Identification of pollution sources in roadside soils of Cairo-Alexandria Highway, Egypt

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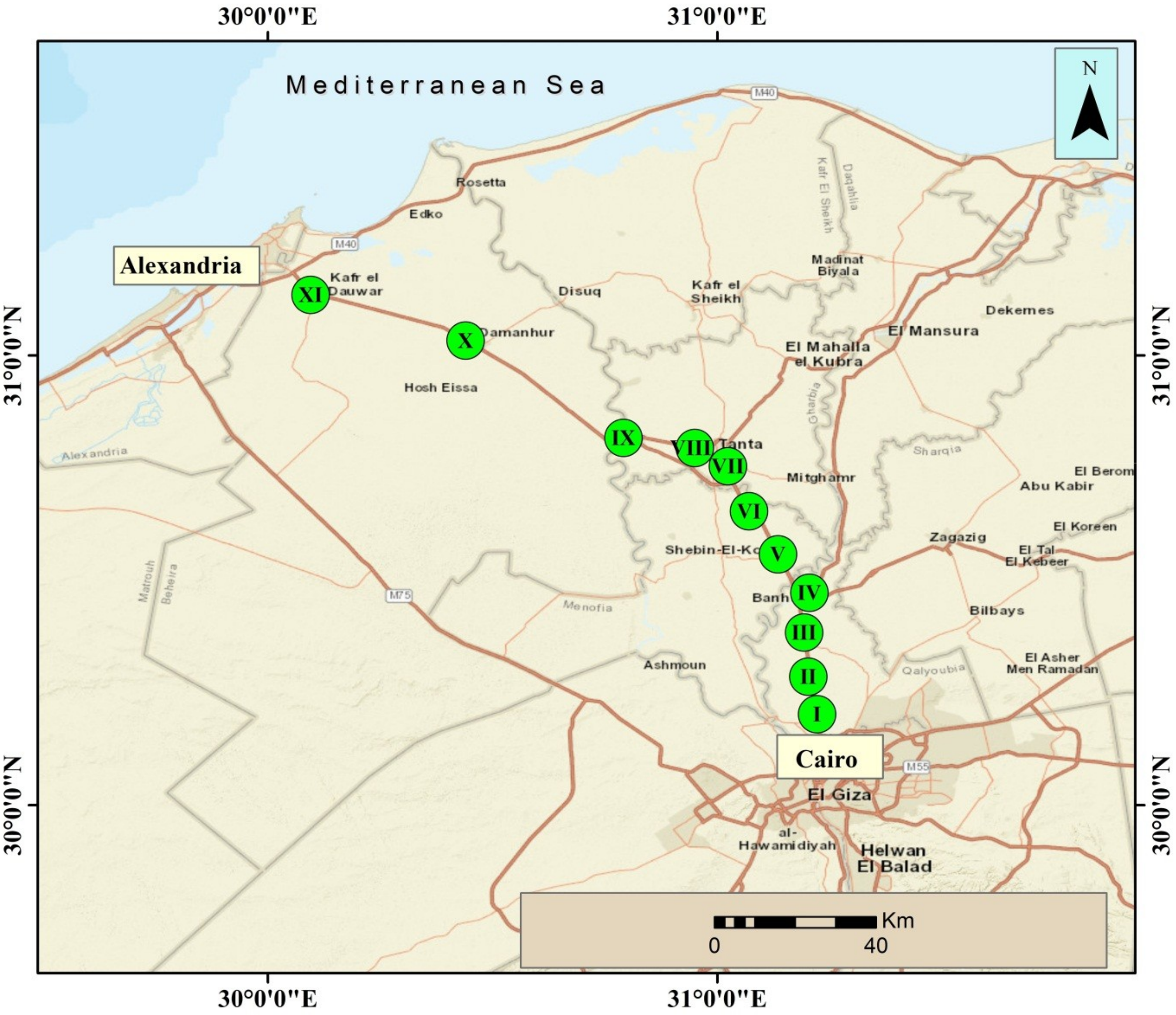

Fig. 1: *Map of sampling sites.*

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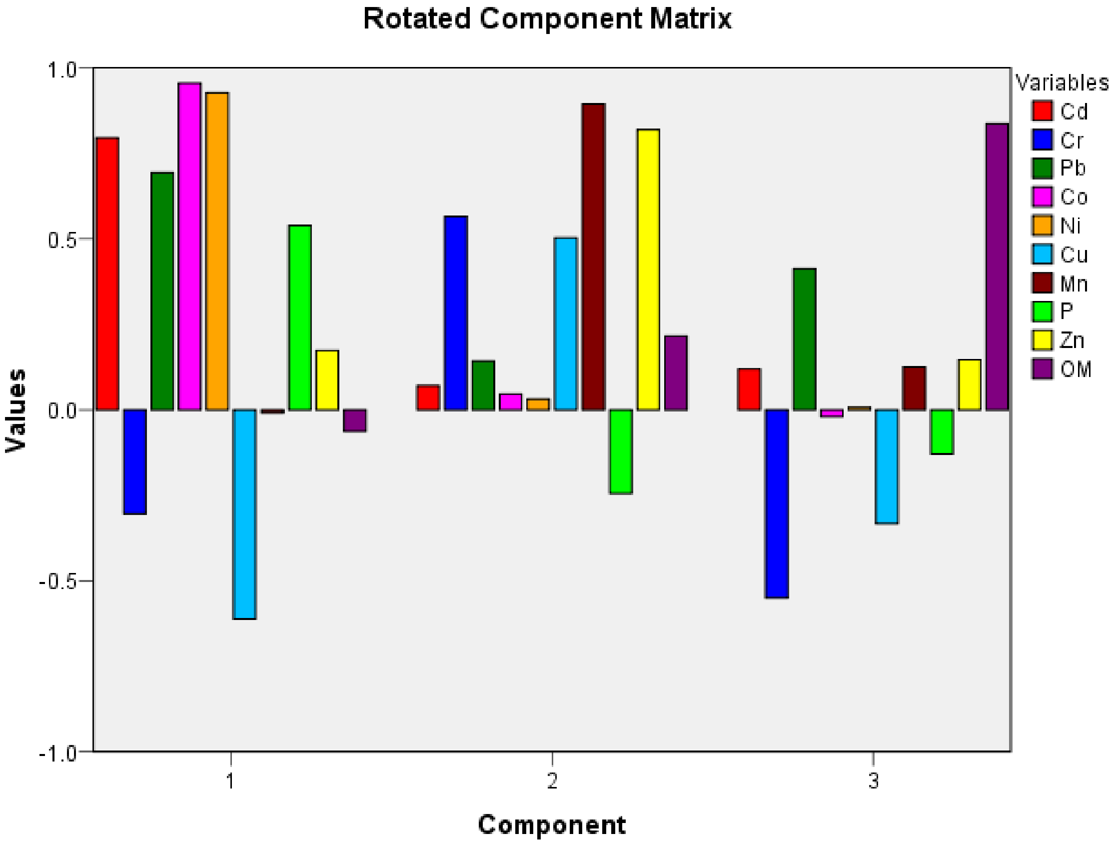

Fig. 2: Principal component loadings of soil data.

Extraction Method: *Principal Component Analysis.*

Rotation Method: *Varimax with Kaiser-Meyer-Olkin Normalization (KMO = 0.631).*

a. Rotation converged in 3 iterations.

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 Y S I S * * * * * * * * * * * * * * * * * * *

 Dendrogram using Ward Method
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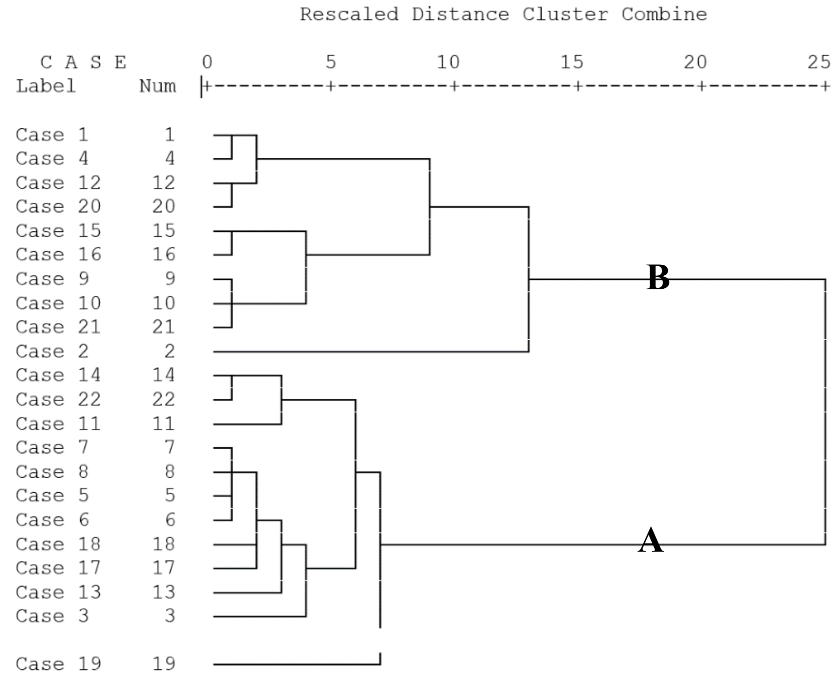

Fig. 3: *Dendrogram providing a graphic summary of the clustering pollution Sources.*

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Abstract

Nile Delta represents 63% of Egypt's fertile agricultural land. Unfortunately, food chain contamination with potentially toxic elements (PTEs) was recorded along Cairo-Alexandria Highway within Nile Delta. This paper aims to identify pollution sources of PTEs (Cd, Pb, Co, Ni, Zn, Cu, Cr, and Mn), using multivariate statistics. Generally, the studied soil is alkaline loam with about 3.69% $CaCO_3$ and 1.97% organic matter. Pollution levels varied widely from uncontaminated to highly contaminated soil. Cd, Pb, Co and Ni showed spatial variability, relatively high enrichment, reflecting their anthropogenic sources. Mn and Cr show more uniform distribution, reflecting their natural source from the geologic parent material of Egyptian soil. Surprisingly, no significant road traffic impact was observed at the sampling sites. Multivariate analysis indicates P-fertilizer is the main pollution source rather than traffic in roadside soils. The prevailing of fertilizers as pollution source may be refer to the expansion in the use of unleaded fuel and the continuous increase in the annual fertilization rate.

Keywords: Potentially toxic elements; anthropogenic impact; roadside soil; multivariate statistics; Egypt

1. Introduction

The Egyptian Delta is of particular importance from a geological and environmental view. It is the food basket for Egyptians (El-Ramady et al. 2019), as it represents two thirds (63%) of the agricultural area in Egypt, and 50% of the population lives on (Fishar 2018). In view of this economic importance, contamination of the food chain with PTEs along the Cairo- Alexandria Highway has been reported in literatures (e.g. Elsokkary, 1978; Abd El-Hameed et al., 1999; Naggar et al., 2014; Hashim et al. 2017). The matter raises concern about consumer health. PTEs are known to negatively affect human health. They are more dangerous than organic and microbiological pollutants, being non-biodegradable materials (Masindi and Muedi 2018). Previous studies have recorded a strong relationship between chronic diseases and PTEs pollution in Egypt (e.g. Salem et al., 2000; El-Harouny et al., 2011; El Sayed et al., 2015). The sourcing and distribution of PTEs is among the most critical concerns for environmental management and decision-making, where pollution management is driven by defining sources. Therefore, this study aims to determine potentially toxic elements (PTEs) concentrations in roadside soils of the Nile Delta, Egypt. Subsequently, pollution level and provenance of PTEs using contamination factor (CF), and multivariate statistics, respectively.

The ecosystem can be loaded with PTEs from natural and anthropogenic sources. P-fertilizers and traffic emissions are essential sources of PTEs (Johansson et al., 2009; Weissengruber et al., 2018). Considerable quantities of PTEs have measured in P-fertilizers and their different ores in Egypt, by Abou El Safa et al (2013), Azzi et al (2017), and Hellal et al (2019). Other studies have recorded the impact of traffic emissions on soil pollution with PTEs (e.g. Ibrahim and Omer 2004; Elnazer et al. 2015). The traffic emissions contributed to soil pollution with Pb, Cd, Co, Cu, Ni, and Zn at Sohag governorate, Egypt (Ibrahim and Omer 2004), and Cd, Pb and Zn at Alexandria-Marsa Matruh, Egypt (Elnazer et al. 2015). Hasballah and El-Henawy 2019 found unacceptable concentrations of lead ambient air at Damietta City, Nile Delta. They attributed this pollution to traffic emissions.

Metals origin controls their environmental behavior. PTE bioavailability varies depending upon the metal origin (Kabata-Pendias 1993; Kabata-Pendias 2010); metals of anthropogenic origin are generally more bioavailable than that of geogenic and pedogenic one, whose origin is difficult to distinguish (Kabata-Pendias 1993; Kobierski and Dabkowska-Naskret 2012). Lithogenic elements are directly derived from the lithosphere (parent material). Whilst pedogenic elements are of lithogenic and anthropogenic origin but their distribution in the soil changes due to pedogenic processes. Anthropogenic elements are those deposited direct or indirect into soil as results of man's activities (Kabata-Pendias 2010; Kobierski and Dabkowska-Naskret 2012).

In this study, contamination factor (CF) is employed to evaluate the level of soil contamination and to infer anthropogenic inputs from the natural one (Said et al. 2019a). CF considered effective index for monitoring contamination over a period of time (Chandrasekaran et al. 2015) where it is based on the comparison of the measured PTEs with its background in the environment. Multivariate statistics are conducted here as a useful tool to assess the possible pollutants sources, where it allows looking into inter-element relationship (Said et al. 2019a). This provides helpful links facilitate unveiling of hidden relationships between environmental data (Said et al. 2020) hence, more precisely describe the environmental geochemical processes and define the sources of pollution. Although statistical associations do not establish direct cause-and-effect relationships, they provide helpful associations from which such relationships can be deduced (Yidana et al. 2012). The statistical processes enable us to discuss the results in an explanatory logic that makes them a powerful tool for enhancing the interpretation process - far more than conventional techniques can do. Hence, the combination of multivariate statistics and the contamination factor (CF) enables exceedances to be highlighted and anthropogenic inputs to be identified.

Study area

The studied road extended within the Nile Delta from coordinate 31°13'19.38"E, 30°12'7.45"N to coordinate 30°5'40.92"E, 31° 8'6.00"N (Fig. 1). The Nile Delta has a special geologic, agricultural and environmental importance because it is stretch of the longest world river; the Nile. It represents about two thirds of the Egyptian agricultural lands and contains about 50% of the Egypt populations. The rapid urbanization in the Delta led to the loss of 1734 Km^2 of Delta fertile soil (Abd-elmabod et al. 2019). The area is characterized by Mediterranean climate (i.e dry mild summer and fairly wet cool winter). Average temperature during winter is about 8 °C while it reaches up to 33 °C in summer, with annual mean temperature of 21 °C. The mean evapotranspiration values between 5.6 and 17.8 mm/season and average rainfall is $37mm^3$ (Abu Khatita 2011). The prevailing winds in the study area come from north or northwest. Like the majority of Egyptian soils, the study area consisted of Nile sediments carried by repeated flooding over different geological periods (Said 1990). These soils were developed from suspended Nile sediment matter formed from the disintegration of the eruptive and metamorphic rocks of the Ethiopian plateau (Omer 1996).

Since the construction of the High Dam in 1968, and subsequent soil degradation through intensive agriculture, more fertilizer has been applied to restore soil fertility (Abd-El Monsef et al., 2015). Application rates of fertilizers increases 2.8% annually (Mohamed et al. 2016). P-fertilizers are the major agrochemical used in the study area.

2. Materials and methods

2.1. Soil sampling and chemical analysis

Twenty two agricultural soil samples (0–15 cm depth) were collected from 11 locations along the road running across the fertile delta region of Egypt (Fig. 1). Each location was represented by two samples were distributed on roadway side (first sample at 3 m distance and second sample at 50 m distance apart from the road in wind direction). Sample map was prepared using ArcGIS10.2 (Desktop 2014). Soil samples were analyzed for their pseudo-total PTEs concentration of eight elements (Cd, Pb, Co, Ni, Zn, Cu, Cr and Mn) and a number of physiochemical parameters. Total PTEs were determined by digestion of one gram pulverized soil sample with aqua regia (3 HCl: 1 HNO_3) and analyzed using atomic absorption spectrophotometer (Buck scientific 205AA). Quality assurance and control was assessed through replicate analysis and selection of most appropriate absorption wavelength. Soil pH was measured in 1:1 soils to water ratio by using HANNA (HI93300) combined electrode. Calcium carbonate percentage ($CaCO_3$%) and Phosphorous (P%) were estimated by the titrimetric and colorimetric methods, respectively. The texture of soil samples was determined using the hydrometer method (Bouyoucos 1962). Soil organic matter content (SOM%) was determined according to the modified Walkley and Black method (USDA2004). High purity chemicals (AR grade), double-distilled water, disposable plastics, clean apparatus and glassware were used during all stages of samples collecting, handling and analysis to prevent contamination. All measurements were completed in triplicate for precision.

2.2. Contamination factor (CF)

Contamination level was assessed using the contamination factor (CF) recognized in (Hakanson 1980) based on the following equation:-

$$\mathbf{CF = C_s/C_b}$$

Where C_s is the concentration of metal in the study samples and C_b is baseline concentration. In this study, Turekian and Wedepohl 1961 was used as C_b (Cd= 0.3 mg/kg, Cr= 90 mg/kg, Pb= 20 mg/kg, Co= 19 mg/kg, Ni= 68 mg/kg, Zn= 95 mg/kg, Cu= 45 mg/kg and Mn= 850 mg/kg). Contamination level was clustered based on the contamination factor as the following; CF <1 low; 1<CF<3 moderate; 3< CF<6 considerable and CF> 6 as high contamination (Hakanson 1980).

2.3. Statistical analysis

Statistical analysis is a powerful tool for data interpretation comparing with conventional techniques. The statistical analysis was performed using SPSS 16.0 software. Although the samples number is relatively low, Principal Component Analysis (PCA) and cluster analysis (CA) were conducted to reveal the masked environmental situation in terms of pollution sources. The minimum sample size recommended for conducting principle component is debatable in the literature. Generally, as the sample size increases, sampling error is reduced. Said et al. (2019a) found that most of the studies (70%) utilizing factor analysis had sample size below 100; some studies were based on sample size ranged from 20 to 40. Further, Graham et al. (2018) recommended that all communalities values should be above the minimum criteria of 0.60 in case of low sample size. In this study, the KMO value of 0.631 indicates that the sample is adequate to perform PCA. Descriptive statistical analysis (minimum, maximum, mean and coefficient of variation) of the soil physico-chemical characteristics and elements contents was performed as a first step towards an initial understanding of their distribution. Subsequently, multivariate statistics were performed including principal component analysis (PCA) and cluster analysis (CA). PCA and CA were employed in an attempt to identify the common sources of PTE in the studied soil (Kelepertzis 2014). The PCA was performed by means of varimax rotation a method that helps to reduce the numbers of variables in fewer high loading components facilitate their interpretation (Chen et al. 2008). Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO MSA) for the set of variables included in the analysis was 0.631. KMO MSA is above the minimum requirement of 0.50 for overall MSA, with Bartlett's test of sphericity (0.00), be less than the level of significance (Tabachnick and Fidell 2007). The CA was developed based on the Ward method using squared Euclidean distances as a measure of similarity between (Cd, Cr, Pb, Co, Ni, Cu, Mn, P, Zn and OM). The clustering results were provided in a dendrogram and were explained in light of PCA.

2.4. Meteorological data

The annual average meteorological data of the study area (Table. 3) was obtained from Abu Khatita 2011. Meteorological data of Sohag and Alexandria- Mersa Matruh coastal zone were calculated from Climate-Data 2015 and Climate-Data 2018. Regarding coastal zone, the annual average was taken for 4 stations, are Alexandria/Borg El Arab, Alexandria/Nouzha, Dabaa, and Mersa Matruh station

3. Result and discussion

3.1. Soil characteristics and Pseudo-total content of PTE:

Analytical data and their descriptive statistical analysis are provided in Table 1. The texture of the studied soil is mainly sandy loam (Table 1), with clay, silt and sand average content of 21.12%, 17.32% and 62.10% respectively. The pH displays a narrow range varying from 7.10 to 8.62, with an average of 8.14 indicating alkaline soil. The total $CaCO_3$ content ranges between 1.30 and 7.10%; averaging 3.69%. Soil organic matter (SOM) ranged from 1.16 – 2.61% averaging 1.97%. Phosphorous content ranged from 0.1 to 0.97 with a high coefficient of variation (C.V= 76.32%). Such heterogeneous distribution of phosphorous content suggests strong anthropogenic impact on the soil chemistry, most probably owing to the variation of fertilizer applications rate, which would be expected given the patchwork of individual fields along the sampling sites. PTEs content, Pb, Cd and Co exhibited wide range of variation (C.V= of 96.85%, 95.22%, and 51.49% respectively), whilst Zn, Ni, Mn, Cr and Cu showed a much narrower range of variation (C.V= of 38.09%, 28.50%, 26.04%, 22.29% and 10.57% respectively).

The contamination factor (CF) indicated that the soil samples ranged from uncontaminated to highly contaminated for the elements measured (Table 2). The studied soil was classified as uncontaminated to highly contaminate with Cd, and low to moderately contaminate with the remaining studied elements. Cd and Pb haven't any biological importance and are toxic even though at very low concentrations (Michalke and Nischwitz 2010). Unlike Zn, Cu, or Ni, accumulation of Cd in vegetation can reach levels that are toxic to animals before the vegetation itself shows any sign of damage (Salomons and Förstner 2012). The homogenous pattern of Mn, Cr (C.V= 26.04%, 22.29% respectively) suggests they are mainly natural in origin and anthropogenic influents are limited. Mn and Cr are principally derived from Parent rocks of Ethiopian basaltic plateau (Omer 1996). Said et al., (2019a) concluded that Mn is of a pedogenic origin in the soil upper Egypt. The uniform pattern of Cu content (C.V= of 10.57%) suggesting that, Cu is mainly controlled by natural origin (lithogenic/pedogenic). Cd, Pb and Co displayed spatial variability and have exceeded their worldwide background values, reflecting their anthropic inputs. Such an anthropic portion can be mobilized under favorable condition, causing serious environmental hazards. Contamination of the plants with these elements at the study area is further evidence of their anthropogenic origin. Hashim et al. (2017) reported, Pb, Ni, Co and Cd concentrations exceeded the permissible limits in some plants at Tokh region (Site No. III). Moreover, Naggar et al. (2014) found Pb and Cd contents above maximum allowable limit in Clover blossoms and cotton at Kafr El-Zayat area (near site No. IX).

Comparing the current data with previous studies at Sohag Governorate and Alexandria- Mersa Matruh highway (Table 3) indicates a marked variation of PTEs content in Egyptian soil, owing to the variation of climate and geology. The present area contains the lowest concentrations of Pb and Zn. Sohag area at narrow Nile valley (Upper Egypt) exhibited the highest content compared to the wider Nile delta (present study) and Alexandria- Mersa Matruh coastal zone in north Egypt. The highest concentrations recorded at Sohag may be attributed to intense aridity in Upper Egypt than Lower Egypt that can lead to higher accumulation of air pollutants over the Sohag area (EEAA 2017). On another hand, the higher Cd and Pb contents at Alexandria- Mersa Matruh highway relative to the present study is most probably related to the primary properties of the soil. The coastal zone at Alexandria-Mersa Matruh has soils typically with a lower organic matter and higher carbonate content (Table 3). The elements are very likely retained strongly by highly calcareous soil, so their soil content increases. However, the lack of organic matter content and essential nutrients in the coastal zone soils makes it a soil of poor fertility (El-Ramady et al. 2019). Low soil fertility requires an increase in the use of inorganic fertilizers, which in turn accumulates more PTEs in the soil. The flooding irrigation at the studied area opposite to dripping irrigation at Alexandria-Mersa Matruh may be lead to leaching and washing out of PTEs from soil. Also, cultivation process which was seasonal at the present study and permanent or even at one season at Alexandria- Mersa Matruh may assessed in the harvesting of PTEs with seasonal plants. One of the most widespread seasonal plants in Nile Delta is Egyptian clover (Trifolium alexandrinum) which was considered as a PTEs bioaccumulator by Bhatti et al. (2016) Comparing to Said et al. (2019b), the Pb, Co, Zn content at El Tebbin industrial area is higher several times more than the present study, due to direct influence of industrial activities.

3.2. Principle components analysis (PCA)

Since the studied soil displayed a relative enrichment in some PTEs compared to Turekian and Wedepohl (1961), PCA was conducted to group the investigated elements according to their anthropic and natural origin. Three principal components were extracted from the soil data explaining 72.03% of the variance (Fig. 2). The first component (PC_1) explains 36.76% representing the majority of the variance in the dataset and includes the anthropogenically affected elements (Co, Ni, Cd, Pb and P). According to earlier discussion, these elements exhibited spatial variability and relatively enriched in the soil as well as exceedance in vegetation, confirmed their anthropic origin. P has been proposed as a tracer for P-fertilizers impact. Inclusion of P in PC_1 implies P-fertilizers (P-fertilizer contains 15%P_2O_5) as the main anthropogenic source (fertilization factor) of this component. P-fertilizers considered main source of PTEs worldwide and field investigation indicated uncontrolled application of P-fertilizers in the study area (600- 1190kg ha^{-1} year^{-1}). High Cd is a marker element for Egyptian fertilizer whereas the Cd content in the Egyptian phosphatic deposits used in P-fertilizer, is 1.16-45.78 μg/g and in the produce fertilizers 0.78 – 3.79 µg/g)Abou El Safa et al. 2013(. The annual average inputs of Pb, and Cd via Phosphate Fertilizers in most of the eastern Mediterranean countries were calculated to be 26, and 6 gha^{-1} year^{-1}, respectively (Azzi et al. 2016). Hellal et al. 2019 determined Cd, Pb and Co contents in Egyptian fertilizers as 5- 19 mg/kg, 10- 20 mg/kg and 4- 11 mg/kg respectively. Cr is controlled by natural composition of soil; it is negatively loaded on PC_1 with an independent trend. Although Ni exhibited narrow range of variation, it had high positive loading with anthropic elements (Cd, Pb, Co and P). The exceedance of Ni in plant of the study area (Hashim et al. 2017) provides further evidence to support anthropogenic impacts. Elements in PC_1 forming definite anthropogenic trend (Co>Ni>Cd>Pb), in line with their CF trend, averaging 1.12, 0.99, 3.06 and 0.82 respectively. The slight shifts in this sequence (i.e. the precedence of Co and Ni over Cd), most probably attributed to the existence of Co and Ni in an anionic form (more than the other elements) and hence were easily absorbed by plants and depletion in the alkaline soil. Elbana et al. (2019) reported that Ni has the lowest sorption affinity for Egyptian soils. Accordingly, high plant pollution with Co and Ni is predicted at the remaining sites with strong anthropogenic influence.

The second component (PC_2) is responsible for 21.77 % of the total variance. It shows significant positive loadings of the low CV elements (Mn, Zn, Cr and Cu) reflecting their natural origin. The presence of Mn and Cr are likely due to parent ultramafic rocks from which the soil is formed (Omer 1996). The relationship between Mn, Zn and Cu contents points to an impact of soil Mn on distribution of these elements, more likely of a pedogenic influence. Elbana et al. (2019) reported that, the Fe/Mn oxides fraction in the Egyptian soil retains considerable contents of Cu and Zn. Association of Zn and Cu with Mn oxides and hydroxides is known in literatures (e.g. McLEAN and Bledsoe, 1992, Kabata-Pendias 2010, Shaheen et al. 2013 and Said et al. 2019b). On other hand, Naggar et al. (2014) detected Cu and Zn in Clover blossoms and cotton grown in soil from Kafr El-zayat area. Biological accessibility of these metals may be attributed to the planting under flooded conditions, reducing them from Mnoxides/hydroxides fraction. Hence, PC_2 can be denoted as a pedogenic factor.

The third component (PC_3) accounts for 13.50% of the total dataset variance. Organic matter content coupled to a lesser extent with Pb, suggesting fuel combustion residues as the main source responsible for this component (Said et al. 2019b). Pb is usually identified as a marker element for traffic activities (Said et al. 2019a); with an origin from leaded gasoline (Awadh 2015; Elnazer et al. 2015; Wang et al. 2017). PC_3 can be named as traffic emission factor. Natural origin of Cr in soil has evidenced by its negative loading on PC_3 to form independent trend. The affinity of Pb for organic matter forming stable organic-Pb complexes is another potential explanation for Pb-OM association (Said 2015).

From our findings through the integration between the current study and previous studies, that, “plant uptake is a function of metal origin”. Naggar et al. 2014 calculated the transfer factors (TF) of some elements from agricultural soils to clover flowers and cotton grown at Kafr El-zayat area in spring and summer season (Table 4). The average TF values arranged in descending order as Pb > Cd > Zn > Cu. Similarly TF calculated from Elsokkary, 1978 Cd (0.73-1.50) > Pb (0.57- 0.85) > Zn (0.38- 0.69). The matter means the statistically identified anthropogenic elements (Pb and Cd) exhibited higher plant uptake than those of pedogenic origin (Zn and Cu) demonstrating the influence of metal origin on phytoavailability. The PCA was carried out based on correlation matrix; accordingly texture has no significant effect on PTE distribution.

3.3. Cluster analysis and spatio-similarity

The cluster analysis results represented a real spatial reflection for what has been predicted by PCA. The dendrogram grouped all samples into two spatial clusters (A and B), indicating different contamination levels (Fig. 3), and pollution sources have been successfully highlighted. Generally, the common feature of group (A) was the high phosphorus content (mostly≥0.5% except samples 13, 18 and 19), with the highest CF (Samples: 5, 6, 7, 8, 13, 14, 17, and 18) and anthropically affected trace originated element contents (Cd, Pb, Co, and Ni). Link of high phosphorus content to contaminated sites, indicates P-fertilizers are likely to be responsible. Whereas group (B) contains P ≤0.2% and was nearly uncontaminated. Unlike the rest of group B, sample No. 2 exhibited low contamination with Cd, Pb, Co, and Ni despite a relatively high P content (0.86%) and can be seen as an outlier, furthest from the other group samples (Fig. 3). This perhaps attributed to variation of fertilizer type because the produced P-fertilizers contain variable contents of

PTEs. On another hand, site no. X is mainly affected by traffic emissions rather than the fertilization process. That why sample no. 19 has the furthest cluster distance from the rest of group (A) controlled by P-fertilizers application (Fig. 3). In this site, sample No. 19 (3 m distance from the road) showed relative enrichment in SOM and PTE compared to the associated sample No. 20 (50 m distance from the road). This suggests, excess PTE and SOM content are related to fuel combustion residues (previously proven by PC_3). Moreover, the reduced variation in phosphorus content at this site makes fertilization impact unlikely. Besides this observation, no clear trends can be noticed with either distance from the roadside, confirming the limited effect of vehicular emissions, and the results from the PCA. The strongest PC is the fertilization factor (PC_1) while traffic emission factor found to be the least influential (PC_3). This observation contrasts earlier studies (Elsokkary, 1978 and Abd El-Hameed et al. 1999) reporting traffic emission as the main source of PTEs pollution in roadside plants. Two possible reasons for this shift in pollution sources from traffic emission to fertilization are: 1- is due to the expand in using unleaded gasoline, the development of automobile engines (MEI, 2011 and EEAA, 2011) and the annual increase in the fertilizer rate by 2.8% (Mohamed et al., 2016). Hasballah and El-Henawy (2019) pointed out the decrease of air load with PTEs in 2019 than 2005 as a result of tetraethyl lead gasoline ban. 2- Another possible reason is the different way of inferring that may be ignored by the previous studies, in addition to the statistical logic used in this study.

4. CONCLUSION

Pollution management is initiated by identifying pollutant source, and metal origin determines its environmental behavior. In this regard, the combination of multivariate statistics and contamination factor successfully separated the anthropogenic elements from those of natural origin. Integration with TF data derived from this and previous studies indicates that biological uptake is closely related to metal origin. Where elements with stronger anthropogenic origin (Pb and Cd) exhibited higher plant uptake than those from pedogenic origin (Zn and Cu). Data assessment with multivariate statistics highlighted fertilizer use as the dominant pollution source in the intensive agricultural system of the Nile delta. This contrasts with the commonly reported influence of transport on roadside soil. This apparent change in source significance highlights the need to review the nature and input of fertilizer use in intensive agricultural systems.

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Texture	pH	%OM	$CaCO_3$%	P (%)	Mn (µg/g)	Cu (µg/g)	Zn (µg/g)	Ni (µg/g)	Co (µg/g)	Pb (µg/g)	Cr (µg/g)	Cd (µg/g)	Distance (m)	Sample No	Locality	Site .No
Sandy clay loam	8.48	1.69	4.90	0.16	1222.00	68.90	105.90	25.20	BDL	BDL	130.30	BDL	3	1	Qaleob	I
Sandy loam	8.41	1.16	5.80	0.86	111.10	55.10	BDL	57.30	14.50	BDL	78.00	BDL	50	2		
Sandy loam	8.19	1.99	6.70	0.95	1203.00	60.20	151.10	76.50	32.60	54.50	119.30	0.30	3	3	Qaha	II
Clay Loam	8.46	1.90	6.70	0.18	1350.00	64.50	103.50	36.50	BDL	1.20	139.10	BDL	50	4		
Sandy loam	7.87	2.05	3.60	0.60	1132.00	52.90	127.30	77.50	25.70	23.80	111.20	0.80	3	5	Tokh	III
Sandy clay loam	8.15	1.87	4.50	0.64	1317.00	56.80	125.00	84.40	27.20	24.50	110.10	2.00	50	6		
Sandy clay loam	8.47	1.87	2.70	0.81	968.00	51.20	82.80	83.00	29.70	20.40	112.10	1.30	3	7	Benha	IV
Sandy loam	8.08	1.92	3.10	0.57	1037.00	54.30	88.60	85.60	34.30	23.60	121.80	1.80	50	8		
Sandy loam	8.31	1.69	3.60	0.11	1020.00	55.30	84.20	67.60	19.40	7.30	111.70	BDL	3	9	Quwaysna	V
Sandy loam	8.36	2.06	2.70	0.10	1000.00	54.30	80.80	80.10	23.50	11.10	119.40	0.60	50	10		
Sandy clay loam	8.06	2.15	3.10	0.71	1046.00	54.50	BDL	72.10	28.60	3.20	107.30	1.70	3	11	Birkat Assab	VI
Sandy loam	7.74	2.31	2.70	0.18	1126.00	59.80	88.20	34.70	7.00	BDL	121.70	BDL	50	12		
Sandy clay loam	8.62	1.35	3.10	0.43	1038.00	56.10	103.00	96.00	38.70	15.50	143.40	2.60	3	13	Tanta	VII
Sandy clay loam	8.43	2.31	1.80	0.97	944.00	50.40	104.60	72.60	25.20	11.50	98.00	0.90	50	14		
Sandy clay loam	8.24	1.92	2.20	0.18	993.00	69.80	108.00	68.90	21.10	0.30	127.50	BDL	3	15	Tanta	VIII
Sandy loam	8.29	2.26	1.30	0.11	987.00	65.50	107.70	80.30	27.50	BDL	114.40	1.40	50	16		
Sandy clay loam	8.45	1.51	1.30	0.74	878.00	54.20	117.60	66.80	24.80	23.90	88.00	1.20	3	17	Kafr El - Zayat	IX
Sandy loam	8.22	2.24	1.80	0.11	971.00	52.00	90.60	80.90	26.80	28.50	104.30	1.40	50	18		
Sandy loam	7.10	2.41	5.40	0.10	940.00	50.50	89.00	82.60	27.50	38.80	24.80	2.10	3	19	Damanhour	X
Sandy loam	7.97	2.32	4.00	0.16	882.00	62.20	78.20	32.50	BDL	BDL	136.30	BDL	50	20		
Sandy loam	7.77	1.64	7.10	0.11	651.00	50.90	78.80	60.10	15.00	20.80	111.70	BDL	3	21	Kafr El - Dawar	XI

Sandy loam	**7.36**	**2.61**	**3.10**	**0.95**	**729.00**	**50.30**	**86.00**	**70.70**	**24.60**	**31.20**	**106.70**	**1.30**	**50**	**22**	
	7.10	**1.16**	**1.30**	**0.10**	**111.10**	**50.30**	**BDL**	**25.20**	**BDL**	**BDL**	**24.80**	**BDL**			**Min**
	8.62	**2.61**	**7.10**	**0.97**	**1350.00**	**69.80**	**151.10**	**96.00**	**38.70**	**54.50**	**143.40**	**2.60**			**Max**
		1.97	**3.69**	**0.44**	**979.32**	**56.80**	**90.95**	**67.81**	**21.53**	**15.46**	**110.78**	**0.88**			**Mean**
	0.38	**0.36**	**1.75**	**0.34**	**255.02**	**6.01**	**34.64**	**19.33**	**11.09**	**14.97**	**24.69**	**0.84**			**Std. D**
	4.67	**18.28**	**47.47**	**76.32**	**26.04**	**10.57**	**38.09**	**28.50**	**51.49**	**96.85**	**22.29**	**95.22**			**%CV**

Table 1: *Summary of soil sample analysis for PTE and main soil properties*

Table 2: *Contamination factors (CF) of investigated elements*

CF (Mn)	CF (Cu)	CF (Zn)	CF (Ni)	CF (Co)	CF (Pb)	CF (Cr)	CF (Cd)	SN
1.44	1.53	1.11	0.37	0.00	0.00	1.45	0.00	1
0.13	1.22	0.00	0.84	0.76	0.00	0.87	0.00	2
1.42	1.34	1.59	1.13	1.72	2.73	1.33	1.00	3
1.59	1.43	1.09	0.54	0.00	0.06	1.55	0.00	4
1.33	1.18	1.34	1.14	1.35	1.19	1.24	2.67	5
1.55	1.26	1.32	1.24	1.43	1.23	1.22	6.67	6
1.14	1.14	0.87	1.22	1.56	1.02	1.25	4.33	7
1.22	1.21	0.93	1.26	1.81	1.18	1.35	6.00	8
1.20	1.23	0.89	0.99	1.02	0.37	1.24	0.00	9
1.18	1.21	0.85	1.18	1.24	0.56	1.33	2.00	10
1.23	1.21	0.00	1.06	1.51	0.16	1.19	5.67	11
1.32	1.33	0.93	0.51	0.37	0.00	1.35	0.00	12
1.22	1.25	1.08	1.41	2.04	0.78	1.59	8.67	13
1.11	1.12	1.10	1.07	1.33	0.58	1.09	3.00	14
1.17	1.55	1.14	1.01	1.11	0.02	1.42	0.00	15
1.16	1.46	1.13	1.18	1.45	0.00	1.27	4.67	16
1.03	1.20	1.24	0.98	1.31	1.20	0.98	4.00	17
1.14	1.16	0.95	1.19	1.41	1.43	1.16	4.67	18
1.11	1.12	0.94	1.21	1.45	1.94	0.28	7.00	19
1.04	1.38	0.82	0.48	0.00	0.00	1.51	0.00	20
0.77	1.13	0.83	0.88	0.79	1.04	1.24	0.00	21
0.86	1.12	0.91	1.04	1.29	1.56	1.19	4.33	22
0.13	1.12	0.00	0.37	0.00	0.00	0.28	0.00	Min
1.59	1.55	1.59	1.41	2.04	2.73	1.59	8.67	Max
1.13	1.27	0.94	0.99	1.12	0.82	1.21	3.06	Av

Table 3: *Comparison of results from this study to previous work in other parts of Egypt existed in literature (range & mean)*

Sohag (Ibrahim and Omer 2004)	**Alexandria-Marsa Matruh Coastal Zone (Elnazer et al. 2015)**	**Current study**	**Parameters**
—	(2.27) 3.15 -1.25	(0.88) 2.60 -0.0	Cd (ppm)
(82.1) 477 -16.3	(38.2) 50.6 -29.2	(15.46) 54.50 -0.0	Pb (ppm)
(21.7) 26.5 -2	—	(21.53) 38.70 -0.0	Co (ppm)
(55.4) 70.6 -29.6	—	(67.81) 96.00 -25.20	Ni (ppm)
(57.0) 95.0 -40.2	—	(56.80) 69.80 -50.30	Cu (ppm)
(96.9) 418.0 -57.0	(43.4) 76.1 -26.6	(90.95) 151.10 -0.00	Zn (ppm)
—	—	(110.78) 143.40 -24.80	Cr (ppm)
—	—	) 1350.00 -111.10 (979.32	Mn (ppm)
3 -1	(0.71) 2.07 -0.03	(1.97) 2.61 -1.16	%OM
6.6 -0.1	(62.4) 90.5 -25.0	(3.69) 7.10 -1.30	CaCO3%
(23.1) 44.0 -4.0	(21.33) 42.4 -4.3	(21.0) 33.0 -8.0	Annual Temp (°C)
(14.4) 33.3 -3.9	(12.61) 32.6 -0.7	8.3.0 -6.9.0	Annual Wind speed (km/h)
0.0	(0.45) 39.12 -0.0	37	Annual Rainfall (mm^3)

Table 4: *PTE content in soil and plant with Transfer factor (TF) in Egyptian delta.*

Component	**Element (mg/kg)**	**Elsokkary, 1978**	**Naggar et al. 2014**
Soil	Cd	0.30	11.82- 12.82
	Pb	11.8	44.20- 79.17
	Zn	64.5	28.50- 52.45
	Cu	—	23.65- 26.80
Plant	Cd	0.22- 0.45	10.03- 12.58
	Pb	6.7- 10.0	55.10- 86.17
	Zn	24.8- 44.5	23.35- 27.37
	Cu	—	9.38- 5.42
Transfer factor (TF)	Cd	0.73- 1.50	0.84- 0.98
	Pb	0.57- 0.85	1.08- 1.24
	Zn	0.38- 0.69	0.52- 0.81
	Cu	—	0.20- 0.39