium (Se) concentrations across different sample sites, measured in milligrams per kilogram. Typically, soil selenium content is estimated to be around 200 milligrams per kilogram (Gardiner *et al.*, 2022). The presented data, validated through repeated standard addition analyses, reveals higher selenium levels in the studied areas compared to the global average. A distinctive characteristic of selenium is its vertical mobility within the soil profile. Unlike many elements, selenium can migrate from lower soil layers to the surface. Chemically, selenium exhibits similarities to sulfate, demonstrating high solubility in water under ambient conditions. However, unlike sulfate, selenium possesses oxidizing properties and is capable of being reduced (Maylan *et al.*, 2022). In strongly acidic environments, selenium forms the hydrogen selenate ion, a component of selenic acid, a potent acid known for dissolving even gold.

Selenium exists in multiple valence states, with elemental selenium representing a less reduced form compared to sulfur. The specific valence state significantly influences selenium toxicity. Selenate, the most oxidized form, is essential for organisms requiring selenium as a micronutrient (Abdelrazek and El Naka, 2022). These organisms possess mechanisms for selenium uptake, metabolism, and excretion. The threshold at which selenium becomes toxic varies across species and is influenced by environmental factors such as pH and alkalinity, which affect the relative concentrations of selenate and selenite. Regions with a history of ancient seas, characterized by evaporation and subsequent selenium enrichment, often exhibit elevated selenium levels. Over extended periods, organisms in these areas have adapted to these conditions (Jegadeesan *et al.*, 2010).

Water washes away the essential soluble minerals from the top soils, resulting in lower selenium levels in these areas. Among the areas of Abu Al-Matamir adjacent to Southern Burj Al Arab, those with a selenium level of 0.429 and 0.339 mg/kg, respectively, and those with a selenium level of 0.365 mg/kg, showed similar results to those due to geographical similarities. Soil selenium levels for some areas show normal to lower soil selenium levels (as determined for area 0.365 mg/kg), while lower levels were found for Abu Al-Matamir with a mean value of 224.7 mg/kg.

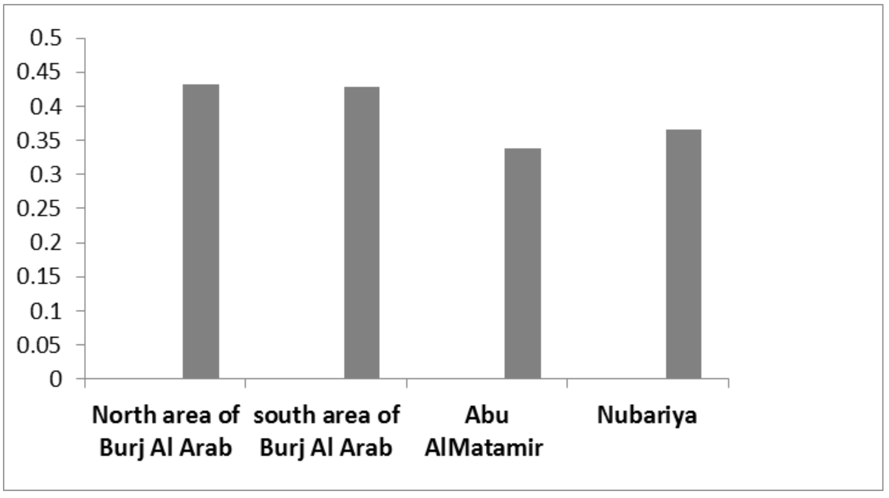

Fig 4. The selenium (Se) contents concentration in soil (mg/kg) with sample sites

The low selenium content of this area compared to other areas may be attributed to different parent materials. The effect of land use on total selenium content is evident in the Abu Al-Matamir area. Whereas the cultivated soil contained only 0.359 mg/kg selenium, the adjacent north and southern areas of Burj Al Arab contained 0.433 and 0.429 mg/kg selenium, respectively. Hartley and Grant (2021) reported that land use may affect selenium content in soil due to showing almost similar results to that for the availability of irrigation water in Burj Al Arab, due to plenty of water flowing in the rivers.

This indicates the movement of selenium minerals from the top soil toward the deeper soil.

Selenium helps to inhibit the damage caused by climate changes such as drought, salinity, heavy metals, and extreme temperatures. Also, Se regulates the antenna complex of photosynthesis, protecting chlorophylls by raising photosynthetic pigments. However, Se concentrations in soils vary widely. Selenium content in clover in 4 selected soil locations in Egypt ranged between 0.45 and 0.89 mg/kg, with an average of 0.72 mg/kg. These values were much lower than those reported by Ravicovitch and Margclin (2023) for alfalfa grown in alluvial calcareous soils (0.339 mg/kg), which had much less total Se (0.1–0.3 ppm) but much higher soluble Se (30% of the total). Also, content in clover grown in the soils of Egypt.

Whoever Selenium content in clover grown in acidic Danish soils (0.044 mg/kg) with similar total and soluble Se content was lower than that in the present study, probably due to differences in soil pH. It is suggested by many investigators that if the selenium concentration in fodder was more than 0.1 mg/kg, selenium-responsive diseases would not occur (Kuttler & Marble, 2020 and Mathias *et al.*, 2022).

Mayland *et al.* (2022) showed that although the minimum requirement for animals was set at 0.1 ppm of selenium, the desirable level in dry feedstuffs is 0.1–0.3 ppm. Taking 0.1 mg/kg selenium in dry feedstuffs as the sufficiency limit, the present study shows that three of the four soil locations produced selenium-deficient clover. 3 out of 4 soil locations produced clover with adequate selenium content. The few locations that produced clover with adequate selenium content are those with high selenium content in north Egypt.

Recommendations: It is including the following points

1- Conduct detailed soil surveys to map the extent of salinity and sodicity problems.

2- Implement appropriate soil reclamation measures if necessary.

3- Select salt-tolerant and sodicity-tolerant crop varieties and improve drainage to reduce salt accumulation.

4- Monitor irrigation water quality and manage irrigation practices to minimize salt buildup.

5- Consider using gypsum or other amendments to improve soil conditions.

Addressing Selenium Contamination

Given the elevated selenium levels in the irrigation water:

Crop Selection: Focus on cultivating crops with higher tolerance to selenium to minimize its uptake.

Monitoring: Regularly monitor soil and plant tissues for selenium accumulation to assess potential risks.

Water Management: Explore alternative water sources or treatment options to reduce selenium concentrations in irrigation water.

By implementing these recommendations, it is possible to improve soil health, enhance crop productivity, and protect the environment from the detrimental effects of salinity, sodicity, and selenium contamination.

CONCLUSION

Our findings indicate that selenium concentrations exceed typical levels in regions experiencing drier conditions with limited irrigation or rainfall. These areas also exhibit a tendency toward alkaline soil conditions, as evidenced by pH measurements. Conversely, the soils of Burj Al Arab, characterized by ample irrigation water, display selenium levels within or below the normal range. It is plausible that the availability of water plays a role in regulating soil selenium content.

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الملخص العربي

تقييم السيلينيوم في النظام الزراعي في شمال غرب الدلتا، مصر

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يعتبر السيلينيوم عنصراً أساسياً لإنقاذ الكائنات الحية. وتعتبر النباتات مصادر حيوية للسيلينيوم العضوي لتجنب مشكلة نقصه لدى الكائنات الحية وجلب الصحة الجيدة. وأظهرت النتائج أن متوسط تركيزات السيلينيوم الكلية في التربة كانت منخفضة قليلاً (٠,٤٣١ و ٠,٣٣٩ و ٠,٣٦٥ جزء في المليون) في مناطق برج العرب وأبو المطامير والنوبارية على التوالي. ولم تظهر النتائج أي ارتباط كبير بخصائص التربة المدروسة. وقد يكون ذلك مرتبطاً بكثافة الزراعة بالقرب من الدلتا والمادة الأم للتربة. إن متوسط تركيز السيلينيوم في البرسيم (٠,٧٢ مجم/كجم) أقل من النطاق المطلوب من ٠,٠٣–٠,١ مجم/كجم للماشية، مما يشير إلى وجود خطر محتمل لنقص السيلينيوم في الماشية التي ترعى على هذه التربة. ويجب تسجيل جودة التربة ومحتوى السيلينيوم في جميع مناطق شمال غرب الدلتا بانتظام لمنع السمية المعدنية أو نقص السيلينيوم فى النباتات المنزرعة.