Al-Azhar Bulletin of Science

Volume 33 | Issue 2 Article 7

12-1-2022

Section: Botany, Microbiology and Zoology

# Impact of wastewater irrigation on chemical composition and heavy metals accumulation in soil (study case: Helwan-El Saff area)

Mervat Elliethy
*Botany and Microbiology Department, Faculty of Science (Girls Branch), Al- Azhar University, Cairo, Egypt.*, mervet@azhar.edu.eg

Abdel Aziz Ragab
*Soil, Water and Environment Research institute Agriculture Research Center Giza, Egypt.*, dazizzezo@gmail.com

Ramadan Bedair
*Botany and Microbiology Department, Faculty of Science (Boys Branch), Al- Azhar University, Cairo, Egypt.*, danbder@yahoo.com

Om Mohamed khafagi
*Botany and Microbiology Department, Faculty of Science (Girls Branch), Al- Azhar University, Cairo, Egypt.*, ommohamedkhafagi2445.el@azhar.edu.eg



## How to Cite This Article

Elliethy, Mervat; Ragab, Abdel Aziz; Bedair, Ramadan; and khafagi, Om Mohamed (2022) "Impact of wastewater irrigation on chemical composition and heavy metals accumulation in soil (study case: Helwan-El Saff area)," *Al-Azhar Bulletin of Science*: Vol. 33: Iss. 2, Article 7.
DOI: https://doi.org/10.21608/absb.2022.140217.1186

*Al-Azhar Bulletin of Science, Section C, Vol. 33, No. 2 (December) 2022, pp. 85-98*
http://doi.10.21608/absb.2022.140217.1186

Al-Azhar Bulletin of Science: Section C

# IMPACT OF WASTEWATER IRRIGATION ON CHEMICAL COMPOSITION AND HEAVY METALS ACCUMULATION IN SOIL (STUDY CASE: HELWAN-EL SAFF AREA)

**Mervat Z. Elliethy [a,*], Abdel Aziz M. Ragab [b], Ramadan I. Bedair [c], Om Mohamed A. Khafagi [a]**
[a] Botany and Microbiology Department, Faculty of Science (Girls Branch), Al-Azhar University, Cairo, Egypt.
[b] Soil, Water and Environment Research institute Agriculture Research Center Giza, Egypt.
[c] Botany and Microbiology Department, Faculty of Science (Boys Branch), Al-Azhar University, Cairo, Egypt.
* Corresponding Author: mervet@azhar.edu.eg
Received: 24 Mar 2022; Revised: 30 May 2022; Accepted: 08 June 2022; Published: 01 Dec 2022

## ABSTRACT

This investigation was conducted on nine sites at Helwan – El Saff area, Cairo, and Giza governorates (polluted area), and three sites, in Metrabeaa village, Monofia governorate (control). This study aimed to assess the impact of wastewater irrigation on soil quality and to test the possibility of using it as an alternative for fresh water in irrigation of agricultural land. Water and soil samples were collected from El-Khashab canal (polluted water) and Al-Bagoria canal (Nile water) and cultivated land sites adjacent to them during two seasons (July 2019 and July 2020). The values of electric conductivity (EC), sodium adsorption ratio (SAR), studied cations, anions and heavy metals were significantly higher; in wastewater samples than in Nile water samples; meanwhile, the opposite was true for hydrogen ion concentration (pH), available nitrogen and phosphorus (N and P). The values of EC, $Ca^{++}$, $Na^{+}$, $Cl^{-}$, $SO_4^{--}$, $CaCO_3$,organic matter (OM) and all studied heavy metals increased in soil irrigated with wastewater as compared with the soil irrigated with Nile water; meanwhile, the opposite was true for pH, $Mg^{++}$, soluble $K^{+}$, and $HCO_3^{-}$. The values of contamination factor followed the order: Co > Cr > Zn > Mn > Fe > Cu > Pb. Moreover, the pollution load index of soil ranged from 25.81 to 16.16. The data of this research revealed that wastewater of El-Khashab canal could effectively be used as fertility source for soil, but there are some risks as heavy metals may threaten sustainable agriculture in the study area.

***Keywords:*** Wastewater; Soil properties; Helwan - El Saff area; El-Khashab canal; Contamination factor; Sustainable agriculture

### 1. Introduction

Water is a vital resource but a severely limited in most countries. Rapid industrial developmental activities and increasing population growth had declined the resources day to day throughout the world [1]. The freshwater scarcity is becoming an increasing problem especially in the semi-arid and arid regions of the world due to geographical aridity and climatic change [2]. The scarcity of water continues to be a major issue for Egypt, which depends almost totally on the Nile River for the country's water resources. According to some studies, Egypt is on track to reach a threshold of "absolute water scarcity" by 2030. The changes of climate, particularly higher temperatures are predictable to shorten growing seasons and reduce agricultural yields in Egypt. Large amounts of water are also lost through evaporation every year, something that climate change will worsen. Not to mention the pollution damage to the Nile, which is widespread [3].

Grand Ethiopian Renaissance Dam will increase the water shortage problem in Egypt. Although, Ethiopia pronounces the dam will advantage downstream neighbors and will have no negative impacts on their water supply, there is no one can deny that the dam will give the upstream country greater control over an international river's flow. A major worry is how filling the huge reservoir which will affect the security of water in Egypt, which relies almost totally on the Nile for its water supply. Depending on how long it takes to fill the reservoir (it has been estimated to take from 3 to 7 years), the Nile flow into Egypt could be decrease by 12-25% during the filling period [4].

The rapid growth of the world's urban population has not only lead to an increase in the demand for the limited available freshwater but has also caused an increase in the amount of wastewater produced year by year [5].The untreated water produced can find its way into water systems such as costal, rivers, lakes and groundwater waters with the potential to cause severe pollution. Wastewater may contain undesirable chemical constituents and pathogens that cause negative environmental and health impacts [6].

Large amounts of water are needed for agricultural land irrigation. If the wastewater can be used as an alternative water source for irrigation purpose, the double problems of negative environmental effects and huge water demand for agricultural irrigation would be solved [7]. The reuse of wastewaters for purposes such as agricultural land irrigation can reduce the amount of water that needs to be extracted from environmental water sources [8]. Wastewater is sustainable source and not only offers an alternative water irrigation source, but also the opportunity to recycle plant nutrients [7]. Its application might ensure the transfer of fertilizing elements, such as organic matter, macro- nutrients and micro-nutrients, into agricultural soil [9]. Hence, wastewater nutrients can improve crop growth [10].Most of wastewater contain heavy metals in an amount sufficient enough to cause soil contamination and toxicity to crop plants. Soil contaminated with heavy metals is a primary way of humans exposure toxic element. Toxic metals can enter the human body by eating of contaminated food crops [11].

Wastewaters can be used for irrigation under controlled conditions to reduce hazard from pathogenic and toxic contaminants of the agricultural products, soils, ground, and surface water. Additionally, it is an important source of nutrient for poor-fertility soils [12]. It is therefore necessary to assess the impacts of wastewater on soil health before planning wastewater irrigation in the long-term. There is need for soil periodic monitoring, to avoid any imbalance in the nutrient supplies or level of heavy metals contamination [13 and 10].

The present study aimed to evaluate some important chemical properties of water of El-Khashab canal which receive large amount of wastewater (industrial, domestic and agricultural wastewater), and the impacts of irrigation with this water on important physicochemical properties and heavy metals accumulation in the soil to assess the benefits and risks of using wastewater as an alternative for fresh water in irrigation of agricultural land.

## 2. Materials and Methods

### *2.1. The study area*

The investigated area (Helwan-El Saff) is located east of the River Nile and south Cairo between long. 31° 17' 48.91146" and 31° 18' 16.38112" E and Lat. 29° 36' 40.19216" and 29° 48' 33.32128" N. Cairo and Giza governorates. Helwan-El Saff area is bounded by El-Maasara area to the North, Atfih area to the South, El Saff wastewater canal and Autostrade highway to the East and Nile River to the West. This area constitutes five population centers namely; El-Maadi, Helwan, Turah, El-Tibein and El-Saff with total area 61,979 $Km^2$ [14] (Fig.1).

Helwan is an industrial area at the southern of Cairo and it is nearby the Nile River. It contains nearly 16.5% of the total industrial activities in great Cairo as Iron and steel, Coke, fertilizers and chemicals, cement, blocks and other industries which scattered in the study area [14]. Some of these industries discharge their wastes to the nearest wastewater treatment plant, on the other hand, most of them are not linked with the sanitation service of the city. Therefore, the wastewater of these units are discharged into the nearest stream, except iron and steel unit, which discharge their effluents into special pipe to treat it with evaporation. Some farmers use this pipe for irrigation of their fields. The sewage water treatment unit of Helwan also discharge its wastes (after primary treatment) into El-Khashab and El-Saff canals, which is used for irrigation. Most of vegetables which supply markets in the city were cultivated in this area and were irrigated with this polluted water [15].

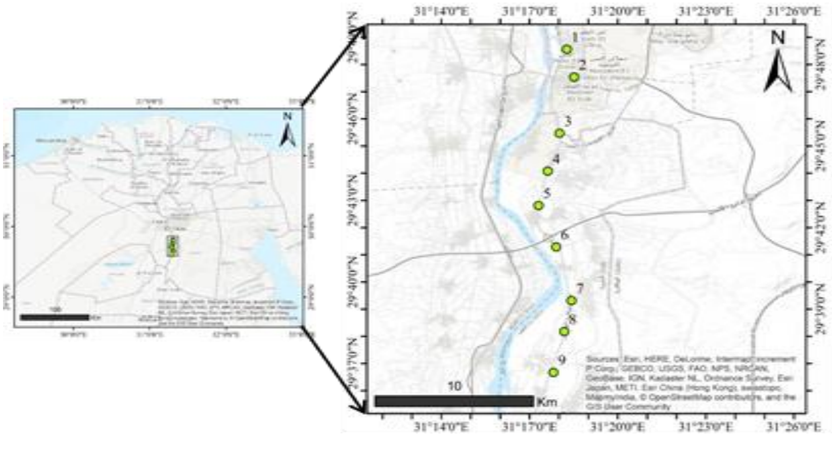


**Figure 1.** Helwan-El Saff main cities.

**Table 1:** Name, locality, Global Positioning System (GPS) coordinates, and altitude above sea level of the selected 9 sites within the study area in Helwan-El Saff

| Site Number | Site name | Latitude (N) | Longitude (E) | Altitude (meter) |
|---|---|---|---|---|
| 1 | Kafr Al-Olow | 29° 48' 33.32128" | 31° 18' 16.38112" | 38 |
| 2 | Al-Hakr Al-Qibly | 29° 47' 32.20652" | 31° 18' 30.9253" | 52 |
| 3 | Al-Shoubak Al-Sharqi | 29° 45' 28.06934" | 31° 18' 1.39432" | 67 |
| 4 | Al-Oteyat | 29° 44' 4.48728" | 31° 17' 37.41472" | 89 |
| 5 | Al-Ikhsas | 29° 42' 48.6243" | 31° 17' 18.56681" | 61 |
| 6 | Al-Marj | 29° 41' 17.15377" | 31° 17' 54.49448" | 63 |
| 7 | Ghammazh Al-Sughra | 29° 39' 18.70643" | 31° 18' 25.73928" | 70 |
| 8 | Ezbet Al-Gmmal | 29° 38' 10.43981" | 31° 18' 11.13419" | 47 |
| 9 | Tal Hammad | 29° 36' 40.19216" | 31° 17' 48.91146" | 77 |

Helwan- El Saff area can be classified into three regions, domestic region, industrial region and agricultural farms. The area comprises a few small villages (Ezabs) connected to the old and worn out sewage network. Some of the scattered communities and houses are not connected to the formal sewage network. They dispose their domestic wastes either in private septic tanks (latrines) or directly to the water canals. Besides industrial wastes, the study area might exhibit some inputs from agricultural activities [16].

### *2.2. Samples and analysis*

Water sample were collected from nine sites (Fig.1) in El-Khashab canal in Helwan – El Saff area. Surface soil samples (0 -30 cm) were collected from each of the nine sites in the cultivated lands adjacent to El-Khashab canal during two seasons (July 2019 and July 2020). Water samples were collected from three sites in Al-Bagoria canal in Metrabeaa village, Monof, El Monofia. Surface soil samples (0 -30 cm) were collected from each of the three sites in the cultivated lands adjacent to Al-Bagoria in Metrabeaa village canal as control.The soil samples were air-dried, ground and sieved through a 2 mm sieve for analyses. The soil texture, organic matter and calcium carbonate were determined according to [17], [18] and [19]**,** respectively. The saturated soil paste was prepared according to [20]. Electrical conductivity (EC) was measured according to [20]. Sodium adsorption ratio (SAR) was calculated in water according to [21]. Soluble carbonates and bicarbonates were determined in soil and water according to [22]. The hydrogen ion concentration (pH), chlorides, calcium, magnesium, sodium and potassium were estimated in soil and water according to [23]. Sulphates were calculated in soil and water as the difference between the total measured soluble cations and the total measured soluble anions. Available nitrogen, phosphorus, and potassium were determined in soil and water according to [24], [23], and [25], respectively. The trace elements (Fe, Mn, Zn, Cu, Co, Cr, and Pb) were determined in water and soil samples according to [26] and [27].

The contamination factor (CF) for soil is “the ratio obtained by dividing the concentration of each heavy metal in the soil by the background concentration of metal” (either from literature or directly determined from a geologically similar and uncontaminated area) [28].

“CF = C soil / C background”

According to [28] **“**the values of Cf < 1 point to low contamination, 1< Cf < 3 point to moderate contamination, 3< Cf < 6 point to considerable contamination and Cf > 6 point to very high contamination”.

The pollution load index (PLI) is “an easy method to prove the deterioration of the soil conditions due to the accumulation of heavy metals" [29] and was calculated as the following formula:

“$PLI=\sqrt[n]{CF_1 \times CF_2 \times CF_3 \times CF_4 \ldots\ldots\ldots CF_n}$ ”

where n is “the represent number of metals and CF is the contamination factor value”.

All obtained data were subjected to statistical analyses. Analyses of variance was done using ANOVA through computer costat package to get the significance according to [30], where mean values were compared using L.S.D at 5% level.

## 3. Results and Discussion

All the data presented in the following tables are the mean of two seasons (July 2019 and July 2020).

### *3.1. Irrigation water*

The data presented in Table 2 show some chemical characteristics of water samples collected from the selected nine sites and water samples of

Nile water (control). The measured parameters were EC, SAR, pH, the soluble cations ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$), the soluble anions ($HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$) and available N, P and K.

### *3.1.1. Electric conductivity (EC)*

The values of EC of water samples collected from the different nine sites ranged from a minimum value of 0.47 $dSm^{-1}$ in site 2 (Al-Hakr Al-Qibly located 3.5 km northward the industrial complex) to a maximum value of 1.97 $dSm^{-1}$ in site 6 (Al- Marj located 7.6 km southward the industrial complex). The differences between the highest value of site 6 and the EC values of all other sites were significant (Table 2).The EC values also showed gradual and significant decline from the highest value of site 6 (adjacent to the industrial area) to the upstream ward through sites 7, 8, and 9. It also decreased gradually from site 6 downstream ward through sites 5, 4, 3, 2, 1. In other words, the more the distance away from the pollution point the less the EC value was (Table 2).The mean value of EC was significantly higher in wastewater (WW) samples than the mean value of EC of Nile water samples (Table 2). Water samples from El-Khashab canal (Helwan- El Saff area) were characterized by higher EC (0.86 dS $m^{-1}$) than River Nile water (0.35 dS $m^{-1}$), and this may be due to industrial wastes which were discharge into the canal, excessive use of fertilizers and pesticides, domestic uses of detergents [16].

**Table 2:** Chemical characteristics of irrigation water of the different sites (average of two summer seasons; Jul. 2019 and Jul. 2020)

| Site No. | EC dS $m^{-1}$ | SAR | pH | Soluble ions ($m_{eq}$ $L^{-1}$) | | | | | | | Macronutrients (mg $L^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^{-}$ | $Cl^{-}$ | $SO_4^{--}$ | N | P | K |
| **Sites under wastewater irrigation** | | | | | | | | | | | | | |
| **1** | 0.59d | 0.93d | 6.93abc | 2.96ef | 1.68cde | 1.40d | 0.14cd | 1.85b | 1.36ef | 2.97d | 8.33c | 0.04b | 5.96cd |
| **2** | 0.47e | 0.70e | 6.96ab | 2.87ef | 1.12e | 0.98f | 0.10e | 1.65de | 1.16f | 2.26de | 8.75bc | 0.01b | 4.21e |
| **3** | 0.61d | 0.86de | 6.81bcd | 3.19de | 1.40cde | 1.31de | 0.16bc | 1.67cde | 1.58de | 2.82d | 9.45a | 0.15b | 6.84bc |
| **4** | 1.04c | 2.05c | 6.76d | 3.99bc | 1.98cd | 3.54c | 0.30a | 2.34a | 3.27c | 4.19c | 9.57a | 0.69a | 12.83a |
| **5** | 0.99c | 1.95c | 6.80cd | 3.57cd | 2.88ab | 3.48c | 0.18b | 1.81bc | 3.16c | 5.14b | 9.01ab | 0.27b | 7.84b |
| **6** | 1.97a | 3.51a | 6.85abcd | 5.12a | 3.15a | 7.13a | 0.16bc | 1.81bc | 6.13a | 7.63a | 5.95d | 0.20b | 6.96bc |
| **7** | 1.26b | 2.71b | 7.00a | 4.51b | 2.16bc | 4.96b | 0.12de | 1.76bcd | 4.41b | 5.57b | 6.46d | 0.25b | 4.96de |
| **8** | 0.52e | 0.76de | 6.88abcd | 2.91ef | 1.46cde | 1.12def | 0.10e | 1.73bcd | 1.30ef | 2.57d | 5.25e | 0.18b | 4.21e |
| **9** | 0.50e | 0.74e | 6.86abcd | 2.49f | 1.23de | 1.01ef | 0.09e | 1.56e | 1.66d | 1.60e | 8.75bc | 0.08b | 3.96e |
| **L.S.D at 0.05** | 0.05 | 0.18 | 0.15 | 0.53 | 0.80 | 0.30 | 0.02 | 0.14 | 0.28 | 0.91 | 0.63 | 0.29 | 1.18 |
| **Mean** | 0.88 | 1.58 | 6.87 | 3.51 | 1.90 | 2.77 | 0.15 | 1.80 | 2.67 | 3.86 | 7.95 | 0.21 | 6.42 |
| **Sites under Nile water irrigation (control)** | | | | | | | | | | | | | |
| **10** | 0.32 | 0.15 | 7.10 | 1.21 | 1.90 | 0.19 | 0.07 | 1.42 | 0.85 | 1.11 | 10.35 | 0.54 | 3.36 |
| **11** | 0.36 | 0.36 | 7.20 | 1.82 | 1.56 | 0.47 | 0.08 | 1.50 | 1.02 | 1.40 | 13.82 | 0.71 | 3.77 |
| **12** | 0.35 | 0.42 | 7.20 | 1.67 | 1.58 | 0.54 | 0.08 | 1.60 | 0.93 | 1.33 | 12.43 | 0.64 | 3.44 |
| **Mean** | 0.34 | 0.31 | 7.17 | 1.57 | 1.68 | 0.40 | 0.08 | 1.50 | 0.93 | 1.28 | 12.20 | 0.63 | 3.52 |
| **L.S.D at 0.05 WW× control** | 0.41* | 0.82* | 0.11* | 1.07* | 0.52 | 1.70* | 0.04* | 0.22* | 1.52* | 1.23* | 2.83* | 0.27* | 1.93* |

### *3.1.2. Sodium adsorption ratio (SAR)*

The values of SAR in the nine collected water samples (Table 2) varied significantly from 0.7 in site 2 to 3.51 in site 6. The presented SAR values revealed similar trend as that of EC values, regarding the gradual decrease in value from the highest value recorded in site 6 towards the upstream direction through sites 7, 8 and 9 and toward the downstream direction of the irrigation canal through sites 5, 4, 3, 2 and 1. Thus, it could be stated generally that, as the distance increase away from the source point of the industrial discharge effluent the SAR values decrease significantly. Table 2 presented that the mean value of SAR increased significantly in wastewater (WW) samples than the mean value of SAR of Nile water samples. According to the guidelines of [31] irrigation water with SAR value ranging from 0 to 10, can be used for irrigation on almost all soils with slight danger of development of damaging levels of exchangeable sodium. However, sodium sensitive crops, such as trees of fruit and avocados may accumulate harmful concentration of sodium.

### *3.1.3. Hydrogen ion concentration (pH)*

Data presented in Table 2 declare that the pH of irrigation water samples of the nine sites ranged between 6.76 to 7 without significant difference between most of sites. According to the guidelines of [21] and [32] all pH values of irrigation water of the present investigation fall in the normal range (6.5-8.5). The mean value of pH decreased significantly in wastewater (WW) samples as compared with the mean value of pH of samples of Nile water (Table 2).

*3.1.4. Soluble ions*

*3.1.4.1. Soluble cations*

Values of the soluble cations $Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$ in irrigation water samples varied significantly from the maximum values recorded in site 4 ($K^{+}$) and site 6 ($Ca^{++}$, $Mg^{++}$ and $Na^{+}$) to minimum values recorded in site 2 ($Mg^{++}$ and $Na^{+}$) and site 9 ($Ca^{++}$ and $K^{+}$). Sites 4, 5 and 6 are adjacent to the pollution source point (industrial complex); while, sites 1, 2, 7, 8 and 9 are far from the center of pollution (Fig. 1 and Table 1). The mean values of the soluble cations in irrigation water samples collected from the nine different sites followed the order: $Ca^{++} > Na^{++} > Mg^{++} > K^{+}$. The mean values of all cations increased significantly (except $Mg^{++}$increased non-significantly) in wastewater (WW) samples as compared with the mean values of Nile water samples (Table 2).

*3.1.4.2. Soluble anions*

The soluble anions ($HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$) varied significantly from the maximum values in irrigation water samples collected from site 4 ($HCO_3^{-}$) and site 6 ($Cl^{-}$ and $SO_4^{--}$) to minimum values of samples collected from site 2 ($Cl^{-}$) and site 9 ($HCO_3^{-}$ and $SO_4^{--}$). The mean values of the soluble anions in irrigation water samples collected from the nine different sites followed the order: $SO_4^{--} > Cl^{-} > HCO_3^{-}$ (Table 2). The mean values of $HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$ increased significantly in samples of wastewater (WW) as compared with the mean values of $HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$ in samples of Nile water.

The addition of sewage waste and released dust of cement factory in the area, household uses of water, fertilizers used in agriculture purposes, action of detergents, and domestic wastewater discharge into canal were most probably responsible for the increase of these ions level in El-Khashab canal [33].

*3.1.5. Macronutrients (available N, P and K)*

The maximum value of available N, P and K in the nine water samples collected from the irrigation canal was recorded in site 4 (Al- Oteyat located 2.1 km southward the industrial complex). The minimum value of N was that of site 8 and the minimum value of P was that of site 2, while the minimum value of K was recorded in water sample of site 9. The maximum values of N, P and K were recorded in site 4 (adjacent to the industrial complex) and these values decreased with increasing the distance from the pollution point either upstream or downstream (Table 2). The mean values of available N and P were significantly lower in wastewater (WW) samples than in samples of Nile water (control); meanwhile, the opposite was true for K.

Some factory wastewater are treated before disposal, however many nutrients and organic chemicals remain in significant concentrations in the treated wastewater. The nutrients contained in these wastewater, e.g. N, P, K and organic matter make it suitable for irrigation, [34].

*3.1.6. Heavy metals*

The results of heavy metals (Fe, Mn, Zn, Cu, Co, Cr, and Pb) content of water samples collected from the different nine sites are presented in Table 3. The content of iron (Fe) in some water samples was higher than the permissible level (0.3 mg $L^{-1}$, [35]). The Fe content of the studied water samples exceeded the permissible level by 446.67 %, 20.00 %, 3.33 % and 113.33%, for water sample of sites 4, 5, 6 and 8, respectively. The maximum and minimum values of Fe were recorded in water sample of sites 4and 2, respectively. The values of Mn exceeded the permissible level (0.1 mg $L^{-1}$, [35]) by 260%, 270%, 350%, 510%, 390%, 610%, 270%, 300% and 310% for water sample of sites 1-9, respectively. The water samples of sites 6 and 1 recorded the highest and lowest values of Mn, respectively.

The maximum value of Zn was recorded in water sample of site 2 and the value decreased significantly until it reached to the minimum values in water sample of sites 1, 4, 5, 6, 7, 8 and 9(non-significant difference among them). The Zn content of all the studied water samples was lower than the permissible level (1.00 mg $L^{-1}$, [35]). The water samples of sites 3 and 2 recorded the highest and lowest values of Cu, respectively. The concentration of Cu in water samples of all sites was greater than the permissible level (0.05 mg $L^{-1}$, [35]) by 608%, 618%, 610%, 606%, 610%, 610%, 606% and 606% for water sample of sites 1 and 3-9, respectively. Cobalt concentration in water samples of all sites was higher than the permissible level, with was non-significant difference among the sites, but the water samples of sites 2, 5, and 6 have the highest value of Co.

The highest Cr value was that of water sample of site 2, with non-significant difference among all sites. The Cr content of the studied water samples higher than the permissible level (0.05 mg $L^{-1}$) by 14%, 22%, 12%, 14%, 12%, 14%, 12%, 12% and 14% for water sample of sites 1-9, respectively. The water sample of site 7 recorded the highest value, while the lowest value was recorded in water samples of sites 2 and 9. The Pb content of the studied water samples exceeded the permissible level (0.01 mg $L^{-1}$, [35]) by 700%, 670%, 680%, 680%, 750%, 690%, 810%, 760% and 670% for water sample of sites 1-9, respectively. The mean values of all studied heavy metals were significantly higher in water samples of Helwan- El Saff area than in samples of Nile water (Table 3).

**Table 3:** Heavy metals content (mg $L^{-1)}$ of irrigation water of the different sites (average of two summer seasons; Jul. 2019 and Jul. 2020)

| Site No. | Micronutrients (mg $L^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fe | Mn | Zn | Cu | Co | Cr | Pb |
| **Sites under wastewater irrigation** | | | | | | | |
| 1 | 0.26c | 0.36e | 0.34c | 0.354a | 0.088a | 0.057a | 0.080ab |
| 2 | 0.25c | 0.37e | 0.61a | 0.036b | 0.089a | 0.061a | 0.077b |
| 3 | 0.29c | 0.45cd | 0.52b | 0.359a | 0.088a | 0.056a | 0.078ab |
| 4 | 1.64a | 0.61b | 0.37c | 0.355a | 0.087a | 0.057a | 0.078ab |
| 5 | 0.36c | 0.49c | 0.37c | 0.353a | 0.089a | 0.056a | 0.085ab |
| 6 | 0.31c | 0.71a | 0.35c | 0.355a | 0.089a | 0.057a | 0.079ab |
| 7 | 0.28c | 0.37e | 0.35c | 0.355a | 0.087a | 0.056a | 0.091a |
| 8 | 0.64b | 0.40de | 0.34c | 0.353a | 0.087a | 0.056a | 0.086ab |
| 9 | 0.29c | 0.41cde | 0.36c | 0.353a | 0.088a | 0.057a | 0.077b |
| L.S.D at 0.05 | 0.10 | 0.07 | 0.06 | 0.054 | 0.01 | 0.009 | 0.01 |
| Mean | 0.48 | 0.46 | 0.40 | 0.32 | 0.09 | 0.06 | 0.08 |
| **Sites under Nile water irrigation (control)** | | | | | | | |
| 10 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| 11 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.003 |
| 12 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.003 |
| Mean | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 |
| L.S.D at 0.05 WW× control | 0.05* | 0.08* | 0.34* | 0.13* | 0.001* | 0.016* | 0.03* |
| The permissible level [35] | 0.30 | 0.10 | 1.0 | 0.05 | - | 0.05 | 0.10 |

The most of heavy metal values of water samples from EL-Khashab canal were exceeded the permissible level, and attributed that to the discharge of large amount of wastewater (domestic and industrial) in this canal which suffered from pollution due to industrial and human activity in this area [33].

### *3.2. Soil characteristics*

The data presented in Table 4 show some chemical characteristics of soil samples collected from the selected nine sites under wastewater irrigation from El-Khashab canal and three sites under Nile water irrigation as control. The measured parameters were EC, pH, the soluble cations ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$), the soluble anions ($HCO_3^{-}$, $Cl^{-}$ and $SO_4^{--}$) and available N, P and K.

#### *3.2.1. Electric conductivity (EC)*

The EC values of soil samples collected from the different nine sites ranged from 1.32 $dSm^{-1}$ in site 2 to 8.54 $dSm^{-1}$ in site 4. Soil EC of the nine sites revealed significant differences between the highest value of site 4 and soil EC values of all other sites. The irrigation with wastewater caused an increase in EC from 893 to 943 µS/cm, in wastewater irrigated soil, while the average value of EC in ground water irrigated soil varied from 600 to 705 µS/cm [9]. The EC proposed the presence of salinity problem which is the most significant factor concerning fields irrigated with wastewater [36].

#### *3.2.2. Hydrogen ion concentration (pH)*

Data presented in Table 4 declare that the pH of soil samples of the nine sites ranged between 7.43 to 7.83 (neutral to slightly alkaline) with non-significant difference among most of sites. The greatest value of pH was recorded in soil samples of site 7, while the lowest value of pH was recorded in soil sample of sites 2. The mean value of pH decreased significantly in soil samples irrigated with wastewater (WW) as compared with the mean value of pH of soil samples under Nile water irrigation (control). The effect of treated wastewater (TWW) on soil (located at Gaza Strip, Palestine) properties studied by [37], and they concluded that there were no badly effects with respect to changes in soil pH, but a significant increase in EC and sodium content was detected in wastewater-irrigated soil.

*3.2.3. Soluble ions (cations and anions)*

The content of soluble cations and soluble anions in soil sample collected from the nine sites of the current study area revealed that the maximum values of soil content of all tested cations and anions were recorded in soil sample of site 4. These maximum values of the all tested cations and anions were significantly different than their corresponding values of all other eight soil samples. Also, it could be noticed from the presented data that the minimum values of $Ca^{++}$, $Na^{+,}$ $Cl^{-}$, and $SO_4^{--}$ were recorded in soil sample of site 2, while the minimum content of $Mg^{++}$ and $K^{+}$ were recorded in soil samples of site 8 and 3, respectively and the lowest content of $HCO_3^-$ was recorded in soil samples of sites 6 and 7 (Table 4). It can be observed that soil samples of site 4 (Al-Oteyat located 2.1 km southward the industrial complex) recorded the highest values of EC, $Ca^{++}$, $Mg^{++}$, $Na^{+}$, $K^{+}$, $HCO_3^-$ , $Cl^-$ and $SO_4^{--}$. It seems that such impact might be due to its location being very close to the industrial complex near site 3, as well as the pollution point present at site 5 as a result of human activities. The mean values of all cations and anions increased non-significantly (except $K^+$ and $Mg^{++}$ and $HCO_3^-$) in soil samples irrigated with wastewater (WW) as compared with the mean values of all cations and anions of soil samples under Nile water irrigation (Table 4).

**Table 4:** Chemical characteristics of soil samples of the different sites (average of two summer seasons; Jul. 2019 and Jul. 2020)

| Site No. | EC dS $m^{-1}$ | pH | Soluble ions (meq $L^{-1}$) | | | | | | | Macronutrients (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ | N | P | K |
| **Sites under wastewater irrigation ( WW)** | | | | | | | | | | | | |
| **1** | 1.50cd | 7.53c | 6.80de | 4.43bc | 2.96b | 0.79abc | 3.46b | 5.93c | 4.72cd | 88.67d | 15.25a | 593.84b |
| **2** | 1.32d | 7.43c | 5.48e | 4.66bc | 2.60b | 0.39cd | 4.01a | 5.37c | 3.77d | 79.33d | 9.60c | 403.85cde |
| **3** | 1.59cd | 7.67b | 8.33cde | 4.35bc | 3.87b | 0.07d | 3.61b | 5.65c | 7.35bdc | 95.67bcd | 12.65b | 183.20f |
| **4** | 8.54a | 7.70b | 35.96a | 16.21a | 30.65a | 1.19a | 4.33a | 39.55a | 41.01a | 130.67a | 11.73b | 544.28bc |
| **5** | 1.65bcd | 7.77ab | 7.67de | 3.91bc | 4.23b | 0.14d | 3.07c | 5.37c | 7.54bcd | 79.33d | 6.27de | 295.54ef |
| **6** | 2.93bc | 7.67b | 14.48bc | 4.73bc | 9.00b | 0.47bcd | 2.83c | 14.12b | 11.72bc | 84.00d | 5.58e | 478.19bcd |
| **7** | 3.13b | 7.83a | 15.79b | 4.86bc | 10.17b | 0.18d | 2.83c | 14.69b | 13.49b | 119.00abc | 7.05d | 274.07ef |
| **8** | 2.05bcd | 7.77ab | 13.16bcd | 2.42c | 3.52b | 0.98ab | 3.07c | 8.62bc | 8.40bcd | 121.33ab | 7.02d | 816.88a |
| **9** | 2.17bcd | 7.50c | 10.53bcde | 6.14b | 5.49b | 0.28cd | 3.54b | 7.91bc | 10.99bcd | 91.00cd | 7.15d | 395.59de |
| **L.S.D at 0.05** | 1.50 | 0.13 | 6.74 | 3.41 | 8.08 | 0.55 | 0.35 | 7.78 | 7.94 | 29.14 | 1.16 | 144.20 |
| **Mean** | 2.76 | 7.65 | 13.13 | 5.75 | 8.05 | 0.50 | 3.42 | 11.91 | 12.11 | 98.78 | 9.14 | 442.83 |
| **Sites under Nile water irrigation (control)** | | | | | | | | | | | | |
| **10** | 2.07 | 7.80 | 7.58 | 5.41 | 4.87 | 0.59 | 4.72 | 5.93 | 7.80 | 115.15 | 10.86 | 660.01 |
| **11** | 2.25 | 8.00 | 9.09 | 8.44 | 6.40 | 0.62 | 5.66 | 6.78 | 12.11 | 184.24 | 12.49 | 739.21 |
| **12** | 1.51 | 7.90 | 6.06 | 6.93 | 3.22 | 0.40 | 3.77 | 3.39 | 9.44 | 115.15 | 11.86 | 620.41 |
| **Mean** | 1.94 | 7.90 | 7.58 | 6.93 | 4.83 | 0.54 | 4.72 | 5.37 | 9.78 | 138.18 | 11.70 | 673.21 |
| **L.S.D at 0.05 WW× control** | 4.87 | 0.11* | 19.34 | 8.69 | 24.24 | 1.26 | 0.83* | 30.23 | 22.14 | 37.18* | 1.56* | 389.61 |

The soluble cations (as $Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$) and anions ( as $Cl^-$, $SO_4^{--}$, and $HCO_3^-$) content was higher in soil under wastewater irrigation (treated domestic wastewater form Bahr El Baqar drain at The Old Haggagia village, Fakous, El Sharkia Governorate) as compared with that under Nile water irrigation. The authors attributed that to adding of soluble salts due to irrigation with wastewater [38].

*3.2.4. Macronutrients (available N, P and K)*

The content of available N in the studied soil samples of the nine sites varied significantly from 130.67 mg $kg^{-1}$ in site 4 to 79.33 mg $kg^{-1}$ in sites 2 and 5.Meanwhile, the content of P ranged from 15.25 mg kg $^{-1}$ in soil sample of site 1 to 5.58 mg kg $^{-1}$ in soil sample of site 6 (Table 4). The soil content of K, varied significantly from the highest value (816.88 mg $kg^{-1}$) in site 8 to the lowest value (183.20 mg $kg^{-1}$) in site 3. The mean value of N and P decreased significantly and K decreased non- significantly in soil samples irrigated with wastewater (WW) as compared with the mean values of N, P and K of soil samples under Nile water irrigation. Wastewater (municipal wastewater) application cause an increasing in P and K (9.01mg $kg^{-1}$ and 405.53 mg $kg^{-1}$, respectively) in the irrigated soils irrespective of fertilizer levels. These nutrients increased consistently over time with applied wastewater. Although K increased significantly with raw wastewater irrigation, it decreased under freshwater irrigation over time due to uptake by the crops [13].

*3.2.5. Calcium carbonate*

The values of $CaCO_3$ in the nine collected soil samples varied significantly from 6.34% in site 5 (Al- Ikhsas located 4.4 km southward the industrial complex) to 38.68 % in site 2 (Al-Hakr Al-Qibly located 3.5 km northward the industrial complex).The mean value of $CaCO_3$ increased significantly in soil samples irrigated with wastewater (WW) as compared with the mean value of $CaCO_3$ of soil samples under Nile water irrigation (Table 5). The effect of polluted water (mixture of domestic and industrial effluents) on El-Saff soils irrigated from El-Khashab canal water studied by [39]. The author showed a slight difference in soil calcium carbonate content of surface soil samples collected from two sites irrigated from El-Khashab canal and Nile water.

**Table 5:** Calcium carbonate, organic matter content (%), mechanical analyses and heavy metals content (mg kg $^{-1}$) of soil samples of the different sites (average of two summer seasons; Jul. 2019 and Jul. 2020)

| Site No. | $CaCO_3$ | OM | Particles size distribution % | | | | Texture | Micronutrients (mg kg$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | % | Coarse sand | Fine sand | Silt | Clay | | Fe | Mn | Zn | Cu | Co | Cr | Pb |
| **Sites under wastewater irrigation ( WW)** | | | | | | | | | | | | | | |
| **1** | 21.4 b | 2.5 abc | 2.0 a | 32.8 ab | 20.4 e | 44.9 abc | Clayey | 213.9 a | 306.7 d | 37.9 b | 3.9 de | 3.8 de | 0.3 b | 4.0 cd |
| **2** | 38.7 a | 2.3 bc | 1.1 d | 32.0 ab | 20.6 e | 46.3 a | Clayey | 137.8 b | 222.6 e | 51.4 a | 26.1 a | 2.6 g | 0.2 b | 9.3 a |
| **3** | 12.7 d | 2.9 a | 1.2 cd | 35.7 a | 17.4 f | 45.7 ab | Clayey | 231.5 a | 336.1 d | 18.5 c | 2.7 e | 3.8 fg | 0.3 a | 8.8 a |
| **4** | 11.0 de | 2.7 ab | 2.1 a | 29.0 b | 26.3 a | 42.6 bc | Clayey | 89.8 c | 440.0 bc | 18.0 c | 4.3 de | 4.5 cd | 0.3 a | 5.1 b |
| **5** | 6.3 f | 2.2 c | 1.2 d | 34.0 a | 23.2 b | 41.8 c | Clayey | 57.9 d | 497.0 ab | 11.3 e | 5.5 d | 5.8 ab | 0.3 b | 3.7 d |
| **6** | 10.3 de | 2.3 bc | 1.6 b | 32.5 ab | 22.5 bc | 43.5 abc | Clayey | 56.8 d | 467.7 abc | 12.2 de | 10.3 c | 5.4 ab | 0.3 b | 5.6 b |
| **7** | 10.0 de | 2.3 bc | 2.0 a | 32.5 ab | 20.8 de | 44.7 abc | Clayey | 34.6 e | 523.2 a | 16.2 cd | 5.3 d | 6.1 a | 0.2 b | 3.6 d |
| **8** | 9.5 e | 2.6 abc | 1.6 b | 32.0 ab | 21.9 cd | 44.5 abc | Clayey | 56.1 d | 416.5 c | 11.6 e | 12.4 b | 5.2 bc | 0.2 b | 5.2 b |
| **9** | 17.2 c | 2.2 c | 1.3 c | 35.0 a | 20.8 e | 43.0 bc | Clayey | 116.6 b | 304.4 d | 18.7 c | 9.5 c | 3.4 ef | 0.2 b | 4.9 bc |
| **L.S.D at 0.05** | 2.8 | 0.4 | 0.1 | 3.8 | 1.1 | 3.3 | _ | 21.1 | 65.7 | 4.1 | 1.8 | 0.7 | 0.04 | 0.1 |
| **Mean** | 15.2 | 2.4 | 1.5 | 32.80 | 21.5 | 44.1 | _ | 110.6 | 390.5 | 21.8 | 8.9 | 4.5 | 0.3 | 5.6 |
| **Sites under Nile water irrigation (control)** | | | | | | | | | | | | | | |
| **10** | 5.7 | 2.2 | 7.8 | 24.2 | 55.0 | 13.0 | silt loam | 26.9 | 25.0 | 1.3 | 6.0 | 0.001 | 0.001 | 5.0 |
| **11** | 4.9 | 2.5 | 11.4 | 28.1 | 47.5 | 13.0 | Loam | 30.9 | 28.8 | 1.5 | 6.9 | 0.001 | 0.001 | 5.8 |
| **12** | 4.9 | 1.9 | 5.1 | 26.9 | 55.0 | 13.0 | silt loam | 22.8 | 21.3 | 1.1 | 5.1 | 0.001 | 0.001 | 4.3 |
| **Mean** | 5.2 | 2.2 | 8.1 | 26.4 | 52.5 | 13.0 | - | 26.9 | 25.0 | 1.3 | 6.0 | 0.001 | 0.001 | 5.0 |
| **L.S.D at 0.05 WW× control** | 3.7* | 0.6 | 2.1* | 6.3* | 3.9* | 6.9* | - | 31.9* | 3.3* | 14.1* | 5.8 | 1.3* | 0.2* | 1.1 |
| **The permissible level [35]** | | | | | | | | 100 | 100 | 10 | 35 | - | - | 0.25 |

*3.2.6. Organic matter*

Data presented in Table 5 declare the OM content in soil samples of the nine sites of the current study. The highest value of OM (2.87%) was recorded in site 3, while the lowest value of OM (2.15 %) was recorded in soil samples of sites 5. The mean value of OM increased non-significantly in soil samples irrigated with wastewater (WW) as compared with the mean value of OM of soil samples under Nile water irrigation (control). The soil OM content is considered one of the most soil properties affected by wastewater irrigation, as has been described by many studies reporting an increase of OM content in wastewater irrigated soils [40 and 6]. Soil OM is crucial as a nutrient pool and in soil structure through the formation of soil aggregates, and also increase the maximum water holding capacity of soil, enhancing the drainage properties and resistance to compaction [41]. Nevertheless, these effects mostly depend on both the structure and amount of OM in the applied wastewater [12].

*3.2.7. Soil texture*

Regarding soil texture or percentage particle size distribution, the data presented in Table 5 revealed that all soil texture classes of the nine sites are clayey. On the other hand, the soil texture classes of control sites are silt loam and loam. These data are in full agreement with [42] who reported that the clay content in soils irrigated with wastewater increased as the irrigation period increased due to the accumulation of clay particles from wastewater effluent. While [39] reported a slight variation in soil texture and calcium carbonate content of samples collected from two sites irrigated from El-Khashab canal and Nile water.

*3.2.8. Heavy metals*

The content of Fe in most of soil samples (except that of site 1, 2, 3, and 9) was lower than the permissible level (100 mg kg$^{-1}$, [35]). The most and the least values of Fe were recorded in soil samples of sites 3 and 7, respectively. The Mn content of the studied soil samples excessed the permissible level (100 mg kg$^{-1}$, [35]) by 206.65%, 122.63%, 236.08%, 339.99%, 397.01%, 367.69%, 423.22%, 316.45% and 204.37% for soil sample of sites 1-9, respectively. The most and the least values of Mn were recorded in soil samples of sites 7 and 2, respectively (Table 5).

The maximum and minimum values of Zn were in soil samples of sites 2 and 5, respectively. The content of Zn of all soil samples was higher than the permissible level (10 mg $kg^{-1}$, [35]**)** by 279.4%, 413.8%, 85.4%, 79.8%, 13.1%, 21.7%, 62.1%, 16.4% and 86.9% for soil sample of sites 1-9, respectively. The soil samples of sites 2 and 3 attained the highest and lowest values of Cu, respectively. The concentration of Cu in soil samples of all sites was lower than the permissible level (35 mg $kg^{-1}$, [35]). The concentration of Co in soil samples of all sites was higher than the permissible level according to [35]. The soil sample of site 7 had the highest value of Co, while the minimum values was that in soil samples of sites 2.

The content of Cr in soil samples of all sites was higher than the permissible level according to [35]. The highest values of Cr were recorded in the soil samples of sites 9 and 8. All Pb values in all soil samples were higher than the permissible level (0.25 mg $L^{-1}$) by 1512%, 3600%, 3424%, 1932%, 1384%, 2128%, 1336%, 1968% and 1860% for soil sample of sites 1-9, respectively [35]. The soil samples of sites 2 and 7 recorded the highest and lowest values of Pb, respectively. The mean values of Fe, Mn, Zn, Co and Cr increased significantly, but Cu and Pb increased non-significantly in soil samples irrigated with wastewater (WW) as compared with the mean values of these metals of soil samples under Nile water irrigation (Table 5).

Wastewater may contain low concentration of heavy metals but, long-term use of this wastewater could accumulate large amounts of heavy metals in soil. Moreover, long-term irrigation of clay soil with wastewater cause increasing in its available Cu, Cd, Pb, Cr, Ni and Zn compared with fresh water irrigated soil [43, 44 and 45].

Soil texture plays an important role in the mobility of metals in soil as affected by the content of fine particles like clay. This clay is important adsorption medium for heavy metals in soils. The clayey soils hold a high amount of metals when compared to sandy one [46].

From the previous data it could be observed that irrigation water and soils in sites around the industrial complex or adjacent to it have the highest values of N, P, K, and OM which improve the soil quality and soil fertility, but at the same time they also have high concentration of soluble salts and heavy metals which led to several soil problems that increase with time. This mean that these sites receive large amount of pollutants (domestic and industrial) which discharged in El-Khashab canal. Also, the gradual decrease in values of most of the studied parameters from the highest values recorded at sites close to the source point pollution (sites around the industrial complex or adjacent to it) towards either the upstream or the downstream of the irrigation canal. Thus, it could be stated that generally, as the distance increases away from the source point of the industrial discharge effluent the values decrease significantly.

Soil health mean “the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans”. In other words it can defined as “the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health” [47]. Briefly, “soil health point to the capability of a soil to deliver ecosystem services”. The soil health reflect how well the soil can do its environmental purposes. A soil is assessed as “healthy” if it provides better ecosystem services relative to undisturbed reference soils of similar type in the same area. Otherwise, the soil is unhealthy, “unable to carry out the normal environmental functions of similar soils in the inherent ecosystem”. Soil health is “a comprehensive term of the relevant soil physical, chemical, and biological properties” [48]. Soil (health) degradation is “the loss of the intrinsic physical, chemical, and/or biological qualities of soil either by natural or anthropic processes, which result in the diminution or annihilation of important ecosystem functions”. Land uses, disturbances, and management practices may change soil properties and subsequently, impact soil health [49]. Soil health degradation became a global main problem that threatens global food security. For agricultural soils, the degradation is typically established as OM decline, compaction, salinization, accelerated erosion, contamination, and loss of biodiversity. High agricultural production may temporarily be took place with high inputs of fertilizers, pesticides, and wastewater, yet sustainable agriculture needs healthy soils. Effective management practices are warranted to restore degraded agricultural soils to the “healthy” status capable of supporting satisfactory food and fiber production while providing other vital ecosystem services [50].

### ***3.3. Pollution quantification***

#### *3.3.1. Contamination factor (CF)*

The soil contamination factor at the nine sites during summer seasons (average of two summer seasons Jul. 2019 & Jul. 2020) are shown in Table 6. The CF values for Fe ranged from 8.62 (site 3) to

1.29 (site 7), the CF values for Mn ranged from 20.90 (site 7) to 8.89 (site 2), the CF values for Zn ranged from 38.34 (site 2) to 8.44 (site 5), the CF values for Cu ranged from 4.34 (site 2) to 0.45 (site 3), the CF values for Co ranged from 6060 (sites 5 and 7) to 2600 (site 2), the CF values for Cr ranged from 310 (site 3) to 210 (site 2) and the CF values for Pb ranged from 1.84 (site 2) to 0.72 (site 7). From the CF mean values of the seven heavy metals, they could be arranged descendingly in the order of: Co > Cr > Zn > Mn > Fe > Cu > Pb. According to [28] classification, Mn, Zn, Co and Cr can cause very high contamination; Fe can cause considerable contamination; Cu and Pb can cause moderate contamination.

**Table 6:** The contamination factor and pollution load index of soil samples collected from different sites (average of two summer seasons Jul. 2019 & Jul. 2020)

| Site No. | The contamination factor for studied heavy metals | | | | | | | Pollution load index (PLI) |
|---|---|---|---|---|---|---|---|---|
| | Fe | Mn | Zn | Cu | Co | Cr | Pb | |
| 1 | 7.96 | 12.25 | 28.31 | 0.65 | 3820.00 | 250.00 | 0.80 | 20.20 |
| 2 | 5.13 | 8.89 | 38.34 | 4.34 | 2600.00 | 210.00 | 1.84 | 25.81 |
| 3 | 8.62 | 13.42 | 13.84 | 0.45 | 3780.00 | 310.00 | 1.75 | 20.41 |
| 4 | 3.34 | 17.57 | 13.42 | 0.71 | 4450.00 | 300.00 | 1.01 | 18.54 |
| 5 | 2.15 | 19.85 | 8.44 | 0.91 | 5810.00 | 250.00 | 0.74 | 16.63 |
| 6 | 2.11 | 18.68 | 9.08 | 1.72 | 5440.00 | 250.00 | 1.11 | 19.11 |
| 7 | 1.29 | 20.90 | 12.10 | 0.88 | 6060.00 | 230.00 | 0.72 | 16.16 |
| 8 | 2.09 | 16.63 | 8.69 | 2.06 | 5150.00 | 240.00 | 1.03 | 18.67 |
| 9 | 4.34 | 12.16 | 13.95 | 1.57 | 3390.00 | 240.00 | 0.98 | 19.08 |
| Mean | 4.12 | 15.59 | 16.24 | 1.48 | 4500.00 | 253.33 | 1.11 | 19.40 |

From the previous data it could be observed that Co was the most metal which caused contamination in soil of the study area. On the other hand, Pb was the least metal which caused contamination in all sits. The high level of soil contamination in the study area with these heavy metals is associated with the spread of many industries in which these metals are used. Fe, Mn, Zn and Cu are used in the iron and steel industry, meanwhile, Pb, Mn and Cr are used in the manufacture of glass. As for the paint industry, Pb, Cr, Zn and Mn are one of its main components. Cr is also used in the textile industry, as well as the clay brick industry. Zn is used in the soap and plastic industries. Most of the elements are used in the manufacture of mineral fertilizers [51]. This is in addition to the presence of these heavy metals in sewage and agricultural wastewater, which are randomly disposed of in El-Khashab Canal.

The spreading of different heavy metals in different particle size fractions of soils under polluted water irrigation in El- Saff area studied by (15). The results showed that the clay fraction had the highest values of all tested heavy metals, while the sand fraction had the lowest. All fractions of soils under industrial wastewater irrigation had the highest amounts of Fe and Mn, while fractions of soils under sewage wastes irrigation had the highest amounts of Zn, Cu, Pb and Cd. Data showed that the amount of heavy metals in the clay fraction was 33, 24, 14, 13, 12 and 10 times that of the sand fraction for Mn, Cu, Fe, Cd, Zn and Pb, respectively. Similar finding were reported by [12].

*3.3.2. Pollution load index (PLI)*

Table 6 shows the PLI values for the soil samples collected from the nine sites of the study area during summer seasons. The PLI of soil samples ranged from 25.81 (site 2) to 16.16 (site 7). The high temperature during summer season may lead to some or all of the following: Evaporation of water from the soil and an increase in the concentration of metals in it, acceleration of the rate of the chemical processes, increase the reactivity and the solubility of high concentration of the different metals in the polluted canals, increase the load of wastewater effluents with the different metals and summer season is, usually, associated with more anthropogenic activity (municipal and industrial) leading to higher metals load in the irrigation canals [52].

The use of wastewater in irrigation of agricultural land presents environmental, health and economic challenges as well as benefits. While some benefits and cons are localized and complicated, others can easily be characterized. For example, the risk associated with exposure to pathogens and heavy metals and salinity of soil are easily classified as cons. Meanwhile, Nutrients source, water resources protection and savings, and farm profitability are benefits. Using of wastewater for irrigation has increased over the years due to these benefits especially in regions that suffer from water scarcity problem. [3]. The type and severity of effect of wastewater irrigation on public health, water resources and soil are not only dependent on the wastewater quality but also on properties of soil ,morphology and physiology of plant, climate, type of irrigation and agricultural management applies. Irrigation with wastewater could support both agriculture and water sustainability. It could be concluded that wastewater surely has a great possibility of being a viable alternative water source for irrigation, but risk prevention barriers should be adopted to decrease the undesirable effects [7].

Agroecology is “the science of applying ecological concepts and principles to the design and management of sustainable food systems”. Agroecological principles are: 1- “use a holistic approach to the identification, the analysis and the resolution of issues related to farming - the agroecosystem is regarded as one and its health as a whole is valued more than the productivity of a single crops”.2- “Enhance the recycling of biomass with a view to optimizing organic matter decomposition and nutrient cycling over time”. 3- “Strengthen the ‘immune system’ of agricultural systems through enhancement of functional biodiversity – natural enemies, antagonists, etc.” 4- “Provide the most favorable soil conditions for plant growth, particularly by managing organic matter and by enhancing soil biological activity”. 5- “Minimize losses of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil and water resources and agrobiodiversity”. 6- “Minimize the use of external, non-renewable resources". 7- “Avoid the unnecessary use of agrochemical and other technology that adversely affect the environment and human health”. 8- “Diversify species and genetic resources in the agroecosystem over time and space at the field and landscape level”. 9- “Enhance beneficial biological interactions and synergies among the components of agrobiodiversity, thereby promoting key ecological processes and services”. 10- “Use local crop varieties and livestock breeds so as to enhance genetic diversity and adaptation to the changing biotic and environment condition”. Most of these principles are realized in a sustainable agricultural system that relies heavily on wastewater irrigation [53].

## 4. Conclusion

From the previous data it could be observed that irrigation water and soils in sites around the industrial complex or adjacent to it have the highest values of N, P, K, and OM which improve the soil quality, but at the same time they also have high concentration of salts and heavy metals which led to several soil problems that increase with the time. This mean that these sites receive large amount of pollutants (domestic and industrial) which discharged in El-Khashab canal. One can conclude that the agricultural land in the study area (Helwan-El Saff) is contaminated with many heavy metals as a result of the aforementioned practices, whether from factories (industrial wastewater), individuals (municipal wastewater) or farmers (agricultural wastewater), which poses a very great danger to the fertility of the agricultural land and its suitability for agriculture. Therefore, the data of the present research revealed that wastewater of El-Khashab canal could effectively be used as fertility source for soil, but there are some risks as heavy metals that may threaten sustainable agriculture in the study area. Therefore, the authors recommended close and periodic monitoring for soluble salts and heavy metals content of both wastewater irrigation canals and soil of agricultural land under wastewater irrigation. Besides that, only crops that do not uptake, translocate nor bioaccumulate high levels of heavy should be selected for cultivation under wastewater irrigation.

**Conflict of interest**

There is no conflict of interest to declare.

## References

[1] Gurjar OP, Meena R, Latare AM, Rai S, Kumar A, Sheshama MK. Effect of sewage wastewater irrigation compare to ground water irrigation on soil physic-chemical properties. Int. J. Chem. Studies 2017; 5(6): 265- 267.

[2] El Youssfi L, Choukr-Allah R, Zaafrani M, Mediouni T, Sarr F, Hirich A. Effect of domestic treated wastewater use on three varieties of amaranth (*Amaranthus* spp.) Under Semi-Arid Conditions. World Academy of Science, Eng. Technol. 2012. P. 62.

[3] Seada T, Mohamed R, Abdou D. The Future of Agriculture in Egypt: Comparative Study of Organic and Conventional Crop Production Systems in Egypt. Version 2- May 2020. Heliopolis University for Sustainable Development, www.hu.edu.eg | hu@hu.edu.eg

[4] Abdelhaleem FS, Helal EY. Impacts of Grand Ethiopian Renaissance Dam on Different Water Usages in Upper Egypt. Br. j. appl. sci. 2015; 8(5): 461-483.

[5] Thapliyal A, Vasudevan P, Dastidar MG, Tandon M, Mishra S. Irrigation with domestic wastewater: responses on growth and yield of ladyfinger (Abelmoschus esculentus) and on Soil Nutrients. J. Environ. Biol. 2011; 32: 645-651.

[6] Ganjegunte G, Ulery A, Niu G, Wu Y. Organic carbon, nutrient, and salt dynamics in saline soil and switch grass (*Panicum virgatum* L.) irrigated with

treated municipal wastewater. Land Degrad. Dev. 2018; 29: 80-90.
[7] Ofori S, Puškáčová A, Růžičková I, Wanner J. Treated wastewater reuse for irrigation: Pros and cons. Sci. Total Environ. 2020; 760: 1-15.
[8] Abegunrin TP, Awe GO, Idowu DO, Onigbogi OO, Onofua OE. Effect of kitchen wastewater irrigation on soil properties and growth of cucumber (*Cucumis sativus*). J. Soil Sci. Environ. 2013; 4(7): 139-145.
[9] AL-Jaboobi M, Tijane M, EL-Ariqi Sh, El Housni A, Zouahri A, Bouksaim M. Assessment of the impact of wastewater use on soil properties. J. Mater. Environ. Sci. 2014; 5 (3): 747-752.
[10] Gatta G, Libutti a, Gagliardi A, Beneduce L, Brusetti L, Borruso L, et al. Treated agro-industrial wastewater irrigation of tomato crop: Effects on qualitative/ quantitative characteristics of production and microbiological properties of the soil. Agric. Water Manag. 2015; 149: 33- 43.
[11] Naz H, Naz A, Ashraf S. Impact of heavy metal toxicity to plant growth and nodulation in Chickpea grown under heavy metal stress. International Journal for Research in Emerging Science and technology, IJREST, 2015; 2(5): 248-260.
[12] Abd-Elwahed MS. Influence of long-term wastewater irrigation on soil quality and its spatial distribution. Ann. Agric. Sci. 2018; 63: 191–199.
[13] Mojid MA, Wyseure GCL. Implications of municipal wastewater irrigation on soil health from a study in Bangladesh. Soil Use Manag. 2013; 29: 384-396.
[14] El-Sayed MH, Shawky HA, Abdel Mottaleb MSA. Geochemistry of water resources and pollution problems in Helwan area, Egypt. Egyptian J. Desert Res. 2004; 54 (2):259-289.
[15] Salem TM, Ahmed ShS, Hamed MA, Abd ElAziz GH. Risk assessment of hazardous impacts on urbanization and industrialization activities based upon toxic substances. Global J. Environ. Sci. Manage.2016; 2(2):163-176.
[16] Awad S, Melegy A, Salman SA, Samy Y, Said I. Hydrochemistry and Quality Assessment of El Tebbin Surface Water, South Cairo, Egypt. Int. J. Environ. 2015; 4 (2): 172-180.
[17] Piper CS. Soil and plant analysis. Adelaide, Australia 1950; 368 p.
[18] Walkley A. A critical examination of rapid method for determining organic carbon in soils. Effect of valuations in digestion conditions and inorganic soil constituents. Soil Sci. 1947; 63: 251-264.
[19] Wright CH. Soil Analysis. Thomas Marley and Co. London, U. K. 1939.
[20] USDA. Diagnosis and improvement of saline and alkali soil. U. S. Salinity Laboratory staff, United States Department of Agriculture. 1969; (USDA). Handbook 2 Ed. 60, USA
[21] Ayers RS, Westcot DW. Water Quality for Agriculture. FAO Irrigation and Drainage 1985; Paper 29, Rome, Italy.
[22] Nelson RE. Carbonate and Gypsum In: Methods of soil analysis: Part 2, 2nd page, C. A. Black (ed). Agronomy homograph No.9 1982; PP. 181.
[23] Jackson ML. Soil chemicals analysis. Prentice-Hall of India. Private, New Delhi, India 1967; 498 p.
[24] Page AL, Miller RH, Keeney DR. Methods of soil analysis. Part 2. Chemical and microbiological properties. American Society of Agronomy. Wisconsin, United States of America 1982; 1159 p.
[25] Black CA (Ed). Methods of Soil Analysis. Amer. Soc. Agron. Inc. Pub. Madison, Wisconsin, USA 1965; PP, 1572.
[26] Christain GD. Medicine, trace elements and atomic absorption spectroscopy. Anal. Ch. 1969; 41, 1.244.
[27] Soltanpour PN, Schwab AP. A new soil test for simultaneous extraction of macro and micro nutrients in alkaline soils. Community of Soil Science, Plant Annals. 1977; 3: 195-207.
[28] Hakanson L. Ecological risk index for aquatic pollution control: sediment logical approach. Water Res. 1980; 14: 975–100.
[29] Varol M. Assessment of heavy metal contamination in sediments of the Tigris River (Turkey) using pollution indices and multivariate statistical techniques. J. Hazard. Mater. 2011; 195: 355-364.
[30] Snedecor G, Cochran W. Statistical Methods, 8th ed. Iowa State Univ., Press Ames Iowa, USA 1989; 325 - 330.
[31] Richards LA (Ed). Diagnosis and improvement of saline and alkali soil. U. S. Dept. Agric. Handbook No. 60 Gov. 1954; Print Out.
[32] FAO, Food and Agricultural Organization. Wastewater treatment and use in agriculture. Irrigation and Drainage 1992; Paper 47, FAO, Rome.
[33] Gedamy YR, El-Aassar AM, Abdel-Gawad AM. Pollutants Detection in Water Resources at El Saff Area and Their Impact on Human Health, Giza Governorate, Egypt. Int. J. Environ.2012; 1(1): 1-14.
[34] Agrama AA, El-Sayed EA. Assessing and mapping water quality (case study: western Delta-Egypt). International Water Technology Journal, IWTJ, 2013; 3(3): 158-169.
[35] WHO/FAO. Joint FAO/WHO Food Standard Program Codex Alimentations Commission 13th Session. Report of the Thirty Eight Session of the Codex Committee on Food Hygiene. United States of America, ALINORM 2007; 07/30/13.
[36] FAO. Food and Agricultural Organization, User's manual for irrigation with treated wastewater. Regional Office for the near East, Cairo, Egypt 2003.
[37] El-Nahhal Y, Tubail K, Mohamad Safi M, Safi J. Effect of treated wastewater irrigation on plant growth and soil properties in Gaza Strip, Palestine. Am. J. Plant Sci. 2013; 4: 1736-1743.

[38] Khafagi OA, Ragab AM, El- Sayed HM, Moursy MM, Mohamed SK. Assessment of macro - nutrients and heavy metals accumulation in soil and four biofuel crop plants under long- term irrigation with wastewater. Int. j. innov. sci. eng. 2018a; 5(8): 2348-7968, (online) www.ijiset.com

[39] Abd El-Hady BA. Compare the Effect of Polluted and River Nile Irrigation Water on Contents of Heavy Metals of Some Soils and Plants. J. agric. biol. sci. 2007; 3(4): 287-294.

[40] Sánchez–González A, Chapela-Lara M, German-Venegas E, Fuentes-Garcia R, del Rio-Portilla F, Siebe C. Change in quality and quantity of soil organic matter stocks resulting from wastewater irrigation in formerly forested land. Geoderma 2017; 306: 99- 107.

[41] Becerra- Castro C, Lopes AR, Vaz-Moreira I, Silva EF, Manaia CM, Nunes OC. Wastewater reuse in irrigation: a microbiological perspective on implications in soil fertility and human and environmental health. Environ. Int. 2015; 75: 117-135.

[42] El-Motaium RA, Badawy SH. Effect of irrigation using sewage water on the distribution of some heavy metals in bulk and rhizosphere soils and different plant species: Cabbage plant (*Brassica oleracea* L.) and Orange trees (*Citurs sinensis* L.) Egypt. J. Soil Sci. 2000; 40 (2): 285-303.

[43] Kwiatkowska-Malina J. Function of organic matter in polluted soil: the effect of organic amendments on phytoavailability of heavy metals. Appl. Soil Ecol., 2018; 123: 542-545.

[44] El- Lawendy WI, Khafagi OA, Abdel- Aal H. Characteristic of treated sewage effluent and its impact on soil properties in El Saff area. Al-Azhar Bull.Sci. 2000; 2 (2): 1-11.

[45] Dotaniya ML, Rajendiran S, Meena VD, Coumar MV, Saha JK, Kundu S, et al. Patra AK. Impact of long-term application of sewage on soil and crop quality in vertisols of Central India. Bull. Environ. Contam. Toxicol. 2018; 4: 1-8.

[46] El Azab HE, Afify AA, Soliman MM. The impact of informal irrigation practices on soil drainage condition, soil pollution and land suitability for agriculture in El Saff area of El Giza Governorate. Egypt. J. Remote Sens. Space Sci. 2015; 18: 163-179.

[47] USDA-NRCS. Soil Health; Natural Resources Conservation Service, U.S. Department of Agriculture: Washington, DC, USA, 2021. Available online: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health.

[48] UNFAO. FAO Soils Portal-Degradation/Restoration; Food and Agriculture Organization of the United Nations: Rome, Italy, 2021. Available online: http://www.fao.org/soils-portal/soil-degradation-restoration/en.

[49] Nunes FC, Alves LJ, Carvalho CCN, Gross E, Majeti P, de Marchi Soares T. Soil as a complex ecological system for meeting food and nutritional security. In Climate Change and Soil Interactions; Prasad, M.N.V., Pietrzykowski, M., Eds.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 229–269.

[50] Guo M. Soil Health Assessment and Management: Recent Development in Science and Practices. Soil Syst. 2021; 5: 61- 81.

[51] Zanin E, Magro JD. Adsorption f heavy metals from wastewater graphic industry using clinoptilolite zeolite as adsorbent. Process Safety and Environmental protection, 2017; 105: 194 -200.

[52] Khafagi OA, Ragab AAM, Marie SM, Mohsen AAA. Effect of wastewater irrigation on some chemical characteristics of soil and grown plants. Egypt.J.Appl. Sci. 2010; 25 (4): 1-18.

[53] Silici L. Agroecology, what it is and what it has to offer. Food and agriculture 2014; 8:1-28.

# تأثير الري بالمياه العادمة على التركيب الكيميائي وتراكم المعادن الثقيلة في التربة (دراسة حالة : حلوان – الصف)

**ميرفت الليثى**[1]**، عبد العزيز رجب**[2] **، رمضان بدير**[3] **، أم محمد خفاجى**[1]

1. قسم النبات والميكروبيولوجى – كلية العلوم (بنات) – جامعة الأزهر، مدينة نصر، القاهرة، مصر
2. معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية
3. قسم النبات والميكروبيولوجى – كلية العلوم (بنين) – جامعة الأزهر، مدينة نصر، القاهرة، مصر

**الملخص**

أجريت دراسة حقلية تم تنفيذها في تسع مواقع بمحافظتي القاهرة والجيزة (حلوان - الصف) ، حيث تم تجمع عينات من التربة والمياه خلال موسمين (يوليو 2019 ويوليو 2020). كما تم تجميع عينات تربة ومياه من ثلاثة مواقع زراعية في قرية ميت ربيعة - منوف- محافظة المنوفية لتستخدم ككنترول. الهدف من هذه الدراسة هو تحديد جودة التربة عند ريها باستخدام المياه العادمة مقارنة بالتربة المروية بمياه النيل لتحديد إمكانية استخدام المياه العادمة كبديل للمياه العذبة في ري الأراضي الزراعية. جمعت عينات مياه من تسعة مواقع في ترعة الخشاب(مياه ملوثة) بمنطقة حلوان - الصف ،كما جمعت عينات من التربة السطحية (0-30 سم) من الأراضي المزروعة القريبة من ترعة الخشاب خلال موسمين (يوليو 2019 ويوليو 2020). جمعت عينات مياه من ترعة الباجورية و عينات من التربة السطحية (0 - 30 سم) من الاراضي المزروعة القريبة من ترعة الباجورية بقرية ميت ربيعة ككنترول. تم تحليل جميع عينات المياه والتربة لتقييم الخصائص الفيزيائية والكيميائية للتربة عند ريها بالمياه الملوثة. أظهرت النتائج أن قيم كلا من التوصيل الكهربي ونسبة ادمصاص الصوديوم وجميع الكاتيونات(الكالسيوم و المغنسيوم والصوديوم والبوتاسيوم) والأنيونات(الكلوريد والبيكربونات والسلفات) والبوتاسيوم المتاح وجميع المعادن الثقيلة محل الدراسة ( الحديد و المنجنيزو الزنك و النحاس و الكوبلت و الكروم و الرصاص) قد زادت في عينات المياه الملوثة مقارنة بعينات مياه النيل (الكنترول) ،ولكن كان العكس صحيح بالنسبة لقيم الأس الهيدروجيني والنتروجين والفسفور. وفي الوقت نفسة، زادت قيم التوصيل الكهربي والكالسيوم والصوديوم والكلوريد والسلفات وكربونات الكالسيوم والمادة العضوية وجميع العناصر الثقيلة محل الدراسة في عينات التربة المروية بالمياه الملوثة مقارنة بعينات التربة المروية بمياه النيل (الكنترول)،وكان العكس صحيح للأس الهيدروجيني والماغنسيوم والبوتاسيوم الذائب والبيكربونات. وأوضحت نتائج عامل التلوث أن المنجنيز والزنك و الكوبلت والكروم تسبب تلوثا عاليا جدا ويسبب الحديد تلوثا كبيرا، اما النحاس والرصاص يسببان تلوثا معتدل في التربة. تتراوح قيم مؤشر حمل التلوث لعينات التربة من 16,16 إلي 25,81. مما سبق يمكن القول أن استخدام المياه العادمة لري الأراضي الزراعية يزيد من محتوي التربة من المادة العضوية وبعض مغذيات النبات ، ولكن في الوقت نفسه يزيد من محتوي التربة من العناصر الثقيلة مما يهدد استمرارية الزراعة في منطق الدراسة.