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Evaluation of Pollution Indices and Biochemical Properties in Soils Contaminated with Heavy Metals in the Middle Nile region, Egypt

Kamal, Nourhan Nasser[1]; Mahmoud, Esawy[1]; Omara, Alaa El-Dein[2]; El-Sharkawy, Mahmoud[1]

[1] Soil and Water Department, Faculty of Agriculture, Tanta University, Tanta, Egypt.
[2] Agriculture Microbiology Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Sakha, Egypt.

Corresponding author: Kamal, Nourhan Nasser; (nourhan.6694@agr.tanta.edu.eg)

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ABSTRACT

Agricultural soils receive a huge number of pollutants that lead to reduce soil quality and increase soil degradation. The aim of this research is to evaluate pollution indices and biochemical properties in soils contaminated with heavy metals in the Middle Nile region, Egypt. The results indicated that the pollution load index (PLI), and the potential ecological risk index (PER) ranged from 1.67 to 6.15 and 73.61 to 318.74, respectively. Pollution indices for the studied samples were classified as (moderately) to highly pollute. It is noted that there is a positive relationship between the soil contamination degree (CD), the organic matter (OM) ($R^2 = 0.938$), and the total count of microbes (TC) ($R^2 = 0.940$), which indicates the effect of heavy metals on them. It is also noted that there are no significant differences between all the studied sites in dehydrogenises enzymes activity, except for the site located near the source of pollution (Z1). The increased concentration of heavy metals in the studied sites led to a decrease in the microbial biomass (MBC), bacteria, fungi, and actinomycetes in the soil. This study would provide a better understanding of the evaluation of pollution indices in soils contaminated with heavy metals and their impact on biochemical properties. As such, it may help the decision-maker find possible ways to treat the polluted lands to preserve the public health.

1. Introduction

Heavy metal pollution is one of the most dangerous types of pollution because it causes serious health and environmental diseases due to its accumulation, non-degradation and high toxicity **(Aycicek *et al.,* 2008)**. Industrial groups cause many problems, including pollution with heavy metals, especially in the surrounding agricultural soil, and in Egypt there are many of them, such as El-Mahla El-Kobra, Kafr Al-Zayat, Kafr Al-Dawar, Burj El-Arab and others. Industrial wastewater contains many dyes, heavy metals and organic pollutants which pollute water and land used for irrigation **(Aslam *et al.,* 2004)**. Heavy metals in effluents are poorly soluble in water. Their bioaccumulation in crops results in reducing yields and becomes toxic to animals and humans, who feed on them, as they become plants rich in minerals **(Stephenson *et al.*, 1995)**. Heavy metals cause many diseases to humans, such as cancer of the gastrointestinal tract, delayed mental development, fragility of immune mechanisms, malnutrition, and reduced immunity **(Rai *et al*., 2019)**. High levels of cadmium in the soil cause sitai-itai disease **(Mitra *et al.*, 2022)**. Toxic metals such as copper, cadmium, chromium, lead, mercury, selenium, nickel and zinc may accumulate in food crops and pose a threat to the environment and human health **(Vineethkumar *et al.*, 2020)**. Cadmium causes many diseases, such as heart disease, kidney and cerebrovascular diseases **(Bernard, 2008)**. Also, long-term exposures to lead contaminated environments may damage the nerves and kidneys **(Pizzol *et al.*, 2010)**. Soil microorganisms play an important role in the biodegradation of wastes. It also contributes to soil structure and crop growth, increases soil fertility, and controls harmful pathogens **(Dubey *et al.*, 2019)**. Microorganisms are affected by heavy metals in polluted areas, and their number decreases in the soil through biochemical inactivation or direct killing **(David *et al.*, 2016, Igiri *et al.*, 2018)**.

El- Mahla El-Kobra is a densely populated area as it contains many factories for dyeing, textiles and other industries. The waters of these factories are discharged into Zefta drain and drain No. 5. The amount of wastewater discharged from El-Mahla El-Kobra area is about 243500 m^3 day^{-1} (136000 m^3 day^{-1} of industrial wastewater and 107500 m^3 day^{-1} of municipal sewage). This wastewater is discharged into Zefta drain (flow rate, 354240 m^3 day^{-1}) and drain No. 5 (flow rate, 265248 m^3 day^{-1}). Most of the water comes out of the factories without treatment, except 63627 m^3 day^{-1} treated in Dawakhlia plant **(Mahmoud and Ghoneim, 2016)**. The water outside these cities is drained into the surrounding surface drains and used by farmers for irrigation in the absence of surface water **(Hernandez *et al.*, 1999, Qadir *et al.*, 1999)**. **Mahmoud and Ghoneim (2016)** found that the heavy metals of irrigated soils from drains Zifta and No.5 in El-Mahla El-Kobra area exceeded the maximum limit of background heavy metals.

Pollution indicators can be considered as a tool and guide for a complete geochemical evaluation of soil environmental conditions **(Mazurek *et al*., 2017)**. Pollution indicators are of great importance in controlling soil quality and ensuring future sustainability, especially in the case of agricultural ecosystems **(Ripin *et al.*, 2014)**. The indices help in determining the accumulation of heavy metals, whether as a result of natural sources or as a result of anthropogenic activities **(Caeiro *et al.*, 2005)**. They also help in monitoring soil quality and sustainability **(Ripin *et al.*, 2014)**. Pollution indices of soil contamination with heavy metals are divided into two types, individual and integrated pollution index **(Qingjie *et al.*, 2008, Rahman *et al.*, 2012)**. Individual indicator sets, such as Geoaccumulation Index (I_{geo}), Nemerow Pollution Index ($PI_{Nemerow}$) Enrichment Factor (EF), and Contamination Factor (CF), are used for unilateral assessment of soil contamination with heavy metals, as well as knowledge of soil content of heavy metals. Integrated pollution index set, such as Degree of contamination (Cd_{eg}), Pollution Load Index (PLI), Potential ecological risk (PER), Modified degree of contamination (MCD) **(Shafie *et al.*, 2013 and Kowalska *et al.*, 2018)**, is a comprehensive method for assessing soil heavy metals in an area, and it uses total concentrations in the calculation for all the analyzed elements. The current research was designed to assess the heavy metals concentrations of V, Co, Cr, As and Cd in composite samples located near drain No.5 and drain Zefta in

Middle Nile Delta, Egypt to detect soil quality and its ecological risks.

2. Materials and Methods

2.1 Description of the study area

El-Mahla El-Kobra area is located at 30°45' E Longitude and 30°34' N. The soil is classified as a *Vertic Torrifluvents*, and its temperature and moisture regimes are *Thermic* and *Torric*, respectively according to **Elbeih *et al.* (2013)**. In June 2019, forty soil samples, which are 0-20 cm depth, were taken from eight soil sites irrigated with drainage water from drains No.5 and drain Zefta for a period of more than 10 years. Five samples were taken from each site, and heavy metals were estimated in them. The experimental site locations of soil samples are presented in Fig. 1. The soil samples were taken to the laboratory for analysis. The soil samples were air-dried at room temperature (25°C) and sieved through 2 mm screen for chemical analysis.

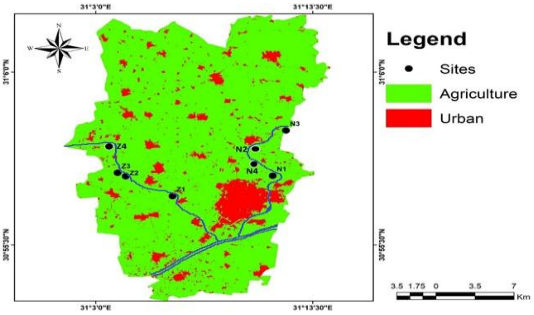

Fig. 1. The experimental site locations of soil samples collected from No. 5 Drain (N) and Zefta Drain (Z)

2.2 Analysis of collected samples

Soil pH was determined in 1:2.5 (soil : water)suspension using pH-meter (Thermo-fisher (HANNA-H12211-02)/USA) and soil electrical conductivity (dS m^{-1}) was recorded using EC-meter (EUTECH-CON2700/USA) in 1:5 (soil : water) suspension, as reported by **Page *et al.* (1982)**. Total carbonate contents were determined volumetrically using Collin's calcimeter and described as percentage of $CaCO_3$ according to **Şenlikçi *et al.* (2015)**.

Total heavy metals in soil samples were measured using ICP Spectroscopy (ICP-ISO Prodigy Plus) after digestion by concentrated H_2SO_4 + H_2O_2 **(Page *et al.*, 1982)**. The target heavy metals were Cd, As, Cr, Co and V, with their specific wavelengths. Soil organic matter (OM) was based on the **Walkley-Black (1934)**.

Chloroform fumigation-extraction method (CFEM) was used to determine soil microbial biomass carbon (MBC) as described by **Ladd and Amato (1989)**.

Dehydrogenase (DHA) activity in soil was measured according to **Tabatabai (1983)**.

2.3 Contamination indices

Different indices are divided according to their purpose into three categories as suggested by **Caeiro *et al.* (2005)**. Namely, background enrichment indices, ecological risk indices and contamination indices. According to **Weissmannová and Pavlovský (2017)**, these indices are commonly classified to two types according to their complexity; these are single indices and composite indices. Single indices are indicators used to assess only one metal contamination,which include contamination factor (C_f^i), and index of geo-accumulation (I_{geo}). The composite indices aim to show the collective influences of several factors and include degree of contamination (DC); modified degree of contamination (mCd); pollution load index (PLI); potential ecological risk index (PERI), and improved Nemerow`s Pollution Index (P_n). The indices used in the present study were selected based on the availability of data and their applications in evaluating the impacts of individual metals and the overall site quality. The standard of pollution levels by different pollution indices are introduced in Table 1.

Table 1.Standards of pollution levels by different pollution indices

Soil Quality	Nil to Very Low contamination	Low contamination	Moderate contamination	Considerable contamination	Very high contamination	Extremely high contamination	Ultra-high contamination	References
C_f^i		$C_f^i < 1$	$1 \le C_f^i \le 3$	$3 \le C_f^i \le 6$	$6 \le C_f^i$			**(Hakanson, 1980)**
CD		$CD < 8$	$8 \le CD \le 16$	$16 \le CD \le 32$	$32 \le CD$			**(Zahran et al., 2015)**
MCD	$MCD < 1.5$	$1.5 \le MCD < 2$	$2 \le MCD < 4$	$4 \le MCD < 8$	$8 \le MCD < 16$	$16 \le MCD < 32$	$MCD > 32$	**(Rahman et al., 2012)**
PLI	$PLI < 1$	$1 < PLI < 2$	$2 < PLI < 3$	$3 < PLI < 4$	$4 < PLI < 5$	$PLI > 5$		**(Jorfi et al., 2017)**
I_{geo}	$I_{geo} \le 0$	$0 < I_{geo} < 1$	$1 < I_{geo} < 2$	$2 < I_{geo} < 3$	$3 < I_{geo} < 4$	$4 < I_{geo} < 5$	$I_{geo} > 5$	**(Gowd et al., 2010)**
PER		$PER \le 50$	$50 < PER \le 100$	$100 < PER \le 150$	$150 < PER \le 200$	$PER > 200$		**(Guan et al., 2014)**
P_n	$0 < P_n \le 0.5$	$0.5 < P_n \le 1$	$1 < P_n \le 2$	$2 < P_n \le 3$	$3 < P_n \le 4$	$4 < P_n \le 5$	$P_n > 5$	**(Saha et al., 2017)**

In each site location of the study area, the contamination factor (C_f^i) is the ratio of the mean concentration of individual metal in soil metal C_{0-1}^i and the reference concentration of individual metal in soil crust C_n^d, according to (**AQCS, 1998)** as indicated in the following equation:

$$Cf = \frac{C_{0-1}^i}{C_n^d} \qquad [1]$$

The contamination degree of the soil (CD) was calculated as the sum of contamination factors C_f^i for all heavy metals, whereas the modified degree of contamination (MCD) represents the average value of pollution indices for all elements ($\boldsymbol{C_f^i}$) as the follows:

$$\mathrm{CD} = \sum_{i=1}^{i=n} CF \qquad [2]$$

$$MCD = \frac{CD}{n} \qquad [3]$$

The geometric average of the impurity coefficients (CF), whichdetermines the contribution of all metals in a given place, is described in indices called pollution load index (PLI). This parameter allows evaluating the level of environmental contamination to undertake monitoring, or to repair activities aimed at improving soil quality. It can be calculated from equation:

$$PLI = (CF1.CF2 \ldots \ldots .CFn)^{\frac{1}{n}} \qquad [4]$$

The index of Geo-accumulation (I_{geo}) enables the assessment of contamination by comparing current contaminated soil (C_n) with the geochemical background value in soil (Bn) as the follows:

$$I_{geo} = Log_2 \frac{\mathrm{Cn}}{1.5\, B_n} \qquad [5]$$

B_n value, stated as ‘‘average shale background value’’ was usually used. However, in this study it is modified to the concentrations of elements in the Earth’s crust. The constant 1.5 allows analyzing natural fluctuations in the content of a given substance in the environment and very small anthropogenic influences.

The Nemerow Pollution Index was applied to allow an integrative evaluation of soil ecosystem quality and was determined for each sampling site as the follows:

$$P_n = \sqrt{\frac{(I_{geomax}^2 + I_{geoave}^2)}{2}} \qquad [6]$$

Where: I_{geomax} is the maximum I_{geo} value, and I_{geoave} is the arithmetic mean value of I_{geo}.

To quantitatively estimate the potential hazards from contaminated soil by heavy metals, the potential ecological risk index (PER) was calculated as the sum of all five heavy metals as the follows:

$$PER = \sum_i^n E_r^i \qquad [7]$$

$$E_r^i = T_r^i * CF \qquad [8]$$

Where E_r^i the potential is ecological risk; T_r^i is the toxic response factor for heavy metal, and C_f^i is the contamination factor as mentioned above. The toxic response factor for V, As, Cd, Cr and Co is 2, 10, 30, 2 and 5, respectively.

2.4 Microbial population counting

1000 gm of each soil sample was heated with 1000 ml of tap water in the autoclave for 30 min. A small amount of calcium carbonate was added, and the soil suspension is filtered through a double filter paper. The turbid filtrate was poured back into the filter until the extract came through clear. 100 ml soil extract was used to count the total microbial population. Soil agar medium **(Allen, 1959)** was used to count the total of bacteria. The composition was as follows: 0.5 gm K_2HPO_4; 1.0 gm glucose; 100 ml soil extract; 900 ml tap water, and 15.0 gm agar. The medium adjusted to pH 6.8-7.0 and sterilized at 121°C for 15 minutes. As for counting the total of fungi, Martin's medium **(Allen, 1959)** was used. The composition was as follows: 10.0 gm Dextrose; 5.0 gm peptone; 1.0 gm KH_2PO_4; 0.5 gm $MgSO_4.7H_2O$; 1 part in 30.000 parts of medium of Rose Bengal; 20 gm agar; 30 ml per 100 ml. cooled medium of Streptomycin solution, and 1000 ml distilled water. The medium was autoclaved at 121°C for 15 minutes. As for Actinomycetes, Jensen's medium was used. It is composed of 2.0 gm dextrose; 0.2 gm casein (dissolved in 10 ml. 0.1 NaOH); 0.5 gm K_2HPO_4, 0.2 gm $MgSO_4.7\ H_2O$; trace of Ferric chloride ($FeCl_3.\ 6\ H_2O$); 15 gm agar, and 1000 ml distilled water. The medium is adjusted to pH 6.5-6.6 and autoclaved at 121°C for 15 minutes **(Allen, 1959)**.

2.5 Statistical analysis

Data were submitted to variance (ANOVA) analysis using PROC GLM of SAS 9.4 (SAS Institute Inc., Cary, NC). Replications and all other variables were considered random and fixed effects, respectively. Means of all variables were isolated using Fisher's protected LSD test at a probability of 5%, according to **Snedecor and Cochran (1980)**.

3. RESULTS

3.1 Some soil properties and heavy metal concentrations of the investigated area

Table 2 describes the soil properties in different soil samples located along drain No. 5 (N) and drain Zefta (Z) in El-Mahla El-Kobra, Egypt. It is noticed that all soil sites are alkaline, with pH varied from 7.38 to 7.73. The salinity of soil sites was significantly differing from 0.47 dS m^{-1} in N3 to 3.10 dS m^{-1} in Z3. It was noticed that soils located near drain No. 5 have more $CaCO_3$ than soils near drain Zefta, as they recorded average values of 5.33% and 3.24%, respectively. Meanwhile, there were significant differences in soil organic matter content and N3 and Z3 recorded the highest percentages with average values of 3.06% and 2.88%, respectively.

Table 2.Some soil characteristics in different soil samples located along No. 5Drain (N) and Zefta Drain (Z)

Samples Sites	pH	EC (dS.cm^{-1})	$CaCO_3$ (%)	OM (%)
N1	7.51±0.06^{ab}	0.62±0.02^{b}	4.20±0.26^{b}	2.65±0.20^{bc}
N2	7.60±0.04^{ab}	1.56±0.03^{ab}	6.95±0.26^{a}	2.99±0.34^{b}
N3	7.73±0.13^{a}	0.47±0.06^{b}	4.06±0.88^{bc}	3.46±0.27^{a}
N4	7.70±0.04^{a}	1.58±0.26^{ab}	6.12±0.60^{a}	2.52±0.47^{c}
Z1	7.60±0.12^{ab}	1.76±0.40^{ab}	4.18±0.55^{b}	2.48±0.17^{c}
Z2	7.58±0.02^{ab}	0.93±0.02^{b}	3.52±0.26^{bc}	2.75±0.17^{bc}
Z3	7.38±0.33^{b}	3.10±2.64^{a}	2.23±0.86^{d}	2.88±0.10^{bc}
Z4	7.55±0.13^{ab}	2.26±2.20^{ab}	3.03±0.17^{cd}	2.85±0.07^{bc}
LSD (0.05)	0.24	0.21	1.13	0.44

The heavy metals concentrations in different location sites represented in Table 3 followed the consecutive ascending order: Cd< As< Cr< Co<V. It was obvious from Table 3 that sites located near drain No. 5 received more V, Co and Cr, with average values of 983.83, 280.77 and 204.55 mg kg^{-1}, respectively. Meanwhile, sites located near drain Zefta was much higher in As and Cd levels, with average values of 88.65 and 56.58 mg kg^{-1}, respectively. The mean concentrations of Cr in both N2 and Z3 sites were under the standard levels set by **(AQCS, 1998)**. The concentrations limits for V, Co, Cr, As and Cd was set according to both **(Alloway, 1990)** and **(Vodyanitskii, 2016)** as the follows: 66, 8.9, 60, 13.4 and 0.26 mg kg^{-1}, respectively.

Table 3. Heavy metals contents (mgkg^{-1}) in different soil samples located along No. 5Drain (N) and Zefta Drain (Z)

Samples sites	V	Co	Cr	As	Cd
N1	4.93± 0.27 ^{d}	3.16±0.26^{e}	3.10±0.08^{a}	20.95± 0.30^{a}	2.16±0.01 ^{d}
N2	18.56± 0.27^{a}	2.18±0.26^{f}	0.68±0.08^{d}	1.38±0.30^{g}	0.35±0.01^{e}
N3	3.80±1.90 ^{de}	7.10±0.05^{b}	3.11±0.23^{a}	8.39±1.17^{d}	2.99±0.30^{c}
N4	13.48± 0.56 ^{b}	5.11±0.41^{c}	3.41±0.08^{a}	12.63± 0.08 ^{c}	2.98±0.21^{c}
Z1	4.80±1.98^{d}	6.81±0.09^{b}	2.06±0.06^{b}	16.63± 0.60^{b}	3.49±0.27^{b}
Z2	7.85±1.86^{c}	7.64±0.12^{a}	1.17±0.74^{c}	5.77±1.07 ^{e}	3.64±0.28^{b}
Z3	2.35±0.07^{e}	4.44±0.21^{d}	0.88±0.04^{cd}	5.74±0.03^{e}	4.75±0.31^{a}
Z4	12.12± 0.35^{b}	3.16±0.04^{e}	2.29±0.01^{b}	3.48±0.03^{f}	3.32±0.40^{bc}
LSD (0.05)	2.08	0.38	0.48	1.08	0.46
CV	14.14	4.4	13.3	6.64	8.94

3.2 Indices of pollution hazards

The contamination factor for the five heavy metals measured in the study area is presented in Table 4. The study locations varied between moderate to very high contamination according to Cf, except in N2 for Cr and Cd, and in Z3 for Cr, whichis considered low contaminated. The sites N2, Z2, N4, N1 and Z3 recorded the highest CF, with V, Co, Cr, As and Cd, respectively.

Table 4. The contamination factor C_f^i for heavy metals content in different soil samples located along No. 5Drain (N) and Zefta Drain (Z)

Samples sites	V	Co	Cr	As	Cd
N1	261.28±14.30^{d}	280.77±4.05^{a}	185.98±4.53^{a}	36.66±3.03^{e}	25.67±0.15^{d}
N2	983.83±2.10^{a}	18.49±15.71^{g}	40.79±13.82^{d}	25.29±0.54^{f}	4.14±3.60^{e}
N3	201.58±29.62^{de}	112.46±1.10^{d}	186.63±4.67^{a}	82.38±4.81^{b}	35.58±2.50^{c}
N4	714.61±4.44^{b}	169.23±8.04^{c}	204.55±3.43^{a}	59.33±1.04^{c}	35.50±3.27^{c}
Z1	254.42±12.67^{d}	222.84±14.39^{b}	123.49±4.90^{b}	78.95±1.42^{b}	41.53±3.36^{b}
Z2	416.23±10.20^{c}	77.33±4.61^{e}	70.30±1.06^{c}	88.653±3.06^{a}	43.29±1.50^{b}
Z3	124.43±3.52^{e}	76.88±0.46^{e}	52.66±2.52^{cd}	51.56±2.42^{d}	56.58±3.63^{a}
Z4	642.61±18.42^{b}	46.67±0.38^{f}	137.56±0.65^{b}	36.63±0.51^{e}	39.52±4.74^{bc}
LSD (0.05)	110.61	14.46	28.90	4.38	5.45

The degrees of contamination (CD) of different location sites are categorized between considerably to very high contaminated. Table 5 illustrates that contamination degree (CD) in three sites, namely, N4, Z1 and N1 are highly contaminated according to CD, with values 37.62, 34.40 and 33.78, respectively.While the other sites are classified as very high contaminated. As for the modified degree of contamination (MCD),which is calculated as the average of contamination degree (CD), it takes the same magnitude as CD, as shown in Table 5. Using the logarithmic conversion of the former data tightens the I_{geo} index compartments down to the range between the minimum and maximum values for a given population of results. Hence, the I_{geo} index makes a variance between a bigger value of different degrees of soil contamination. Table 5 showed the average range of I_{geo} values for different soil sample sites as it ranged from 3.6 to 4.65. The sites Z3 and N2 are classified as very high to extremely high contaminated according to I_{geo}. The highest geo-accumulation index has been noted in N4 site, with value of 4.65. To assess the level of pollution from heavy metals in particular soil sites, the pollution load index (PLI) has been used in Table 5. It has been noted that there were significant differences ($p>0.05$) between different sites in PLI and confined between 1.67 and 6.15. The soils near drain No. 5 in N4 site and soils near drain Zefta in Z1 sites are considered extremely contaminated; according to PLI index which recorded 6.15 and 5.15%, respectively.

To complete the evaluation of soil ecosystem quality, the Nemerow Pollution Index (P_n) was used. Table 5 showed that P_n in all location sites were classified as very high contaminated, except for Z3 location which can be categorized as considerably contaminated. However, to some extent, the evaluation to include integrative ecological risks, potential ecological risk index (PER) has been considered. The ecological risk for all sites in Table 5 are categorized as ultra-high contaminated, except for N2 and Z4 which assorted as moderate to very high contaminated sites, respectively.

Table 5. The pollution indices in samples located along Drain No. 5 (N) and Drain Zifta (Z)

Treatments	CD	MCD	PLI	Pn	PER
N1	**34.40±0.58b**	**6.86±0.12b**	**4.62±0.06bc**	**3.130±0.04d**	306.10±3.53a
N2	**23.15±1.37d**	**4.63±0.27d**	**1.67±0.53f**	**3.53±0.03ab**	73.61±3.53e
N3	**25.40±1.21cd**	**5.08±0.24cd**	**4.62±0.26bc**	**3.22±0.02cd**	222.97±10.07c
N4	**37.62±2.03a**	**7.52±0.41a**	**6.15±0.12a**	**3.63±0.02a**	275.15±0.34b
Z1	**33.78±2.58b**	**6.76±0.52b**	**5.15±0.68b**	**3.52±0.02b**	318.74±12.71a
Z2	**26.08±0.52c**	**5.22±0.10c**	**4.30±0.08cd**	**3.25±0.03c**	223.11±8.02c
Z3	**18.16±0.18e**	**3.63±0.04e**	**3.01±0.03e**	**2.88±0.04e**	228.68±8.04c
Z4	**24.38±0.69cd**	**4.88±0.14cd**	**3.99±0.11d**	**3.18±0.03cd**	179.07±12.45d
LSD (0.05)	**2.39**	**0.48**	**0.57**	**0.10**	14.64

3.3 Effect of soil pollution on soil bio-chemical activity

Table 6 indicated the diversity population counts of micro-organisms including bacteria, fungi and actinomycetes. It has been noticed that the total count of bacteria was high in soils near drain No.5 in N1 site with average values of 7.41 log CFU g^{-1}, whereas the lowest value is recorded for N4 with average value of 6.11 log CFU g^{-1}. The soils near drain Zefta recorded the increase in fungi counts. Z4 registered the highest total fungi count with a percentage of 29.2% more than the lowest site located in N4. The actinomycetes count in Z4 increased to reach 5.83 log CFU g^{-1}, whereas N1 recorded the lowest value with 4.78 log CFU g^{-1}.

Table 6. Total count (log CFU g-1) of bacteria, fungi and actinomycetes in different soil samples located along No. 5Drain (N) and Zefta Drain (Z)

Treatments	Bacteria	Fungi	Actinomycetes
N1	7.41 ± 1.22	3.22 ± 0.44	4.78 ± 0.98
N2	7.03 ± 1.09	3.31 ± 0.68	5.09 ± 1.01
N3	6.81 ± 0.87	3.58 ± 0.38	5.26 ± 1.09
N4	6.11 ± 0.84	3.01 ± 0.33	5.87 ± 0.93
Z1	4.08 ± 1.11	3.87 ± 0.49	5.81 ± 0.83
Z2	5.26 ± 1.28	3.65 ± 0.76	5.22 ± 0.79
Z3	7.96 ± 0.97	3.17 ± 0.29	5.67 ± 0.96
Z4	7.87 ± 0.81	3.89 ± 0.58	5.83 ± 1.05

As for the assessment of soil enzymes activity, the dehydrogenase activity (µM/g soil/hr) was presented in Fig. 2. It has been noticed that there were no significant differences ($p>0.05$) between all site in dehydrogenase enzymes activity except for Z1. The activity of dehydrogenase activity in soil Z2 recorded the highest value of 0.146 µM/g soil/ hr, whereas the lowest value was recorded with Z1 site.

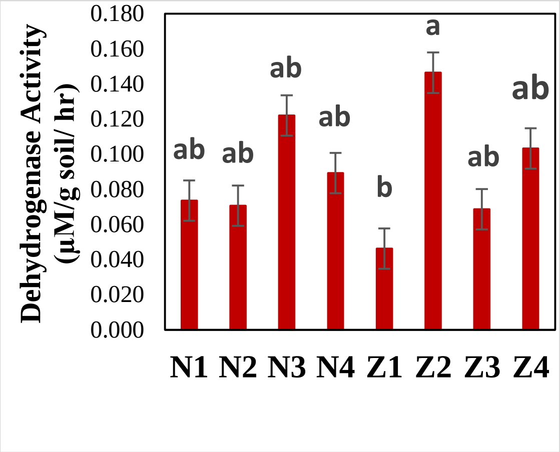

Fig. 2. The dehydrogenase activity (µM/g soil/ hr) in different samples located along No. 5Drain (N) and Zefta Drain (Z)

The soil located near drain No.5 sites showed a marked positive effect in MBC compared to soils located near drain Zefta. The soil microbial biomass in N3 recorded the highest MBC with average value of 2.78%, whereas Z1 and Z4 recorded the lowest MBC with average 0.51 and 0.46%, respectively.

4. Discussion

Soil is a sophisticated and dynamic system, and each change in practical physicochemical characteristics of heavy metal would obviously change the fate of heavy metals in the soil system. The results of soil properties demonstrated that all soil sites were weak alkaline with pH ranged from 7.38 to 7.73, which affects both heavy metals forms and mobility and the distribution and abundance of microorganisms **(Lenart and Wolny-Koładka, 2013)**. The salinity of soil samples ranged from non-saline (S0: EC< 2 dS m^{-1}) to slightly saline (S1: EC 2-4 dS m^{-1}) with $CaCO_3$ ranged from 2.23 to 6.95%. It has been reported that the presence of calcium in $CaCO_3$ form has a great effect on heavy metal adsorption **(Ahmad *et al.*, 2012)** m, particularly the active $CaCO_3$ **(Mourid, 2014)**. Soil organic matter has various effects on soil metals behavior through a huge sorption capacity of metal, retention, mobility and bioavailability of metals **(Quenea *et al.*, 2009)**. The soil samples in different location sites have organic matter content varied between 2.48% to 3.46%.

The ecological risks of heavy metals were evaluated based on different strategies, such as total concentration, single-metal pollution index (CF and Igeo) and multi-metal pollution indexes (CD, MCD, PLI, Pn and PER).All heavy metals concentrations (Cd, As, Cr, Co and V) in different sites near Drain No. 5 and Drain Zeftaexceeded the threshold value. The concentrations limits for V, Co, Cr, As and Cd was set according to **AQCS (1998), Alloway (1990) and Vodyanitskii (2016)** as the follows: 66, 8.9, 60, 13.4 and 0.26 mg kg^{-1}, respectively, and all of them indicate heavy metals pollution. The pollution at these sites might be caused as a result of the intense industrial activities. In addition, the elevation of heavy metals concentrations may be due to the irrigation with the wastewater from the drains. These drains receive different human and industrial activities such as various fungicides, fertilizers, insecticides, alloys, pigments, waste incineration, construction, demolition, cooking utensils, and old tires.

The contamination factor index provides the fundamental basis for counting of complex indices series and the degree of soil contamination with all tested heavy metals **(Hołtra and Zamorska-Wojdyła, 2020)**. As presented in Table 4, the high values in coefficient of variation (*CV* ≈ 4.4 :14.14*)* revealed more spatial variations and manifested high degrees of anthropogenic contribution. The contamination factor commonly points to a high~~er~~ degree of soil polluted with metals. Therefore, to exclude the interference of human behavior, protrusive manufacturing activities and parent materials, the geoaccumulation index, is used to accurately reverberate the contamination by utilizing the geochemical background of heavy metals **(Abd-El-Hady and Abdelaty, 2022)**. The I_{geo} indices in Table 5 showed that the high concentration of heavy metals especially Cr element in site N4 could be the result of the elevation of the geoaccumulation index with average value of 4.65, whereas the lowest value of I_{geo} is recorded for Z3 with very high contamination level.

As for multi element pollution indices, they include CD, MCD, PLI, Pn and PER as presented in Table 5. In accordance with CD, MCD and PLI, all soil sites are classified as very high contaminated, which indicate a very high polymetallic contamination with average values (Avg_CD 30.14, MCD 6.02, PLI 4.27) for drain No. 5 sites, and (Avg_CD 25.38, MCD 4.02, PLI 4.11) for drain Zefta sites, respectively. As mentioned by **(Salman *et al.,* 2019)** the high contamination factor results in increase of CD and MCD. These results illustrated that all soil sites were highly contaminated, and that soils near drain No. 5 were more contaminated than soils near drain Zefta. This can be attributed to the bad human behavior and the excessive industrial disposal in these sites. There were significant differences in all soil samples with Pn and PER indexes. The maximum/minimum values of both indexes (Pn_ 3.66/2.88 and PER_ 318.74/73.61), respectively, indicate probable environmental pollution especially with hazards from Cr and V elements.

It has been reported that soil fertility depends on its soil enzyme activities, which negatively affected by heavy metals contamination. **Karaca *et al.* (2010)** reported that as enzyme activities play critical roles in soil chemical and biological reactions, their inhibition by heavy metals has received considerable attention and has been well discussed by many researchers recently. **Lee *et al.* (2002)** demonstrated that most enzyme activities (dehydrogenase, acid phosphatase and glucosidase) decreased in polluted soils, especially in spots contaminated by heavy metals, and that is reflected in soil microbial activity. It has been noticed from Fig. 2 that there were no significant differences (p>0.05) between all sites in dehydrogenase enzymes activity, except for Z1. Soil microorganisms perform many vital processes and are involved in maintaining soil health and quality. **Olaniran *et al.,* (2013)** reported that the presence of microorganisms in contaminated soils represent several indicators such as its role in heavy metals immobilization/bioremediation, increment of eco-soil quality and transformation of heavy metals into less toxic forms. The results indicated that the total count of bacteria and fungi increased in soil sites located near drain Zefta with average values of 5.63 and 3.65 log CFU g^{-1}, whereas it was 5.25 and 3.28 log CFU g^{-1} in soil sites near drain No. 5, respectively. On the contrary, the actinomycetes counts recorded the opposite direction as it is more in drain No.5 (8%) than in drain Zefta. These findings revealed that bacteria and fungi are affected by the increase of pollution more than the actinomycetes. This was correlated to the MBC in different soil locations. The soil located near drain No.5 sites showed a marked positive effect in MBC compared to soils located near drain Zefta. Fig. 5 showed the regression between soil microbial biomass and concentrations of heavy metals in the soil. The data illustrated that there is positive regression between MBC and heavy metals concentrations in the soil. Yet, the regressing is highly correlated with V concentration (R= 0.95), which indicates that V is essential for these kinds of microbes. The lowest connection is found with Cr and As metals with (R= 0.012). This reveals that microbes are more sensitive to these two elements. **Pande *et al.* (2002)** explained that in both ecological tracking investigations and ecological toxicology, the amount of soil organic matter mineralization has been routinely used to measure the metal toxicity. The correlation between soil organic matter (%) and soil contamination degree (CD) and total count of microbes (TC) in soil (log CFU g^{-1}), in different samples located along drain No. 5 (N) and drain Zefta (Z), are presented in Fig. 6. The data showed a significant correlation between soil OM and CD (R= 0.94) and TC (R= 0.94), which means the reduction of mineralization in the soils affected by high degree of pollution.

5. Conclusions

It can be concluded that the studied soils were alkaline with pH varied from 7.38 to 7.73 and different salinity ranged from 0.47 to 3.10 dS m^{-1} with no significant differences in soil organic matter content. The heavy metals concentrations in different location sites followed the consecutive ascending order: Cd< As< Cr< Co<V. These findings play an important role in determining the soil quality and can help local authorities to take action in terms of treatment purposes. High values of contamination factor of both Co and Cd were found in sites near drain Zefta, whereas V, Cr and as were located in sites near drain No. 5. The ecological indices, including single indices (CF, I_{geo}) and multi-element pollution indices (CD, MCD, PLI, Pn and PER), illustrated that all soil sites are polluted and ranged from highly to extremely high contaminated in accordance with different sources of industrial and human activities.

As for bio-chemical activity of the soil, the data revealed that soil dehydrogenase activity was similar in all sites, and that the soil microbes were affected by soil contamination. There was also a positive regression between MBC and heavy metals concentrations in soil. Organic matter content in the soil polluted with multi-heavy metals are affected relatively by the contamination degree and by the soil total count of microbes.Declaration of competing interest: The authors declare that they have no conflict of interest.

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