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Environmental Assessmentof El-Gharbia Main Drain Water

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SAMPLES of water, sediments and aquatic plants were collected from different sites along EL-Gharbia main drain. The sampling processes were carried out seasonally. The collected samples were subjected for a series of analyses, in terms of total and available contents of macro nutrients and potentially toxic elements (PTEs), biological investigation (pathogens contents) and chemical oxygen demand (COD) and biological oxygen demand (BOD). Water samples taken at most of the study sites during the year can be regarded acceptable for agricultural use, but only under particular conditions. On the other hand, these waters are not appropriate for agricultural use from a biological point of view. Enrichment factor (EF) values of the sediments were low for Mn, Zn, Co, B, Co, Cr, Ni and Pb in all seasons and at most sites. Unlike the EF values of the aforementioned PTEs, the enrichment factor for cadmium was generally, high at most sites within the four seasons. EF values of Pb were moderate at most sites. The bioaccumulation factor (BCF) values of the shoot of aquatic plants were generally, high for all elements in all seasons; except for Mn and Pb in summer and winter seasons at some sites, Zn in winter season at some sites, Cu and Ni in all seasons at some sites, and Co in autumn and winter seasons. The BCF values of the roots were high for all the elements in all seasons; except for Cu in the summer and winter seasons at some sites, Zn in the winter season at some sites, and Pb in summer season at some sites. Principal component analysis (PCA) revealed that these metals were originated from natural (Cd, Co, B and Cu) and anthropogenic (Fe, Zn, Mn, Cu, Ni and Cr) sources.

Keywords: Environment, Wastewater,potentially toxic elements, Aquatic plant and Sediment

Introduction

Water is the most important substance for human being and living organisms. In addition, it is a vital golden key to every country's growth (Abdelhafez *et al*. 2020).As a result, one of the primary problems limiting Egypt's sustainability is a shortage of water (Abbas *et al*. 2021).The Nile River is Egypt's most important water resource, accounting for around 80% of the country's water budget (55.5 billion m^3 $year^{-1}$). This fixed water share is insufficient to meet Egyptian demands (Farid et al. 2014); nevertheless, owing to competition for water resources with the upper Nile basin countries, this share is expected to be considerably decreased (Abdelhafez et al. 2021). Therefore, there is actual need to maximize alternative water resource use efficiency, i.e., drainage water, underground water, etc. There are many physical, chemical and biological characteristics that determine the usability of water in various types of applications.Human activities alter land use and land cover; consequently, altering the water balance and in turn, the relative importance of processes that regulate water quality. In addition to the various issues, each human activity has a potential cyclical and cascading effect on water quality and

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quantity along hydrologic pathways (El-Kholy *et al.,* 2015). As a result, existing water resources should be re-evaluated regularly to ensure that they're safe use for food production(Nabwi*et al*., 2018). This might take place while considering several characteristics of water, i.e., pH (Hegazi *et al*., 2019), salinity and sodicity hazars (Abbas *et al*., 2020), Mg-hazards, chloride content (Hegazi *et al*., 2019; Abdelhafez *et al*., 2021), BOD and COD (Farid *et al*., 2019) as well as their contents of potentially toxic elements (Abdelhafez*et al*., 2015; Ali *et al*., 2016; Ibrahim *et al*., 2016; Abbas and Bassouny, 2018; Elshazly *et al*., 2019; Bassouny and Abbas, 2020; Bassouny *et al*., 2020).

The pH is an important variable in determining water quality since it affects many biological and chemical activities in a water body, as well as all processes related to water supply and treatment(Goher *et al.,* 2017). Ghazi (2012) monitored the quality of El-Gharbiamain drains water and he found that EC values increased slightly with northward direction. Also, sodium adsorption ratio (SAR) showed a similar trend of EC values. Gaafer *et al.* (2009) showed that drainage water of Kafr Dokmiss recorded the highest contents of Ca^{++}, Mg^{++}, Na^{+} and K^{+} cations as well as HCO_3^-, Cl^- and $SO_4^{=}$ anionscompared to the corresponding ions of the Nile water and mixed water. The presence of potentially toxic elements (PTEs) in water resources is important factor controlling its application for different applications. For example, elevated concentrations of PTEs in drainage water may hinder its application for agriculture, since these metal ions might be toxic for the growing plants (Abdelhafez et al., 2021). Anter *et al.,* (2012) revealed that PTEs concentrations in drainage water were higher in summer season than in winter season.

The concentrations of Cd, Cr, Ni, Cu, Pb and Zn beside of Fe, Mn and Co are commonly present in very low concentrations in wastewater (Martijin and Huibers 2001). For biological characteristics, the numbers of microbial growth may vary depending on the season and the relative temperature; for example, El-Fadaly *et al.* (2019) observed that the maximum total bacterial count was 4400 $\times 10^3$ CFU /mL in spring, while the lowest value was recorded in autumn. Emara *et al.* (2016) revealed that, total bacterial count showed approximate similarity in between different seasons. Values of total coliform count showed mostly similar pattern in spring and summer with higher values, while in autumn and winter values of the total coliform were lower.

Because of the natural routes of elements in the environment, bottom sediments usually contain some amount of metals. However, the mere existence of heavy metals in sediments does not signify pollution or a hazard to the ecosystem; rather, their enrichment over natural levels does (Olatunde *et al.,* 2014). Moore et al. (2011) found that selected heavy metal concentrations (Cu, Mo, Pb, Zn, and Ni) in sediment exceeded the maximum allowed values. The impact of natural and anthropogenic sources on the degree of heavy metal pollution in the environment has been studied using a variety of geochemical and statistical calculations. Among these methods, contamination factor (CF) as a vital geochemical evaluation method and principal component analysis (PCA) as a stistical evaluation method for environmental contamination with PTEs (Abdelhafez and Li 2014 and 2015; Barbieri, 2016; Goher *et al.* 2017).Most of the wetlands and lakes suffer from the deterioration of water quality and environmental imbalance related to the increasing anthropogenic activities, particularly in developing countries, that may threaten water resource,eco function and human health (Elsayed *et al.*2019).

Therefore, the present study has been under taken to carry out an environmental assessment of El-Gharbia main drain water to determine, to what extent; this water can be reused safely for irrigation purpose.

Materials and Methods

El-Gharbia drain is a drain with a length of 68 kilometers, including 46 kilometers within the Governorate of Kafr El-Sheikh and ends in the Mediterranean Sea (**Fig.1**). Many factories discharge their waste water in this drain, making it a hotbed of toxins.Due to periodic irrigation water shortages, farmers were forced to utilize the water from this drain against their will for irrigation. Furthermore, for a number of villages and centers, including "Bella," "Hamoul," "Sidi Salem," "Baltim," and a portion of "Riyadh," this wastewater became the primary supply of irrigation water.

Water, sediments and aquatic macrophytes plants were sampled from different sites along El-Gharbia drain as shown in Table 1 and Figure 1.

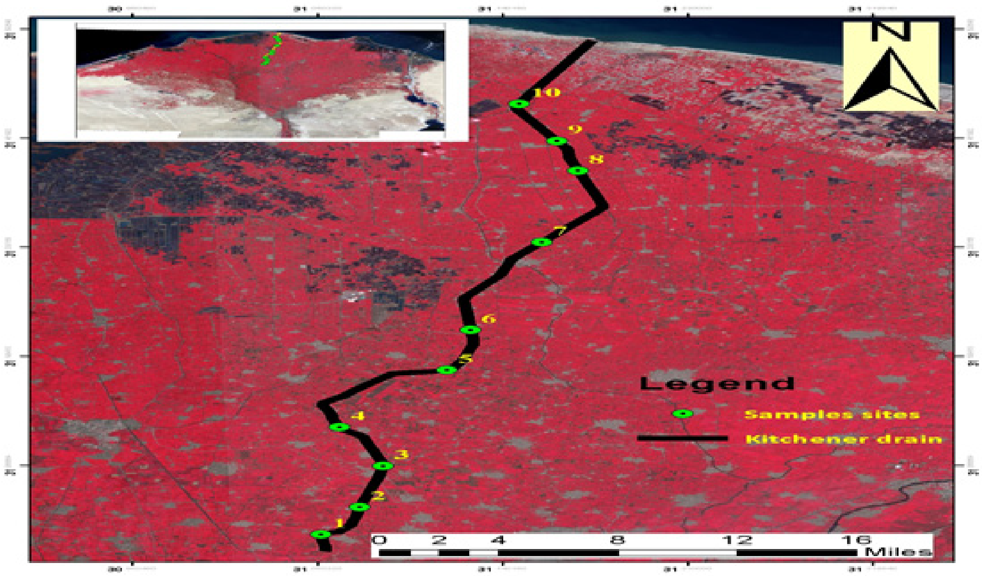

Fig. 1: The study area (El-Gharbiadrain)

TABLE 1. The area of study and its coordination details

Site	Location	
Site 1	Al-Sijaiyyah	31° 3’ 7.088” E, 30° 58’ 59.279” N
Site 2	Izbat Al-Insha	31° 4’ 15.262” E , 31° 0’ 57.910” N
Site 3	Nimrat Al-Basal	31° 4’ 56.258” E , 31° 3’ 56.452” N
Site 4	Kafr Dakhamis	31° 3’ 38.992” E , 31° 6’ 45.202” N
Site 5	Al Karakat	31° 6’ 47.020” E , 31° 10’ 53.090” N
Site 6	Izbat Nile	31° 7’ 28.610” E , 31° 13’ 48.860” N
Site 7	El Hamoul	31° 9’ 33.131” E , 31° 20’ 9.668” N
Site 8	Qaryah No. (7)	31° 10’ 36.717” E , 31° 25’ 21.084” N
Site 9	Qaryah No. (11)	31° 9’ 58.838” E , 31° 27’ 30.539” N
Site 10	Izbat Bahari	31° 8’ 52.829” E , 31° 30’ 11.750” N

Water sampling

Water samples used for irrigation practices were collected from each site in pre-cleaned high-density polyethylene bottles; thereafter, 1mL of concentrated HNO_3 100mL^{-1}was added to each sample to prevent the precipitation of metal ions on the surface of the polypropylene vials (Abdelhafez and Li 2014).A set of the water samples was used for micro nutrients and potentially toxic elements (PTEs) determination and another one was set aside for the chemical analyses of pH, EC, anions and cations according to the method described by Environment Protection Authority (EPA, 2007).A third set of bottles were sterilized and used to collect water samples for the biological tests.The collected water samples were transported to the lab in ice tanks and stored in the refrigerator until they were analyzed.

Sampling of sediments

Superficial sediments were collected from the bottom of the stream at the abovementioned sites along El-Gharbia drain by using a grab sampler. The sediments were sampled twice at each site and packed in two plastic bags, the first for determining total and available macro nutrients as well as PTEs elements (Fe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni, and Pb), and the second for determining biological parameters controlling the suitability of the considered waters for irrigation. Aquatic plants were wet digested using a sulphuric and perchloric acids mixture according to the procedure of Benton and Jones (2001).

Methods of analysis

Electrical conductivity (EC)and pH in water samples were measured by using an EC and pHmeter *WTW Series Cond 720.* Anionsand cations weredetermined according toprocedures ofICARDA (2013).Soluble Fe, Mn,Zn,Cu,B,Cd,Co,Cr, Ni and Pb were determined according to Clesceri*et al.* (2005). TotalFe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni and Pbin sediments samples were digested by aqua regia (hydrochloric acid and nitric acid 3:1)according to the description of Cottenie *et al.* (1982).Elements soluble in water,extracted fromsediments and presented in digestion of aquatic plantswere determined by using Inductively Coupled Plasma (ICP) Spectrometry (Ultima 2 JY Plasma) according to Environmental Protection Agency (EPA, 1991).

Microbiological analysis

Biochemical parameters including parasites, (COD) and (BOD) in watersamples were determined according to the methods described byAPHA (1992). In addition, total coliform;fecal coliform,salmonella and shigella populationsin water and sedimentsamples were determined according to the methods described by APHA (1992).

Enrichment Factor (EF)

EF is calculated by comparing the concentration of a test element with that of a reference element (Liu *et al.,* 2005). In this study, the value of the enrichment factor wascalculated as expressed by Buat-Menard and Chesselet (1979) as follows:

$$\mathbf{EF= ((C_m/(C_{background})/(Fe_m/(Fe_{background}))} \quad \text{Equation (1)}$$

Where,

C_m is the concentrationof the examined element at the study site.

$C_{background}$ is the concentration of the reference element in the study site.

Fe_m is the concentration of the examined element in the control sample.

$Fe_{background}$ is the concentration of the reference element in the control sample.

The background of each study elements was adopted from Faiz et al. (2012) with an average value of Fe 47000, Mn 850, Zn 95, Cu 45, B 100, Co 19, Cd 0.3, Cr 90, Ni 68 and Pb* 23.90*(Expressed as mg kg^{-1}).Iron was used as a reference element because of its high abundance in soil and the fact that it mainly originates in soil from the earth crust (Abdelhafez and Li, 2014). The value obtained from the control sample is used as the reference value (Rashed, 2008).

Bio concentration factor (BCF)

The BCF is calculated according to **Liu *et al.* (2006)** using the following equation:

$$BCF = C\ plant / C\ sediment \quad \text{Equation. (2)}$$

where: - C plantis the concentration of elements in the plant and C sediment is the concentration of the sameelements in the sediment on dry weight basis.

Principal component analysis (PCA)

Since the dataset of investigated PTEs in sediment samples in the spring season revealed higher quantities of PTEs, a principal component analysis with varimax normalized rotation was done using the SPSS 13.0 software for Windows (SPSS Inc., Chicago, IL, USA). The PCA method was used to determine the sources and origins of the metals examined. As indicated by Gracia et al. (2004), factor analysis (FA) was used, and the number of significant principal components (PC) was chosen based on varimax loadings: Varimax

TABLE 2. Different degrees of enrichment factor (EF) for sediments or soil

EF class	Degree of contamination level
EF < 2	Deficiency to mineral enrichment factor (indicates that the predominant source of element is the Earth crust)
EF = 2-5	Moderate enrichment factor (another source rather than the Earth crust such as human activities)
EF = 5-20	Significant enrichment factor
EF = 20-40	Very high enrichment factor
EF > 40	Extremely high enrichment factor

loadings of greater than 0.71 were deemed excellent, and loadings of less than 0.32 were considered bad, and all major factors derived from the variables were kept with eigenvalues < 1.0.

Results and Discussion

Chemical properties of irrigation water inEl-Gharbia drain sites

The chemical properties of the drain water are summarized in Table 3.Data show that the pH values for El-Gharbia drain watervaried between 6.91 to 7.38 in spring season, 6.74 to 7.40 in summer season, 6.08 to 6.97 in autumn season and 7.41 to 8.06 in winter season. The highest values for pH were found at sites 1 in spring season; 10 in summer season; 8 in autumn season and 6 in winter season.On the other hand, the lowest values for pH were found at sites 9, 1, 3 and 10 for spring, summer, autumn and winter seasons, respectively. These pH values are within the normal range reported by Ayers and Westcot (1985),whoindicated that a pH range from 6.5 – 8.4 is suitable for irrigation purpose. As a result, there are no limitations in terms of pH when it comes to using these waters for irrigation. The pH of irrigation water, on the other hand, is not crucial criteria for managing water quality, according to Balkhair and Ashraf (2016), because it is buffered by the soil and most crops can withstand a wide pH range.

One of the most significant indicators for determining the quality of agricultural water is electrical conductivity (EC). The salinity of the soil may be connected to the salinity of the irrigation water, resulting in detrimental effects on plant growth, agricultural product type, and quantity. The values of EC along El-Gharbia drain are presented in Table (2), which reveals that the EC values of the drain water differed along the water stream from a site to another and from a season to another. The lowest values of EC were 0.68, 0.87, 0.54 and 0.67 dS m^{-1}in spring, summer, autumn and winter seasons, respectively while the corresponding highest ones were 1, 96, 2.24, 2.20 and 1.98 dS m^{-1} for the same respective seasons. The lowest EC values were found at site No. 3 in all seasons, whereas the highest EC values were found at site No. 10 in all seasons. The degree of restriction on the reuse of El-Gharbia drain water for irrigation, according to Ayers and Westcot (1985), was,generally, slight to restricted; except for the water of site No.3 in spring, summer, autumn, and winter, which was suitable for irrigation.

The concentrations of the examined cations in El-Gharbia drain water are shown in Table 3. The results show that Na+ is the most abundant cation at all of the examined sites along the drain and throughout the year, followed by Ca^{2+} and Mg^{2+}, with K^+ being the least abundance. The soluble anions, on the other hand, can be arranged in all seasons (spring, summer, and autumn) descending by the following order: $HCO_3^- > SO_4^{2-} > Cl^-$, whereas only in winter the order changed and followed the sequence $HCO_3^- > Cl^- > SO_4^{2-}$, with the exception of two sites (6 and 10) where the sequence was $HCO_3^- > SO_4^{2-} > Cl^-$. Most of the water samples under investigation, according to Ayers and Westcot (1985), are likely to present growing issues when used for irrigation. As a result, using such waters for irrigation should be done under particular circumstances, such as implementing the leaching requirements based on the EC of the soil, the type of plant to be grown, and the season of the year. SAR values ranged from 2.98 to 4.45 in spring season, 2.91 to 4.52 in summer season, 2.56 to 4.96 in autumn season and 1.78 to 5.31 in winter season. According to Ayers and Westcot (1985), the studied water at the various sites is not predicted to produce sodicity problems when used for irrigation purposes. The aforementioned finding is confirmed by the values of Mg ratio presented in Table 2 and the corresponding ones of residual sodium carbonate at the same table, wherethe Mg ratio did not exceed 50 % and RSC were negative, indicating that no sodicity is expected.

Soluble PTEs in water ofEl-Gharbia drain

Table 4 shows the PTEs values at study sites during various seasons of the year. The average values of solubleFe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni and Pb are (0.03, 0.15, 0.28, 0.00, 0.01, 0.00, 0.00, 0.03, 0.00 and 0.00 in spring season corresponding to 0.26, 0.11, 0.01, 0.00, 0.02, 0.00, 0.00, 0.00, 0.00 and 0.26 in the Summer season,0.10, 0.09, 0.00, 0.00, 0.19, 0.00, 0.00, 0.06, 0.12 and 0.10 in theAutumn seasonand 0.09, 0.02, 0.13, 0.02, 0.08, 0.00, 0.00, 0.00, 0.00 and 0.04mg L^{-1}in the winter season. The measured values of these PTEs are, generally,below the permissible limits according to Pratt (1972) and WHO (1992).But,sites No.1,4 and 9 for Mn in spring season, sites No.2 and 10 for Mn and site No.1 for B in summer season, site No.9 for Mn and sites No.4 and 8 for B in autumn season and site No.9 for Mn and site No.3 for B in winter season showed values exceeded the permissible values.

TABLE 3. Chemical composition of El-Gharbia drain waterat the different sites within the year seasons

Season	Site No.	pH	EC dS m^{-1}	Anions (mmolcL^{-1}) CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Cations(mmolc L^{-1}) Ca^{++}	Mg^{++}	Na^+	K^+	SAR	RSC	Mg Ratio
Spring	Site 1	7.38	1.54	N.d.	0.50	8.50	6.37	4.50	2.50	8.05	0.32	4.30	-6.50	35.71
	Site 2	7.26	1.40	N.d.	0.50	8.50	4.98	3.50	2.50	7.70	0.28	4.45	-5.50	41.66
	Site 3	7.29	0.68	N.d.	0.50	4.50	1.79	2.00	1.00	3.65	0.14	2.98	-2.50	33.33
	Site 4	7.04	1.32	N.d.	0.50	8.50	4.18	3.50	2.50	6.90	0.28	3.98	-5.50	41.66
	Site 5	7.04	1.44	N.d.	1.00	8.50	4.87	4.50	2.50	7.05	0.32	3.77	-6.00	35.71
	Site 6	6.96	1.76	N.d.	1.00	9.50	7.06	5.50	3.50	8.20	0.36	3.87	-8.00	38.88
	Site 7	7.26	1.56	N.d.	1.00	9.50	5.07	4.50	2.50	8.25	0.32	4.41	-6.00	35.71
	Site 8	7.09	1.70	N.d.	1.50	10.00	8.08	6.50	3.50	9.10	0.48	4.07	-8.50	35.00
	Site 9	6.91	1.64	N.d.	1.50	8.50	6.36	5.50	2.50	8.00	0.36	4.00	-6.50	31.25
	Site 10	6.95	1.96	N.d.	0.50	10.50	5.79	5.50	2.50	8.75	0.22	4.38	-7.50	31.25
Min		6.91	0.68	N.d.	0.50	4.50	1.79	2.00	1.00	3.65	0.14	2.98	-	31.25
Max		7.38	1.96	N.d.	1.50	10.50	8.08	6.50	3.50	9.10	0.48	4.45	-	41.67
Average		7.12	1.50	N.d.	0.85	8.65	5.46	4.55	2.55	7.57	0.31	4.02	-	36.02
Summer	Site 1	6.74	1.21	N.d.	0.50	7.50	4.07	3.50	2.50	5.65	0.42	3.26	-5.50	41.66
	Site 2	7.07	1.27	N.d.	0.50	8.50	3.68	3.50	2.50	6.20	0.48	3.59	-5.50	41.66
	Site 3	7.30	0.87	N.d.	0.50	9.50	3.55	3.50	2.50	7.25	0.30	4.19	-5.50	41.66
	Site 4	7.40	1.28	N.d.	0.50	8.50	3.78	3.50	2.50	6.30	0.48	3.46	-5.50	41.66
	Site 5	7.36	1.16	N.d.	1.00	7.00	3.58	3.50	2.50	5.10	0.48	2.94	-5.00	41.66
	Site 6	7.35	1.36	N.d.	0.50	5.00	3.17	2.50	1.75	4.25	0.20	2.91	-3.75	41.17
	Site 7	7.32	1.30	N.d.	0.50	7.50	4.96	3.50	2.50	6.75	0.28	3.90	-5.50	41.66
	Site 8	7.35	1.66	N.d.	0.50	9.50	6.57	4.50	3.50	8.25	0.32	4.13	-7.50	43.75
	Site 9	7.39	1.73	N.d.	1.00	9.50	6.78	5.50	3.50	7.80	0.48	3.68	-8.00	38.88
	Site 10	7.40	2.24	N.d.	1.00	14.50	6.85	6.50	4.50	10.60	0.75	4.52	-10.00	40.90
Min		6.74	0.87	N.d.	0.50	5.00	3.17	2.50	1.75	4.25	0.20	2.91	-	38.89
Max		7.40	2.24	N.d.	1.00	14.50	6.85	6.50	4.50	10.60	0.75	4.52	-	43.75
Average		7.27	1.41	N.d.	0.65	8.70	4.70	4.00	2.83	6.82	0.42	3.66	-	41.47
Autumn	Site 1	6.85	1.74	N.d.	0.50	9.50	7.37	4.50	3.50	8.95	0.42	4.48	-7.50	43.75
	Site 2	6.86	1.44	N.d.	0.50	8.50	5.28	4.50	2.50	7.00	0.28	3.74	-6.50	35.71
	Site 3	6.08	0.54	N.d.	0.50	6.50	3.17	3.00	2.50	4.25	0.42	2.56	-5.00	45.45
	Site 4	6.88	1.69	N.d.	1.00	8.50	7.37	5.50	3.50	7.40	0.47	3.49	-8.00	38.88
	Site 5	6.95	1.73	N.d.	1.00	9.50	6.78	5.50	3.50	7.80	0.48	3.68	-8.00	38.88
	Site 6	6.93	2.16	N.d.	1.00	13.50	7.08	6.50	3.50	11.10	0.48	4.96	-9.00	35.00
	Site 7	6.91	2.20	N.d.	1.00	12.50	8.48	6.50	4.50	10.50	0.48	4.47	-10.00	40.90
	Site 8	6.97	1.66	N.d.	1.00	9.50	6.06	4.50	3.50	8.10	0.46	4.05	-7.00	43.75
	Site 9	6.53	1.84	N.d.	1.00	10.50	6.88	5.50	3.50	8.90	0.48	4.20	-8.00	38.88
	Site 10	6.49	1.76	N.d.	1.00	10.50	6.07	5.50	4.50	7.35	0.22	3.28	-9.00	45.00
Min		6.08	0.54	N.d.	0.50	6.50	3.17	3.00	2.50	4.25	0.22	2.56	-	35.00
Max		6.97	2.20	N.d.	1.00	13.50	8.48	6.50	4.50	11.10	0.48	4.96	-	45.45
Average		6.75	1.68	N.d.	0.85	9.90	6.45	5.15	3.50	8.14	0.42	3.89	-	40.62
Winter	Site 1	7.98	1.47	N.d.	2.45	5.76	6.73	4.23	3.83	6.40	0.50	3.19	-5.61	47.51
	Site 2	7.97	1.25	N.d.	2.26	4.92	5.23	4.23	2.53	5.22	0.44	2.84	-4.50	37.42
	Site 3	7.85	0.67	N.d.	1.60	2.20	3.45	2.25	2.16	2.65	0.19	1.78	-2.81	48.97
	Site 4	7.94	1.33	N.d.	2.26	4.92	6.38	3.94	3.33	5.83	0.46	3.06	-5.01	45.80
	Site 5	7.98	1.98	N.d.	2.26	9.83	9.32	3.94	5.41	11.49	0.57	5.31	-7.09	57.86
	Site 6	8.05	1.66	N.d.	2.45	7.46	7.16	4.23	4.35	8.00	0.50	3.86	-6.13	50.69
	Site 7	7.92	1.38	N.d.	2.26	5.42	5.63	3.66	3.61	5.65	0.39	2.96	-5.01	49.65
	Site 8	7.60	1.51	N.d.	2.45	5.42	7.09	4.79	3.26	6.40	0.52	3.19	-5.60	40.49
	Site 9	8.06	1.61	N.d.	2.45	6.10	7.59	4.79	3.78	7.00	0.57	3.38	-6.12	44.10
	Site 10	7.41	1.59	N.d.	2.45	6.61	7.04	4.79	3.52	7.20	0.59	3.53	-5.86	42.35
Min		7.41	0.67	N.d.	1.60	2.20	3.45	2.25	2.16	2.65	0.19	1.78	-	37.43
Max		8.06	1.98	N.d.	2.45	9.83	9.32	4.79	5.41	11.49	0.59	5.31	-	57.86
Average		7.88	1.45	N.d.	2.29	5.86	6.56	4.09	3.58	6.58	0.47	3.31	-	46.49
Guidelines		6.5-8.40[a]	0.7-3.0[a]	-	1.5-8.5[a]	4.0-10[a]	-	-	-	3.0-9.0[a]	-	10-18[b]	-	-

(Ayers and Westcot 1985) b- Mostara and Roy (2008). *N.d. Not Detected

TABLE 4. Soluble contents of the PTEs in El-Gharbia drain water at different sites

Season	Site No.	mgL^{-1}									
		Fe	**Mn**	**Zn**	**Cu**	**B**	**Cd**	**Co**	**Cr**	**Ni**	**Pb**
Spring	Site 1	0.03	0.30	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 2	0.02	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 3	0.02	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 4	0.03	1.00	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 5	N.d	0.02	1.06	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 6	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 7	0.02	N.d	0.91	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 8	0.03	0.00	N.d	N.d	0.02	N.d	N.d	N.d	N.d	N.d
	Site 9	0.09	0.20	N.d	N.d	0.04	N.d	N.d	N.d	N.d	N.d
	Site 10	0.05	N.d	0.79	N.d	0.08	N.d	N.d	0.27	N.d	0.02
	Min.	0.02	N.d	0.79	N.d	0.02	N.d	N.d	0.27	N.d	0.02
	Max.	0.09	1.00	1.06	N.d	0.08	N.d	N.d	0.27	N.d	0.02
	Average	0.04	0.30	0.92	N.d	0.05	N.d	N.d	0.27	N.d	0.02
Summer	Site 1	1.21	0.04	0.07	N.d	0.10	N.d	N.d	N.d	N.d	N.d
	Site 2	0.04	0.40	0.01	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 3	0.09	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	0.60
	Site 4	0.11	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	0.30
	Site 5	0.24	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	0.01
	Site 6	0.01	N.d	N.d	N.d	0.02	N.d	N.d	N.d	N.d	0.80
	Site 7	0.28	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	0.01
	Site 8	0.04	0.20	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 9	0.17	0.15	N.d	N.d	0.03	N.d	N.d	N.d	N.d	0.02
	Site 10	0.37	0.28	N.d	N.d	0.03	N.d	N.d	N.d	N.d	0.90
	Min.	0.01	0.04	0.01	N.d	0.02	N.d	N.d	N.d	N.d	0.01
	Max.	1.21	0.40	0.07	N.d	0.10	N.d	N.d	N.d	N.d	0.90
	Average	0.26	0.21	0.04	N.d	0.04	N.d	N.d	N.d	N.d	0.38
Autumn	Site 1	0.05	0.14	N.d	N.d	0.02	N.d	N.d	N.d	0.40	N.d
	Site 2	0.04	0.07	N.d	N.d	N.d	N.d	N.d	N.d	0.40	N.d
	Site 3	0.04	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d	N.d
	Site 4	0.08	0.06	N.d	N.d	1.00	N.d	N.d	N.d	N.d	N.d
	Site 5	0.21	0.12	N.d	N.d	0.01	N.d	N.d	N.d	0.10	N.d
	Site 6	0.03	0.03	N.d	N.d	0.04	N.d	N.d	N.d	0.02	N.d
	Site 7	0.07	0.00	N.d	N.d	0.03	N.d	N.d	0.60	0.01	1.00
	Site 8	0.06	0.12	N.d	N.d	0.70	N.d	N.d	N.d	N.d	N.d
	Site 9	0.34	0.25	N.d	N.d	0.03	N.d	N.d	N.d	0.10	N.d
	Site 10	0.11	0.16	N.d	N.d	0.03	N.d	N.d	N.d	0.20	N.d
	Min.	0.03	N.d	N.d	N.d	0.01	N.d	N.d	0.60	0.01	1.00
	Max.	0.34	0.25	N.d	N.d	1.00	N.d	N.d	0.60	0.40	1.00
	Average	0.10	0.10	N.d	N.d	0.23	N.d	N.d	0.60	0.18	1.00
Winter	Site 1	0.18	N.d	0.03	0.06	0.06	N.d	N.d	N.d	N.d	0.40
	Site 2	N.d	N.d	0.02	N.d	0.04	N.d	N.d	N.d	N.d	N.d
	Site 3	N.d	N.d	0.02	0.15	0.40	N.d	N.d	N.d	N.d	N.d
	Site 4	N.d	N.d	0.93	N.d	0.04	N.d	N.d	N.d	N.d	N.d
	Site 5	0.15	N.d	0.03	N.d	0.05	N.d	N.d	N.d	N.d	N.d
	Site 6	N.d	N.d	0.04	N.d	0.05	N.d	N.d	N.d	N.d	N.d
	Site 7	0.10	0.02	0.15	N.d	0.02	N.d	N.d	N.d	N.d	N.d
	Site 8	N.d	N.d	N.d	N.d	0.05	N.d	N.d	N.d	N.d	N.d
	Site 9	0.20	0.23	0.02	N.d	0.06	N.d	N.d	N.d	N.d	N.d
	Site 10	0.25	N.d	0.12	N.d	0.07	N.d	N.d	N.d	N.d	N.d
	Min.	N.d	0.02	0.02	N.d	0.02	N.d	N.d	N.d	N.d	0.40
	Max.	0.25	0.23	0.93	0.15	0.40	N.d	N.d	N.d	N.d	0.40
	Average	0.18	0.12	0.15	0.10	0.08	N.d	N.d	N.d	N.d	0.40
Guidelines FAO (1985)		5	0.2	2	0.2	0.7	0.01	-	0.1	0.2	5

Chemical and biological parameters

The values of COD and BOD in El-Gharbia drain water along the different sites are presented in Table 5. These values showed high levels of both the parameters ranging from 220.77 to 970.25 mg L^{-1} , and76.33 to 312.2 mg L^{-1} respectively in the spring season,225.2 to 990.11 mg L^{-1},and89.93 to 410.13 mg L^{-1},respectively in the summer season,215.88 to 889.22 mg L^{-1} and, 61.19 to 323.15 mg L^{-1} irrespectively in the autumn season corresponding to198.34 to 720.11 mg L^{-1}and56.77 to 250.51 mg L^{-1},respectively in the winter season . According to Alberta (2000), the values generally exceeded the maximum limits of water for agricultural reuse (unrestricted crop) in Egypt, with the exception of sites No. 5, 6, 7, 8, 9 and 10 for BOD in the spring season, sites No. 1 and 2 for BOD in the summer season, and sites 1, 2, 3, 8, 9 and 10 for BOD in the autumn and winter seasons. The increase in pollutant loading is mostly attributable to untreated water spilling into the water supply as a result of increased home drainage down the drain stream. Generally, the descending order for COD and BOD within the seasons of the year wassummer >spring >autumn >winter. This might be related to the high temperatures experienced throughout the summer, which promote microbial activity. Shankhwar*et al.* (2015) observed that, the annual average organic pollutant loadis highest in the summer season.

Water coliforms, both total and fecal, are perhaps the most commonly utilized bacterial bio indicator, both in the past and currently. Coliforms can be studied as a group for water pollution detection or as fecal coliforms, with E. coli being the most commonly utilized species for this purpose. This is because an enteric coliform comes near to matching the overall characteristics necessary for a bio indicator of water pollution. As a result, the most commonly used bacteriological criteria to define water pollution are a certain concentration of total coliforms or/and fecal coliforms, both of which vary depending on the country and the purpose of water use, such as potable water, swimming pool water, irrigation water, aquaculture, and so on (Said 1996). As shown in Table 4 total coliforms and fecal coliforms counts exhibit a similar pattern, with total coliforms having higher values than fecal coliforms.Both ofthese bio-indicators showed values exceeding the permissible limits according to FAO (1992) and WHO (1992).According to FAO (1992), Salmonellae and Shigella bacteria count values were higher than the permissible limits at sites (2 and 3) in Spring, (2, 3, 4, 5, 6) in Summer, (2 and 5) in Autumn and (5,6 and 10) in winter season,; however, these bacteria were not detected in water along the rest of El-Gharbia drain water sites.

Totalcontents of the PTEs insediments ofEl-Gharbia drain sites

Sediments are important sinks for different pollutants such as PTEs, and they also play a key role in the immobilization of pollutants in aquatic systems under favorable conditions, as well as in water-sediment interactions (Abbas *et al.,* 2014).Data presented in Table 6 show the total concentrations of Fe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni and Pb in sediments ofEl-Gharbia drain at different sites within the different seasons. The average concentrations of tested elements during study seasons varied from 41626.6 to 76135.5 mg kg^{-1} for Fe, 875 to 1657.9 mg kg^{-1} for Mn, 64.6 to 486.9 mg kg^{-1} for Zn, 32.4 to 155.5 mg kg^{-1} for Cu, 29.9 to 138.25 mg kg^{-1} for B, 1.7 to 54.76 mg kg^{-1} for Cd, 17.5 to 57.91 mg kg^{-1} for Co, 5.3 to 776.8 mg kg-1 for Cr, 41.7 to 297.35 mg kg^{-1} for Ni and 1.8 to 224 mg kg^{-1} for Pb. Clearly, the level of PTEs at the study sites exceeded the maximum allowable limits of EPA (2007).

Enrichment factor (EF) of the PTEs in sediments

Calculating a normalized enrichment factor (EF) for element concentrations over natural background levels was a typical method for estimating the anthropogenic influence on soil pollution. Table 7 shows the EF values of PTEs in sediments at several locations along El-Gharbia drain. EF values varied between 0.1 and 2 may be considered natural variability, but ratios higher than 2 suggest considerable enrichment with PTEs, owing mostly to human inputs. Clearly, Mn, Zn, Cu, B, Co, Cr, and Ni had low EF values at most of the sites throughout the year, with the exception of Mn and Co, which had moderate EF values at site No. 10 in the Autumn and Spring seasons. EF values for Cu were moderate at site No. 7 in the Summer season, and sites No. 7 and 10 in the Autumn season. In the Spring season, all sites except site No. 10 had exceptionally high EF values of Cd, sites No. 5 and 6 had extremely high EF values in Autumn season; and in the Winter season, sites No. 1, 2, 6, 7, and 8 had extremely high EF values. EF values of Cd were quite high at sites 3 and 9. In the Summer, EF values for Ni were moderate at sites No. 4 and 5; sites No. 2, 3, 9, and 10 in Autumn season; and in the winter,

TABLE 5. COD, BOD,total coliforms,fecalcoliforms; Salmonella and Shingella counts of El-Gharbia drain water. Alberta (2000) b- FAO (1992).

Site No.	Spring					Summer				
	COD	BOD	Total Coliforms	Fecal Coliforms	Salmonella & Shigella	COD	BOD	Total Coliforms	Fecal	Salmonella & Shigella
Site 1	931.11	312.2	90×10^5	12×10^5	Not detected	261.15	89.93	52×10^5	15×10^5	Not detected
Site 2	970.25	309.11	220×10^5	25×10^5	15×10^3	254.13	99.16	96×10^5	31×10^5	2×10^3
Site 3	425.33	130.75	281×10^5	98×10^5	40×10^3	225.2	105.22	83×10^5	17×10^5	3×10^3
Site 4	310.16	119.17	60×10^5	18×10^5	Not detected	985.3	360.79	110×10^5	22×10^5	5×10^3
Site 5	280.14	97.13	30×10^5	11×10^5	Not detected	981.12	386.61	230×10^5	145×10^5	50×10^3
Site 6	225.1	88.11	35×10^5	13×10^5	Not detected	990.11	410.13	220×10^5	170×10^5	11×10^3
Site 7	243.91	95.81	71×10^5	19×10^5	Not detected	550.19	123.18	95×10^5	30×10^5	Not detected
Site 8	241.83	90.75	20×10^5	8×10^5	Not detected	330.22	110.24	80×10^5	19×10^5	Not detected
Site 9	235.33	93.86	68×10^5	20×10^5	Not detected	281.55	119.11	105×10^5	22×10^5	Not detected
Site 10	220.77	76.33	51×10^5	11×10^5	Not detected	230.13	122.3	90×10^5	20×10^5	3×10^3
Site No.	Autumn					Winter				
Site 1	233.41	71.11	15×10^5	5×10^5	Not detected	203.66	58.81	12×10^5	3×10^5	Not detected
Site 2	231.52	67.33	51×10^5	19×10^5	2×10^3	218.22	63.31	37×10^5	14×10^5	Not detected
Site 3	215.88	61.19	31×10^5	6×10^5	Not detected	205.11	66.63	20×10^5	4×10^5	Not detected
Site 4	889.22	312.65	82×10^5	15×10^5	Not detected	690.13	235.44	60×10^5	13×10^5	Not detected
Site 5	871.11	323.15	180×10^5	21×10^5	3×10^3	720.11	250.51	150×10^5	18×10^5	2×10^3
Site 6	401.21	141.23	140×10^5	14×10^5	Not detected	395.56	170.46	110×10^5	15×10^5	1×10^3
Site 7	295.31	300.11	43×10^5	12×10^5	Not detected	275.8	95.22	33×10^5	9×10^5	Not detected
Site 8	235.31	73.82	45×10^5	14×10^5	Not detected	255.13	88.3	17×10^5	5×10^5	Not detected
Site 9	220.2	89.71	18×10^5	9×10^5	Not detected	198.34	72.29	15×10^5	8×10^5	Not detected
Site 10	275.19	95.66	21×10^5	7×10^5	Not detected	211.35	56.77	31×10^5	18×10^5	1×10^3
Guidelines	150[a]	100[a]	-	< 60[b]	< 60[b]	150[a]	100[a]	-	< 60[b]	< 60[b]

TABLE 6. Potential toxic elements (PTEs)contents in El-Gharbia drain's sedimentsites

Seasons	Sites No.	mg kg^{-1} Fe	Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
Spring season	Site 1	47791.0	940.7	71.90	47.80	51.60	2.30	25.00	76.40	66.10	50.10
	Site 2	48662.3	857.0	78.30	47.60	47.20	2.40	25.00	93.50	65.90	52.30
	Site 3	53591.4	943.9	92.80	64.60	44.50	2.70	28.10	75.80	60.30	43.90
	Site 4	45023.1	1035.0	95.00	63.00	45.60	3.70	32.40	74.10	65.30	63.20
	Site 5	75214.9	1513.1	110.95	78.30	76.30	3.60	36.55	143.55	121.50	96.95
	Site 6	56030.0	1183.5	78.10	61.80	52.00	3.00	27.50	134.30	110.80	93.70
	Site 7	49257.2	1142.6	104.10	64.40	55.60	2.50	23.20	178.10	117.90	102.40
	Site 8	66310.9	1422.6	95.90	78.80	73.15	4.20	43.50	108.50	79.10	69.60
	Site 9	76135.5	1571.1	109.20	103.90	72.05	3.80	38.60	143.80	107.80	85.40
	Site 10	46957.7	917.5	98.40	120.33	109.72	54.76	57.91	81.70	65.70	69.84
	Min.	45023.1	857.0	71.90	47.60	44.50	2.30	23.20	74.10	60.30	43.90
	Max.	76135.5	1571.1	110.95	120.33	109.72	54.76	57.91	178.10	121.50	102.40
	Average	56497.4	1152.7	93.47	73.05	62.77	8.30	33.78	110.98	86.04	72.74
Summer season	Site 1	42575.6	775.2	73.10	74.80	55.10	2.40	22.20	719.20	123.10	114.80
	Site 2	44374.1	946.6	84.00	59.00	36.50	2.40	22.70	557.50	62.50	51.50
	Site 3	42895.6	877.7	64.60	73.00	34.50	2.20	21.50	147.40	51.40	36.70
	Site 4	51322.9	849.4	80.70	51.30	50.70	2.60	25.00	365.00	236.60	224.00
	Site 5	48363.8	981.7	70.80	49.90	55.20	2.00	24.90	279.30	172.70	158.80
	Site 6	46872.6	961.3	68.80	57.60	45.00	3.30	23.00	776.80	103.00	93.30
	Site 7	46488.8	893.5	486.90	135.20	43.00	3.10	22.20	174.50	53.40	38.60
	Site 8	51315.1	949.0	143.40	60.40	54.20	1.90	23.90	763.30	84.00	69.80
	Site 9	44445.2	901.1	86.30	65.00	35.70	2.50	24.20	116.30	60.30	59.30
	Site 10	41626.6	936.7	119.70	62.00	29.90	1.70	20.60	91.90	41.70	30.30
	Min.	41626.6	775.2	64.60	49.90	29.90	1.70	20.60	91.90	41.70	30.30
	Max.	51322.9	981.7	486.90	135.20	55.20	3.30	25.00	776.80	236.60	224.00
	Average	46028.0	907.2	127.83	68.82	43.98	2.41	23.02	399.12	98.87	87.71
Autumn season	Site 1	67108.3	1269.9	139.25	108.80	62.05	3.15	32.40	93.50	80.15	98.60
	Site 2	69030.7	1657.9	148.40	79.25	70.35	4.25	32.25	78.90	297.35	104.95
	Site 3	68105.3	1347.8	132.40	89.20	66.45	3.50	28.45	80.15	202.75	70.85
	Site 4	75586.4	1366.0	177.70	79.15	97.05	3.23	34.40	143.55	133.55	86.60
	Site 5	72234.8	1409.9	176.05	80.75	86.30	27.38	21.30	134.30	109.55	70.24
	Site 6	71673.3	1644.4	117.75	80.30	71.35	29.30	23.00	178.10	130.13	112.90
	Site 7	76224.7	1397.8	150.15	155.50	75.20	4.25	23.90	140.40	97.30	115.65
	Site 8	70976.9	1397.9	160.90	83.25	83.75	5.10	21.00	143.80	71.30	52.05
	Site 9	67341.6	1522.1	147.75	86.75	88.20	4.60	24.20	81.70	272.18	37.10
	Site 10	41626.6	1514.1	141.95	90.40	138.25	3.95	25.00	178.10	141.70	224.00
	Min.	41626.6	1269.9	117.75	79.15	62.05	3.15	21.00	78.90	71.30	37.10
	Max.	76224.7	1657.9	177.70	155.50	138.25	29.30	34.40	178.10	297.35	224.00
	Average	67990.8	1452.8	149.23	93.34	83.89	8.87	26.59	125.25	153.60	97.29
Winter season	Site 1	54289.8	989.3	152.10	68.00	48.60	29.18	20.90	38.80	83.90	10.40
	Site 2	50639.5	1422.5	140.20	52.30	44.00	30.65	20.80	56.00	57.50	9.80
	Site 3	45665.2	940.1	79.20	32.40	36.40	6.35	17.50	5.30	51.40	6.90
	Site 4	51080.0	1351.0	201.60	55.70	43.20	6.15	22.00	40.60	80.70	15.50
	Site 5	52290.3	1098.6	188.50	73.30	73.70	6.18	22.50	87.00	141.20	15.90
	Site 6	50419.4	1617.7	104.90	47.40	50.80	27.38	20.10	91.60	71.10	5.10
	Site 7	51954.5	1018.6	92.10	51.20	54.10	27.38	20.70	8.70	160.30	5.60
	Site 8	47741.9	902.2	130.00	50.70	71.45	31.65	19.80	17.20	168.70	34.50
	Site 9	51265.4	1241.9	81.70	50.30	70.05	7.41	19.40	39.00	225.10	1.80
	Site 10	59471.7	1154.8	87.10	59.60	105.42	7.40	21.50	57.00	109.30	98.70
	Min.	45665.2	902.2	79.20	32.40	36.40	6.15	17.50	5.30	51.40	1.80
	Max.	59471.7	1617.7	201.60	73.30	105.42	31.65	22.50	91.60	225.10	98.70
	Average	51481.8	1173.7	125.74	54.09	59.77	17.97	20.52	44.12	114.92	20.42
Critical limit (EPA 2007)		> 1.7	> 300	> 90	> 25	-	-	-	> 25	> 20	> 40

EF values for Ni were moderate at sites No. 7, 8, and 9. Values of EF for Pb were low in the Autumn season at sites 5, 8, and 9, but moderate in the Spring, Summer and Winter seasons. EF values were low at site No. 3 throughout the spring season. High EF values for Pb were observed in the Summer at sites No. 1, 4 and 5 and in the Autumn at site No. 10. Based on the contamination factor values, the tested soils were categorized as low and moderately polluted with Fe, Mn, Zn, B, Cu, Co, Cr, and Ni at all of the study sites along El-Gharbia drain throughout the year. Cd contamination ranged from moderate to high at all locations throughout the year. At all sites within the study, Pb was characterized by low to high (EF) values.

Biological characterization of El-Gharbia drainsediments

Table 8 shows total coliform and fecal coliform counts in El-Gharbia drain sediments. The obtained results reveal that total coliform and fecal coliform counts follow a similar pattern, with both exceeding FAO (1992) and WHO permitted limits (1992).The highest values of total coliforms wererecorded at site No.3 in the spring season, sites No. 2 and 3 in the autumn season;and site No. 2 in the winter season. On the other hand, the lowest counts oftotal coliforms wererecorded at site No. 8 in all seasons.In all seasons, the highest fecal coliform levels were found at site No. 3, whereas the lowest comparable fecal coliform values were recorded at site No. 1 in the spring, sites No. 5 and 8 in the summer, site No. 8 in the autumn, and site No. 8 in the winter season.

Only at sites 2 and 3 according to FAO (1992) were Salmonellae and Shigella counts higher than the permissible limits in sediments of all the studied sites along the El-Gharbia drain during the year, while they were not detected at any of the other sites during the year. Bioconcentration factor (BCF) for aquatic plant grown in El-Gharbia drain water.Data presented in Tables9and 10 revealsthat each plant has specified ability to accumulate elements in its tissue.All shoots of theaquatic plants were hyper-accumulator for Fe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni and Pb at all sites within the four seasons except Hyacinth with Cu at sites No. 5 and 8, Reeds with Cu at sites No.2 and 7 and Hyacinth with Ni at sites No. 4 in spring season. Reeds with Mn at sites No. 7 and 10, Hyacinth with Cu at sites No. 1 and 8, Reeds with Cu at sites No. 2 and 10, Reeds with Co at site No. 7, Hyacinth with Ni at sites No. 1, 4, 8 and 9, Hyacinth with Pb at sites No. 1, 4 and 8 and Reeds with Pb at sites No. 2 and 5 in summer season. Reeds with Cu and Ni at site No. 7, Hyacinth with Co at site No. 2 and Reeds with Co at sites No. 1 and 4 in autumn season. Reeds with Mn, Co and Ni at sites No. 6, 3 and 4 respectively, Hyacinth with Zn at sites No. 7, 9 and 10, Reeds with Zn at sites No.1, 2, 4, 5 and 8, Reeds with Cu at sites No.1, 2, 5, 8 and 10 and Hyacinth with Cu and Co at site No. 7 in winter season. All roots of aquatic plants grown in El-Gharbia drain are hyper-accumulators for Fe, Mn, Zn, Cu, B, Cd, Co, Cr, Ni, and Pb at all sites throughout the four seasons, with the exception of Hyacinth for Cu and Pb at site No. 1 during the Summer season and for Zn in Winter season at sites 7 and 10. The ability of aquatic plants for accumulating specific elements might be attributed to one or more of the following reasons: 1- plant absorb heavy metals, translocate them through tonoplast and accumulate in vacuoles, thereby, protecting cell metabolism from metal toxicity (Sekar et al., 2004), 2-binding of the cationic element form to the anionic sites in the cell wall (Zhu, et al., 1999), 3-binding to nonproteinaceous polypeptides (Phyto chelations) and accumulate in the vacuole (Sacchi et al., 1999).

The descending order for PTEs in shoot for Hyacinth plants were B > Cr > Fe >Pb>Zn> Mn > Cd > Co > Ni > Cu for Spring, B > Zn >Fe>Cr>Mn> Cd >Co>Pb>Cu>Ni for Summer, Cr>B> Fe >Pb>Ni>Mn>Co>Zn> Cu >Cd for Autumn and Cr > B > Fe >Pb>Cd>Mn>Ni>Co> Cu>Zn for Winter. The descending order for PTEs in root for Hyacinth plants were Fe >Cr>Zn> B > Co >Mn>Pb>Cd>Ni>Cu, B > Fe >Cr>Zn> Mn > Cd > Pb >Ni>Co> Cu, Cr >Pb> Ni >Fe>B>Co> Mn >Zn> Cu > Cd and Cr > Pb > Ni > Fe > B >Mn>Cd> Co> Cu>Zn for Spring, Summer, Autumn and Winter respectively.

The descending order for PTEs in shoot for Reeds plants were Cr>B>Zn>Fe> Pb >Co> Cd >Mn> Ni > Cu, B > Cr >Zn>Fe>Cd>Co>Ni>Mn>Cu>Pb, B>Cr> Fe > Zn >Mn>Cd>Cu>Ni>Pb> Co and B>Cr> Fe >Pb>Cd>Ni>Mn>Co>Cu>Zn for Spring, Summer, Autumn and Winter respectively. And the descending order for PTEs in root for Reeds plants wereCr>Zn> Fe >B>Co>Pb> Cd >Mn> Ni > Cu. for Spring, B>Cr>Zn>Fe>Cd>Pb>Ni>Co>Mn> Cu. for Summer, Cr>Ni>Pb>Zn>B>Fe> Cd>Mn>Cu> Co, for Autumn and Cr>B> Fe>Pb>Ni>Cd>Mn>Cu>Co>Znfor Winter.

TABLE 7. Enrichment factor (EF) for the PTEs in sediments of El-Gharbia drain sites

season	Sites	Enrichment factor EF								
		Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
Spring	Site 1	1.09	0.74	1.04	0.51	7.54	1.29	0.83	0.96	2.06
	Site 2	0.97	0.80	1.02	0.46	7.73	1.27	1.00	0.94	2.11
	Site 3	0.97	0.86	1.26	0.39	7.89	1.30	0.74	0.78	1.61
	Site 4	1.27	1.04	1.46	0.48	12.87	1.78	0.86	1.00	2.76
	Site 5	1.11	0.73	1.09	0.48	7.50	1.20	1.00	1.12	2.53
	Site 6	1.17	0.69	1.15	0.44	8.39	1.21	1.25	1.37	3.29
	Site 7	1.28	1.05	1.37	0.53	7.95	1.17	1.89	1.65	4.09
	Site 8	1.19	0.72	1.24	0.52	9.92	1.62	0.85	0.82	2.06
	Site 9	1.14	0.71	1.43	0.44	7.82	1.25	0.99	0.98	2.21
	Site 10	1.08	1.27	2.19	1.10	182.70	3.05	0.91	0.97	2.92
Summer	Site 1	1.01	0.87	1.79	0.61	8.83	1.29	1.46	2.00	5.30
	Site 2	1.18	0.94	1.39	0.39	8.47	1.27	1.85	0.97	2.28
	Site 3	1.13	0.84	1.57	0.38	8.04	1.24	1.79	0.83	2.60
	Site 4	0.92	0.78	1.04	0.46	7.94	1.20	1.68	3.19	8.58
	Site 5	1.12	0.72	1.08	0.54	6.48	1.27	1.81	2.47	6.46
	Site 6	1.13	0.73	1.28	0.45	11.03	1.21	1.97	1.52	3.91
	Site 7	1.06	1.99	3.04	0.43	10.45	1.18	1.96	0.79	3.32
	Site 8	1.02	1.38	1.23	0.50	5.80	1.15	1.66	1.13	2.67
	Site 9	1.12	0.96	1.53	0.38	8.81	1.35	1.37	0.94	2.62
	Site 10	1.24	1.42	1.56	0.34	6.40	1.22	1.15	0.69	3.89
Autumn	Site 1	1.05	1.03	1.69	0.43	7.35	1.19	0.73	0.83	2.89
	Site 2	1.33	1.06	1.20	0.48	9.65	1.16	0.60	2.98	2.99
	Site 3	1.09	0.96	1.37	0.46	8.05	1.03	0.61	2.06	2.05
	Site 4	1.00	1.16	1.09	0.60	6.68	1.13	0.99	1.22	2.25
	Site 5	1.08	1.21	1.17	0.56	59.39	0.73	0.97	1.05	1.91
	Site 6	1.27	0.81	1.17	0.47	64.04	0.79	1.30	1.25	3.10
	Site 7	1.01	1.01	2.06	0.46	8.74	0.78	0.96	0.88	2.98
	Site 8	1.09	1.12	1.23	0.55	11.26	0.73	1.06	0.69	1.44
	Site 9	1.25	1.09	1.35	0.62	10.70	0.89	0.63	2.79	1.96
	Site 10	2.01	1.69	2.27	1.56	14.87	1.49	2.23	2.35	5.87
Winter	Site 1	1.01	1.39	1.31	0.42	84.21	0.95	0.37	1.07	3.71
	Site 2	1.55	1.37	1.08	0.41	94.82	1.02	0.58	0.78	2.98
	Site 3	1.14	0.86	0.74	0.37	21.79	0.95	0.58	0.78	2.88
	Site 4	1.46	1.95	1.14	0.40	18.86	1.07	0.42	1.09	4.45
	Site 5	1.16	1.78	1.46	0.66	18.50	1.06	0.87	1.87	2.85
	Site 6	1.77	1.03	0.98	0.47	85.08	0.99	0.95	0.97	2.70
	Site 7	1.08	0.88	1.03	0.49	82.57	0.99	0.29	2.13	2.79
	Site 8	1.04	1.35	1.11	0.70	103.85	1.03	0.41	2.44	3.48
	Site 9	1.34	0.79	1.02	0.64	22.66	0.94	0.40	3.03	2.18
	Site 10	1.07	0.72	1.05	0.83	19.49	0.89	0.50	1.27	3.26

TABLE 8. Biological indicators of El-Gharbia drain sediments at different sites

Site No.	Total Coliforms	Fecal Coliforms	Salmonella & Shigella	Total Coliforms	Fecal Coliforms	Salmonella & Shigella
		Spring season			**Summer season**	
Site 1	123 X 10^5	18 X 10^5	Not detected	129 X 10^5	30 X 10^5	Not detected
Site 2	280 X 10^5	45 X 10^5	25 X 10^3	? 300 X 10^5	50 X 10^5	35 X 10^3
Site 3	> 300 X 10^5	120 X 10^5	53 X 10^3	> 300 X 10^5	170 X 10^5	62 X 10^3
Site 4	83 X 10^5	29 X 10^5	Not detected	92 X 10^5	36 X 10^5	Not detected
Site 5	42 X 10^5	19 X 10^5	Not detected	53 X 10^5	27 X 10^5	Not detected
Site 6	51 X 10^5	22 X 10^5	Not detected	67 X 10^5	31 X 10^5	Not detected
Site 7	113 X 10^5	31 X 10^5	Not detected	163 X 10^5	42 X 10^5	Not detected
Site 8	41 X 10^5	19 X 10^5	Not detected	49 X 10^5	27 X 10^5	Not detected
Site 9	133 X 10^5	40 X 10^5	Not detected	161 X 10^5	55 X 10^5	Not detected
Site 10	92 X 10^5	31 X 10^5	Not detected	110 X 10^5	37 X 10^5	Not detected
		Autumn season			Winter season	
Site 1	97 X 10^5	15 X 10^5	Not detected	71 X 10^5	12 X 10^5	Not detected
Site 2	260 X 10^5	37 X 10^5	19 X 10^3	193 X 10^5	27 X 10^5	9 X 10^3
Site 3	195 X 10^5	93 X 10^5	48 X 10^3	166 X 10^5	63 X 10^5	21 X 10^3
Site 4	54 X 10^5	23 X 10^5	Not detected	47 X 10^5	18 X 10^5	Not detected
Site 5	39 X 10^5	16 X 10^5	Not detected	30 X 10^5	11 X 10^5	Not detected
Site 6	41 X 10^5	23 X 10^5	Not detected	38 X 10^5	16 X 10^5	Not detected
Site 7	77 X 10^5	21 X 10^5	Not detected	61 X 10^5	13 X 10^5	Not detected
Site 8	27 X 10^5	14 X 10^5	Not detected	22 X 10^5	10 X 10^5	Not detected
Site 9	75 X 10^5	28 X 10^5	Not detected	63 X 10^5	19 X 10^5	Not detected
Site 10	58 X 10^5	17 X 10^5	Not detected	49 X 10^5	12 X 10^5	Not detected

TABLE 9. Bio-concentration factor (BCF) for shoot of aquatic plants grown in El-Gharbia drain water at different sites

Seasons	Sites	Name of Plant	Fe	Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
Spring season	Site 1	Reeds	35.20	2.37	13.37	1.11	27.47	10.08	4.50	709.62	1.72	26.31
	Site 2	Reeds	14.69	2.11	41.14	0.47	36.23	6.73	1.33	229.05	1.57	16.24
	Site 3	Hyacinth	28.44	10.77	6.55	1.43	81.38	5.30	10.00	22.11	1.76	14.44
	Site 4	Hyacinth	57.66	14.23	19.01	2.00	84.66	3.04	5.68	8.79	0.25	18.63
	Site 5	Hyacinth	19.69	11.69	10.57	0.69	356.40	7.20	2.55	112.44	6.95	21.04
	Site 6	Reeds	43.12	2.44	19.17	13.55	72.23	6.61	33.85	86.54	3.40	30.24
	Site 7	Reeds	16.00	9.63	34.87	0.76	77.73	6.25	1.66	300.87	2.54	16.11
	Site 8	Hyacinth	59.52	23.33	11.15	0.64	39.10	14.10	4.29	29.29	2.34	15.42
	Site 9	Hyacinth	38.65	3.07	30.94	4.76	45.81	3.20	4.77	123.23	5.31	13.20
	Site 10	Reeds	28.53	12.29	74.05	1.20	280.77	1.82	2.70	81.00	9.29	28.72
Summer season	Site 1	Hyacinth	2.95	9.51	10.33	0.63	176.56	4.66	1.98	5.22	0.99	0.29
	Site 2	Reeds	4.91	1.20	24.26	0.90	131.91	6.65	1.69	1.04	2.84	0.38
	Site 3	Hyacinth	50.66	20.34	10.36	1.27	263.80	10.17	3.69	17.08	3.23	3.67
	Site 4	Hyacinth	10.95	11.07	48.00	4.24	560.26	3.53	2.14	18.12	0.59	0.59
	Site 5	Reeds	24.32	1.97	11.93	1.41	99.04	7.92	3.88	37.68	2.95	0.90
	Site 6	Reeds	10.19	2.36	32.27	1.47	23.58	13.31	13.17	44.44	1.78	1.82
	Site 7	Reeds	2.23	0.55	21.51	1.20	48.15	4.41	0.64	138.89	1.12	1.00
	Site 8	Hyacinth	12.06	3.25	8.79	0.75	320.63	1.57	1.64	40.38	0.39	0.97
	Site 9	Hyacinth	9.40	10.08	11.80	1.77	499.02	6.67	3.56	1.29	0.05	3.80
	Site 10	Reeds	6.35	0.43	14.36	0.49	2247.00	14.56	1.20	29.22	6.34	1.23
Autumn season	Site 1	Reeds	9.42	6.95	32.70	6.22	254.91	3.04	0.81	50.00	2.56	2.05
	Site 2	Hyacinth	16.35	10.38	8.12	3.59	10.13	5.95	0.38	176.39	8.04	8.68
	Site 3	Hyacinth	62.53	27.33	12.35	15.36	226.60	5.41	8.43	933.58	79.23	78.58
	Site 4	Reeds	49.25	4.22	36.55	2.47	95.15	3.44	0.76	7.66	1.34	1.30
	Site 5	Hyacinth	46.28	12.99	8.95	3.56	152.94	6.33	1.46	258.50	3.05	2.92
	Site 6	Hyacinth	30.60	15.13	13.36	13.68	85.90	7.47	38.43	154.89	7.89	8.91
	Site 7	Reeds	12.72	2.62	23.71	0.81	28.46	4.43	1.13	19.65	0.96	1.56
	Site 8	Hyacinth	114.55	23.46	11.61	2.04	28.03	5.19	20.81	124.64	7.36	8.49
	Site 9	Reeds	9.80	1.02	10.84	1.42	25.66	3.78	1.14	92.24	3.71	2.72
	Site 10	Reeds	27.70	8.29	2.67	1.69	94.04	4.36	1.53	93.02	3.13	3.04
Winter season	Site 1	Reeds	5.88	3.19	0.89	0.80	107.98	10.89	1.51	71.73	1.04	7.24
	Site 2	Reeds	12.59	1.23	0.99	0.90	283.94	2.86	1.60	186.83	3.96	7.44
	Site 3	Reeds	41.14	13.01	1.91	2.04	202.60	2.59	0.83	260.98	29.65	44.29
	Site 4	Reeds	23.87	6.39	0.93	1.68	101.56	6.83	2.80	74.81	0.81	3.01
	Site 5	Reeds	20.25	4.58	0.67	0.56	141.22	16.48	3.40	191.39	3.94	8.44
	Site 6	Reeds	16.94	0.70	1.05	1.99	105.77	16.06	2.32	144.31	2.88	8.44
	Site 7	Hyacinth	8.19	1.87	0.51	0.64	55.61	4.64	0.79	189.63	2.69	6.72
	Site 8	Reeds	19.83	3.64	0.92	0.42	189.02	10.28	2.82	95.52	4.31	10.49
	Site 9	Hyacinth	44.20	6.60	0.75	2.32	88.65	8.03	2.40	216.69	3.51	10.34
	Site 10	Hyacinth	12.18	1.16	0.59	0.10	90.65	6.32	1.48	37.49	3.36	7.88

TABLE 10. Bio-concentration factor (BCF) for root of aquatic plants grown in El-Gharbia drain water at different sites

Seasons	Sites	Name of Plant	Fe	Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
Spring season	Site 1	Reeds	56.76	7.97	107.45	1.86	13.76	14.11	12.00	1461.54	2.66	28.31
	Site 2	Reeds	22.55	4.07	68.35	3.50	14.59	28.40	2.83	656.07	9.07	24.68
	Site 3	Hyacinth	36.03	15.35	11.61	2.60	41.49	11.22	64.00	104.04	2.50	15.24
	Site 4	Hyacinth	283.93	52.00	38.33	2.35	36.82	15.11	40.64	36.60	7.21	38.80
	Site 5	Hyacinth	121.68	12.81	19.44	2.52	123.40	22.85	28.36	141.26	14.08	27.05
	Site 6	Reeds	147.17	8.93	45.27	21.45	39.89	18.55	107.29	99.36	11.57	39.97
	Site 7	Reeds	50.78	19.96	67.44	1.67	43.67	11.08	17.98	339.97	4.70	18.10
	Site 8	Hyacinth	195.11	61.01	78.06	12.61	29.62	36.34	11.22	131.79	5.65	21.32
	Site 9	Hyacinth	52.14	4.11	155.84	8.52	26.86	8.20	11.32	159.27	6.06	15.00
	Site 10	Reeds	61.31	15.60	184.57	4.45	92.95	7.27	12.46	106.58	12.41	34.61
Summer season	Site 1	Hyacinth	5.93	10.23	19.94	0.66	101.25	8.42	6.69	6.30	21.87	0.83
	Site 2	Reeds	27.16	3.16	75.43	4.09	50.16	14.70	5.47	4.22	9.69	2.96
	Site 3	Hyacinth	52.23	21.58	19.11	1.56	124.70	17.56	8.22	19.12	6.09	3.67
	Site 4	Hyacinth	61.68	29.49	72.08	7.68	142.31	10.76	6.90	36.96	4.26	4.68
	Site 5	Reeds	59.14	8.40	36.06	4.75	34.19	12.21	6.71	85.51	7.19	3.16
	Site 6	Reeds	68.57	3.14	81.91	4.40	9.63	24.32	19.73	148.61	12.43	13.40
	Site 7	Reeds	25.40	2.57	47.59	3.04	19.92	8.29	2.23	722.22	6.90	5.33
	Site 8	Hyacinth	75.78	9.52	16.94	1.75	141.25	13.73	3.02	103.21	3.54	3.18
	Site 9	Hyacinth	64.20	39.46	18.73	5.79	222.05	14.87	7.16	3.91	2.71	47.50
	Site 10	Reeds	11.07	1.65	72.07	2.50	1135.00	36.03	3.15	30.52	13.74	32.33
Autumn season	Site 1	Reeds	56.13	10.86	113.40	12.52	107.59	10.39	2.16	7566.67	173.29	83.98
	Site 2	Hyacinth	40.47	40.37	11.21	29.50	4.48	15.51	2.67	5673.61	119.71	133.16
	Site 3	Hyacinth	70.50	31.43	24.92	16.79	166.70	10.21	27.86	1119.40	126.92	88.09
	Site 4	Reeds	52.07	5.02	154.58	6.68	43.85	12.11	2.82	478.28	61.94	97.75
	Site 5	Hyacinth	61.37	16.61	24.22	4.59	77.50	15.40	4.07	15500.00	91.09	96.83
	Site 6	Hyacinth	116.30	27.93	53.25	33.73	40.64	18.70	69.57	1369.57	33.11	34.20
	Site 7	Reeds	16.36	6.20	74.36	2.32	13.97	8.48	9.11	4860.58	180.32	181.12
	Site 8	Hyacinth	216.90	62.07	31.53	4.32	13.66	21.25	153.23	12881.88	363.86	431.62
	Site 9	Reeds	40.02	2.23	28.96	5.30	11.11	13.21	3.17	4757.76	163.21	178.57
	Site 10	Reeds	33.04	16.26	42.60	2.91	42.55	9.31	3.69	4550.00	82.51	76.93
Winter season	Site 1	Reeds	10.19	7.22	1.93	1.14	25.00	31.89	2.56	687.35	30.31	37.35
	Site 2	Reeds	31.37	3.69	4.70	35.13	133.33	14.76	4.42	1161.71	41.83	38.73
	Site 3	Reeds	44.62	15.35	2.37	14.73	85.48	6.27	2.70	455.08	47.73	49.05
	Site 4	Reeds	122.10	18.52	4.50	5.06	46.72	15.24	5.09	876.92	30.82	25.39
	Site 5	Reeds	83.56	8.70	1.70	2.08	78.06	25.56	6.43	1070.38	42.38	51.58
	Site 6	Reeds	76.93	2.95	1.97	1.69	64.74	26.61	5.01	332.20	13.78	21.85
	Site 7	Hyacinth	35.61	3.85	0.98	1.50	14.18	12.29	6.22	1558.99	79.02	63.48
	Site 8	Reeds	86.44	9.97	1.63	2.70	103.04	19.83	12.07	3293.71	164.27	192.87
	Site 9	Hyacinth	87.56	28.63	1.25	2.91	54.72	13.49	6.63	1171.13	61.19	108.20
	Site 10	Hyacinth	24.95	1.44	0.84	2.03	45.00	2.22	3.72	923.50	42.06	45.88

Principal Component analysis

Figure 2 shows the rotated matrix component with an average total cumulative variance of 83.61 %, two components were identified. Ni, Cr, Mn, Pb, Fe, and Zn dominated component 1, accounting for 48.87 % of the total variances. Component 2 was dominated by Co, B, Cu, and Cd, accounting for 34.74 % of the total variances. These results demonstrate that the studied PTEs were originated from two different sources. We hypothesis that Co, B, Cu and Cd are originated from natural source, i.e., parent rocks, while Ni, Cr, Mn, Pb, Fe and Zn may be originated from anthropogenic source. Abdelhafez and Li (2014) and Abdelhafez et al. (2021) found that unmanaged anthropogenic activities may build up the levels of PTEs in the environment, which are considered a major cause of environmental pollution.

Conclusion

A monitoring study was performed to investigate the contamination level of El-Gharbia Main Drain Water. To attain this aim, water, sediments and aquatic plants were collected from different sites along EL-Gharbia main drain. The sampling processes were carried out seasonally. The collected samples were chemically and biologically evaluated, in terms of total and available contents of potentially toxic elements (PTEs), biological investigation (pathogens contents) and chemical oxygen demand (COD) and biological oxygen demand (BOD) and major pathogens contents. On one hand, the chemical characteristics of the tested water samples indicate that these waters were suitable for agricultural application (irrigation). On the other hand, waters are not appropriate for agricultural use from a biological point of view. PCA analysis revealed that the some of the studied PTEs i.e., Cd,Co, B and Cu were originated from natural sources while Fe, Zn, Mn, Cu, Ni and Cr were originated from anthropogenic sources.

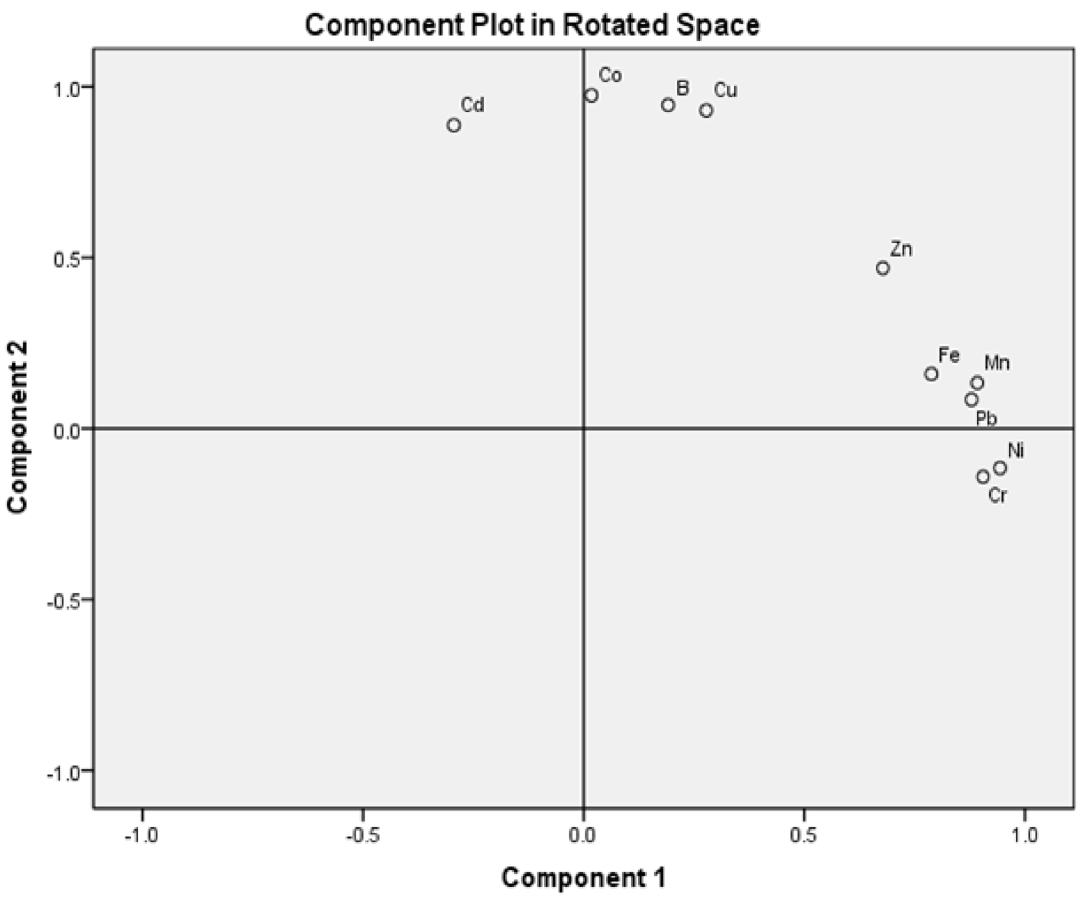

Fig.2. Loading plots of PCA analysis of the studied PTEs in sediment samples

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