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EFFECT OF TREATED WASTEWATER APPLICATION ON SOIL CHARACTERISTICS AT ABU-RAWASH AND ARAB ABU SAED AREAS, EGYPT

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ABSTRACT: Abu- Rawash and Arab Abu Saed Sites are located at the western and southern parts of Giza Governorate, Egypt respectively. They represent two sites irrigated with sewage effluent. Twelve soil profiles as well as eleven water samples were collected by using Global Position System (GPS). Soil samples were obtained to represent two depths: i.e. surface (0-30 cm) and sub-surface (30-60 cm). Water samples were collected at the vicinity of sampled soil. Physical and chemical characteristics of the collected 24 soil samples and 11 water samples were determined. Cluster analysis was performed on effluent and surface soil analytical data separately. Spatial distribution based on GIS images was produced using the inverse distance weighted (IDW) feature in Arc-GIS 10.4 software.

According to ECw and SAR values, the water sources in two sites are of a reasonable quality that can be used for irrigation with few restrictions**.** It is noteworthy that, although most macro, micro-nutrients and ionic contents are relatively high in the two sites as compared to the fresh irrigation water, yet their levels are still within the recommended maximum limits of Egyptian code and world water.

Cluster analysis (CA) of the effluents' analytical data (excluding TDS) at each domain is depicted for Abu Rawash and Arab Abu Saed. For both areas, two predominant clusters were present. Cluster (1) combine elements: P, Fe, Mn, Zn, Cu, Cd, Cr, Ni, B and Pb. This interrelationship may infer that these elements were of a similar origin not natural.

The cluster of Abu Rawash soils K^+ , Zn^{--}, $CaCO_3$,Cu and pH infer to K, Zn and Cu elements are related to $CaCO_3$; while, N, SO_4^{--}, Cl^-,HCO_3^-, Na^+, Ca^{++}, Mg^{++}, silt, sand ,depth and SP refer to the relation of soluble ions with soil characteristics. In Arab Abu Saed cluster soils Zn, Mn, clay, pH, and SAR infer to Zn and Mn elements are related to clay; However, SO_4^{--}, Cl^-, Na^+, Ca^{++}, Mg^{++}, HCO_3^- refer to the relation of soluble ions with soil characteristics. Also, N, P, K, Fe, Zn and Mn are more associated with the proportions of silt, clay, $CaCO_3$ and, to a lesser extent, with the SAR and pH value. The soils in Abu Rawash area are older than the soils in Arab Abu Saed area, therefore soil dismantling event in Abu Rawash area due to frequent service processes.

In Abu Rawash site, the spatial distribution pattern of the available of N, K, Mn, Cu, B, Co, Cr, Ni and Pb are generally similar, with elevated levels in the eastern side which may be affected by El-Muhit drain**.** In Arab Abu Saed site, the higher values of major elements (P, Fe, Zn, Cd, Cr, Ni and Pb) were concentrated mostly in the northern and north western side near the sources of effluent. These observations clearly demonstrated that near El-Saff drain plays a key role in the pollutants distribution in this areas**.**

Keywords: Wastewater, CA, GIS, Spatial distribution, Soil characteristics, Abu Rawash, Arab Abu Saed**.**

INTRODUCTION

Abu- Rawash and Arab Abu Saed are located at the western and southern parts of Giza Governorate, Egypt. They represent two sites irrigated with water contaminated with sewage effluent. Also, the usage of such low quality waters may create problems through their different contents of soluble salts and pollutants; particularly sandy soil in Egypt has been practiced in Cairo. Abu-Rawash sewage farm

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was established in 1944. The farm was irrigated by the flood system. There is a main wastewater treatment plant at Abu Rawash area with maximum effluents 1,450,000 m3/day (Mohamed, 2015). The main wastewater treatment discharge into the Barakat drain that reaches the extension of El- Mouhit drain and then El Rahawy drain that discharges finally huge amounts of wastewater at the Rosetta branch. The surface water system includes the El Mansuriya canal that is passing the area. There are many open drains in the study area that are giving a chance for the wastewater and excess irrigation water to move down to the subsurface causing recharge to the groundwater aquifer.

El-Ashry et al. (2011) studied the chemical characterization of sandy soils irrigated with sewage effluent for extended periods at Abu-Rawash. Soil samples from the surface (0-30 cm) and sub-surface (30-60 cm) layers were collected from Abu-Rawash sewage farms. The collected soil samples represented soils under different landscapes irrigated with sewage effluent for varied extended periods ranging between 0 and 82 years. Results exhibited definite remarkable chronological changes in the soil pH, EC, organic matter and surface area particularly during the first ten years of irrigation with sewage effluent.

Arab Abu Saed sewage station was established in 1992 and drains its water in El Saff Canal to irrigate agriculture areas. There is a water logging problem in Arab Abu Saed area due to the high elevation of El Saff Canal compared to the surrounding agriculture land.

Badawy and Helal (2002) studied the chemical composition of the sewage effluent of Helwan drainage station which irrigated Arab Abu Saed cultivated area. They found that the metals can be arranged in the following order: Fe > Zn > Pb > Mn > Ni > Cr > Co > Cd > Cu. They also reported that continuous irrigation with sewage effluent, with or without annual addition of sludge lead to: 1) decreasing soil pH and total carbonate content, 2) increasing organic carbon, clay and available P and K, and 3) increasing contents of heavy metals.

The multivariate analyses are normally used to identify the combined effect of several measured variables and the influence of external parameters on given distribution (Ragosta et al., 2002). In the present study, cluster analysis (CA) technique has been applied. Cluster analysis was performed to further classify elements of different sources on the basis of the similarities of their chemical properties. As the variables have large differences in scaling, standardization was performed before computing proximities, which can be done automatically by the cluster analysis procedure. A dendrogram was constructed to assess the cohesiveness of the clusters formed, in which correlations among elements can readily be seen (Yongming et al., 2006). The application of hierarchical classification approach is well known for the interpretation of data and provides a valuable tool for reliable and effective monitoring and management (Singh et al., 2009).

The present study aims to investigate some physical and chemical characteristics of wastewater and soil within two locations representing at Abu-Rawash and Arab Abu Saed Soils. This will include the quantification of soluble ions, macro- and micronutrients and heavy metals in these contaminated soils as well as the main chemical make-up of water sources used within each area. An evaluation of the impact of the continued use of untreated mix of sewage and industrial wastewater on these soils will be presented. Statistical analysis will be used to assess the spatial distribution of some macro- and micronutrients and heavy metals in the surface layer of soils in order to correlate it with GIS images obtained.

MATERIALS AND METHODS

1. Study areas: Abu-Rawash and Arab Abu Saed:

This study was carried out the two areas of Egypt namely Abu-Rawash administratively falls within Giza Governorate, west of the Greater Cairo (Figure 1). It stretches over 30290 feddans (Feddan = 4200 m^2) and extends between the longitude 31° 4` 26.61`` and 31° 7` 47.15`` E and latitude 30° 5` 4.38`` and 30° 6` 34.79`` N. Arab

Abu Saed lies also within Giza Governorate, south of Cairo City, however, it falls under the Greater Cairo Urban Region (Figure 2), where this area covered 2392 feddans between longitude 31° 20` 33.28`` and 31° 23` 12.55`` E and latitude 29° 41` 11.73`` and 29° 44` 17.27`` N.

2. Soil and water sampling:

This study was carried out during the year 2017 by following the land throughout the year. Twelve soil profiles as well as eleven water samples were collected by using Global Position System (GPS) (Figs 1 & 2). Soil profile was obtained to represent two depths: (0-30 cm) and (30-60 cm) surface and sub-surface sample. Water samples were collected from the same check points. Water samples were collected by Nansen bottle and poured into polyethylene containers (2 Liter). Water samples were passed through Watman 42 filters. Next, 1 ml samples were added to 65% nitric acid and again filtered and stored in polyethylene containers. Table (1) shows the location of soil sites and effluent sources of each area during the sample collection program.

Table 1. Soil profiles and effluent sampled sites at Abu-Rawash and Arab Abu Saed areas during 2017 (reference Figures 1 and 2)

Area	# Effluents sampled	# of Soil Profiles (description)
Abu-Rawash	1, 2, 3, 4 and 5	1, 2, 3, 4and 5 (agricultural land)
Arab Abu Saed	6,7,8,9,10 and 11	6, 7, 8, 9,10,11 and 12 (agricultural land)

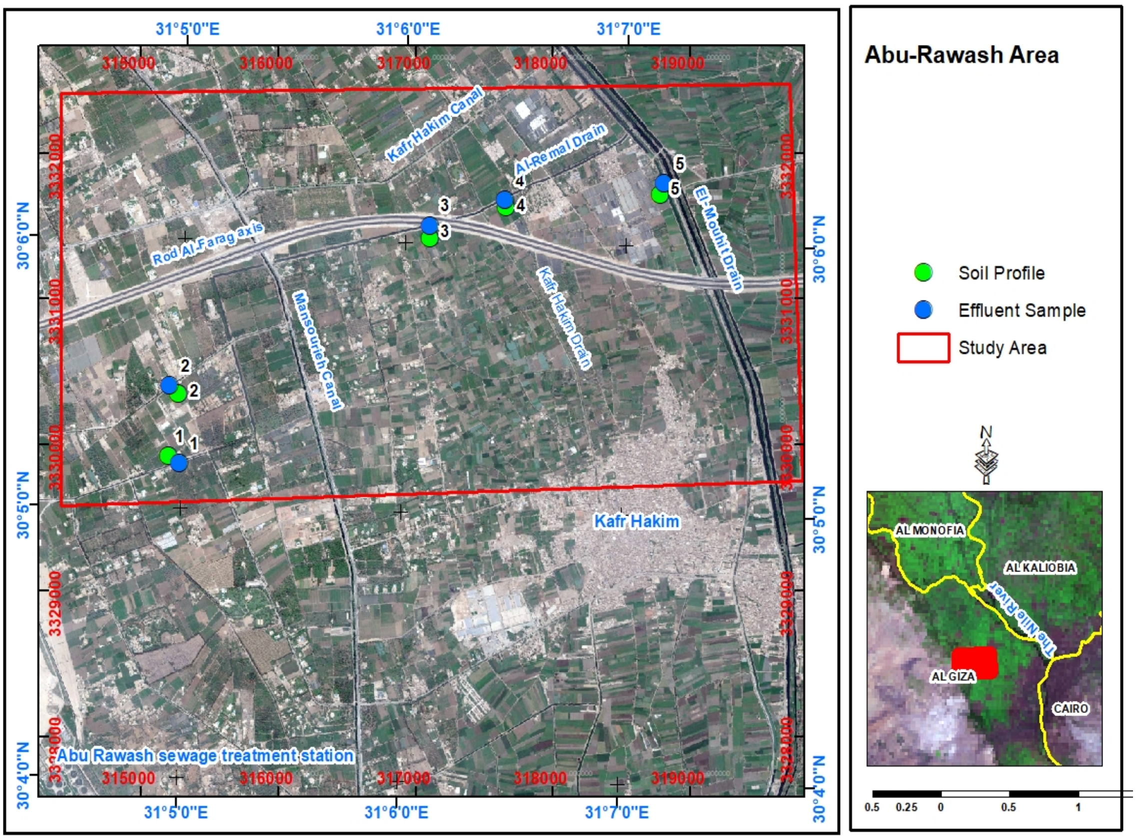

Figure (1): Satellite image of the Abu-Rawash study sites indicating soil profiles and effluent samples.

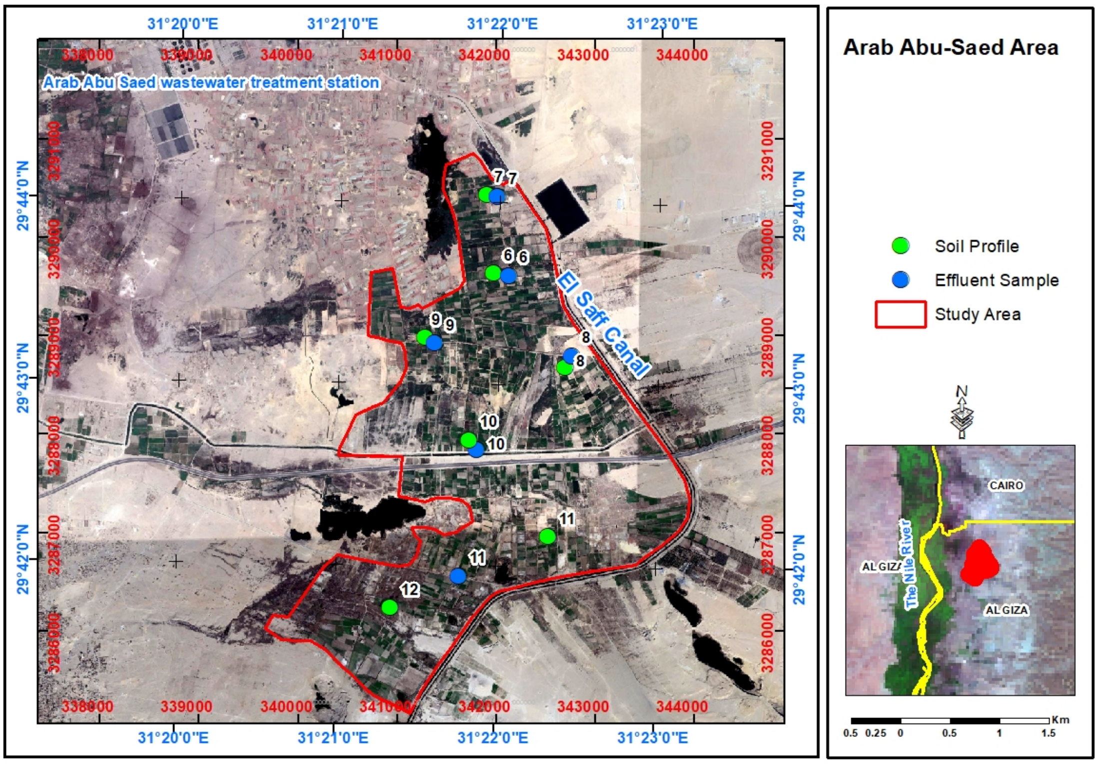

Figure (2): Satellite image of Arab Abu Saed study sites indicating soil profiles and effluent samples.

3. Soil and effluent physical and chemical characterization:

Physical and chemical characteristics of the collected 2٤ soil samples (represent 12 profiles) and 11 water samples were analytically according to Estefan et al. (2013). Physical characteristics determined were particle size distribution, texture and $CaCO_3$%. The chemical analyses of soil and water included: pH, electrical conductivity (EC_e), saturation percentage (SP); soluble cations and anions: Ca, Mg, Na, K, Cl, SO_4, CO_3 and HCO_3. SAR was determined according to Miller and Curtin (2006) method. Nitrate and ammonium–nitrogen was determined using the Kjeldahl method (Estefan et al., 2013). Also, Ca, Mg, Na, and K were measured by flame photometry. Macro (P), micro-nutrients (B, Fe, Zn, Mn, and Cu), and heavy metals (Cd, Co, Ni, Pb, and Cr) were determined in the available form in soil samples and water using ICP Spectrometry (USEPA, 1993).

4. Statistical Analysis:

Cluster Analysis (CA) was performed on effluent and surface soil analytical data separately using 'StatistiXL 1.8' incorporated within the Microsoft Excel 2010 (Microsoft ® Windows 2010) software program. Pearson correlation coefficients were performed to measure the association between soil variables of interest to evaluate the magnitude of the association, or correlation, as well as the direction of the relationship. The resulting distance matrix and clustering strategy report were depicted graphically as dendrograms that will be further used in the data interpretation.

Spatial distribution and GIS imaging of some macro-and micronutrients and heavy metals:

Spatial distribution based on GIS images was produced using the inverse distance weighted (IDW) feature in Arc-GIS 10.4 software to interpolate the elemental and heavy metal concentrations in soil surfaces within each of the studied areas to establish the required comparison with analytical data obtained. The IDW provides a deterministic method for multivariate interpolation with a known scattered set of points which computes an average value for unsampled locations using values from nearby weighted locations (Ali and Moghanm, 2013). This process creates surface data from sampled points which can be used to represent land use or soils data features and in spatial decision-making concerning physical and human geography (Haithcoat, 1999).

RESULTS AND DISCUSSION

1. Effluent characterization and statistical evaluation of main attributes:

Tables (2) and (3) show the mean of major chemical and physical parameters of the water samples at Abu-Rawash and Arab Abu Saed areas respectively.

Overall, these effluents had a pH values ranged between 6.62 and 7.60 which was within the permissible limits for agriculture according to Ayers and Westcot (1985). The corresponding relatively low pH values are mainly due to the effect of the nature of suspended matter of the sewage effluent. It is contains organic acids that may reduce the pH of this water (Mollahoseini, 2013). Near neutral to basic effluent pH was linked to the mixing of industrial effluents with sewage wastewater (Khalaf and Gad, 2015 and Hussein et al., 2019).

The average values of water salinity as expressed by EC, were 0.84 and 1.55 dS/m at Abu-Rawash and Arab Abu Saed sites, respectively reflecting the effect of total soluble solids in both two water sources. These values refers that the salinity level of both the studied irrigation waters is more related to the nature of its sources as affected by pollutants. These low quality waters are in second category (0.75-3.00 dS/m) for Abu-Rawash and Arab Abu Saed water, i.e. these waters are of increasing problems according to Ayers and Westcot (1985). On other words, these water sources are considered moderately saline according to USDA/NRCS (2004).

Table (2): Mean physical [(pH, EC (dS/m), TDS (mg/l) and SAR)] and soluble ions (CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--}, Ca^{++}, Mg^{++}, Na^+ and K^+) (mg/l) of the effluents samples in the studied areas.

Site	Sample No	pH	EC (dS/m)	TDS (mg/l)	Soluble anions (mg/l)				Soluble cations (mg/l)				SAR
					CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	
Abou-Rawash	1	6.83	0.64	409.6	0.00	30.50	159.53	65.76	30.00	12.15	86.25	4.69	3.35
	2	7.6	1.03	659.2	0.00	30.50	194.98	204.96	70.00	18.23	116.15	8.60	3.19
	3	6.75	0.74	473.6	0.00	30.50	194.98	65.76	50.00	18.23	74.75	4.69	2.3
	4	6.84	0.66	422.4	0.00	30.50	159.53	75.36	40.00	12.15	79.35	4.69	2.82
	5	6.95	1.12	716.8	0.00	30.50	230.43	200.64	70.00	30.38	115.00	7.04	2.89
	Average	**6.99**	**0.84**	**536.32**	**0.00**	**30.50**	**187.89**	**122.50**	**52.00**	**18.23**	**94.30**	**5.94**	**2.91**
Arab Abu Saed	**6**	6.7	1.24	793.6	0.00	30.50	265.88	210.24	70.00	30.38	140.30	10.95	3.52
	7	6.8	1.25	800	0.00	30.50	267.65	213.12	70.20	30.62	141.91	11.34	2.51
	8	6.62	1.26	806.4	0.00	30.50	301.33	171.84	70.00	30.38	144.90	10.95	3.64
	9	7.31	2.47	1580.8	0.00	61.00	584.93	344.64	150.00	54.68	280.60	18.77	4.98
	10	6.65	1.53	979.2	0.00	30.50	336.78	252.96	90.00	30.38	185.15	8.60	4.3
	11	6.75	1.52	972.8	0.00	30.50	336.78	248.16	90.00	30.38	182.85	8.60	4.25
	Average	**6.82**	**1.55**	**992**	**0.00**	**35.58**	**348.89**	**240.16**	**90.03**	**34.47**	**179.29**	**11.53**	**3.79**

Table 3: Mean macronutrients (NH_4, NO_3, K, and P), micro-nutrients (Fe, Mn, Zn, Cu and B) and some heavy metals (Cd, Co, Cr, Ni, and Pb) (mg/l) of effluents sampled in the studied areas.

Site	Sample No.	Concentration mg /l													
		NH_4	NO_3	P	K	Fe	Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
		soluble elements in water													
Abu-Rawash	**1**	7.700	4.200	0.025	4.692	0.671	0.040	0.320	0.040	0.100	0.019	0.000	0.003	0.016	0.020
	2	4.130	10.29	0.032	8.602	0.250	0.032	0.210	0.023	0.090	0.002	0.001	0.002	0.001	0.021
	3	16.80	3.920	0.014	4.692	0.176	0.047	0.341	0.015	0.200	0.015	0.001	0.004	0.020	0.032
	4	13.09	3.010	0.010	4.692	0.106	0.233	0.025	0.032	0.050	0.006	0.000	0.002	0.041	0.005
	5	11.20	2.800	0.048	7.038	0.145	0.049	0.062	0.041	0.120	0.004	0.000	0.005	0.021	0.008
	Average	**10.584**	**4.844**	**0.026**	**5.943**	**0.270**	**0.080**	**0.192**	**0.030**	**0.112**	**0.009**	**0.0004**	**0.003**	**0.020**	**0.017**
Arab Abu Saed	**6**	7.210	6.370	0.023	10.948	0.500	0.032	0.006	0.321	0.090	0.002	0.000	0.003	0.010	0.030
	7	7.170	6.330	0.026	11.339	0.620	0.021	0.012	0.354	0.080	0.003	0.003	0.002	0.002	0.021
	8	14.35	6.650	0.019	10.948	0.320	0.042	0.015	0.425	0.130	0.002	0.000	0.003	0.002	0.032
	9	2.030	6.370	0.016	18.768	0.420	0.112	0.004	0.132	0.110	0.001	0.002	0.002	0.001	0.011
	10	7.210	9.800	0.036	8.602	0.620	0.047	0.009	0.420	0.020	0.000	0.001	0.001	0.002	0.008
	11	14.91	3.010	0.030	8.602	0.255	0.056	0.003	0.225	0.010	0.001	0.000	0.001	0.003	0.042
	Average	**8.813**	**6.422**	**0.025**	**11.535**	**0.456**	**0.052**	**0.008**	**0.313**	**0.073**	**0.002**	**0.001**	**0.002**	**0.003**	**0.024**

Average values of sodium adsorption ratio (SAR) were 2.91 and 3.79 for Abu-Rawash and Arab Abu Saed sites, respectively (Table 2). The suitability of these effluents for use in agricultural irrigation indicated by the SAR was less than 9.0 (ECP 501, 2005) reflecting its non-sodic nature. Therefore according to ECw and SAR values, these water sources are of a reasonable quality that can be used for irrigation with few restrictions.

In general, the distribution pattern of soluble cations in the studied waters follows the descending order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$, for Abu Rawash and Arab Abu Saed sites (Table 2). The soluble anions could be arranged in the following order $Cl^- > SO_4^{--} > HCO_3$ for both the two studied sites. The concentration of chlorides (Cl) is higher than 4.0 meq/l (approx. 142.0 mg/l), and according to Ayers and westcot (1985), this source is considered slight to moderate concerning its use in irrigation. The dominance of both soluble Na^+ and Cl^- denotes that NaCl is the probable dominant salt in the corresponding low quality water category. As well, the Cl content of the tested effluents was more than its sulfate content. This may be attributed to the fact that the raw sewage was contributing activity of these wastewater streams in both locations.

In general data in Table (3) showed that most of these effluents samples had high NH_4 content relative to their NO_3, except the samples number 2, 9 & 10. This increase was higher for Abou Rawash effluents compared to this Arab Abu Saed (Table 3).

The heavy metals and micro-nutrients are arranged in a descending order of Fe > Zn > B > Mn > Cu > Ni > Pb > Cd > Cr > Co in Abu-Rawash water and Fe > Cu > B > Mn > Pb > Zn > Ni > Cd > Cr > Co in Arab Abu Saed water (Table 3). The presence of B in surface water was attributed to detergents and / or cleaning agents emitted with urban and industrial effluents as well as B being a component in some fertilizers (Ezechi et al., 2012). High boron content in irrigation waters was reported to increase the solubility of elements such as Pb, Cu, Co, Ni and Cd thus increasing their potential toxicity. It is noteworthy that, although the contents of the previous elements are relatively high in the two studied sites as compared to the fresh irrigation water, yet their levels are still within the recommended limits of Egyptian code and world water (ECP 501, 2005).

Cluster analysis CA of the effluents' analytical data (excluding TDS) at each domain is depicted in Figures 3 and 4 for the Abu-Rawash and Arab Abu Saed, respectively. For both areas, two predominant clusters were present. Cluster (1) combine elements: P, Fe, Mn, Zn, Cu, Cd, Cr, Ni, B and Pb. This interrelationship may infer that these elements were of a similar not natural origin. Cluster (2) include soluble ions (Na^+, SO^{--}_4, Cl^-, Ca^{++}, Mg^{++}, HCO^-_3 and K^+) indicate that these waters are of the same source. The sub-cluster including pH, nitrates, EC and SAR content may enforce the fact that sewage (either raw or primary treated) made up the predominant load in both areas.

For Abu Rawash effluents, a relationship between Zn, Fe and B was noted. This may be referring to the decomposition of ferromagnesian minerals which was enhanced by the presence of B, as indicated previously by Abd-Elrahman (2015). Cluster of pH and NO_3 refer to an oxidation process were performed from NH_4 to NO_3. Also, the presence of separate NH_4 indicate that parts of irrigation waters was untreated. However, in Arab Abu Saed, cluster including pH, NH_4 and NO_3 refer to that these irrigation waters were treated.

Statistical comparison of sampled Effluents points:

Figure 5 reveals the similarities between the examined effluent points using CA clustering strategy of the analytical data in Tables 2 and 3 for both locations. From these figures, it was observed that effluents points at (1, 3 and 4) and (2 and 5) were grouped as two sub-clusters for Abu Rawash waters while points at (6, 7 and 8) and (10 and 11) were singled as another two cluster for Arab Abu Saed waters, an aspect that will be elaborated upon herewith. Each cluster indicates that these waters are of the same treatments.

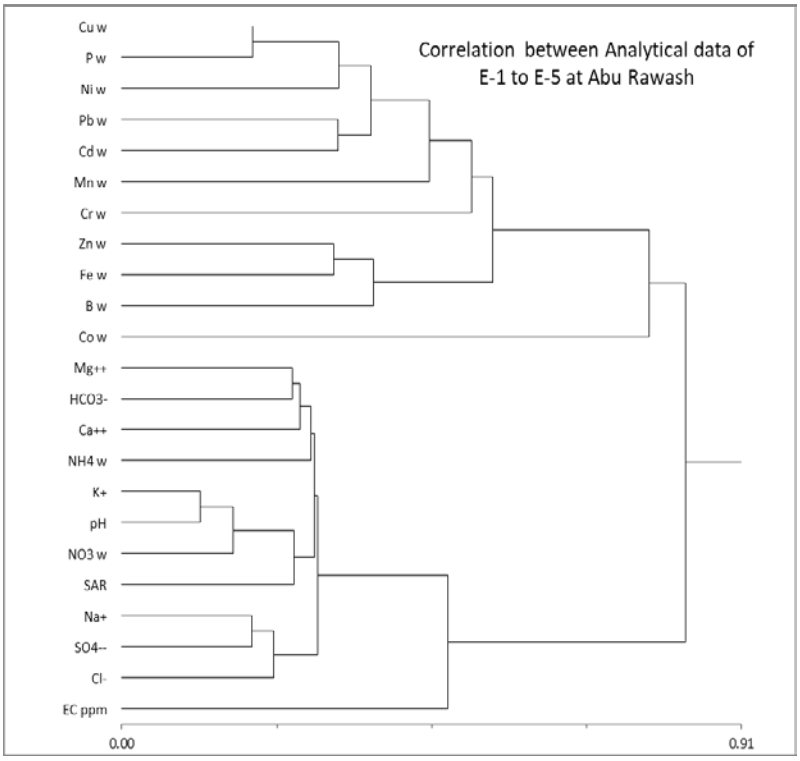

Figure 3. Dendrogram correlating the analytical content of the sampled effluents at (1 to 5) (excluding TDS) at Abu Rawash Site.

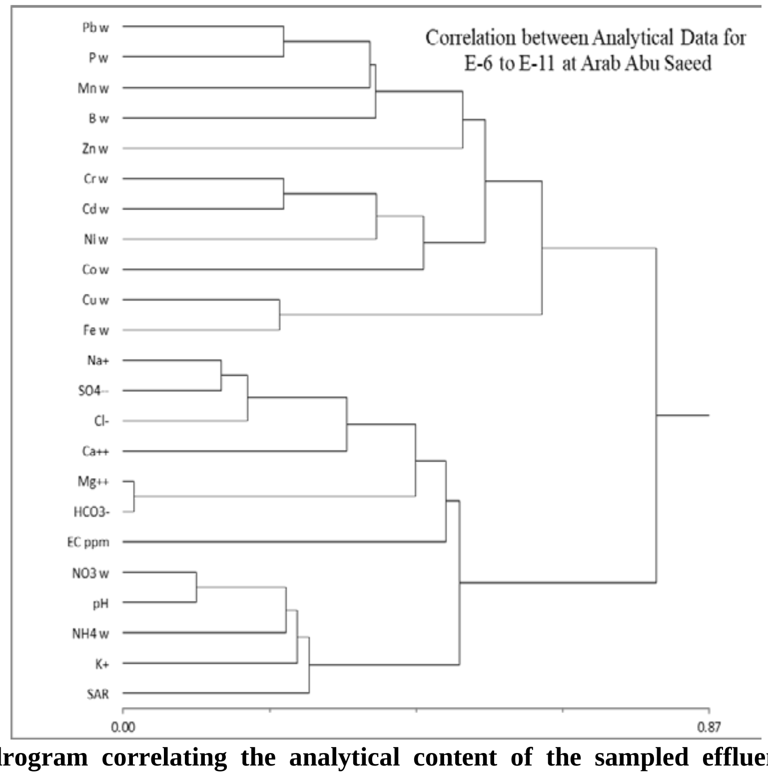

Figure 4. Dendrogram correlating the analytical content of the sampled effluents at (6 to 11) (excluding TDS) at Arab Abu Saed Site.

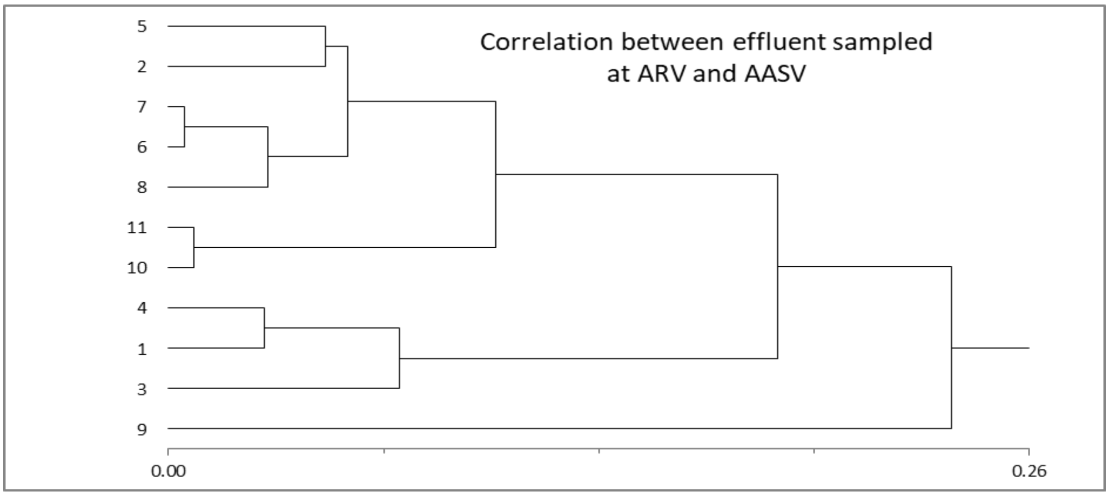

Figure 5. Dendrogram correlating the sampled effluent points at Abu Rawash Village (ARV) (1 to 5) with those at Arab Abu Saed Village (AASV) (5 to 11).

Generally, In the case of Abu Rawash Figure 1 indicates points at #3 and 4 were located within the Al-Remal drain. However, points at #5 was located within the El-Muhit drain. In the case of Arab Abu Saed, Figure 2 reveals points at #6, 7, 8, 10 and 11-located along the El Saff Canal -received their loads from primary treatment sewage wastewater plants located near of the farm area. On the other hand, effluent at # 9 was located along the stream resulting from the merging with the industrial wastewater of Helwan. In this respect, effluent at points # 9 has the collective characteristics of untreated industrial and domestic effluents. This is supported by the analytical data indicating that effluents at #9 had low NH_4 content that was coupled with high TDS, EC, and K values relative to others.

2. Soil characteristics and the delineation of the main characteristics:

Tables (4 & 5) provide the physicochemical parameters of the twenty four soil profiles collected from the twelve soil profiles in the two studied areas at two successive depths, (0-30 and 30-60 cm). The results indicate that most of the soil samples (21 samples) had a sandy loam texture (representing 87.5% of the studied samples) which is amenable for crop growth (Singh and Dhillon, 2004). However the texture of most soil samples does not obviously change with depth.

The calcium carbonate content (%) of the investigation soils samples ranged between 6.7 and 23.7 %. The lowest calcium carbonate content was recorded for the soil of Abu Rawash (Table, 4). On the other hand, the highest content of calcium carbonate was found in the soil of Arab Abu Saed. This may be related to the nature of parent materials of soils in both sites. The relatively high $CaCO_3$ content in Arab Abu Saed soil is mostly related to the precipitation of dissolved $Ca(HCO_3)_2$ in a form of secondary $CaCO_3$ in this soil. At Abu-Rawash soil, the relatively low $CaCO_3$ content is probably due to the solubility reaction in the presence of CO_2 (carbonation process).

The saturation percentage (SP) values of the studied soils ranged between 20.0 and 45.0 % with an average of 27.1 and 26.3 for Abu Rawash and Arab Abu Saed, respectively (Table, 5). This parameter reflects the coarse texture of the studied soils. In general, the saturation percentage of the studied soil seems to increase with increasing the clay and silt content.

The soil pH values of the studied area varied between 6.85 and 8.07. In most soil samples the pH of the surface layers was lower than that of the subsurface ones, especially for those of Arab Abu Saed soil (Table, 5). Rattan et al. (2005)

reported that, the long term use of sewage water in irrigating crops revealed a decrease in the soil pH by 0.4 unit below the initial pH value. Yao et al. (2013) showed that, the soil pH values of the sewage water irrigated sites were slightly lower than those of the controlled sites at the same depths. Wastewater-irrigated soils contained higher organic carbon and nitrogen contents, which could promote microorganism activity to break up organic nitrogen molecules into inorganic nitrogen and H^+. Meanwhile, wastewater itself may carry H^+ into irrigated soils too. These two aspects could result in lower pH values in sewage water-irrigated soils. Moreover, Dheri et al. (2007) indicated that the production of organic acids due to the anaerobic decomposition of organic matter was a principal cause for the reduced pH in the soil irrigated with waste water.

Table (4): Physicochemical analyses of soil profiles sampled collected from the two studied areas.

Site	Profile No.	Depth (cm)	Sand %	Silt %	Clay %	Texture	$CaCO_3$ %
Abu-Rawash	1	0-30	72.60	20.30	7.10	Sandy loam	11.70
		30-60	91.40	4.20	4.40	Sand	10.50
	2	0-30	73.50	20.30	6.20	Sandy loam	9.50
		30-60	72.90	21.50	5.60	Sandy loam	6.70
	3	0-30	72.70	20.10	7.20	Sandy loam	8.40
		30-60	73.50	20.20	6.30	Sandy loam	9.60
	4	0-30	71.30	21.80	6.90	Sandy loam	17.60
		30-60	71.90	20.30	7.80	Sandy loam	21.30
	5	0-30	27.56	21.32	51.12	Clay	8.70
		30-60	22.43	25.27	52.30	Clay	10.60
	Average		**64.98**	**19.53**	**15.49**		**11.46**
Arab Abu Saed	6	0-30	72.00	20.50	7.50	Sandy loam	10.80
		30-60	73.20	19.90	6.90	Sandy loam	17.80
	7	0-30	73.70	20.10	6.20	Sandy loam	12.70
		30-60	72.80	22.10	5.10	Sandy loam	18.50
	8	0-30	73.50	19.60	6.80	Sandy loam	9.50
		30-60	73.20	21.10	5.7	Sandy loam	12.70
	9	0-30	73.70	20.20	6.10	Sandy loam	14.50
		30-60	72.90	21.80	5.30	Sandy loam	19.70
	10	0-30	73.10	20.20	6.70	Sandy loam	11.80
		30-60	71.00	19.50	9.50	Sandy loam	12.50
	11	0-30	72.80	22.10	5.10	Sandy loam	11.70
		30-60	72.00	20.50	7.50	Sandy loam	20.40
	12	0-30	72.70	21.10	6.20	Sandy loam	11.50
		30-60	73.60	20.10	6.30	Sandy loam	23.70
	Average		**72.87**	**20.63**	**6.49**		**14.84**

Table (5): Chemical analyses of soil profiles sampled at the two studied areas

Site	Profile No.	Depth (cm)	SP %	pH	EC dS/m	TSS (mg/l)	Soluble anions (mg/l)				Soluble cations(mg/l)				SAR
							CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	
Abou-Rawash	1	0-30	23.5	7.13	1.64	1049.60	0.00	91.50	301.33	305.28	110.00	30.38	184.00	14.08	3.08
		30-60	21.0	6.85	0.56	358.40	0.00	30.50	124.08	75.36	30.00	12.15	67.85	4.69	2.09
	2	0-30	22.0	7.33	1.12	716.80	0.00	91.50	230.43	152.64	70.00	30.38	108.10	18.77	2.16
		30-60	20.0	7.85	0.35	224.00	0.00	30.50	70.90	47.04	20.00	6.08	43.70	3.13	1.70
	3	0-30	25.0	8.07	1.68	1075.20	0.00	91.50	283.60	348.48	110.00	30.38	193.20	14.08	3.23
		30-60	27.5	7.24	1.52	972.80	0.00	61.00	336.78	224.16	90.00	30.38	180.55	12.51	3.27
	4	0-30	23.5	7.12	0.72	460.80	0.00	30.50	159.53	104.64	50.00	18.23	69.00	7.04	1.66
		30-60	20.0	7.47	0.43	275.20	0.00	30.50	106.35	36.48	20.00	6.08	60.95	4.30	2.37
	5	0-30	43.5	8.00	1.96	1254.40	0.00	91.50	354.50	387.84	130.00	42.53	209.30	18.77	3.17
		30-60	45.0	8.00	1.06	678.40	0.00	30.50	230.43	171.36	70.00	18.23	123.05	8.60	2.60
	Average		**27.1**	**7.51**	**1.10**	**706.56**	**0.00**	**57.95**	**219.79**	**185.33**	**70.00**	**22.48**	**123.97**	**10.60**	**2.53**
Arab Abu Saed	6	0-30	31.0	7.56	3.04	1945.60	0.00	122.00	655.83	473.76	190.00	66.83	341.55	20.33	4.24
		30-60	25.0	7.86	0.47	300.80	0.00	30.50	124.08	32.16	30.00	6.08	58.65	4.69	1.93
	7	0-30	28.5	7.67	2.96	1894.40	0.00	91.50	584.93	555.36	210.00	66.83	300.15	20.33	3.59
		30-60	25.0	7.69	2.52	1612.80	0.00	91.50	514.03	440.16	170.00	54.68	267.95	20.33	3.55
	8	0-30	30.0	7.65	6.24	3993.60	0.00	183.00	1223.03	1193.76	370.00	164.03	665.85	55.52	5.76
		30-60	20.0	8.01	0.92	588.80	0.00	30.50	194.98	152.16	50.00	18.23	113.85	8.60	2.75
	9	0-30	30.5	7.84	2.24	1433.60	0.00	61.00	514.03	328.80	130.00	54.68	243.80	29.33	3.58
		30-60	22.5	7.93	1.20	768.00	0.00	30.50	265.88	190.56	70.00	30.38	132.25	8.60	2.64
	10	0-30	25.0	7.61	0.96	614.40	0.00	30.50	230.43	123.36	50.00	18.23	123.05	8.60	2.97
		30-60	25.0	7.75	1.04	665.60	0.00	30.50	230.43	162.24	70.00	18.23	118.45	8.99	2.50
	11	0-30	32.5	7.10	19.40	12416.00	0.00	518.50	4094.48	3359.04	1170.00	516.38	2058.50	136.07	10.02
		30-60	27.5	7.81	4.08	2611.20	0.00	152.50	691.28	900.00	230.00	115.43	439.30	25.42	4.74
	12	0-30	25.0	7.63	3.92	2508.80	0.00	152.50	797.63	679.20	250.00	91.13	425.50	25.42	4.59
		30-60	20.0	7.69	2.76	1766.40	0.00	91.50	478.58	602.40	190.00	66.83	273.70	25.42	3.40
	Average		**26.3**	**7.70**	**3.70**	**2365.71**	**0.00**	**115.46**	**757.11**	**656.64**	**227.14**	**91.99**	**397.33**	**28.40**	**4.02**

Note SP: Saturation Percent EC: Electrical Conductivity TSS: Total Soluble Salts SAR: Sodium Adsorption Ratio

The electrical conductivity values of the saturated soil paste extract (ECe) of the studied soils ranged from 0.35 to 19.4 dS/m with an average value of 1.1 and 3.7 dS/m for Abu Rawash and Arab Abu Saed, respectively (Table, 5). The usage of low quality water at Arab Abu Saed site resulted in a relatively higher soil ECe value, which is evidently by a proportionally increase of irrigation water salinity (Table 2). Most of the cultivated soil samples had low salinity (ECe < 4dS/m). In most soil samples, the surface layers showed higher ECe values than the subsurface ones due to the salt accumulation of these soils. El-Desoky and Gameh (1998) found that, the sustained use of sewage water in irrigation caused increases in the salinity of the soils, especially in the surface layers. Also, Roshdy (2009) indicated that the use of sewage water in irrigation could result in a salt accumulation in soils which may limit its use under arid and semi-arid conditions. These results similar to that of El-Ashry et al. (2011) for remarkable chronological changes in the soil pH, EC, organic matter and surface area particularly during the first ten years of irrigation with sewage effluent in Abu Rawash site.

In general, the content pattern of soluble cations in the soils followed the ascending order: Na^{+}> Ca^{2+}> Mg^{2+}> K^{+}. Also, the soluble anions could be categorized in the following descending order: Cl^{-}> SO_4^{2-}> HCO_3^{-}. The dominance of soluble Na^{+} and Cl^{-} indicates that NaCl is the dominant salt (Table, 5).

Values sodium adsorption ratio (SARe) of the studied soils samples ranged from 1.66 to 10.02 with an average value of 2.53 and 4.02 for Abu Rawash and Arab Abu Saed, respectively (Table, 6). Most of studied soils samples were non alkaline (SAR <13) according to Abegunrin et al. (2013).

Table (6) shows the impact of irrigation with sewage water on the soil content of available NPK of the studied soils samples. Many processes like cultivation increase the rate of decay and oxidation of organic matter in soil (Young and Young, 2001), which in turn lowers the total N content in soil, as supply of this element in soil primarily, depends on organic matter (Havlin et al, 2002) but with a high population and limited land condition.

Content of the available nitrogen in the studied soils varied ranged from 32.0 to 228.0 mg/kg (Table, 6). Generally, increases in the available N of all studied soil samples occurred as a result of the sewage water effect. Concentrations of available N in Abu Rawash soils are higher than Arab Abu Saed soils with average of 149.5 and 93.78 mg/kg, respectively (Table, 6). Hussain et al. (2002) found that the sewage water contained organic and inorganic compounds that included nutrients like nitrogen. Also, Afifi et al. (2011) revealed that the use of sewage water in irrigation led to an increase in the total nitrogen contents of the soil after harvesting. This may be due to the high concentration of nitrogen in the sewage water.

Content of the available phosphorus in the studied soil samples are ranged from 6.74 to 92.44 mg/kg (Table, 6). In general, increases in the content of available phosphorus in most studied soils irrigated with sewage water were high. However, concentrations of available P in Abu Rawash soils are relatively higher than Arab Abu Saed soils with average of 37.17 and 32.73 mg/kg, respectively. El-Khateeb et al. (2012) indicated that the available phosphorus of the forest soils clearly increased as result of the irrigation with sewage water; their results varied due to the period of irrigation. Use of domestic sewage water in irrigation can provides essential nutrients to the crops and improves the fertility level of soils (Ladwani et al., 2012). In addition, Kharche et al. (2011) found that the sewage irrigated soils recorded high available P levels indicating their significant additions through sewage water a slow grade cheap fertilizer.

Content of the available potassium in the studied soil samples are ranged from 23.8to 251.8 mg/kg (Table, 6). Generally, content of the available potassium in most studied soil samples increased as a result of the long-term irrigation with sewage water, especially in the surface soil layers. Concentrations of available P in Arab Abu Saed soils are relatively higher than Abu Rawash soils with average of 116.5 and 95.90 mg/kg, respectively. Ghafoor et al. (1999)

Table (6): The content (mg /kg) of available elements in soil samples at the two studied area.

Site	Profile No.	Depth (cm)	Concentration mg kg^{-1}												
			N	P	K	Fe	Mn	Zn	Cu	B	Cd	Co	Cr	Ni	Pb
Abu-Rawash	1	0-30	166.00	14.490	91.40	13.18	1.624	1.760	1.172	0.025	0.088	0.026	0.004	0.094	0.158
		30-60	121.00	37.326	23.80	44.06	10.316	9.364	4.060	0.032	0.294	0.032	0.054	0.646	0.674
	2	0-30	107.00	35.112	89.60	16.38	4.256	3.116	3.100	0.050	0.109	0.032	0.006	0.162	0.260
		30-60	196.00	13.712	49.20	7.012	1.45	0.884	1.504	0.014	0.047	0.022	0.003	0.070	0.142
	3	0-30	112.00	79.884	131.80	73.21	7.122	12.472	6.720	0.025	0.488	0.032	0.024	0.648	0.600
		30-60	154.00	92.444	157.20	145.74	12.098	14.150	8.940	0.042	0.972	0.046	0.016	0.876	0.822
	4	0-30	141.00	47.800	86.20	49.38	4.810	10.104	5.198	0.041	0.329	0.024	0.010	0.506	0.534
		30-60	116.00	30.428	40.60	16.90	2.978	1.890	1.774	0.035	0.113	0.024	0.002	0.182	0.198
	5	0-30	203.00	12.946	158.80	11.82	24.560	2.940	6.084	0.068	0.079	0.156	0.012	0.928	0.926
		30-60	179.00	7.590	130.30	15.03	20.916	1.838	6.090	0.016	0.100	0.146	0.002	0.792	0.824
	Average		**149.5**	**37.173**	**95.89**	**39.271**	**9.013**	**5.852**	**4.464**	**0.035**	**0.262**	**0.054**	**0.013**	**0.49**	**0.514**
Arab Abu Saed	6	30-60	132.00	59.842	176.26	72.19	23.956	18.382	4.734	0.088	0.481	0.340	0.120	0.694	0.682
		0-30	77.00	37.480	133.60	37.02	4.546	5.468	1.896	0.038	0.247	0.052	0.126	0.294	0.374
	7	30-60	228.00	16.812	102.20	23.63	7.334	4.458	1.704	0.380	0.158	0.094	0.030	0.362	0.360
		0-30	110.00	20.412	74.40	3.25	1.284	0.832	0.356	0.142	0.022	0.028	0.025	0.076	0.118
	8	30-60	78.00	36.088	120.00	49.10	6.160	17.570	5.392	0.118	0.327	0.060	0.104	0.636	0.660
		0-30	70.00	16.686	52.40	10.92	1.822	2.178	0.746	0.010	0.073	0.026	0.058	0.154	0.114
	9	30-60	85.00	89.150	251.80	53.70	14.256	25.078	5.202	0.182	0.358	0.122	0.170	0.926	0.740
		0-30	46.00	24.746	221.00	27.01	4.630	5.776	1.732	0.084	0.180	0.034	0.076	0.334	0.108
	10	30-60	124.00	74.364	44.00	71.25	2.944	15.056	2.246	0.124	0.475	0.006	0.184	0.256	0.268
		0-30	124.00	43.046	24.20	44.47	2.528	10.482	1.664	0.088	0.296	0.006	0.090	0.170	0.170
	11	30-60	67.00	12.790	147.00	20.09	5.250	4.682	2.030	2.332	0.134	0.050	0.032	0.466	0.470
		0-30	32.00	7.862	68.20	12.55	3.922	0.858	0.742	0.280	0.084	0.012	0.140	0.176	0.190
	12	30-60	105.00	12.180	128.00	26.02	5.120	1.564	0.926	0.242	0.173	0.050	0.081	0.270	0.286
		0-30	35.00	6.740	88.00	14.51	2.882	0.520	0.512	0.108	0.097	0.340	0.055	0.068	0.108
	Average		**93.786**	**32.728**	**116.504**	**33.265**	**6.188**	**8.065**	**2.134**	**0.301**	**0.222**	**0.087**	**0.092**	**0.349**	**0.332**

reported that the irrigation with sewage water increased the total potassium. Saffari and Saffari (2013) also indicated that the irrigation with sewage water increased the soil potassium contents.

Content of the available iron (Fe) in the studied soil samples ranged from 7.01 to 145.74 mg/kg (Table, 6). Concentrations of available Fe in Abu Rawash soils are relatively higher than that in Arab Abu Saed soils with an average of 39.3 and 33.3 mg/kg in the two areas respectively. Considering the critical levels suggested by USDA/NRCS (2004), it is revealed that all of the studied soils are higher many times in the content of available Fe than the adequate levels of available Fe.

The amounts of avialable Mn in the studied soils ranged between 1.28 and 24.56 mg/kg (Table, 6). The content of available Mn in Abu Rawash soils are relatively higher than Arab Abu Saed soils, where this content have an average of 9.01 and 6.2 mg/kg, in the two areas respectively. According to the critical levels of Mn given by USDA/NRCS(2004); the majority of the studied soil samples contain adquate of available Mn.

The obtained data of avialble Zn in studied soil profiles ranged from 0.52 to 25.08 mg/kg (Table, 6). Concentrations of available Zn in Arab Abu Saed soils are relatively higher than Abu Rawash soils where its content appeared an average of 8.06 and 5.85 mg/kg in the two areas respectively. Regarding, the critical levels suggested by USDA/NRCS (2004), most of the subsequent layers of studied soils profiles have an adequate level of available Zn. Considering the vertical distribution of extractable Zn, it is characterized by decrese with depth in most of the studied profiles.

The contents of avialble Cu in the studied soils ranged from 0.35 to 8.94 mg/kg (Table, 6). The contents of available Cu in Abu Rawash soils are relatively higher than Arab Abu Saed soils appeared an average of 4.46 and 2.13 mg/kg in the two areas respectively. According to the critical levels of extractable Cu reported by USDA/NRCS (2004); the majority of the studied layers contain adquate levels of available Cu. Regarding the vertical distribution of the extractable Cu in the studied profiles, it is stated that Cu distribution is characterized by decrease distribution with depth in most of the studied profiles.

The contents of avialble B in the studied soils ranged from 0.025 to 2.332 mg/kg (Table, 6). The contents of available B in Abu Rawash soils are relatively lower than Arab Abu Saed soils appeared an average of 0.035 and 0.301 mg/kg in the two areas respectively.

The influence of anthropogenic activities as a major source of heavy metals in the soil, as well as dust, plants and sediments was observed by many studies (Fagbote and Olanipekun, 2010; Omran and El Razek, 2012; Yan et al., 2013; Sofianska et al., 2013 and Yadav et al., 2013). The guidelines of some pollutants elements in soil not settled. Egyptian law 4/94 did not include standard limit in dust and soil, or also in air except for lead in air (El-Gammal et al., 2011). Data declare large differences in the amounts detected for each element from place to another horizontally and vertically, confirming the effect of latitude and depth.

Contents of five elements (Cd, Co, Cr, Ni, Pb) representing the most prominent heavy metals, that pollute the soils from sewage water, are listed in Table 6. The decreasing order of the studied soils in concentration: Pb > Ni > Cd > Co > Cr at Abu Rawash area and Ni > Pb > Cd > Cr > Co at Arab Abu Saed area. Available Pb, Ni and Cd are relatively higher in Abu Rawash than Arab Abu Saed soils, while Cr and Co are relatively higher in Arab Abu Saed than Abu Rawash soils. Concentrations of these elements generally decreased vertically with soil depth except Pb which in all profiles increased with depth except profiles Nos. 1 and 3 of Abu Rawash soils. This illustrates the mobility potential of heavy metals down the soil profile. The study on vertical variations of heavy metals concentrations in soils with depth was able to illustrate potential trends in heavy metals contaminations, which might draw a picture for the historical variations of local contaminations through the temporal analysis on soils. Excessive mineral fertilization addition which commonly contains considerable quantities of available elements had led to accumulation of these metals in soil (Abdelhafez et al., 2012). These can be controlled through sewage water treatment and effective farm management practices. Although levels of heavy metals in sewage effluents are relatively low, the long term application of wastewater on agricultural lands often results in the accumulation of elevated levels of these metals in the soils, but this depends upon the period of its application (Ratten et al., 2005).

Statistical evaluation of soil characteristics: the effect of wastewater application:

Undoubtedly, microelements have a specific role in soil fertility and plant growth. In this context, chemically extractable levels of micronutrients may be a reliable guide for the assessment of their availability (El-Gundy, 1988). Pearson Correlations of the obtained soil data (physical and chemical characteristics and available elements) for the studied 12 soil profiles are provided in Figures 6 and 7. From these dendrograms, the effect of prolonged use of sewage wastewater upon the soil elemental composition was more evident in the number of sub-clusters obtained for Abu Rawash relative to Arab Abu Saed. The solubility of most heavy metals, dissolution and precipitation of soil minerals was reported to be controlled by its pH (Barrow, 1986).

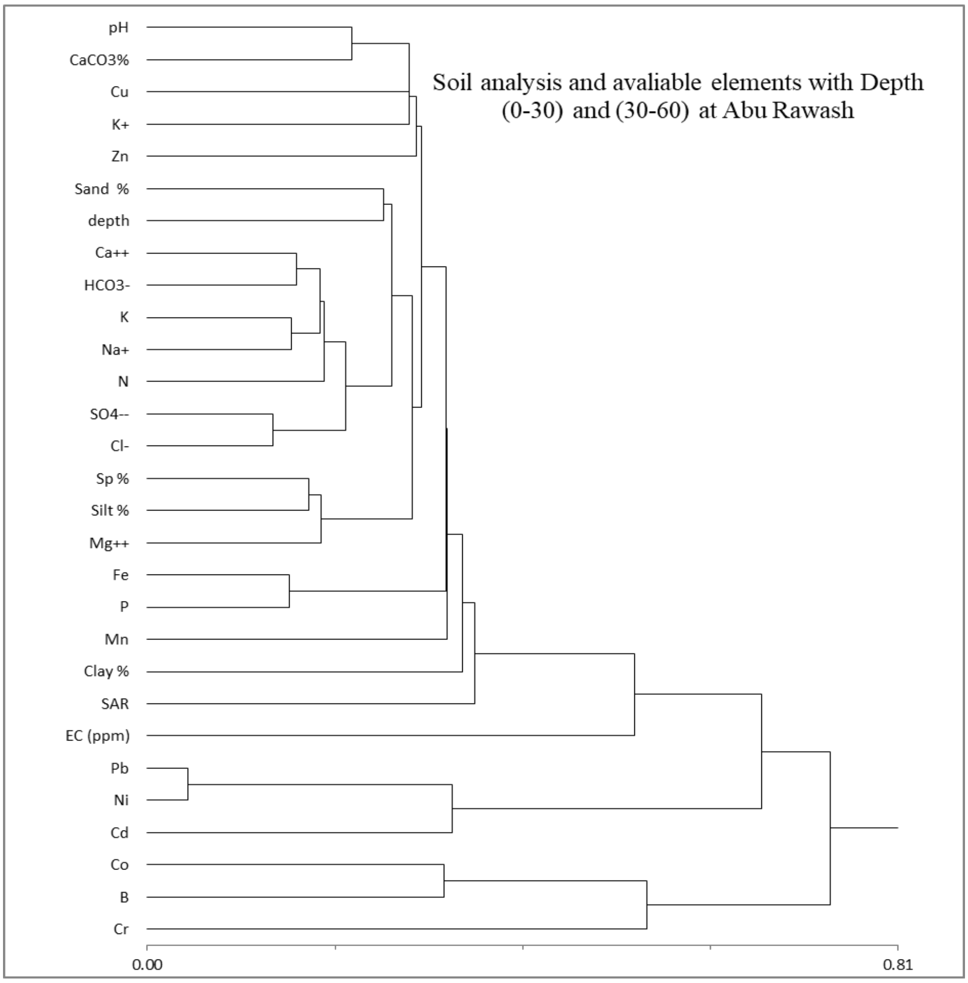

Figure 6. Dendrogram obtained of main physical and chemical available elements content per profile depth at the Abu Rawash Site using Pearson Correlation.

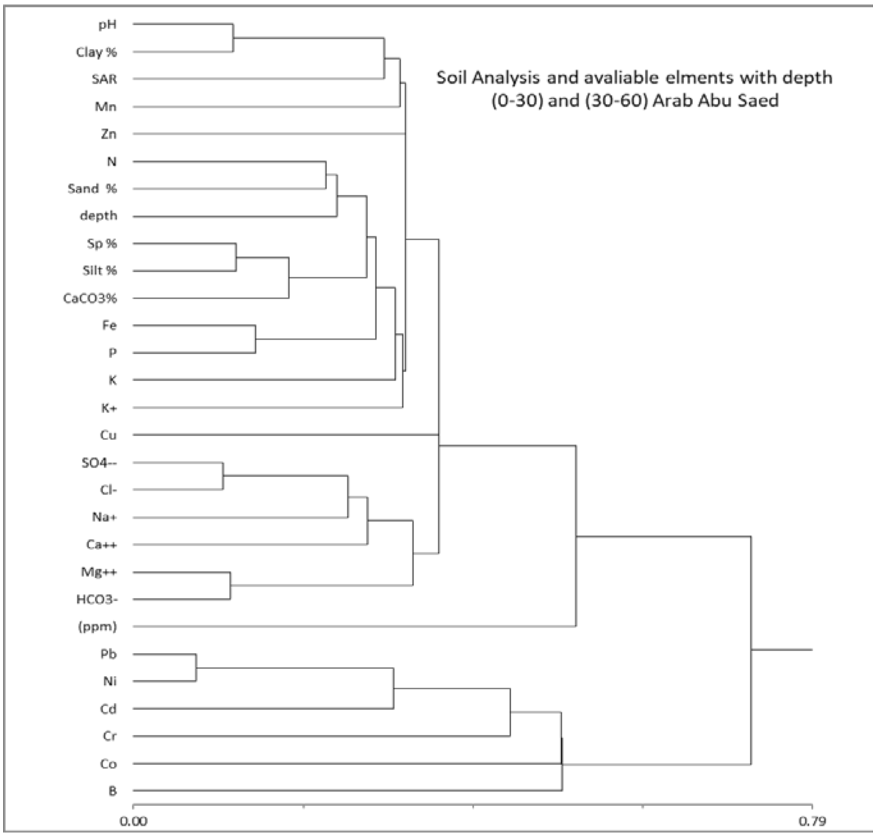

Figure 7. Dendrogram obtained of main physical and chemical available elements content per profile depth at Arab Abu Saed Site using Pearson Correlation.

a- Abu Rawash area:

Abu Rawash data has three main clusters (Figure 6). Cluster (1) splits into three subclusters: (A) infer to K, Zn and Cu elements and pH are related to $CaCO_3$; (B) (N, SO_4^{--}, Cl^-, HCO_3^-, Na^+, Ca^{++}, Mg^{++}, silt, sand ,depth and SP) refer to the relation of soluble ions with soil characteristics. The connection of these elements with the silt and sand fractions implied that they were retained in the surface layers or that they were consumed during crop production with the repeated application of sewage wastewater and (C) Fe and P and Mn. The other two clusters elements (2) Co, B & Cr and (3) Cd, Ni& Pb are separately from first one indicating another source for these heavy metals (not natural).

b- Arab Abu Saed area:

Figure (7) shows that there are two main clusters. Cluster (1) splits into three sub clusters: (A) infer to Zn and Mn, elements are related to clay; and to a lesser extent, with the SAR and pH value. (B) (N, P, K, Fe, silt, $CaCO_3$) indicate that N, P, K, Fe, Zn and Mn are more associated with the proportions of silt, and $CaCO_3$ and (C) (SO_4^{--}, Cl^-, Na^+, Ca^{++}, Mg^{++}, HCO_3^-) refer to the relation of soluble ions with soil characteristics. Cu showed a slight association with all the soil characteristics parameters. Cluster (2) is related to B, Co, Cr, Cd, Ni, Pb indicating no association between them and soil characteristics. Similar results were reported by Badawy and Helal (2002). The lack of such correlations suggests that the later heavy metals were may be derive from anthropogenic origin.

The soils in Abu Rawash area are older than the soils in Arab Abu Saed area, therefore soil dismantling event in Abu Rawash area due to frequent service processes.

Spatial Distribution of available topsoil elements content in the studied areas:

Due to the high spatial variability of soil, the collected soil samples can only represent the soil quality of the sample points themselves. Under the support of GIS, the spatial structure of macro- and micronutrients as well as heavy metals in soil can be simulated by the inverse distance weighted interpolation (IDW) method based on geostatistics, and the spatial distribution pattern of elements content can be visually expressed. Hereby, we used the inverse distance weighted (IDW) interpolation method to estimate the value of the regionalized variables of the unsampled points by Arc GIS 10.4 software, and finally generated the spatial distribution of macro- and micronutrients as well as heavy metals in the two studied areas. Spatial distributions of macro- and micronutrients as well as heavy metals concentrations in surface soil layer in the studied areas are shown in Figures (8 & 9).

1- Abu-Rawash area:

It can be seen from Figure (8) that the spatial distribution pattern of the available elements N, K, Mn, Cu, B, Co, Cr, Ni and Pb are generally similar, with elevated levels in the eastern side of the study area and may be affected by the El-Muhit drain. The similarity of spatial distribution pattern of different these soil elements indicated that these pollutants were strongly controlled by polluted water of the drain. While the P, Fe, Zn and Cd elements are distributed in the center of the study area. This feature is obviously different from other elements and may be related to the special geological background of the study area. In other words, this observation may indicate lower impressibility of these element contents in the soil near from the drain.

2- Arab Abu Saed area:

Figure (9) shows the spatial distribution of selected available elements for the soil, the values significantly differed in different locations. It appeared that the higher values of major elements (P, Fe, Zn, Cd, Cr, Ni and Pd) were concentrated mostly in the northern and north western side of the study area-near the source of sewage water. These observations clearly demonstrated that near El-Saff drain plays a key role in the pollutants distribution in this area. However, the high values of Co and B elements were focused on the northeast and southwest edge of the study area, which less influenced by anthropogenic activities.

Conclusions

The present research was done in order to study the effects of the sewage water on some soil chemical properties. On the basis of currently available data, the soil salinity level remained normal and the sodium level indicated by the soil sodium adsorption ratio (SARe) was below the critical level of 13, indicating no threat to the soil quality. Hence the soils could be suitable for crop production. The irrigation with sewage water also improved the chemical properties and fertility status of the studied soils. It increased levels of N, K, and P in the soils while it decreased the pH and $CaCO_3$ of the soils. Sewage water irrigation also reduces the use of other water sources especially fresh water that can be used elsewhere such as for drinking. Other factors have to be considered and studied with using sewage water in irrigation including the presence of chemical contaminants as well as salinity impacts on the soil structure.

Although levels of heavy metals in sewage effluents are relatively low, the long term application of wastewater on agricultural lands often results in the accumulation of elevated levels of these metals in the soils, but this depends upon the period of its application. The effect of prolonged use of sewage wastewater upon the soil elemental composition was more evident in the number of sub-clusters obtained for Abu Rawash relative to Arab Abu Saed.

Future research and development must focus on the use of sewage water in agriculture because fresh water sources for agriculture are diminishing while the amounts of sewage water from cities are rapidly increasing due to rapid population explosions and industrialization.

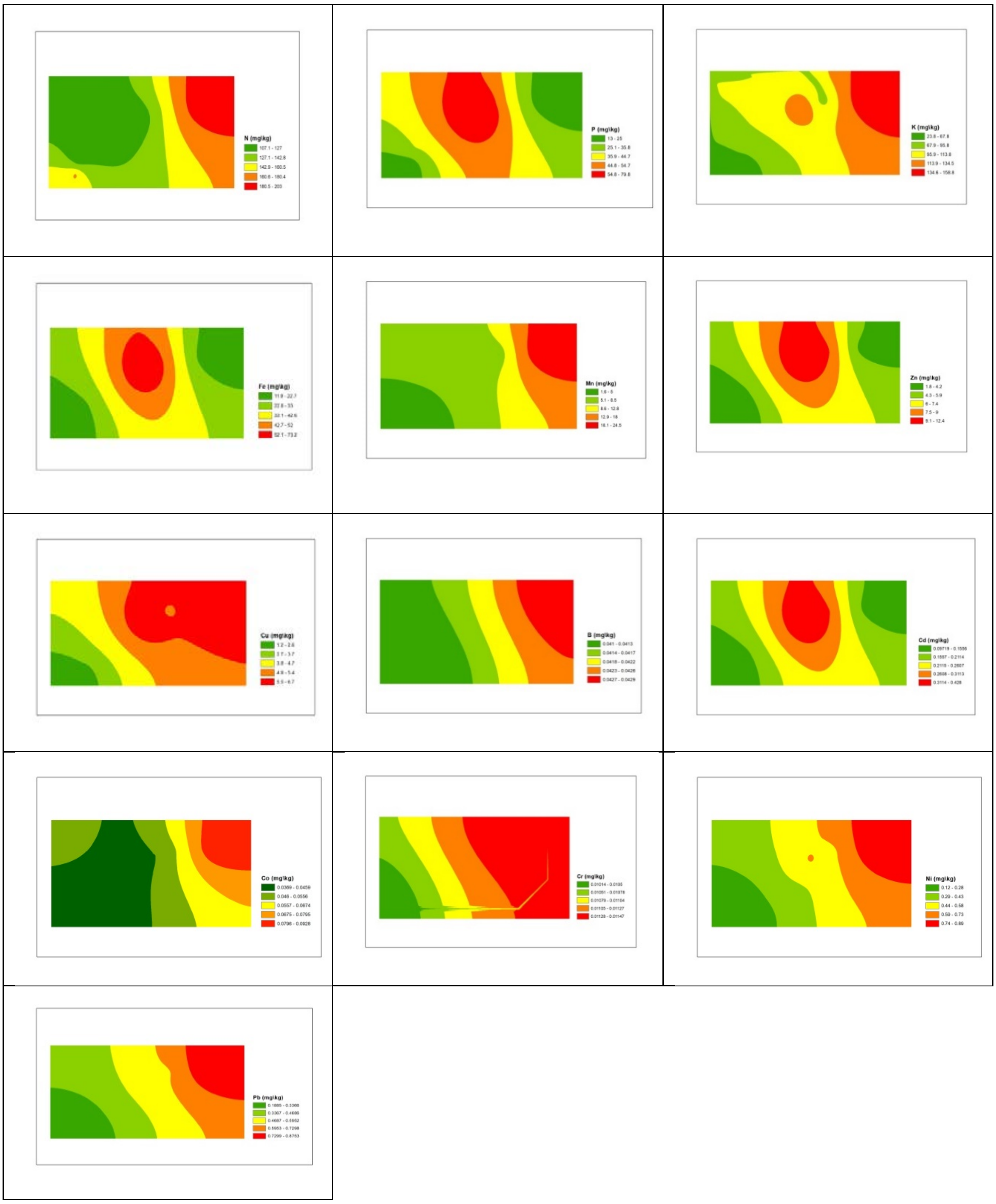

Fig. (8): Spatial distribution of macro- and micronutrients as well as Heavy metals concentrations in surface soil layer of Abu-Rawash area.

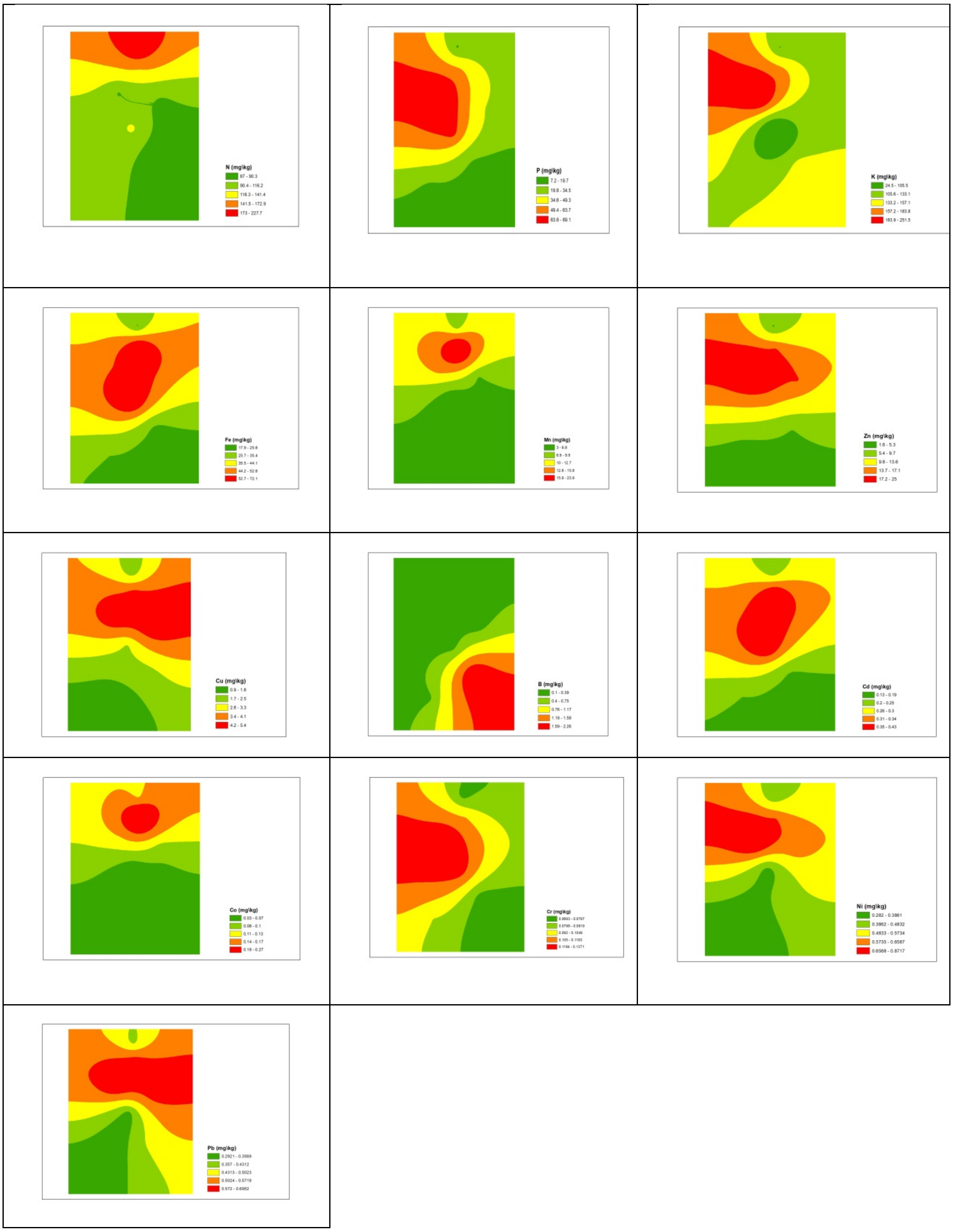

Fig. (9): Spatial distribution of macro- and micronutrients as well as Heavy metals concentrations in surface soil layer of Arab Abu Saed area.

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تأثير استخدام مياه الصرف المعالجة على خصائص التربة في منطقتي أبو رواش وعرب أبو ساعد ، مصر

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الملخص العربى

يقع موقعى الدراسة أبو رواش وعرب أبو ساعد في الأجزاء الغربية والجنوبية من محافظة الجيزة علي الترتيب. وهما يمثلان موقعين مرويين بمياه الصرف المعالجة. تم جمع اثني عشر قطاعًا تربة بالإضافة إلى ١١ عينة مياه باستخدام نظام تحديد المواقع العالمي (GPS). تم الحصول على عينات من التربة لتمثل عمقين: السطح (٠-٣٠ سم) والعمق السفلي (٣٠-٦٠ سم). تم جمع عينات المياه بالقرب من عينات التربة. تم تحديد الخصائص الفيزيائية والكيميائية لـ ٢٤ عينة تربة و ١١ عينة ماء. تم إجراء تحليل العنقودى على البيانات التحليلية للمياة المعالجة والتربة السطحية بشكل منفصل. تم إنتاج التوزيع المكاني باستخدام ميزة ترجيح المسافة العكسية (IDW) في برنامج Arc-GIS 10.4.

وفقًا لقيم ECw و SAR ، فإن مصادر المياه هذه ذات جودة معقولة يمكن استخدامها للري مع قيود قليلة. وتجدر الإشارة إلى أنه على الرغم من أن محتويات معظم العناصر الغذائية الصغرى والكبرى والعناصر الثقيلة مرتفعة نسبيًا في الموقعين مقارنة بمياه الري العذبة ، إلا أن مستوياتها لا تزال ضمن الحدود القصوى الموصى بها للكود المصري والمياه العالمية.

تم وصف التحليل العنقودي للبيانات التحليلية للمياة المعالجة (باستثناء الاملاح الكلية الذائبة) في كل منطقتى أبو رواش وعرب أبو ساعد ، ظهر مجموعة من العناصر مرتبطة مع بعضها: P و Fe و Mn و Zn و Cu و Cd و Cr و Ni و B و Pb. قد نستنتج من هذه العلاقة المتبادلة أن هذه العناصر كانت من نفس المصدر وليست طبيعية.

وجد فى التحليل العنقودى للبيانات التحليلية للتربة بمنطقة ابو رواش ان K^+ و Zn و Cu و pH مرتبطة بـ $CaCO_3$ ؛ بينما وجد N، SO_4^{--}، Cl^-، $HCO3^-$، Na^+، Ca^{++}، Mg^{++} مرتبطة بالطمي ، الرمل ، العمق و SP تشير إلى علاقة الأيونات الذائبة بخصائص التربة.و في منطقة عرب أبو ساعد ، وجد ان(Zn و Mn و pH و SAR) مرتبطين بوجود الطين. كذلك ، يشير وجود $SO4^{--}$، Cl^-، Na^+، Ca^{++}، Mg^{++}، HCO_3^- إلى علاقة الأيونات الذائبة بخصائص التربة. ووجد ايضا ارتباط N و P و K و Fe و Zn و Mn بشكل أكبر بنسب الطمي والطين و $CaCO_3$ وبدرجة أقل مع SAR وقيمة pH. تعتبر التربة في منطقة أبو رواش أقدم من التربة في منطقة عرب أبو ساعد ، لذلك حدث تفكيك للتربة في منطقة أبو رواش بسبب عمليات الخدمة المتكررة.

في موقع أبو رواش ، يتشابه نمط التوزيع المكاني للعناصر (N ،K ، Mn ، Cu ، B ، Co ، Cr ، Ni ، Pb) بشكل عام ، مع وجود مستويات مرتفعة في الجانب الشرقي ويعزى ذلك بتاثرها بوجود مصرف المحيط . أما في موقع عرب أبو ساعد ، تركزت القيم الأعلى للعناصر الرئيسية (P، Fe، Zn، Cd، Cr، Ni، Pb) في الجانب الشمالي والشمالي الغربي بالقرب من مصادر الصرف. أظهرت هذه الملاحظات أن توزيع الملوثات كانت أعلى بالقرب من مصرف الصف الموجود بالمنطقة.

الكلمات المفتاحية: CA، GIS، التوزيع المكاني، خصائص التربة السطحية، أبو رواش، عرب أبو ساعد.