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Effects of Industrialization Processes in Giza Factories (Egypt) on Soil and Water Quality in Adjacent Territories

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Abstract

Industrialization processes in Giza governorate (Egypt) brings various organic and inorganic contaminants to surface and ground waters therein. Arable lands located nearby these industrial activities use such waters for irrigation; nevertheless, the contaminants that may exist in irrigation waters adversely affect soil quality and crop yields. Accordingly, periodic monitoring of water quality in this area has become an obligation to ensure its safe use for irrigation. Eighteen irrigation (canals and drain) water samples were collected from different industrial locations nearby the arable lands across Giza governorate in 2019 for quality evaluation. A control (well water) sample was also collected from this governorate so far away from the industrial zone for data comparison. Generally, the studied locations are located within the arid region and maybe the ground waters there are hydraulically connected. The salinity of the collected waters ranged from medium to high according to the classification of FAO. No sodicity, B or Mg hazards were detected in all water samples. On the other hand, the studied water samples were all classified as very hard water since their values of total hardness (TH) ranged from 154.5-293.5 mg L^{-1}. Concentrations of Co and Pb in all water samples were below the permissible levels while Cd toxicity was detected in almostall water samples. Ni-hazard was identified in only one location. Besides, soils were sampled from the locations nearby the water resources. The principal component analyses indicate that the abovementioned potentially toxic elements (PTEs) in soil originated from almost one distinct source (weathering of rocks along the river path and not from different industrial origins). Their concentrations were below the permissible levels in all soil locations, in spite of that, almost all soils exhibited low pollution levels with PTEs according to the calculations of pollution load index. Concerning the correlations between the total PTEs contents in soil versus soil characteristics, Cd and Co contents were correlated significantly and positively with the CaCO$_3$ content in soils while Pb was significantly correlated with soil organic matter, and Ni with soil pH. In conclusion, the discharges of the factories in the industrial zone of Giza should be monitored periodically to avoid further negative environmental consequences on the surroundings. Also, there is an intensive need to remediate contaminated wastewater prior to their discharges to the surrounding environment.

Keywords: Potentially Toxic elements; Irrigation water quality; Soil pollution; water hardness; The industrial zone

1. Introduction

Pollution is one of the major threats that negatively affect not only man health (Azizullah et al., 2011) but also the surrounding ecology (Alvarenga, 2022; Kumar et al., 2022; Wang et al., 2022). Generally, soils and water resources receive many contaminants via unmanaged anthropogenic activities (Ozmen et al., 2006; Elewa, 2010; Tabrez et al., 2022). In this

context, potentially toxic elements are of special concern, because these contaminants do not undergo degradation in soil, subsequently signify long term potential environmental risks (Abdelhafez et al., 2014; Abbas and Bassouny, 2018; Mohamed et al., 2018; ElShazly et al., 2019 a and b; Bassouny et al., 2020;El-Shwarby et al., 2022).

Industrial activities bring various organic and inorganic contaminants (Wei et al., 2022) that

deteriorate surface and ground waters (Yuce et al., 2006) andalso may lead to soil degradation (Abd-El-Hady and Abdelaty, 2022). These contaminants accumulate on soil surfaces through successive irrigations (Abdelrazek, 2019; Hegazy et al., 2019; Alnaimy et al., 2021;Abuzaid and Jahin, 2022); get absorbed by plants and concentrated within their edible parts (Hashim et al., 2017; Farid et al., 2020; El-Ramady et al., 2021;Hegab et al., 2021;Sarhan et al., 2021); hence adversely affect crops yieldquantity and quality (Ali et al., 2016; Ibrahim et al., 2016; Abosena et al., 2021; Gavrilescu, 2022). This probably points towards serious public health threats (Elehinafe et al., 2022). Moreover, wastewatersmay have indirect impacts on the nearby arable lands irrigated with fresh water via the hydraulic continuity (Farid et al., 2020). Accordingly, precise monitoring of water quality in the areas adjacentto the industrial activities is essential to ensure its safe use for irrigation.

In the highly populated area of Giza governorate (Egypt) (Youssef et al., 2020), there exists a combination of agricultural, industrial and urbanization activities (Abu El Ella et al., 2017). Groundwater therein is highly polluted with potentially toxic elements (Abu El Ella et al., 2017). Also, irrigationcanalssuch as the one that irrigates Kerdasa agricultural areas is contaminated with PTEs (Metwally et al., 2016). Additionally, these canals contain organic (pesticide) residues (El-Kabbany et al., 2000). For that reason, arable lands in Giza may exhibit high levels of contamination with PTEs e.g. Pb (low to medium risk), Cr (medium to high risk), As (high to very high risk) and Cd (very high risk)(Salman et al., 2018). Contaminants are bounded mainly to the fine soil fractions (Wahba, 2006),and organic components (Sayad et al., 2021). A point to note is that farmers in this area may use the drain water for irrigating their vegetable crops such as cabbage and eggplant and such awater is severely contaminated with PTEs (Farrag et al., 2016; Taha et al., 2019). Furthermore, vegetables,grown thereon,may also contain protozoa (Gad et al., 2020).

The current study aims at assessing the suitability of water for irrigation of the arable lands adjacent to the industrial area in Giza governorate, Egypt andevaluating their consequent impacts on soil quality. To attain this aim, nineteen water samples were collected from different locations, irrigated with water either irrigationcanals, drains or wells. Also,

soils were sampled from the arable lands within the same locations nearby the water resources. We anticipate that the quality of these waters, in terms of salinity (EC), total hardness (TH) as well as the hazards of sodicity (SAR), Mg (Mg-ratio) and residual sodium carbonate (RSC), were within the acceptable rangebecause of their association with the fresh Nile water(Hypothesis 1), yet they may exhibithigh levels of potentially toxic elements, namely cadmium (Cd), cobalt (Co), lead (Pb) and nickel (Ni) (Hypothesis 2) and these contaminants have different origins (via hydraulic continuity with the ground water of the different industrial zones, hypothesis 3). Accordingly, irrigating the nearby arable landswith such waters raises the total content of PTEs in soils to reach unacceptable levels and display ecological risks (Hypothesis 4).

2. **Materials and Methods**

Soil and water sampling

Water samples were collected from 18 different industrial locations in Giza governorate i.e. "3" from Mariouteya Canal (S_1, S_4 and S_{15}), "one" from railway Canal, "2" from Mansourieh Canal(S_2 and S_5), "2" from the Tamwa Canal(S_{13} and S_{17}), "6" from Al-Jizawiya Canal (S_3, S_6, S_9, S_{11}, S_{12} and S_{14}), "one" from Saqarya Canal (S_{16}), "one" from a Canal of Tamur(S_7),"one" from the Ocean drain(S_{18}) and "one" from Hawamdiya Canal (S_8). Generally, waters of these areas were severely affected by chemical and agrochemical industries (Abu El Ella et al.,, 2017). They may also receive the deposits of brick factories (Salman et al., 2018), sewage water, building debris and garbage (Youssef, 2022).

A submersible well water sample was also collected at the Bahariya Oasis (S_{19}) as a reference one away from the industrial activities of this government. The sampling sites are displayed in Fig. 1. These samples were placed in 500 mL high-density polyethylene (HDPE) bottles, then immediately sealed and transferred to the lab. Collected water samples were acidified with HCl, prior to determination of PTEs according to Abdelhafez et al. (2021), to prevent the precipitation of metal ions. Afterwards, these samples were analysed for their chemical characteristics within less than a week as outlined by Nollet and De Gelder (2014) and the results are presented in Table 1.
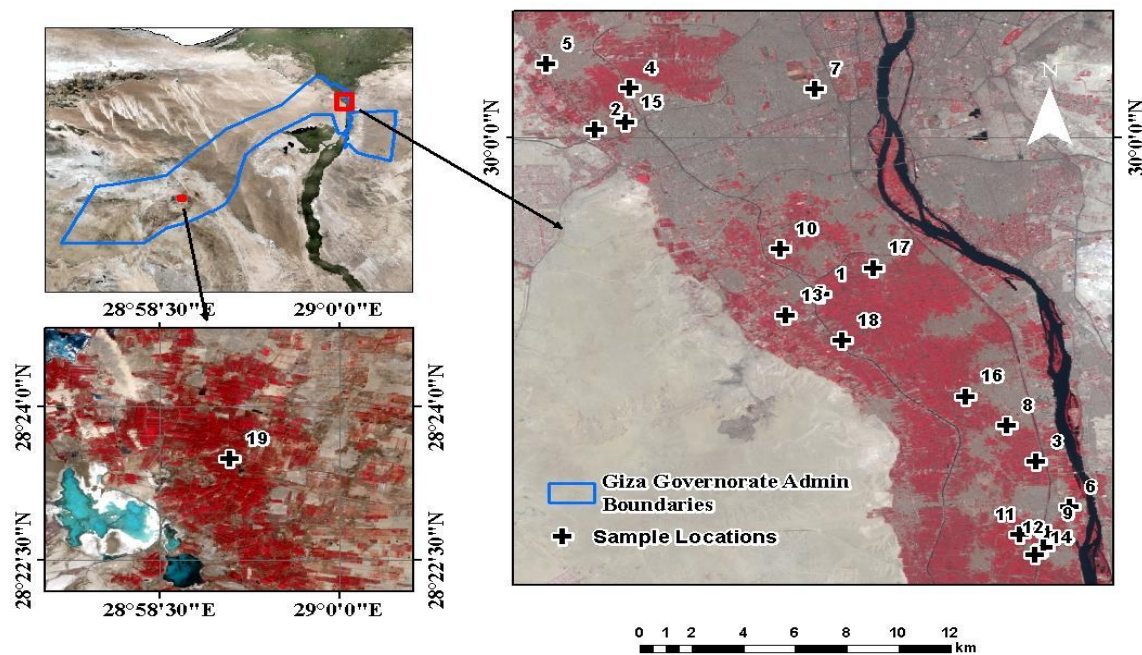
Fig 1. Map displaying the studied area and the sampling locations

Soil and water analyses

Soil samples were also collected from the surface layer (0-30 cm) of the nearby arable lands that were irrigated with these waters and transferred immediately to the lab.These samples were air dried, crushed and sieved to pass through a 2-mm sieve then analysed for their physical and chemical characteristics as outlined by Klute (1986) and Sparks et al. (1996), respectively as shown hereafter:

Soil analyses

Soil texturewas determined by the international pipette method using sodium hexa meta-phosphate as a dispersing agent, bulk density by the soil core method, calcium carbonates by calcimeter, soil organic matter by the modified Walkely and Black method , soil pH by a pH meter (HANNA Model HI-9321) in 1:2.5 (soil: water) suspension, Electric conductivity (EC) by EC meter in saturated soil paste extract, calcium and magnesium by titration against versenate, carbonates and bicarbonates by titration against HCl and chloride by the Mohr's method. Portions of soil subsamples (equivalent to 0.5 grams, on dry weight basis) were digested usinga tri-acid mixture (HNO$_3$:H$_2$SO$_4$:HClO$_4$, 10:4:1) according to Sahrawat et al. (2002). Totalcontents of PTEs in soil and the soluble contents in the sampled waterswere determined by Inductively Coupled

Plasma Optical Emission (ICP-OES - Perkin Elmer Optima 5300, USA).

Quality control measures

All chemicals were of analytical grade. Prior to the quantitative measurements, glassware was rinsed, overnight, in diluted nitric acid (10%), and then washed several times with deionized water. All analyses were conducted in triplicates and three blanks were included to ensure the accuracy of the obtained measures.

Irrigation water quality indexes and data processing

This study used four basic parameters to evaluate the quality of irrigation water, including salinity hazards (EC), sodium adsorption ratio (SAR), residual sodium carbonates (RSC), and metal ions that, if present in high amounts, may cause ionic imbalance in plants or toxicity (USSL Staff, 1954; Zaman *et al.*, 2018). The calculations of SAR and RSC were computed according to Ayers and Westcot (1994) as follows:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \qquad \text{Eq 1}$$

$$RSC = (CO_3^{2-}+HCO_3^-)-(Ca^{2+}+Mg^{2+}) \qquad \text{Eq 2}$$

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The above calculations were considered while taking into account concentrations of cations and anions in mmol$_c$ L^{-1}. Calculations of total hardness (TH), expressed as mg L^{-1}, was also included as outlined byTwort et al. (1994)

$$\text{Total hardness (TH)} = (\text{Ca}^{+2} + \text{Mg}^{+2}\ ) \times 50 \quad \text{Eq 3.}$$

Where concentrations of Ca^{2+} and Mg^{2+} are expressed in mmol$_c$L^{-1} and 50 is the equivalent weight of calcium carbonate. According to USEPA (1986), there are different classes of water hardness i.e. soft (0–60 mg L^{-1}), moderately hard (60–120 mg L^{-1}), hard (120–180 mg L^{-1}) and very hard (> 180 mg L^{-1}).

Water pollution with PTEs was assessed based on the calculations of Yan et al. (2022) as follows:

Pollution index (PI) =
(concentration of each individual parameter)/ (Permissible level of this parameter)   Eq 4

$$\text{Comprehensive pollution index (CPI)} = \frac{1}{n}\sum \text{PI}$$
$$\text{Eq 5}$$

Where n: parameters number. The water quality is classified into clean: (values 0–0.2), sub clean: (values 0.21–0.4), slightly polluted: (values 0.41–1.0), moderately polluted: (values 1.01–2.0), and severally polluted: (values >2.0) (Shakir *et al.*, 2017).

Soil pollution with PTEs was evaluated according to Abdelhafez et al. (2015) as follows:

$$\text{Contamination factor (CF)} = \frac{\text{concentration of each individual parameter}}{\text{Background level in soil}}$$
$$\text{Eq. 6}$$

Pollution load index (PLI)$\sqrt{CF_1 \times CF_2 \times CF_3 \times CF_4 \ldots}$ Eq 7

The background levels of PTEs in soil were adopted from Kabata-Pendias and Pendias (2001) because there is no reference background levels in Egypt. The level of soil pollution was then evaluated according to Kumar et al. (2013) as follows: low (CF<1), moderate (1≤CF≤3), high (3≤CF≤6) and severe (CF>6)

Furthermore, a principal component analysis (PCA), with varimax normalized rotation, was applied via SPSS 18 statistical software to categorize the sources and origins of investigated metal ions to verify the third hypothesis. In addition to that, Pearson correlations were conducted with the same statistical software to validate the fourth and fifth hypotheses. Graphical representations were plotted via the SigmaPlot 10 software.

2. RESULTS AND DISCUSSION

The chemical characteristics of the investigated water samples

The pH values of the studied water samples did not exceed the permissible levels of FAO (Ayers and Westcot, 1994) and ranged from 6.5 to 8.5. Most waters were slightly acidic (pH ranged from 6.35-7.05) (Table 1). Water salinityor electrical conductivity (EC) values indicate medium salinity hazards (Class II) according to FAO (Ayers and Westcot, 1994) in most of sampling sites,except for waters collected from the sites S$_7$, S$_{11}$, S$_{13}$, S$_{14}$, S$_{16}$, S$_{18}$ and S$_{19}$ which exhibited high salinity hazards (Class III)according to FAO. Generally, the EC values of both the well and the drain water were higher than the corresponding ones of the canal water.

No associated Na, B or Mg hazards were detected in all water samples as all values were below the permissible levels of FAO (Ayer and Westcot, 1994) i.e. SAR<13, 0.7 mg B L^{-1}and Mg-ratio<50%, respectively. Likewise, no hazards were associated with residual sodium carbonate (all RSC values were negative ones). On the other hand, the studied water samples were all classified as very hard waters (TH ranged from 154.5-293.5 mg L^{-1}) according to USEPA (1986) and this may lead to scale deposits in the piping system; hence become unsuitable for sprinkle and dripping irrigation systems (Vander 2003). Based on the above results, we could not accept the first hypothesis.

Potentially toxic elements (PTEs) in the investigated water samples

Concentrations of Co and Pb in all water samples did not exceed the permissible levels recommended by FAO i.e. 0.05 mg Co L^{-1}and 5 mg Pb L^{-1}(Ayers and Westcot, 1994) (Fig 2). On the other hand, Cd toxicity (MPL= 0.01 mg L^{-1}) was detected in nearly all water samples, while Ni hazard (MPL= 0.2 mg L^{-1}) was identified in only the drain water sample (S$_{18}$). A point to note is that the level of Ni in the well water sample of S$_{19}$was equivalent to its permissible level and this result might indicate long-term adverse health effects when using this water for irrigation.
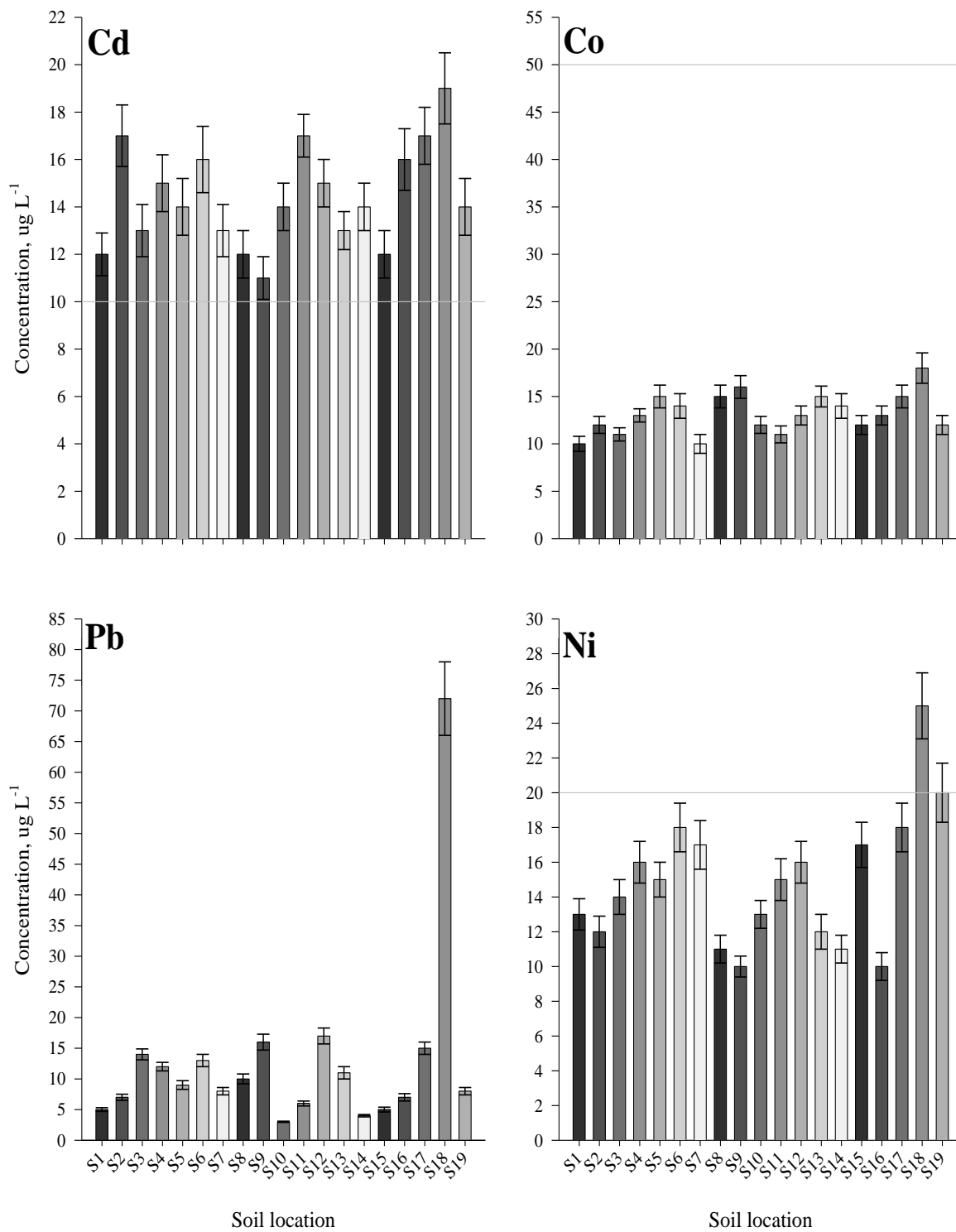
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Fig 2. Concentrations of PTEs (mean± standard deviation) in irrigation water. Maximum acceptable level (MAL) is presented by the grey-line, except for Pb because its MAL is 5000 µg L^{-1}.

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Table 1. Chemical characteristics of the investigated water samples

Location	pH	EC (dSm⁻¹)	Soluble ions (mmol$_c$ L⁻¹)								RSC	Mg ratio%	SAR	B	TH (mgL⁻¹)
			Ca^{2+}	Mg^{2+}	Na$^+$	K$^+$	Cl⁻	CO$_3^{2-}$ +HCO$_3^-$	SO$_4^{2-}$					
Fresh water canals															
S1: Mariouteya –Shabramant	6.88	0.49	2.61	1.53	0.46	0.32	1.63	2.25	1.04	-1.89	36.90	0.31	**0.009**	207.00
S2: Mansourieh.kafrghitati	7.05	0.66	2.77	1.98	1.76	0.14	1.54	2.43	2.68	-2.32	41.60	1.14	**0.011**	237.50
S3: Al-Jizawiya1	6.90	0.52	2.95	0.87	0.71	0.69	1.43	2.59	1.20	-1.23	22.70	0.51	**0.008**	191.00
S4: Mariouteya.Faisal	6.87	0.66	3.65	1.59	0.45	0.98	1.32	2.76	2.59	-2.48	30.30	0.27	**0.01**	262.00
S5: Mansourieh - Kerdasa	6.92	0.60	3.17	1.34	1.25	0.33	1.28	2.92	1.89	-1.59	29.70	0.83	**0.007**	225.50
S6: Al-Jizawiya2	6.40	0.64	2.26	1.76	1.59	0.84	1.19	2.02	3.24	-2.00	43.70	1.12	**0.005**	201.00
S7: Tamur– Omrania	6.45	0.78	2.49	1.95	2.48	0.97	1.29	2.18	4.42	-2.26	43.90	1.66	**0.003**	222.00
S8: Hawamdia	6.35	0.67	2.86	1.43	1.67	0.82	1.95	2.27	2.56	-2.02	33.30	1.14	**0.006**	214.50
S9: Al-Jizawiya3	6.55	0.60	2.65	1.43	1.19	0.78	1.83	2.35	1.87	-1.73	35.00	0.83	**0.004**	204.00
S10: Giza	6.48	0.55	1.75	1.34	1.58	0.91	1.98	2.49	1.11	-0.60	43.30	1.27	**0.012**	154.50
S11: Al-Jizawiya4	6.44	0.79	2.89	1.73	2.75	0.54	0.87	2.98	4.06	-1.64	37.40	1.80	**0.011**	231.00
S12: Al-Jizawiya5	6.61	0.66	3.11	1.41	1.98	0.18	1.63	2.84	2.21	-1.68	31.10	1.31	**0.013**	226.00
S13: TamwaShabramant	6.52	0.86	3.98	1.89	2.37	0.37	1.91	2.32	4.38	-3.55	32.10	1.38	**0.006**	293.50
S14: Al-Jizawiya6	6.45	0.97	3.45	1.76	3.81	0.69	1.87	2.53	5.31	-2.68	33.70	2.36	**0.002**	260.50
S15: Mariouteya. Haram	6.70	0.58	2.16	1.55	1.34	0.75	1.62	2.78	1.40	-0.93	41.70	0.98	**0.004**	185.50
S16: Sakarya - Hawamdiya	6.56	0.75	3.87	0.91	1.86	0.89	1.73	2.18	3.62	-2.6	19.00	1.20	**0.01**	239.00
S17: Tamwa Abu -Al-Nomros	6.40	0.74	2.94	1.82	1.95	0.72	1.93	2.57	2.93	-2.19	38.20	1.26	**0.009**	238.00
Drain water															
S18: Almuhit-drain	6.79	1.34	3.87	3.07	5.32	1.23	5.76	2.88	4.85	-4.06	44.2%	2.85	0.014	347.00
Well water															
S19: the Bahariya Oasis	6.85	1.76	5.89	3.65	7.12	0.95	6.82	2.95	7.84	-6.59	38.2%	3.26	0.012	477.00

RSC: residual sodium carbonate, **SAR:** sodium adsorption ratio, **TH:** total hardness

Based on these results, it can be deduced that using the investigated waters for irrigation is associated with potential health risks; thus, we validate the second hypothesis. Mainly, the drain water exhibits higher levels of PTEs than the other two sources (canal water and the well water). Such increases were noticeable in Pb and Ni while recordingcomparable results for Cd and Co. Comprehensive pollution index with PTEs was then calculated for all water samples based on the above data and the results are presented in Table 2. The obtained values fluctuated from 0.418-0.771 which indicates that all water samples exhibited slight pollution with PTEs. The highest CPI value was recorded in S_{18}; and generally, the variations among CPI values were comparable.

Principal component analysis (PCA)

Concentrations of PTEs in water samples were analysed via the principal component analysis (PCA) with Varimax rotation. The calculated value of "Kaiser-Meyer-Olkin MSA" (MSA=0.656) was acceptable in addition to the significance of theBartless test of sphericity ($P < 0.001$). This indicates that the sampling is satisfactory. Only one component (with eigen value>1.0)was found responsible mainly of the existence of all investigated PTEs in waters, which comprised approximately 60%of the variance (Table 3). Such a result highlights that these PTEs originated mostly from the same sources, probably via weathering the rocks along the river pass from the Ethiopian plateau to the studied area.Maybe, the industrial activities have raised, to some extent, the concentrations of investigated PTEs in some locations(Abdel-Satar, 2005; Abdel-Satar et al., 2017), yet the governmental

regulations in Egypt may effectively lessen and control the release of these contaminants to the surroundings. Moreover, the slope range in the Nile delta is enough to flush many contaminants continuously to the Mediterranean Sea (Bassouny and Abbas, 2020) or even dilute their concentrations through water runoff (Abdel-Satar, 2005). Based on the above results, we could not approve the third hypothesis

Table 2. Comprehensive pollution index of water samples with PTEs

	Cd	Co	Pb	Ni	Comprehensive pollution index (CPI)
S_1	1.200	0.200	0.065	0.450	0.479
S_2	1.700	0.240	0.060	0.550	0.638
S_3	1.300	0.220	0.070	0.400	0.498
S_4	1.500	0.260	0.080	0.500	0.585
S_5	1.400	0.300	0.075	0.350	0.531
S_6	1.600	0.280	0.090	0.250	0.555
S_7	1.300	0.200	0.085	0.150	0.434
S_8	1.200	0.300	0.055	0.300	0.464
S_9	1.100	0.320	0.050	0.200	0.418
S_{10}	1.400	0.240	0.065	0.600	0.576
S_{11}	1.700	0.220	0.075	0.550	0.636
S_{12}	1.500	0.260	0.080	0.650	0.623
S_{13}	1.300	0.300	0.060	0.300	0.490
S_{14}	1.400	0.280	0.055	0.100	0.459
S_{15}	1.200	0.240	0.085	0.200	0.431
S_{16}	1.600	0.260	0.050	0.500	0.603
S_{17}	1.700	0.300	0.090	0.650	0.685
S_{18}	1.900	0.360	0.125	0.700	0.771
S_{19}	1.400	0.240	0.100	0.600	0.585

(Pollution index (PI) spans Cd, Co, Pb, Ni columns)

Table 3.Principal of component analysis

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.395	59.871	59.871	2.395	59.871	59.871
2	0.898	22.456	82.328			
3	0.531	13.276	95.604			
4	0.176	4.396	100.000			

Soil physical and chemical characteristics

Soils of the studied area were mostly clayey ones (10 sites namely S_2, S_4, S_6, S_7, S_9, S_{11}, S_{12}, S_{14}, S_{16} and S_{17}) (Table 4). Only three locations exhibited sandy clay textural class i.e. S_1, S_{10} and S_{15}. Other three locations are clay loam (S_3, S_5, S_8) while the loam textural class was found in only S_{13} and S_{18}. Just only S_{19} exhibited a sandy textural class. In general, the values of both bulk density and the hydraulic

conductivity were higher in lighter textured soils (L, SCL and S) than in the ones whose textures are clayey. Concerning soil EC and ESP, most of the soils, under investigation, were neither saline nor sodic(EC<4 dS m^{-1} and ESP<15) except for soils of the sites S_{18} and S_{19} which were slightly saline and non-sodicaccording to the US Salinity Laboratory Staff in 1954.

Table 4.Soil physical and chemical characteristics

Locations	Sand (%)	Silt %	Clay %	Textural class	BD, Mg m⁻³	HC, cm h⁻¹	pH	EC (dS m⁻¹)	ESP (%)	CaCO₃ (g kg⁻¹)	Gypsum (g kg⁻¹)	SOM (g kg⁻¹)	CEC (cmol$_c$ kg⁻¹)
S1: Mariouteya. Shabramant	51.11	21.76	27.13	SCL	1.42	6.85	7.26	0.85	9.65	17.5	11.7	14.7	31.95
						Fresh water canals							
S2: Mansourieh.kafrghitati	25.40	24.82	49.78	C	1.17	0.51	7.08	0.96	10.44	24.3	14.2	15.9	40.83
S3: Al-Jizawiya1	28.47	37.41	34.12	CL	1.29	6.49	7.12	0.79	12.27	30.7	10.8	16.8	38.36
S4: Mariouteya.Faisal	38.20	16.23	45.57	C	1.09	0.68	7.17	0.68	14.03	21.8	12.5	23.2	40.67
S5: Mansourieh – Kerdasa	36.59	29.23	34.18	CL	1.27	6.53	7.16	1.04	13.82	25.7	16.7	22.9	38.48
S6: Al-Jizawiya2	21.77	29.89	48.34	C	1.19	0.50	7.69	1.12	12.74	23.9	19.6	22.2	39.57
S7: Tamur- Omrania	23.21	12.04	64.75	C	1.07	0.45	7.05	0.81	12.67	24.8	21.1	18.6	32.03
S8: Hawamdia	34.95	29.81	35.24	CL	1.08	6.50	7.23	0.93	11.93	25.6	10.9	19.8	34.24
S9: Al-Jizawiya3	38.12	16.21	45.67	C	1.05	0.72	7.35	0.69	10.69	28.2	18.4	21.1	37.31
S10: Giza	50.87	20.89	28.24	SCL	1.43	6.88	7.41	0.72	13.54	30.6	19.3	21.9	36.96
S11: Al-Jizawiya4	18.59	8.86	72.55	C	1.02	0.40	7.64	1.57	8.92	20.9	24.2	23.7	34.35
S12: Al-Jizawiya5	26.43	23.46	50.11	C	1.21	0.52	7.55	1.64	10.78	13.7	22.6	23.2	28.89
S13: TamwaShabramant	26.98	47.19	25.83	L	1.25	3.45	6.99	0.92	9.43	27.2	21.6	22.5	38.80
S14: Al-Jizawiya6	22.86	12.35	64.79	C	1.11	0.47	7.01	1.17	7.32	28.4	14.9	20.8	31.09
S15: Mariouteya. Haram	52.80	19.94	27.26	SCL	1.44	6.91	7.82	1.38	8.28	31	12.7	18.7	34.29
S16: Sakarya - Hawamdiya	25.93	22.65	51.42	C	1.22	0.47	7.78	0.75	6.92	19.4	11.4	24.4	40.38
S17: Tamwa Abu -Al-Nomros	36.05	17.83	46.12	C	1.03	0.75	7.42	0.86	11.86	21.3	10.7	23.8	31.19
						Drain water							
S18: Almuhit-haram	28.21	46.21	25.58	L	1.23	3.39	7.91	2.23	8.99	28.1	16.3	27.5	34.44
						Well water							
S19: the Bahariya Oasis	98.50	0.80	0.70	S	1.53	14.13	7.99	2.81	14.22	43.6	25.1	24.8	36.28

*pH was determined in 1:2.5 (soil: water) suspension, EC: electric conductivity determined in 1:2.5 (soil: water) suspension, EC: electric conductivity determined in soil paste extract, BD: bulk density, HC: Hydraulic conductivity, ESP: exchangeable sodium percentage (adsorbed sodium on soil particles determined by ammonium acetate, expressed as a percentage of soil CEC), SOM: soil organic matter, CEC: cation exchange capacity. Textural classes: SCL: sandy clay loam, C: clay, CL: clay loam, L:loam

These soils also contain 17.5-31 g kg^{-1} as CaCO$_3$, 10.7-24.2 g kg^{-1} as gypsum, 14.7 -24.4 g kg^{-1} as SOM and their CEC values were within the range of 28.89-40.83 cmol$_c$ kg^{-1}. Increasing soil CEC is an indicator of good soil quality and fertility (**Zgorelec et al., 2019**). Probably, the relatively high CEC values in most soils can be attributed to the presence of clay, except for S$_{19}$ (0.7% clay),whose relatively high content of organic matter might be responsible for such increases.Maybe, soil in this location received high doses of organic amendments to increase its productivity of the crops grown therein.

Potentially toxic elements (PTEs) in soils

Concentrations of the studied PTEs in all soil locations, which were cultivated for ages, were below the permissible levels, introduced by The European Commission (2010) (at soil pH>7) i.e.1.5 mg Cd kg^{-1}, 750 mg Co kg^{-1}, 0 mg Ni kg^{-1} and 100 mg Pbkg^{-1} (Fig 3). These results could not; therefore, validate the fourth hypothesis as they indicate no potential health threats were found in associationwith PTEs contamination levels in such soils.
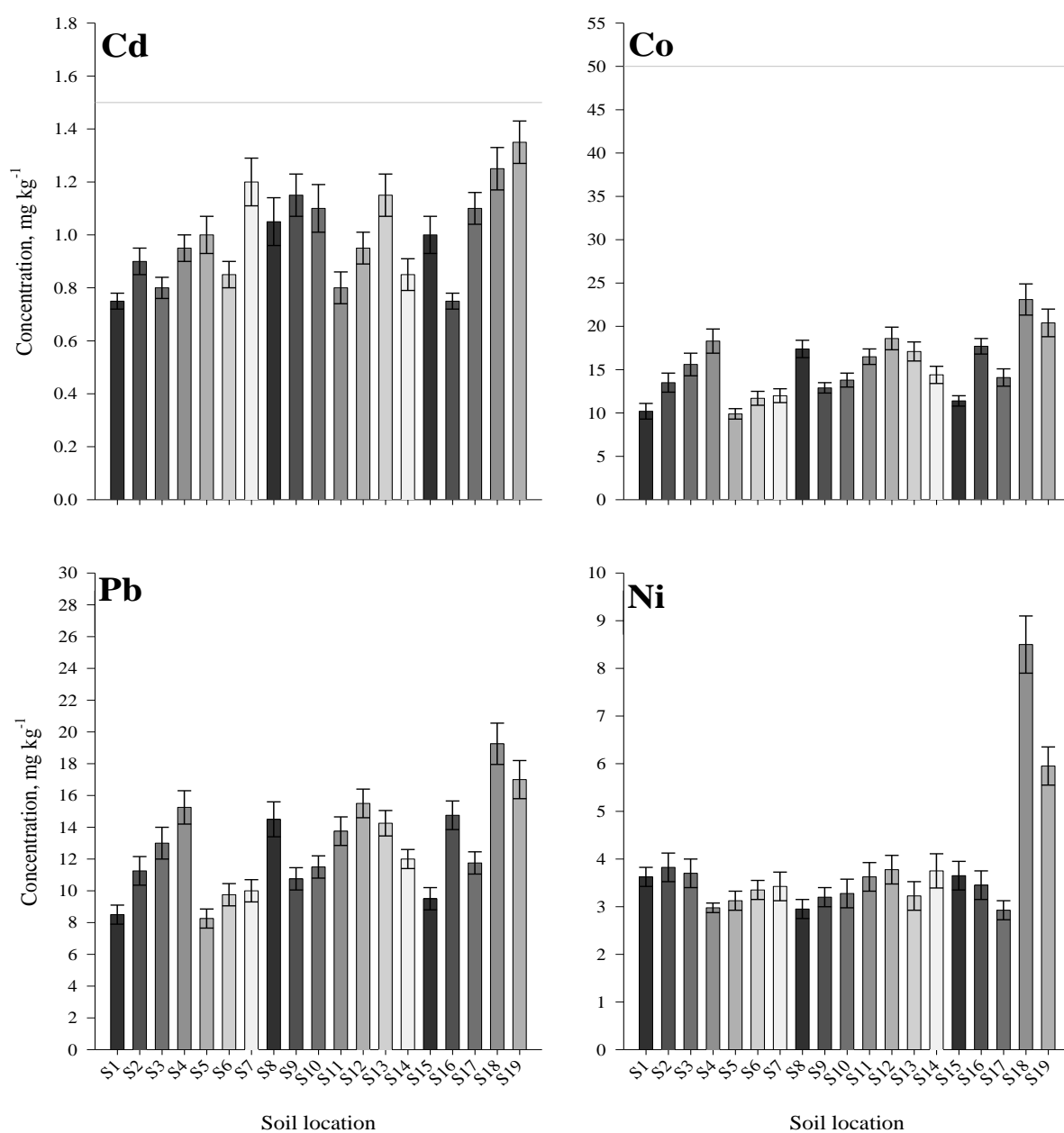

Fig 3.Concentrations of PTEs (mean± standard deviation) in soil.Maximum acceptable level (MAL) is presented by the grey-line, except for Pb and Ni because their MALs are 100 mg Pb kg^{-1} and 70 mg Ni kg^{-1}

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To evaluate the level of soil contamination with PTEs, based on the calculations of each of the contamination factor and pollution load index, almost all soils were of low pollution level with PTEs, except for the one that is irrigated with the drain water (S_{18})(Table 5). This location was of moderate pollution. Probably, theaccumulation of PTEs in soils is managed by a series of biogeochemical processes, which in turn, is controlled by soil physical and chemical characteristics (Verla et al., 2019).This point would be discussed later.

Table 5 Contamination factor (CF) and the pollution load index (PLI) for the investigated locations

	Contamination factor (CF)				Pollution load index (PLI)
	Cd	**Co**	**Pb**	**Ni**	
S_1	1.21	1.02	0.30	0.14	0.23 **Low**
S_2	1.45	1.35	0.40	0.15	0.34 **Low**
S_3	1.29	1.56	0.46	0.14	0.36 **Low**
S_4	1.53	1.83	0.54	0.11	0.42 **Low**
S_5	1.61	0.99	0.29	0.12	0.24 **Low**
S_6	1.37	1.17	0.35	0.13	0.27 **Low**
S_7	1.94	1.20	0.36	0.13	0.33 **Low**
S_8	1.69	1.74	0.52	0.11	0.42 **Low**
S_9	1.85	1.29	0.38	0.12	0.34 **Low**
S_{10}	1.77	1.38	0.41	0.13	0.36 **Low**
S_{11}	1.29	1.65	0.49	0.14	0.38 **Low**
S_{12}	1.53	1.86	0.55	0.15	0.48 **Low**
S_{13}	1.85	1.71	0.51	0.12	0.45 **Low**
S_{14}	1.37	1.44	0.43	0.14	0.35 **Low**
S_{15}	1.61	1.14	0.34	0.14	0.30 **Low**
S_{16}	1.21	1.77	0.53	0.13	0.39 **Low**
S_{17}	1.77	1.41	0.42	0.11	0.34 **Low**
S_{18}	2.02	2.31	0.69	0.33	1.02 **Moderate**
S_{19}	2.18	2.04	0.61	0.23	0.79 **Low**

Accordingly, a correlation study was conducted between PTEs contents in the studied soil locations in relation to their contents in irrigation waters and the results are presented in Table 6. Also, the relations among PTEs contents in soil versus soil physical and chemical characteristics (clay%, pH, EC, $CaCO_3$, soil organic matter) were included. Results obtained herein indicate that soil-Cd was significantly and negatively correlated with clay content in soil while positively correlated with the calcium carbonate content. Probably, Cd is a highly mobile contaminant in soil (Dong et al., 2019; Kubier et al., 2019); thus it may be easily substituted from the surface functional groups of clay minerals by the other metal ions

(Ahmadipour et al., 2014). On the other hand, $CaCO_3$ may effectively immobilize Cd in the form of $CdCO_3$ precipitate (Dang et al., 2021).

Cobalt (Co) was correlated positively with soil pH, $CaCO_3$ content and soil organic matter whilenegatively correlated with the clay content in soil.Although, the mobility of Co in soil is less than that of Cd (Kubier et al., 2019); yet Co mobilitycould bedetectable(Medyǹska-Juraszek et al., 2020) in highly contaminated soils (Jović et al., 2017). On the other hand, Co sorption on soil particles may be lessened considerably in presence of high soluble Na and Ca ions (Anguile et al., 2013), like in case of the studied soils. This is because Na and Ca ions were adsorbed on clay factions in soil, while counteracted against Co sorption on these particles and this might explain the negative correlation between Soil-Co and the clay content in soil. On the other hand, Co mobility may be negatively affected by increasing soil organic matter (Lange et al., 2016) and calcium carbonate contents (Jalali and Majeri, 2016). In spite of that, some results indicate that organic matter increased Co mobility (Lange et al., 2016). Generally, the reduced conditions increase Co-solubility while organic-Co complexes becomein the form of precipitates under high pH (Shaheen et al., 2014). It is worthy to mention that soil Cd was not correlated significantly with Cd in irrigation water. Also, soil-Co was not correlated significantly with Co content in irrigation water. Probably, Cd and Co are found as impurities in fertilizers that are extensively been applied in the studied locations to boost crop production (Abdelhafez et al., 2012).

Soil –Pb was correlated positively with its content in irrigation water as well as soil organic matter and soil EC. This might occur because Pb binds to the dissolved organic matter (Weng et al., 2002) and precipitates in the form of Pb-humate (Landrotand Khaokaew, 2018). May be, there isa positive relationship between soil EC and the concentrations of dissolved PTEs in soil (Pérez et al., 2014); yet in our study the positive correlation between soil EC and soil-Cd seemed to be not significant. Ni was also correlated significantly and positively with each of Ni-content in irrigation water and with soil pH. Under the reduced conditions, Ni solubility increase considerably (Shaheen et al., 2014), while under high pH values this solubility decreased because of its impacts on the surface charge of soil adsorbents (El-Naggar et al., 2021).

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Table 6. Coefficient of determination "r²" values calculated for the relations between PTEs content in soil and the corresponding ones in water as well as soil physical and chemical characteristics

	PTEs in irrigation water				Soil characteristics				
	Cd	Co	Pb	Ni	clay	pH	EC	CaCO₃	SOM
Soil-Cd	-0.063	0.388	0.374	0.467*	-0.482*	0.184	0.436	0.579**	0.405
Soil-Co	0.354	0.368	0.723**	0.753**	-0.510*	0.546*	0.772**	0.468*	0.478*
Soil-Pb	0.440	0.342	0.569*	0.363	-0.218	0.400	0.566*	0.157	0.635**
Soil-Ni	0.458*	0.318	0.805**	0.705**	-0.403	0.555*	0.783**	0.375	0.428

*. Correlation is significant at the 0.05 level (2-tailed), **. Correlation is significant at the 0.01 level (2-tailed).

Conclusion

Delicate increases in concentrations of PTEs in both canal and ground water resources of Giza (southwest the Delta area in Egypt) were detected due to the industrial activities therein; consequently, the quality of irrigation water declined slightly. Also, the levels of PTEs increased in soils; especially the one that is irrigated with drain water. Despite that soil contaminants did not exceed the permissible levels. There is an actual need to monitor precisely the discharges of the factories in the industrial zone of Giza to avoid further negative environmental consequences on the surroundings.

4. Conflicts of interest

There are no conflicts to declare.

5. Formatting of funding sources

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7. References

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