

# Heavy Metals Distribution in Soils of Some Egyptian Localities

Osama A. Abyan<sup>1</sup>, Rania M. Mahdy<sup>1</sup>, Doaa I. Zaki<sup>1</sup>, Shima A. Amer<sup>1</sup> and Said A. Shetaiad<sup>2</sup>

<sup>1</sup>Nuclear Materials Authority.

<sup>2</sup>Faculty of Science, Al-Azhar University.

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**Abstract:** Fertilizers, indispensable as they may be nevertheless materials that also clearly cause serious environmental contamination, notably in agricultural soils. The dire necessity for increased food production has been more marked than ever before. Thirty soil and fourteen fertilizer samples were collected from three governorates (El Sharqia, El Giza, and El Fayoum), studied mineralogically, and analyzed by X-ray fluorescence technique for heavy and trace elements determination. The fluctuation of heavy metals and trace elements in the studied soils could be related to the use of industrial and organic fertilizers, in addition to anthropogenic effects. All the studied hazard parameters on different types of soils indicate a greater degree of contamination in the El Sharqia region in comparison with EL Fayoum and El Giza for higher nickel and zirconium contents. The ecological risk assessment of fertilizers exhibits that both types of fertilizers pose a moderate ecological risk, with Superphosphate samples showing slightly higher risk due to the presence of V and Zn.

**Keywords:** Fertilizers, contamination, Heavy Metals.

## 1 Introduction

Environmental pollution with heavy metals is a global issue that requires great attention to combat. The rapid population growth in Egypt, especially in the Nile delta, has led to increasing industrial and commercial activity. An unorganized urbanization has been established in some places with no information about the hazards that will affect our natural system resources, such as air, water (surface and ground), and soil, creating environmental and public health problems. Soils may become contaminated by the accumulation of pollutants through emissions from the rapidly expanding industrial areas, mine tailings, industrial effluents, petrochemicals, paints, fertilizers, animal manures, sewage sludge, pesticides, etc [1]. Heavy metals are a general term that describes a group of elements with an atomic density greater than 6 g/cm<sup>3</sup>. Most of these metals are among the essential nutrients needed by plants, animals, and Humans in low concentrations, but they turn into toxic substances when present in quantities exceeding the permissible limits. Heavy metals are one of the most persistent and toxic contaminants that are inserted into the soil either naturally by weathering of the parent rock or anthropogenically by urbanization and deforestation. The mobility of the metal is controlled by pH, Eh, cation

exchange capacity of the solid phase, competition with other metal ions, soil composition, and its concentration in the soil solution. All metals are toxic at higher concentrations, although Fe, Zn, Cu, and Mg are essential metals as they have important roles in the biological system; higher concentration of them makes them toxic. Although heavy metals that have a relatively high density are highly poisonous even at low concentrations. Some heavy metals such as Fe, Co, Ni, Cr, Cd, Pb, Zn, Mn, and Cu are regarded as serious pollutant metals in aquatic ecosystems due to their environmental persistence, toxicity, and ability to incorporate into food chains [2].

Environmental pollution with heavy metals is a global issue that requires great attention to combat. The rapid population growth in Egypt, especially in the Nile Delta, has led to increasing industrial and commercial activity. An organized urbanization has been established in some places with no information about the hazards that will affect our natural system resources, such as air, water (surface and ground), and soil, creating environmental and public health problems. Soils may become contaminated by the accumulation of pollutants through emissions from the rapidly expanding industrial areas, mine tailings, industrial effluents, petrochemicals, paints, fertilizers, animal manures, sewage sludge, pesticides, etc. The environmental

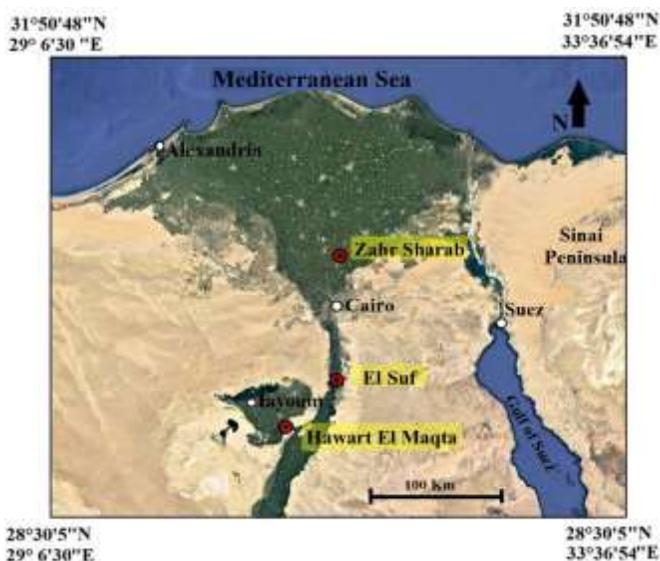
\*Corresponding author e-mail:

stability of heavy metals, coupled with their great use in the study area, led to the accumulation of large levels of heavy metals in the environment. A part of these metals is absorbed by plants (depending on soil type, climatic factors, and plant type) and thus enters the human food chain, and another part is transferred to the groundwater, which may lead to toxic effects on the environment.

This study aims to detect the effect of industrialization and urbanization on the soil content of some potentially toxic heavy metals.

## 2 Materials and Methods

Some soil samples were collected from some localities like ( EL Fayoum, Hawaret El Maktea), (EL Sharqia, Zahr Sharab), and Giza, El Safe. On the other hand, the gypsum and super phosphate fertilizer samples used in fertilization were collected from markets (Figure 1).



**Fig. 1:** Location map of the sites under investigation.

Thirty soil and fourteen fertilizer samples were analyzed by the X-ray fluorescence technique. In order to physically obtain the soil samples, a spiral bar was rotated to a depth of one metre. On fused beads, the X-ray Fluorescence (XRF) Spectrometry method was used to determine the trace elements (Cr, Cu, Ni, Zn, Zr, Sr, Y, Rb, V, Nb, Pb, and Ba) for the chosen soil and fertilizer samples in the labs of Egypt's Nuclear Materials Authority. The trace elements were measured using a Philips PW 1480 X-ray spectrometer X unique II with an automated sample changeover (PW e 1510). The samples were determined for 3 selected samples using XRD spectroscopy and X-ray Fluorescence (XRF) Spectrometry technique on fused beads.

The collected samples were sieved into three fractions: <math><800\mu\text{m}</math>, <math>800\mu\text{m}-63\mu\text{m}</math>, and <math>>63\mu\text{m}</math>. The size fraction ranging between <math>800\mu\text{m}-63\mu\text{m}</math> for each sample was subjected to heavy liquid separation using bromoform solution (sp. gr. 2.81 g/cm<sup>3</sup>) to separate the heavy minerals. The heavy fractions resulting from the bromoform separation were subjected to separate their magnetite content using a hand magnet. The residue fractions were subjected to magnetic fractionation using Frantz Isodynamic Magnetic Separator (Model LB 1) under the following conditions: transverse slope 5, longitudinal slope 20° and step of current = 0.2, 0.5, 1.0, and 1.5 amps. The picked mineral grains were analyzed by the X-ray diffraction (XRD) technique for mineral identification. These analyses were carried out in the laboratories of the Nuclear Materials Authority (NMA), Cairo, Egypt.

The Contamination Factor (CF) was calculated by [3] to assess the level of pollution for each metal relative to its background value [4]. The CF is defined as:

$$CF = \sum_{i=1}^n \frac{C_m}{C_b}$$

Where  $C_m$  is the concentration of the metal in the sample, and  $C_b$  is the background value of the metal. The values of the background shale value were used in this study [5]  $CF < 1$ : Low contamination,  $1 \leq CF < 3$ : Moderate contamination,  $3 \leq CF < 6$ : Considerable contamination,  $CF \geq 6$ : Very high contamination

### 2.2 Degree of Contamination (Cd)

The Degree of Contamination (Cd) was calculated to provide an overall measure of pollution for each sample [6, 7]. This method was also adapted from [3], who introduced Cd as a measure of the overall contamination level in sediments. It is the sum of the contamination factors (CF) for all metals:

$$C_d = \sum_{i=1}^n CF^i = \sum_{i=1}^n \frac{C_m}{C_b}$$

N represents the number of metals, while CF refers to a single contamination factor. Four terminologies for  $C_d$  were:  $C_d < 8$ : Low degree of contamination,  $8 \leq C_d < 16$ : Moderate degree of contamination,  $16 \leq C_d < 32$ : Considerable degree of contamination, and  $C_d \geq 32$ : Very high degree of contamination.

### 2.3 Pollution Load Index (PLI)

The Pollution Load Index (PLI) was calculated to reflect the overall pollution status of the area [4, 6]. The PLI, adapted from [8], is defined as the nth root of the product of the contamination factors (CF) for all metals:

$$PLI = (CF_1^i \cdot CF_2^i \cdot CF_3^i \dots \dots CF_n^i)^{1/n}$$

Where N is the number of measured metals, and CF is the contamination factor.  $PLI < 1$ : No pollution,  $PLI = 1$ : Baseline level of pollution, and  $PLI > 1$ : Pollution exists.

## 2.4 Geoaccumulation Index (Igeo)

$C_n$  is the concentration of the metal in the sample, and  $B_n$  is the background value of the metal. The contamination level classification categories and definition values [9] are as follows:

$I_{geo} \leq 0$ : Unpolluted,  $0 < I_{geo} \leq 1$ : Unpolluted to moderately polluted,  $1 < I_{geo} \leq 2$ : Moderately polluted,  $2 < I_{geo} \leq 3$ : Moderately to heavily polluted,  $3 < I_{geo} \leq 4$ : Heavily polluted,  $4 < I_{geo} \leq 5$ : Heavily to extremely polluted, and  $I_{geo} > 5$ : Extremely polluted.

The Geoaccumulation Index ( $I_{geo}$ ) was calculated to assess the level of metal accumulation in the environment [4]. This method was adapted from [9], who introduced the  $I_{geo}$  as a measure of metal accumulation in sediments.

The  $I_{geo}$  is defined as:

$$I_{geo} = \log_2 \left( \frac{C_n}{1.5B_n} \right)$$

## 2.5 Potential Ecological Risk Index (RI)

The Potential Ecological Risk Index (RI) was calculated by [3] to evaluate the overall ecological risk posed by all heavy metals [10]. The RI is defined as the sum of the potential ecological risk factors ( $Er$ ) for all metals:

$$RI = \sum_{i=1}^n Er^i = \sum_{i=1}^n Tr^i \cdot CF^i = \sum_{i=1}^n Tr^i \cdot C_m / C_b$$

Where CF is the contamination factor and  $Tr^i$  refers to toxic response factors for common metals: Cr = 2, Cu = 5, Ni = 5, Zn = 1, V = 2, Pb = 5. The terminology of RI is:  $RI < 150$ : Low ecological risk,  $150 \leq RI < 300$ : Moderate ecological risk,  $300 \leq RI < 600$ : Considerable ecological risk,  $RI \geq 600$ : Very high ecological risk.

## 2.6 Nemerow Pollution Index (NPI)

The Nemerow Pollution Index (NPI) was calculated according to [11] to provide a comprehensive measure of pollution [10]. The NPI is defined as:

$$NPI = \sqrt{\frac{(CF)_{mean}^2 + (CF)_{max}^2}{2}}$$

Where CF means and CF max are the mean and maximum value of the CF of all the elements studied.  $NPI < 1$ : No pollution,  $1 \leq NPI < 2$ : Low pollution,  $2 \leq NPI < 3$ : Moderate pollution,  $NPI \geq 3$ : High pollution

## 3 Results and Discussion

### 3.1 Distribution of heavy and trace elements in different soil varieties:

The concentration of the heavy metals and trace elements Cr, Cu, Ni, Zn, Zr, Ga, Sr, Y, Rb, V, Nb, Pb, and Ba is presented in Table 1. In general, the distribution patterns of heavy metals in the sediment samples characterized were on the following.

From table 1 and figure 2, it is clear that the high concentration of some heavy in sediment samples were on the following order  $Ba > V > Zr > Sr, Cr, Ni > Rb > Cu > Pb > Ni > Zn > Y > Nb > pb$  due the fluctuation of metals in soil which may be related to the using of the industrial and organic fertilizers. The obtained results show that the levels of these metals in most sites were higher than the values [12, 13].

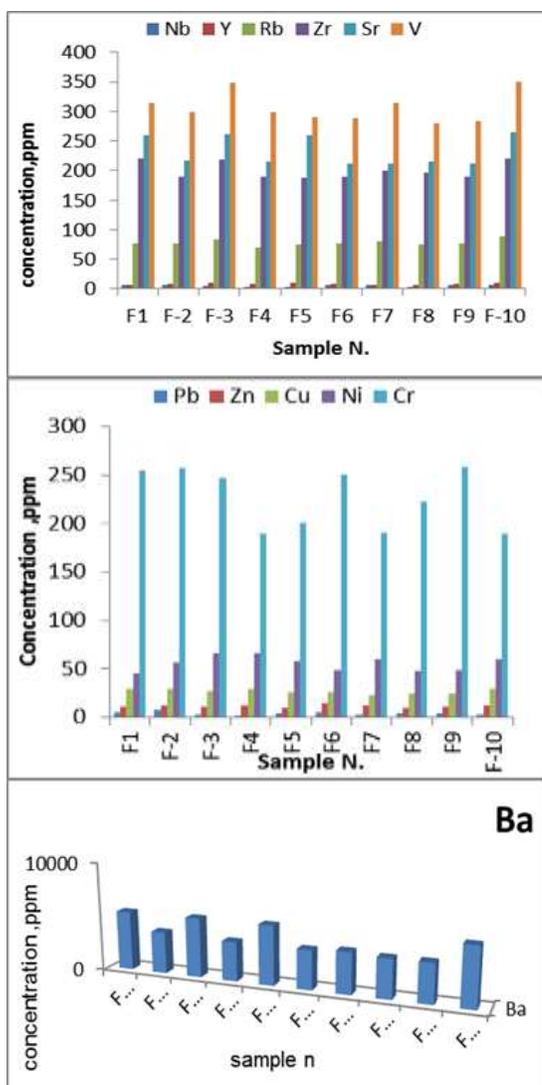
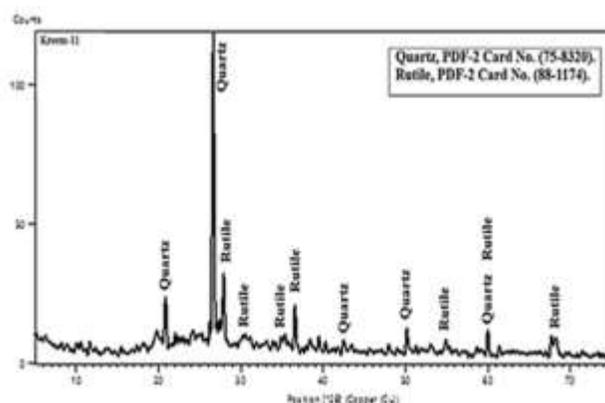
#### 3.1.1 EL Fayoum

The concentration of Cr ranged between 190 and 258 mg/kg with an average concentration of 226 mg/kg (Table 1 and Figure 2), also the V concentration ranged from 288 to 351 mg/kg. In addition, the concentration of Zr ranged between 188 to 222 mg/kg. Also, the high concentration of Sr could be due to the use of gypsum and superphosphate fertilizers. These results were consistent with [14].

The concentrations of heavy metals (Cr, Cu, Ni, Zn, Zr, Y, V, Nb, and Pb) vary significantly across the three locations. In EL Fayoum, the metals can be ordered by their average concentrations as follows:  $V = 300.6$  ppm,  $Cr = 226.7$  ppm  $> > Zr = 197.6$  ppm  $> Ni = 57.1$  ppm,  $Cu = 26.3$  ppm  $> Zn = 11.6$  ppm  $> Y = 8.6$  ppm  $> Nb = 5.3$  ppm  $> Pb = 3.9$  ppm. Cr and V are the most abundant metals in this region, with Cr ranging from 190 to 258 ppm, peaking in samples F-2 and F9. However, Ni and Zr concentrations are relatively low compared to the other regions. Although the relatively low Zr concentration. The XRD pattern of the heavy liquid separated soil samples (Figure 3) clarified the presence of rutile, which could be related to the derivation from old black sand soil.

**Table 1.** Heavy and trace elements of EL Fayoum soil samples.

Sample No.	Cr	Cu	Ni	Zn	Zr	Sr	Y	Rb	V	Nb	Pb	Ba
F1	255	29	45	11	220	260	6	77	315	6	5	5393
F-2	257	29	57	12	189	217	9	77	299	6	8	3797
F-3	247	27	66	11	219	261	10	84	349	5	3	5420
F4	190	29	66	12	190	215	9	70	299	3	2	3590
F5	201	26	58	10	188	260	11	75	290	4	4	5430
F6	250	26	49	14	189	212	8	77	288	7	5	3584
F7	191	23	60	12	199	212	7	80	315	6	3	3787
F8	223	25	48	10	197	215	7	75	280	3	4	3580
F9	258	25	49	11	190	212	8	77	283	6	4	3594
F-10	190	29	60	12	221	265	11	88	351	7	3	5429

**Fig. 2:** Concentration trace and heavy elements in ppm of the studied soil samples (EL Fayoum area).**Fig. 3:** XRD patterns of El Fayoum heavy liquid separated soil samples.

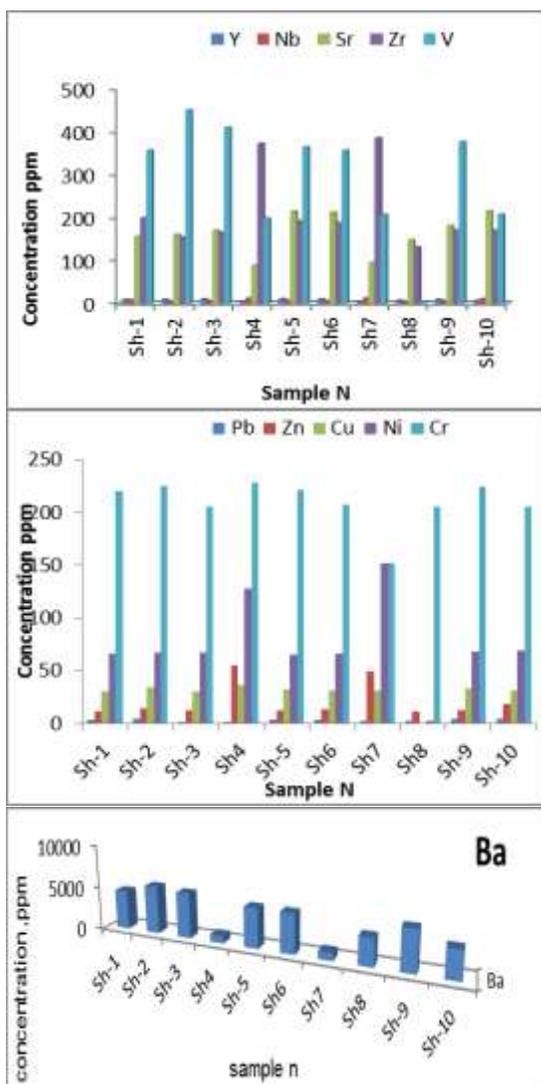
### 3.1.2 EL Sharqia

From Table 2 and Figure 4, the high concentration of some heavy elements such as Cr, Zr, Sr, and V may be due to the fluctuation of metals in soil because of using industrial and organic fertilizers, in addition to anthropogenic effects. The obtained results show that the levels of these metals in most sites and throughout different seasons were higher than the [12, 13].

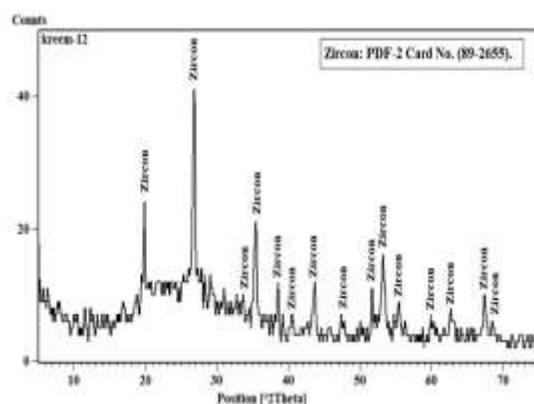
In EL Sharqia, the metals are ordered as: V = 292.1 ppm > Zr = 210.6 ppm > Cr = 202.7 ppm > Ni = 76.2 ppm > Cu = 30.1 ppm > Zn = 20.6 ppm > Y = 8.1 ppm > Nb = 7.1 ppm > Pb = 3.4 ppm. Ni and Zr show particularly high concentrations, especially in samples Sh4 (128 ppm Ni) and Sh7 (152 ppm Ni), with Zr reaching 372 ppm in Sh4 and 385 ppm in Sh7. This region has the highest Ni and Zr concentrations among the three locations. XRD pattern of the separated heavy minerals indicates the presence of zirconium silicate (Figure 5).

**Table 2.** Heavy and trace elements of EL Sharqia soil samples.

Sample No.	Cr	Cu	Ni	Zn	Zr	Sr	Y	Rb	V	Nb	Pb	Ba
Sh-1	220	30	66	12	199	156	9	88	356	8	4	4577
Sh-2	225	34	67	15	154	160	9	80	450	5	5	5567
Sh-3	205	30	67	13	165	170	10	81	410	6	2	5244
Sh4	228	36	128	55	372	88	5	3	198	12	2	863
Sh-5	221	32	65	13	192	214	11	86	364	7	4	4607
Sh6	207	31	66	14	187	212	10	84	356	6	4	4576
Sh7	152	31	152	49	385	94	4	2	207	12	3	901
Sh8	205	u.d	3	12	131	147	7	67	5	4	3	3156
Sh-9	224	33	68	13	170	181	9	79	376	6	5	4677
Sh-10	205	31	69	18	170	215	7	79	207	11	5	3245



**Fig.4:** Concentration of trace and heavy elements in ppm EL Sharqia governorate. of the studied soil samples(El Sharqia area).



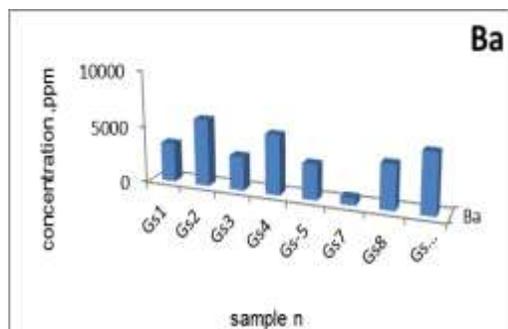
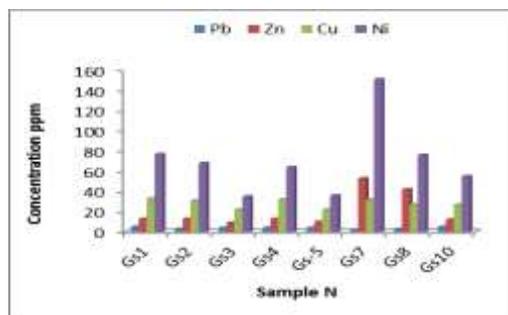
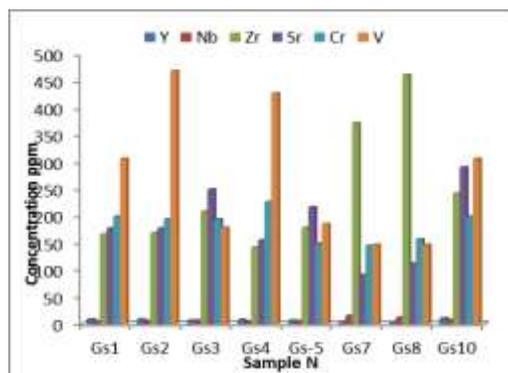
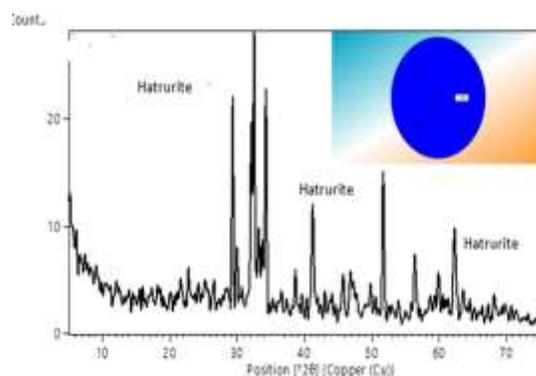
**Fig.5:** XRD patterns of EL Sharqia heavy liquid separated soil samples.

### 3.1.3 Giza

Also in Giza, the trace elements are ordered as: V = 269.9 ppm > Zr = 229.6 ppm > Cr = 183.1 ppm Ni = 71.6 ppm > Cu = 27.5 ppm > Zn = 21.4 ppm > Y = 7.9 ppm > Nb = 7.6 ppm > Pb = 3.6 ppm. Zr is the most prominent metal, reaching 461 ppm in Gs8, followed by Ni, which shows significant variation (35–151 ppm), particularly in Gs7 (151 ppm). Giza has the highest average Zr concentration among the three locations. Overall, Sharqia has the highest average concentrations of Ni and Zr, while Giza has the highest average Zr concentration. EL Fayoum shows lower concentrations of most metals, except for Cr and V, which are relatively high; these data are represented in Table 3 and Figure 6. The XRD pattern of the separated heavy minerals indicates the presence of zirconium silicate (Figure 7).

**Table 3.** Heavy and trace elements of the El Giza soil samples.

Sample No.	Cr	Cu	Ni	Zn	Zr	Sr	Y	Rb	V	Nb	Pb	Ba
Gs1	199	33	77	13	166	177	9	66	306	6	5	3454
Gs2	194	31	68	13	168	177	9	75	468	6	3	5932
Gs3	194	22	35	9	208	249	7	57	178	7	4	3007
Gs4	226	32	64	13	142	155	8	68	427	5	4	5275
Gs-5	149	22	36	10	178	216	7	67	185	6	4	3111
Gs7	145	32	151	53	372	91	4	2	147	15	2	630
Gs8	157	27	76	42	461	112	3	2	147	12	3	3935
Gs10	199	27	55	12	242	290	11	79	306	8	5	5293

**Fig. 6:** Concentration of trace and heavy elements in ppm of the studied soil samples (EL Giza area).**Fig.7.** XRD patterns of EL Giza heavy liquid separated soil samples.

Barium can be a useful indicator of phosphorus in agricultural runoff because a strong positive correlation exists between their concentrations in surface water samples. This suggests that increased barium levels in surface water may be linked to agricultural runoff sources, allowing for the identification of specific sources of phosphorus pollution and the development of targeted mitigation strategies [15].

The concentrations of heavy metals in the studied locations (EL Fayoum, EL Sharqia, and Giza) were compared with data from other regions in Egypt (Table 4) to contextualize the findings (Table 1, 2 and 3) Chromium (Cr) levels in this study (182.875–226.2) were significantly higher than those reported in Bahr El Baqar (106.96), [16], Kafr El-Sheikh (18.89), [17], Menofia (40.01), [18] and Gharbia (133.4) [19], with EL Fayoum showing the highest concentration.

Copper (Cu) concentrations (26.8–28.8) were generally lower than those in Bahr El Baqar (65.7) [16], Qalubia (252.4) [20], and Gharbia (61.3) [19], but higher than in Menofia (11.65) [18] and Kafr El-Sheikh (32.43)[17].

Nickel (Ni) levels (55.8–75.1) were comparable to those in Bahr El Baqar (73.22) [16] and Gharbia (80.6) [19] but exceeded those in Kafr El-Sheikh (27.64) [17] and Menofia (26.03) [18].

In contrast, zinc (Zn) concentrations (11.5–21.4) were notably lower than in other regions, such as Bahr El Baqar (90.56), Qalubia (184), and Gharbia (105.3).

Vanadium (V) levels (270.5–306.9) were higher than those reported in Gharbia (215), with EL Fayoum exhibiting the highest value.

Lead (Pb) concentrations (3.7–4.1) were significantly lower than in other regions, including Bahr El Baqar (36.64), Qalubia (69.58), and Menofia (43.91). These findings suggest that the studied areas may be influenced by unique environmental or anthropogenic factors, resulting in elevated levels of Cr, Ni, and V, but reduced levels of Zn and Pb compared to other regions in Egypt [21-26].

### 3.2 Hazards of the studied heavy and trace elements:

The environmental impacts of different elements should be determined by many hazard parameters such as Contamination Factor (CF), Degree of Contamination (Cd), Pollution Load Index (PLI), Geo accumulation Index (Igeo), Potential Ecological Risk Index (RI), and Nemerow Pollution Index (NPI).

#### 3.2.1 Contamination Factor (CF)

The contamination factor (CF) indicates the level of pollution for each metal relative to its background value (Figure 8). In EL Fayoum, the metals can be ordered by their average CF values as follows:  $Cr = 2.47 > V = 2.34 > Ni = 0.83 > Zr = 1.23 > Cu = 0.60 > Y = 0.32 > Nb = 0.50 > Zn = 0.12 > Pb = 0.19$ . Chromium has the highest CF values (2.11–2.87), indicating moderate contamination, while other metals like Cu, Ni, and Zn show low CF values (0.51–0.97). In EL Sharqia, the metals are ordered as:  $Ni = 1.12 > Zr = 1.37 > Cr = 2.24 > V = 2.22 > Cu = 0.66 > Nb = 0.68 > Zn = 0.22 > Y = 0.30 > Pb = 0.20$ . Chromium CF values are similar (1.69–2.53), but Nickel shows higher CF values in Sh4 (1.88) and Sh7 (2.24), indicating significant contamination. Zirconium also has elevated CF values in EL Sharqia, particularly in Sh4 (2.33) and Sh7 (2.41). In Giza, the metals are ordered as:  $Zr = 1.56 > Ni = 1.03 > Cr = 2.09 > V = 2.18 > Cu = 0.63 > Nb = 0.65 > Zn = 0.21 > Y = 0.28 > Pb = 0.19$ . Chromium CF values range from

1.61 to 2.51, with Nickel showing higher CF values in Gs7 (2.22) and Gs8 (1.12). Overall, EL Sharqia exhibits higher CF values for Nickel and Zirconium compared to EL Fayoum and Giza, suggesting a greater degree of contamination in this region. Giza also shows elevated CF values for Zr, while EL Fayoum has moderate CF values for Cr and V.

#### 3.2.2 Degree of Contamination (Cd)

The degree of contamination (Cd) provides an overall measure of pollution for each sample. In EL Fayoum, Cd values range from 7.97 to 9.47, indicating moderate contamination (Figure 8). The highest Cd values are observed in samples F3 (9.47) and F-10 (9.05), primarily due to elevated Cr and V levels. This region shows moderate contamination. In EL Sharqia, the average Cd value is 9.04, with a range of 4.09 to 11.03. The highest Cd values are observed in Sh4 (11.03) and Sh7 (10.52), where Ni and Zr concentrations are significantly elevated. This region has the highest Cd values, indicating the highest overall contamination. In Giza, the average Cd value is 8.71, with a range of 6.33 to 10.17. The highest Cd values are observed in Gs7 (10.17) and Gs4 (9.43), where Zr and Ni concentrations are high. Giza shows moderate contamination, with Cd values slightly lower than EL Sharqia. In general, EL Sharqia has the highest average Cd value, indicating the highest overall contamination. Giza and EL Fayoum have similar average Cd values, but Giza shows higher variability due to elevated Zr levels in some samples.

#### 3.2.3 Pollution Load Index (PLI)

The pollution load index (PLI) reflects the overall pollution status of the area. In EL Fayoum, PLI values are relatively low (0.0002–0.0044), indicating minimal pollution (Figure 8). In EL Sharqia, PLI values are higher (0.0004–0.0182), with Sh4 and Sh7 showing the highest values (0.0182 and 0.0144, respectively). This suggests a higher pollution load in EL Sharqia compared to EL Fayoum. In Giza, PLI values range from 0.0002 to 0.0087, with Gs7 showing the highest value (0.0087). While Giza has lower PLI values compared to EL Sharqia, it still exhibits a moderate pollution load, particularly in samples with elevated Nickel and Zirconium concentrations.

**Table 4.** Average metal concentrations (mg/kg) estimated in the present study in comparison with other agricultural soils.

Location	Cr	Cu	Ni	Zn	Zr	Y	V	Nb	Pb	References
Bahr El Baqar region	107.0	65.7	73.2	90.6	-	-	-	-	36.6	[16]
Qalubia (Abu Zaabal city)	-	252.4		184.0	-	-	-	-	69.6	[20]
Kafr El-Sheikh (Qallin)	18.9	32.4	27.6	49.0	-	-	-	-	21.2	[17]
Menofia (Quweisna)	40.0	11.7	26.0	50.9	-	-	-	-	43.9	[18]
Gharbia (Kafr El-Zayat)	133.4	61.3	80.6	105.3	-	-	215.0	-	19.1	[11]
EL Fayoum	226.2	26.8	55.8	11.5	200.2	8.6	306.9	5.3	4.1	this study
EL Sharqia	209.2	28.8	75.1	21.4	212.5	8.1	292.9	7.7	3.7	this study
Giza	182.9	28.3	70.3	20.6	242.1	7.3	270.5	8.1	3.8	this study

### 3.2.4 Geo accumulation Index (Igeo)

The geo accumulation index (Igeo) assesses the level of metal accumulation in the environment. In EL Fayoum, most Igeo values are negative (Figure 8), indicating that the area is generally unpolluted. However, Chromium shows slightly positive Igeo values in some samples, suggesting minor contamination. In EL Sharqia, Igeo values for Nickel and Zirconium are positive in Sh4 and Sh7, indicating moderate pollution. For example, Nickel in Sh4 has an Igeo value of 0.33, while Zirconium in Sh7 has an Igeo value of 0.68. In Giza, Igeo values are mostly negative, except for Nickel and Zirconium in Gs7, which show positive values (0.57 and 0.63, respectively). Overall, EL Sharqia exhibits higher levels of metal accumulation compared to EL Fayoum and Giza.

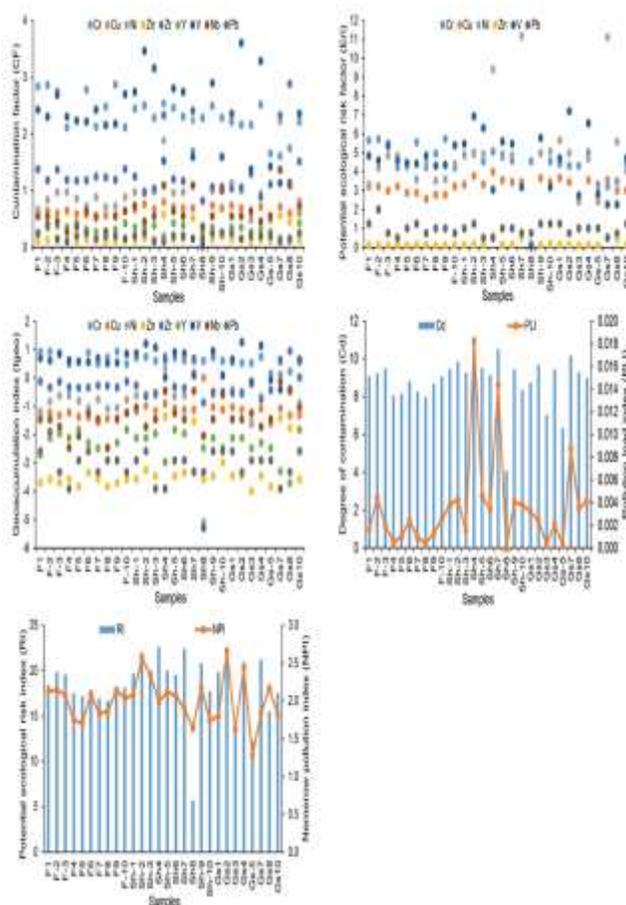
### 3.2.5 Potential Ecological Risk Index (RI)

The potential ecological risk index (RI) evaluates the ecological risk posed by heavy metals (Figure 8). In EL Fayoum, RI values range from 16.67 to 19.85, indicating low to moderate ecological risk. In EL Sharqia, RI values are significantly higher, ranging from 5.73 to 22.60, with Sh4 and Sh7 showing the highest values (22.60 and 22.45, respectively). This suggests a higher ecological risk in EL Sharqia compared to EL Fayoum. In Giza, RI values range from 12.35 to 21.20, with Gs7 showing the highest value (21.20). While Giza has lower RI values compared to EL Sharqia, it still exhibits moderate ecological risk, particularly in samples with elevated Nickel and Zirconium levels.

### 3.2.6 Nemerow Pollution Index (NPI):

The Nemerow pollution index (NPI) provides a comprehensive measure of pollution (Figure 8). In EL Fayoum, NPI values range from 1.70 to 2.15, indicating low to moderate pollution. In EL Sharqia, NPI values are higher, ranging from 1.64 to 2.57, with Sh2 and Sh4 showing the highest values (2.57 and 1.99, respectively). This suggests a higher level of pollution in EL Sharqia compared to EL Fayoum. In Giza, NPI values range from

1.27 to 2.66, with Gs2 and Gs4 showing the highest values (2.66 and 2.44, respectively). While Giza has lower NPI values compared to EL Sharqia, it still exhibits moderate pollution, particularly in samples with elevated Nickel and Zirconium concentrations.



**Fig.8:** Calculated ecological indices: contamination factor (CF), geo accumulation index (Igeo), potential ecological risk factor (Eri), potential ecological risk index (RI), degree of contamination (Cd), pollution load index (PLI), and Nemerow pollution index (NPI) of samples.

### 3.3 Fertilizer

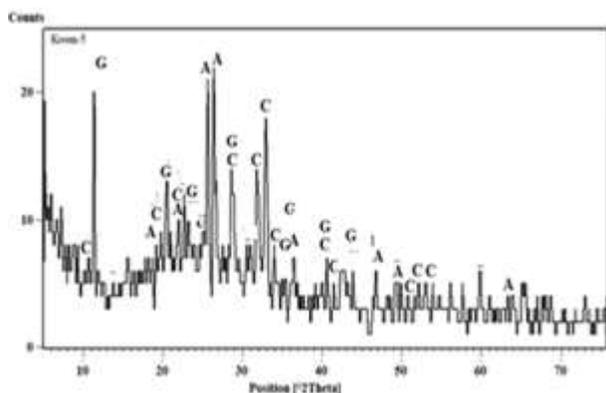
Distribution of heavy and trace elements in different fertilizers:

#### 3.3.1 CASO<sub>4</sub>.2H<sub>2</sub>O

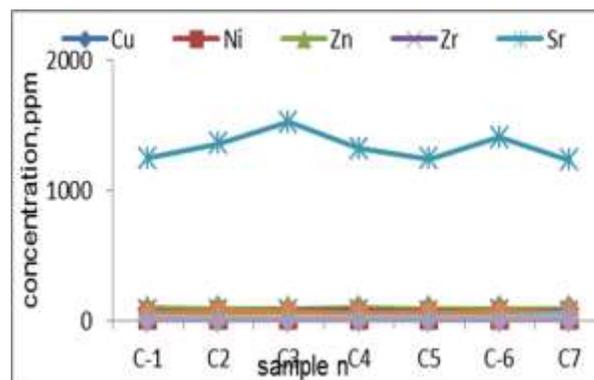
**Table 5.** Trace and heavy elements of Gypsum Fertilizer.

Sample No.	Cu	Ni	Zn	Zr	Sr	Y	V	Nb	Pb	Ba
C-1	88	17	99	68	1249	53	26	4	14	u.d
C2	90	16	93	73	1362	64	23	4	15	u.d
C3	84	16	92	77	1528	67	23	4	20	u.d
C4	93	21	99	77	1323	61	25	4	15	2
C5	91	22	93	67	1244	60	23	4	11	2
C-6	91	15	94	73	1407	64	23	4	15	u.d
C7	91	22	94	67	1231	60	61	4	11	2

Cr, Ga, and Rb were nd.



**Fig.9:** XRD pattern of Gypsum Fertilizer.



**Fig.10:** Concentration ppm of some heavy metals and radioactive elements in Gypsum Fertilizer (CASO<sub>4</sub>.2H<sub>2</sub>O).

#### 3.3.2 Ca (H<sub>2</sub>PO<sub>4</sub>).

**Table 6.** Trace and heavy elements of Super Phosphate Fertilizer

Sample No.	Cr	Cu	Ni	Zn	Zr	Ga	Sr	Y	Rb	V	Nb	Pb	Ba
S1	16	18	18	21	105	u.d	33	4	u.d	5	3	u.d	22
S2	98	28	6	112	26	u.d	1188	100	31	400	u.d	5	3108
S3	92	27	5	111	23	u.d	1123	102	40	435	u.d	6	3000
S4	49	16	49	55	128	u.d	40	9	u.d	5	3	6	17
S5	95	29	5	114	25	u.d	1153	103	45	439	u.d	6	3130
S6	54	18	50	57	131	35	48	10	u.d	6	3	6	23
S7	101	30	6	117	27	u.d	1194	110	36	440	u.d	6	3118

### 3.4 Heavy Metal Concentrations.

The concentrations of heavy metals vary significantly between the two types of fertilizers and across individual samples. In Gypsum Fertilizer, Cu concentrations are relatively high, ranging from 84 to 93 ppm, with the highest concentration observed in sample C4 (93 ppm). Ni concentrations are lower, ranging from 15 to 22 ppm, while Zn concentrations are consistently elevated, ranging from 92 to 99 ppm. Zr concentrations range from 67 to 77 ppm, and Pb concentrations are relatively low, ranging from 11 to 20 ppm.

In Superphosphate samples, the heavy metal concentrations show greater variability. Cr concentrations range from 16 to 101 ppm, with the highest concentration in sample S7 (101 ppm). Zn concentrations are also high, ranging from 21 to 117 ppm, with the maximum in sample S7. Notably, V concentrations are extremely high in Superphosphate samples, reaching up to 440 ppm in sample S7, which is significantly higher than in Gypsum Fertilizer samples (where V concentrations range from 23 to 61 ppm). Pb concentrations in Superphosphate samples range from non-detectable (ND) to 6 ppm, which is lower than in Gypsum Fertilizer samples.

### 3.5 Hazards of the used fertilizers.

The contamination factor is a measure of the level of contamination for each metal relative to a baseline. For Gypsum Fertilizer, the CF values for Cu range from 1.87 to 2.07 (Figure 13), indicating moderate contamination. The CF values for Zn are also moderate, ranging from 0.97 to 1.04. The degree of contamination, which aggregates the CF values for all metals, ranges from 6.97 to 7.67 for Gypsum Fertilizer, suggesting a moderate to high level of overall contamination. In Superphosphate samples, the CF values for Cr range from 0.18 to 1.12 (Figure 13), with the highest CF observed for Zn at 1.23 in sample S7.

The degree of contamination for Superphosphate samples ranges from 2.18 to 11.19, with the highest Cd value in sample S7, indicating a higher overall contamination level compared to Gypsum Fertilizer. This is largely driven by the high concentrations of V and Zn in Superphosphate samples.

The geoaccumulation index ( $I_{geo}$ ) is used to assess the extent of metal accumulation in the samples. For Gypsum Fertilizer, the  $I_{geo}$  values for Cu range from -2.77 to -2.21 (Figure 13), indicating minimal to moderate accumulation. The  $I_{geo}$  values for Zn range from -1.84 to -1.64, suggesting slight accumulation. In Superphosphate samples, the  $I_{geo}$  values for Cr range from -3.08 to -0.42, with the highest accumulation observed for Zn in sample S7 ( $I_{geo} = -0.28$ ). These values suggest that while some metals are accumulating, the overall accumulation is not at alarming levels.

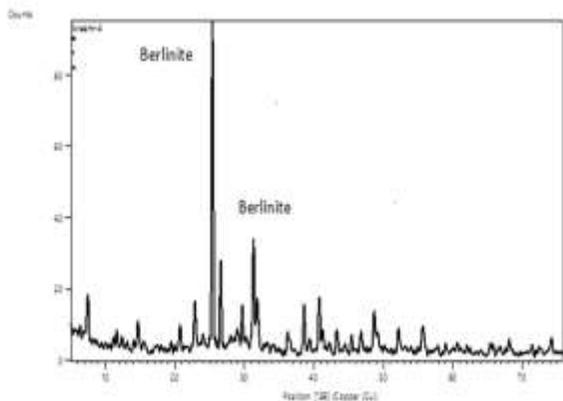


Fig.11: XRD pattern of Super Phosphate Fertilizer.

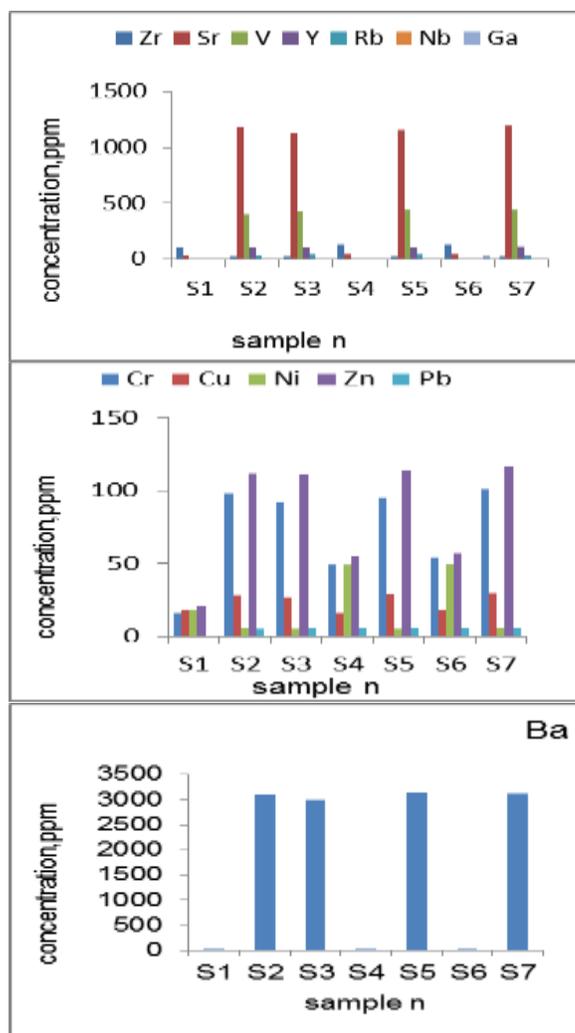


Fig. 12: Concentration ppm of some heavy metals and radioactive elements in Super Phosphate Fertilizer.

The pollution load index provides an overall measure of pollution by considering the combined effect of multiple metals. For Gypsum Fertilizer, the PLI values are relatively low, ranging from 0.0028 to 0.0073 (Figure 13), indicating minimal pollution. In contrast, Superphosphate samples have slightly higher PLI values, ranging from 5.51e-07 to 0.0074, with the highest PLI in sample S7. Despite the higher

concentrations of V and Zn in this sample.

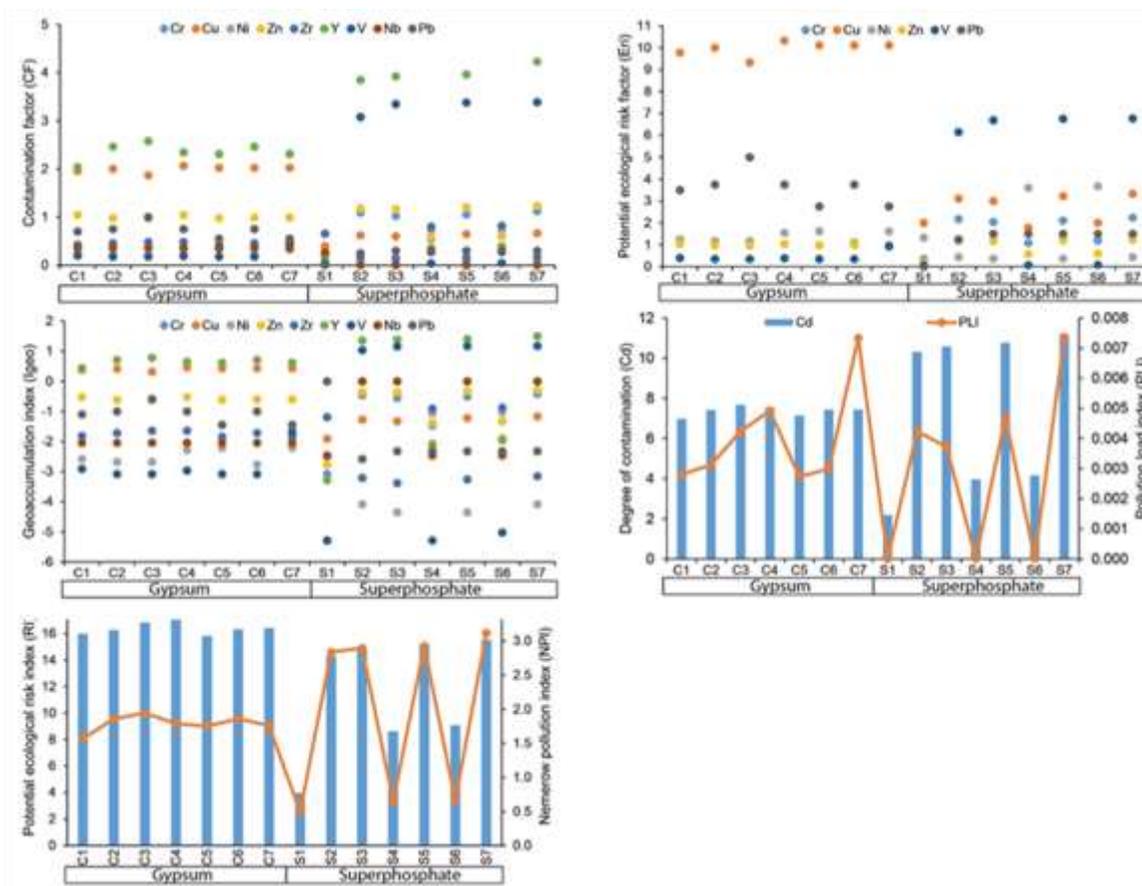
### 3.6 Ecological Risk Assessment.

The potential ecological risk factors (Eri) for individual metals and the overall potential ecological risk index (RI) were calculated to assess the environmental impact of heavy metal contamination. For Gypsum Fertilizer, the RI values range from 15.81 to 17.05 (Fig. 13), indicating a moderate ecological risk. The highest RI value is observed in sample C4 (17.05), driven by elevated concentrations of Cu and Zn.

PLI values in Superphosphate, the overall pollution levels remain relatively low.

In Superphosphate samples, the RI values are more variable, ranging from 3.98 to 15.52, with the highest risk observed in sample S7 (15.52). This is primarily due to the high concentrations of V and Zn in this sample.

The Nemerow Pollution Index (NPI), which provides a comprehensive measure of pollution, ranges from 1.57 to 1.94 for Gypsum Fertilizer and from 0.49 to 3.12 for Superphosphate. The highest NPI value is observed in sample S7 (3.12), indicating a higher level of pollution compared to other samples. This is consistent with the high



**Fig.13:** Calculated ecological indices: contamination factor (CF), geoaccumulation index (Igeo), potential ecological risk factor (Eri), potential ecological risk index (RI), degree of contamination (Cd), pollution load index (PLI), and Nemerow pollution index (NPI) of Fertilizers.

## Implications and Conclusions

The fluctuation of heavy metals and trace elements in the studied soils could be related to the use of the industrial and organic fertilizers, in addition to anthropogenic effects. All the studied hazard parameters on different types of soils indicate a greater degree of contamination in the El Sharqia region in comparison with EL Fayoum and El Giza. The data reveal significant differences in heavy metal concentrations and contamination levels between Gypsum Fertilizer and Superphosphate. While Gypsum Fertilizer shows moderate contamination with elevated levels of Cu and Zn, Superphosphate samples exhibit higher variability, with extremely high concentrations of V and Zn in some samples. The ecological risk assessment indicates that both types of fertilizers pose a moderate ecological risk, with Superphosphate samples showing slightly higher risk due to the presence of V. The geoaccumulation index (Igeo) suggests that while some metals are accumulating, the overall accumulation is not at alarming levels. However, the high concentrations of certain metals, particularly in Superphosphate, warrant further investigation and monitoring to mitigate potential environmental and health risks.

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