Egypt. J. Bot. **Vol. 63**, No.1, pp. 209-231 (2023)

Egyptian Journal of Botany

http://ejbo.journals.ekb.eg/

Effects of Untreated Wastewater Irrigation on Peanut (*Arachis hypogea*) Productivity and Human Health

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WASTEWATER irrigation is used by farmers when water becomes scarce. This work aims to study the effects of wastewater irrigation on the agrarian economy and human health. Irrigation water and soil samples were collected from the Shibin drain and the Al Sharqawia canal. The physicochemical features of the drainage water, canal water, polluted soil, and unpolluted soils were analyzed. The vegetative and productivity traits of peanut plants were evaluated including to their mineral nutrient content, primary metabolic products, and heavy metal content. Irrigation with wastewater resulted in lower pod, seed, and biomass productivity, with reductions of 50%, 52.5%, and 42.9% respectively. Chlorophyll *a* and chlorophyll *b* levels were also decreased but carotenoid levels were increased. Wastewater irrigation resulted in a decrease in carbohydrate content, crude protein, lipid, content crude energy, and growth energy, Heavy metal concentrations increased, specifically those of Fe, Mn, Zn, Co, Cu, Pb, and Cd. Peanut plants were found to accumulate heavy metals and store Zn, Mn, Cu, Pb, and Cd in their seeds, proving hazardous to human health. Irrigation with wastewater negatively impacts the general economy and human well-being; therefore, this study recommends the enactment of legislation that prohibits irrigation with untreated drainage and prevents the disposal of domestic, industrial, and agricultural wastewater into irrigation canals.

Keywords: *Arachis hypogea*, Bioaccumulation, Canal water, Drainage water, Health risk index, Productivity.

Introduction

In Egypt, as in many developing countries, agriculture is the primary user of water, followed by industrial and domestic consumption (El Bedawy, 2014). One challenge facing Egypt is how to promote best practices in the management and development of limited water resources, cultivated lands, and energy to address the requirements of the growing population (El Bedawy, 2014; Daher, 2022). Recently, more efforts have been directed at managing and utilizing the available water resources; however, more work is needed to achieve a balance between the available water resources and the water needs of an increasing populace (Alnaggar, 2003; Allam & Allam, 2007; Bavumiragira et al., 2022).

Hossain (2015) reported that water is the most valuable resource to humanity. Indeed, water represents the most remarkable input for the development of the economy and sustainability practices (El Bedawy, 2014). Water is the main requirement for food production ("No Water, No Food") and globally, water deficiency is a great problem. By 2025, over half of the world"s population will suffer from water scarcity, which affects the economy, social development, and human health (Makhadmeh, 2021). Unfortunately, countries that suffer from water scarcity depend on unsuitable solutions, such as the use of untreated wastewater (Falkenmark, 1976; Haarstrick & Bahadir, 2022). In agricultural systems, wastewater can find its way to irrigation canals that are used because of their enrichment with organic residues and mineral nutrients.

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Received 23/05/2022; Accepted 08/011/2022
DOI: 10.21608/ejbo.2022.124879.1931
Edited by: Prof. Dr. Fawzy M. Salama, Faculty of Science, Assuit University, Assuit, Egypt.

Wastewater is a source of toxic metals (Balkhair & Ashraf, 2016). Human drivers, e.g., domestic, industrial, and commercial activities, are the main sources of wastewater production. With the exponential increase in construction, population, industry, and domestic water supplies, the volume of wastewater production has grown larger. (Alobaidy et al., 2010).

Wastewater application to croplands can improve the physical properties and nutrient content of soils (Jatav et al., 2022). Irrigation with wastewater saves water, phosphorus, and nitrogen and supplies soils with organic matter (Siebe, 1998). However, there is concern about the accumulation of toxic elements (Fe, Mn, Zn, Cu, Pb, and Cd) from domestic and industrial sources. In many countries, farmers irrigate crops with industrial wastewater because of the lack of alternative sources. Treated wastewater from municipal sewage treatment plants can become supply water for crops, containing high levels of macro- and micro-nutrients and heavy metals (Patil et al., 2014; Nyika, 2022).

Irrigation water quality affects soil properties, crop productivity, and human health (Shainberg & Oster, 1978; Abuzaid & Jahin, 2021). In particular, the application of untreated mixed wastewater (miscible, industrial, and agriculture) results in crop yield reduction and deterioration of the soil's physicochemical properties, reducing crop production and quality. Assessment of the health risk index evaluates potential health impacts on populations exposed to toxic media, representing a key procedure in the management of serious substances, planning for treatment policy, and control measures (Khan & Husain, 2001; McGraph et al., 2004).

Due to a shortage of Nile water supply to Egyptian irrigation canals in many cultivated sectors of land, farmers have been forced to irrigate crops using untreated wastewater. Therefore, this study aims to evaluate the impact of irrigating peanut crops with untreated mixed wastewater on soil properties, crop productivity, yield quality, nutritional value, and human health.

Material and Methods

Study area

The Shibin Al Kanater sector was chosen for this study as an example of one of the many sectors in Egypt that use canal and drainage water for crop irrigation. Shibin Al Kanater is a sector of the Al-Kalubeya governorate located in the southeast of the Nile delta. There are two sites located in the study area: one unpolluted and one polluted. The unpolluted site receives irrigation water from the Sharkawia canal, while the polluted from the Shibin drain (Fig. 1).

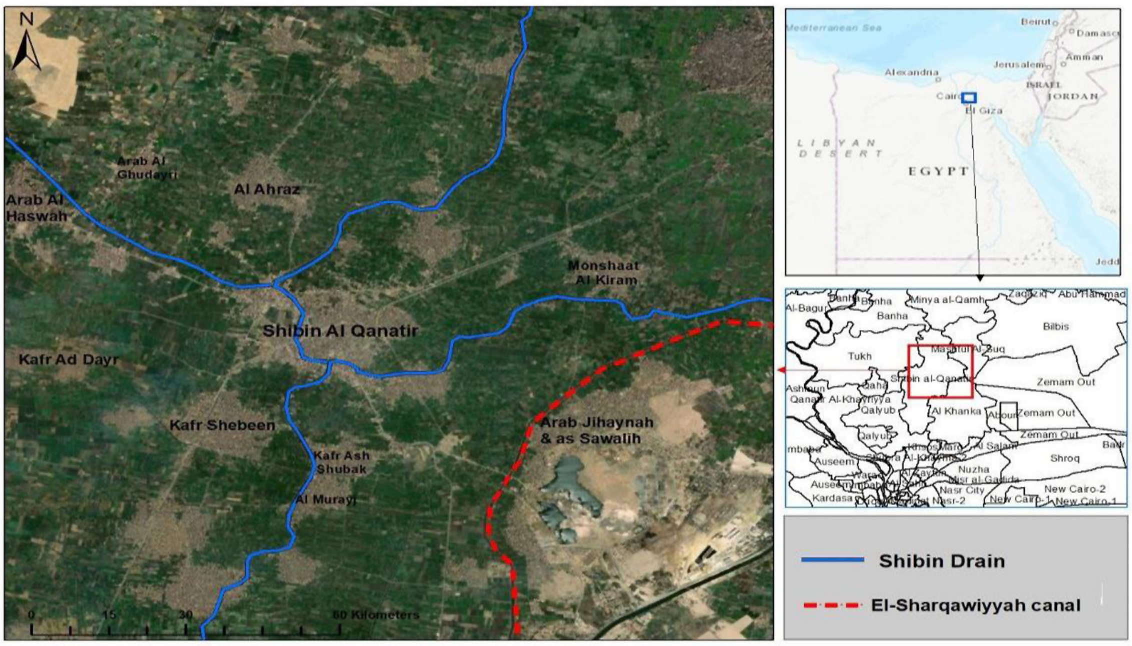


Fig. 1. Map location of the study sites

Species of study

The peanut crop is considered an important export crop that cultivates well in sandy and light-yellow soils where other field crops cannot be grown. It requires acidic soils, preferably at pH 5.9–7 (Fleischer et al., 2003; Yasser et al., 2014). Peanuts are used as an organic fertilizer to increase soil fertility, as they add nitrogen to the soil through the nodule bacteria. As an oily crop, peanut seeds have around 35%–47% oil and 27% protein and contain vitamins B & F, riboflavin, and thiamine. Peanut oil contains high amounts of antioxidants and polyunsaturated fatty acids, which is desirable for human health as these reduce the levels of cholesterol and low-density lipoprotein content in blood. Consequently, this can reduce the risk of coronary heart disease (Win et al., 2011; Gulluoglu et al., 2016). Moreover, peanuts are a source of inorganic nutrients (P, Mg, Ca, and K) (Shasidhar et al., 2017). In Egypt, the average area planted with peanuts in the period 1995–2012 was 70.137 thousand feddans (Yasser et al., 2014). Fleischer et al. (2003) reported that peanut plant is sensitive to any type of contamination throughout its growth, developing stages, and storage period.

Water sampling and analysis

Subsurface composite samples of canal and drain water used in crop irrigation were sampled (1 liter) in triplicates (n= 3) in acid-washed polypropylene bottles for chemical analysis. The pH and total dissolved salts (TDS) were measured in the field using a multi-probe system, model hydra lab surveyor. Biological and chemical oxygen demand (BOD and COD) were determined in canal and drain water according to Standard Methods for Examination of Water and Wastewater (APHA, 2005). Chlorides were estimated by direct titration against silver nitrate using 5% potassium chromate as an indicator. Sulfates were estimated turbidimetrically as barium sulfate using a spectrophotometer set to 500 nm. Nitrates were determined using NaOH, H_2SO_4, and sodium salicylate as analytical reagents, and nitrites were estimated using the sulfanilamide diazotization method. Phosphates were determined using the direct colorimetric molybdenum blue method using the spectrophotometer set to 690nm (Allen, 1989). The concentrations of Fe, Cu, Mn, Zn, Cd, Pb, and Co were determined using an Atomic Absorption Spectrophotometer (Shimadzu AA-6200) according to Standard Methods for Examination of Water and Wastewater (APHA, 2005).

Soil sampling and analysis

Five peanut (*Archis hypogea*) crop farms were selected at each site: five polluted (irrigated with drainage water) and five unpolluted (irrigated with canal water). Five composite soil samples were collected from each site (polluted and unpolluted), including topsoil from a depth of 0–30 cm. The soil samples were transferred to the lab in plastic bags, then air dried and passed through a 2-mm sieve to remove debris, before being packed in paper bags for analysis. Aqueous soil extracts were prepared at a ratio of soils (g) to distilled water (ml) of 1:5. The pH values were measured with a glass electrode pH meter (Model 9107 BN, ORION type) and electrical conductivity (EC) with a conductivity meter (60 Sensor Operating Instruction Corning). CO_3^{-2} and HCO_3^- were determined by titration against 0.1 N HCl using phenolphthalein and methyl orange indicators. Chlorides were estimated by direct titration against silver nitrate solution using 5% potassium chromate as an indicator and sulfates were estimated by the turbidimetric method as barium sulfate at 500 nm. Calcium and magnesium were determined titrimetrically versus 0.01N EDTA disodium salt using meroxide and erichrome black T as indicators. Potassium was determined using a flame photometer. Heavy metals (Cd, Fe, Mn, Pb, Co, and Zn) were determined using the Atomic Absorption Spectrophotometer. All procedures for soil analysis are outlined in more detail by Allen (1989).

Plant sampling and analysis

Five farms of *A. hypogea* crop irrigated with canal water and others irrigated with drainage water were selected at the study sites. On each farm, five quadrats (0.50 × 0.50m) were randomly selected. All plants within each quadrat were harvested at the end of the season, packed in polyethylene bags, and transferred to the lab. The plants were cleaned and washed with tap water and washed twice with distilled water to remove any waste or dust.

Growth and production traits

In each quadrat, the total number of individuals (individual m^{-2}) was counted. The length of the roots and shoots was measured with measuring tape. The single-sided leaf area was estimated by the Tracing Paper method. The peanut plants were separated into roots, shoots, and pods and left to dry in the air. The constant dry weight of each part was recorded. After air drying, the number of pods per plant, the number of seeds per pod, the weight of seeds per plant, and the weight of one thousand seeds were determined. The crop productivity was expressed as ton $fed^{-1}year^{-1}$.

Photosynthetic pigments

The photosynthetic pigments (chlorophyll a & b and carotenoids) were determined using the spectrophotometric method described by Allen (1989). Fresh peanut leaves from each quadrat were collected and combined to make three composite samples. Chlorophyll and carotenoids were extracted from a known fresh weight (about 2g) of leaves in 50% (v/v) acetone in complete darkness and kept overnight at 4°C. The supernatant was filtered and measured spectrophotometrically using aqueous acetone as a blank at three wavelengths: 663, 644, and 453 nm.

The concentration of each pigment fraction in $\mu g\ ml^{-1}$ was calculated from the following equations:

$$\text{Chlorophyll a} = 10.3\ E_{663} - 0.918\ E_{644} = \mu g/mL \quad (1)$$

$$\text{Chlorophyll b} = 19.7\ E_{644} - 3.87\ E_{663} = \mu g/mL \quad (2)$$

$$\text{Carotenoids} = 4.2\ E_{452.5} - (0.0264\ \text{chlorophyll a} + 0.4260\ \text{chlorophyll b}) \quad (3)$$

Finally, the pigment contents were calculated as the fresh weight of leaves ($mg\ g^{-1}$).

Inorganic nutrients

Three composite samples, from the roots, shoots, and seeds of the studied plants were taken from each farm (unpolluted and polluted). Oven-dried samples (at 70°C until constant weight) were homogenized by grinding in a metal-free plastic mill and then passed through a sieve of 2-mm mesh size.

To estimate minerals and heavy metals, plant powders (0.2g) were digested in an acid mixture (H_2SO_4 and $HClO_4$). The clear digests were filtered and diluted to 50 ml using double-de-ionized water. The total nitrogen of plant roots, shoots, and seeds was determined using the Kjeldahl method. Phosphorus content was determined by the molybdenum blue method using a spectrophotometer (model CECIL CE 1021). Potassium was estimated using a flame photometer (CORNING M410). Calcium, magnesium contents and heavy metals (Fe, Co, Cu, Mn, Zn, Pb, and Cd) were determined using Atomic Absorption Spectrophotometry as outlined by Allen (1989).

Organic nutrients

The crude protein (CP) was calculated by multiplying the nitrogen concentration by 6.25 (Adesogan et al., 2000).

After the extraction of total carbohydrates (nitrogen-free extract, “NFE”) and total soluble sugars as described by Chaplin & Kennedy (1994), both quantities were estimated colorimetrically by the phenol sulfuric acid method as described by Dubois et al. (1956) using a spectrophotometer at wavelength 490nm. Ether extract (crude fat) content was estimated by extracting the dried material of the plant samples with ether. Crude fiber content (CF) was then determined by the Soxhlet extraction method (Colowick & Kaplan, 1957).

Digestible crude protein (DCP) was calculated according to equation 4, taken from Demarquilly & Weiss (1970):

$$\text{DCP (asDM \%)} = 0.929\ \text{CP (in \%DM)} - 3.52 \quad (4)$$

The total digestible nutrients (TDN) were calculated using equation 5, from Naga & El–Shazly (1971):

$$\text{TDN (in \% dry matter)} = 0.623\ (100 + 1.25\ \text{EE}) - \text{CP}\ 0.72 \quad (5)$$

where EE and CP are the ether extract and crude protein percentages, respectively.

The digestible energy (DE) was estimated following equation 6, from NRC (1984):

$$\text{DE (Mcal kg}^{-1}) = 0.0504\ \text{CP (\%)} + 0.077\ \text{EE (\%)} + 0.02\ \text{CF (\%)} + 0.000377\ (\text{NFE})^2\ (\%) + 0.011\ \text{NFE (\%)} - 0.152. \quad (6)$$

The metabolized energy (ME) was calculated using equation 7, taken from Garrett (1980):

$$\text{ME} = 0.82\ \text{DE} \quad (7)$$

The net energy (NE) was calculated using equation 8 from (Le Houérou, 1980)

$$\text{Net energy (NE)} = 0.50\ \text{ME} \quad (8)$$

The gross energy (GE) was calculated using equation 9, from NRC (1984):

GE (Kcal 100 g^{-1})= 5.72 TP (%) + 9.5 EE (%) + 4.79 CF (%) + 4.03 NFE (%) (9)

Data analysis

Pollution index

The degree of soil pollution by each heavy metal was assessed using pollution index (PI) calculated as: PI = C_c / C_r, where C_c and C_r represent the estimated heavy metal concentration and its allowable concentration in soil (Liu et al., 2005).

Bioaccumulation factor (BF)

Heavy metal concentrations of soils and plants were calculated on the basis of dry weight (mg kg-1 dry weight). Bioaccumulation factor (BF) is an index of the plant ability for concentrating a metal in parallel to its concentration in the soil (Ghosh & Singh, 2005) and was calculated as: BF= C_{Root}/C_{Soil}, where C_{Root} and C_{Soil} is the heavy metal concentration in plant root and soils, respectively.

Translocation factor (TF)

The translocation factor or mobilization ratio (TF), assessed to determine the relative translocation of metals from the belowground root to the aboveground shoot of the plant species (Gupta & Sutar, 2008), was calculated as TF= C_{shoot}/C_r, where C_{shoot} and C_r are the heavy metal concentrations in plant shoot and root, respectively. The translocation of trace metals from the shoot to the plant seeds was also determined as TF = C_{seed}/C_{shoot}.

Health risk index

To assess the health risk of any pollutant in the edible parts of the plant, it is necessary to estimate the level of exposure, by detecting routes of exposure to target organisms. The daily intake of metals (DIM) was calculated according to the average consumption of polluted plants for adults and children. It was estimated as DIM = (C_{metal} × C_{factor} × $D_{food\ intake}$)/$B_{average\ weight}$ (Khan et al., 2008) where C_{metal} represents the heavy metal concentrations in plant parts (mg kg^{-1}), C_{factor} is a conversion factor, $D_{food\ intake}$ is the daily intake of vegetables, and $B_{average\ weight}$ is the average body weight. The conversion factor 0.085 was used for converting the dry weight of vegetables to the fresh weight (Rattan et al., 2005). The average daily intakes for adults and children were considered to be 0.345 and 0.232 kg per person per day, respectively, and the average body weights for adults and children were 55.9 and 32.7 kg, respectively (Arora et al., 2008; Asgari & Cornelis, 2015).

The health risk index (HRI) associated with consumption of the polluted plants was calculated as the ratio of the estimated exposure factor of a crop to the oral reference dose of the toxic metal (Singh et al., 2010). An HRI value greater than one is not safe for human health (USEPA, 2012) and may pose health hazards for consumers. The oral reference doses for metals are as follows: 0.001 for Pb and Cd, 3.01 for Co, 0.02 for Ni, 1.5 for Cr, 0.3 for Zn, 0.14 for Mn, 15.0 for Fe, and 0.04 for Cu (FAO/WHO, 2001; WHO, 2006; US-EPA, 2010).

Statistical analysis

The statistical differences in the variables of water, soils, and plants of the polluted and unpolluted sites were evaluated using a T-test. After testing the data for normality, a one-way analysis of variance (ANOVA-1) was used to assess the significance of variations tested by Duncan's multiple ranges at P < 0.05 using SPSS software (SPSS, 2006).

Results

Statistical analysis detected significant variation in the physicochemical variables between the two sources of irrigation (Table 1). Shibin drainage water was characterized by a mild alkaline to neutral pH (7.07), a very low concentration of dissolved oxygen (DO: 0.46), and nitrates (NO_3^-: 119.0µg/L). It had high electric conductivity (EC: 1593.0 µs/cm), and high concentrations of BOD_5, COD, cations, and anions (HCO_3^-, Cl^-, NO_2^-, NH_4^-, SO_4^- and PO_4^-) when compared with Sharkwia canal water. In addition, higher concentrations of all heavy metals (Fe, Pb, Cd, Cu, Co, Mn, and Zn) were recorded in the drainage water than in the canal water.

Figure 2 indicates that Sharkwia canal and Shibin drain water are both polluted with Fe, Cd, Cu, Mn, and Zn (PI > the unit) but that the PI of the metals in the drainage water is greater than in the canal water. The PI of Co in the drainage water was more than the unit (3.2) but in the canal water, it was less (0.6). The PI of Pb was low in the canal water (0.16), but in the drainage water, it had a critical value (0.84).

TABLE 1. Physico-chemical properties of the irrigation water sources, Sharkwia canal and Shibin drain in the study area

Water variable		Sharkwia canal	Shibin drain	T-value
pH		8.18±1.28	7.07±0.58	12.8**
Ec (μs cm^{-1})		534.0±42.30	1593.0±162.42	11426.5***
BOD_5		3.00±0.43	13.80±1.05	20.4***
COD		5.36±0.48	30.0±4.25	153.8***
DO		5.40±0.62	0.46±0.04	18.64***
Ca^{++}		38.70±4.52	85.60±9.62	178.2***
Mg^{++}	mg L^{-1}	18.10±1.95	31.80±2.64	58.2**
K^{+}		3.16±0.24	21.34±1.28	45.78***
HCO_3^{-}		200.0±25.6	342.0±36.84	482.3***
Cl^{-}		36.60±3.85	228.0±26.53	648.5***
SiO_2^{--}		5.14±0.62	11.30±1.17	44.6**
NO_2^{-}		15.0±2.40	39.8±33.45	120.5***
NO_3^{-}		216.0±19.6	119.0±11.72	78.6**
NH_4^{-}		452.3±37.60	21336.0±1125.36	1866.5***
SO_4^{--}		41.40±5.64	125.0±8.62	176.2***
PO_4^{--}		58.30±7.62	1351.0±96.47	448.5***
TP		82.0±6.89	1930.0±152.69	117.8***
Fe^{+++}	μg L^{-1}	430±20.5	493.8±22.6	165.2**
Co^{++}		0.03	0.16	12.2**
Pb^{++}		0.82±0.03	4.2±0.23	28.1***
Cd^{++}		0.2±0.01	0.6±0.04	16.42***
Cu^{+}		25.4±2.42	26.2±3.51	3.56
Mn^{++}		25.8±2.42	57.4±4.68	85.6***
Zn^{++}		6.2±0.42	8.8±0.65	17.6**

, * significant variation at P<0.01, 0.001

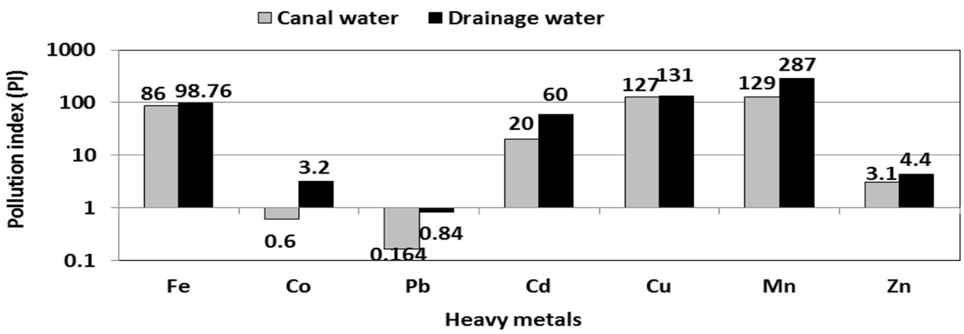


Fig. 2. Pollution index of heavy metals in canal and drainage irrigated water

Soil analysis

Statistical analyses showed that irrigation with drainage water significantly altered the physicochemical properties of soil. Significant variations between canal and drainage water soil samples were detected in all soil variables except pH and Zn. The poluted and unpoluted soil tended to be neutral where the pH ranged between 6.95 (polluted) and 7.01 (unpolluted). The EC of soil irrigated with drainage water was higher than that of soil irrigated with canal water (297.33±3.18 and 283.0 ± 1.05μs cm^{-1}, respectively). All anions (Co_3^{-2}, HCO_3^{-1}, Cl^{-1}, and SO_4^{-2}) and cations (Ca^{++}, Mg^{++}, and K^{+}) recorded a higher concentration in soils irrigated with drainage water (Table 2). Similarly, heavy metals recorded higher concentrations in the soils irrigated with drainage water. The concentrations of Cd, Cu, and Zn in the polluted and unpolluted soils were more than their permissible concentrations documented by CHHSL Permissible Limits, as the PI of these three metals was 15.8, 1.2, and 4.8 for unpolluted soils and 18.1, 2.0 and 5.6 for polluted soils, respectively (Fig. 3).

TABLE 2. Physico-chemical properties of soils irrigated with canal and drainage water

Soil variables		Water source		T-value
		Canal	Drainage	
pH		7.01±0.01	6.95±0.05	1.25
Ec (µs cm^{-1})		283.0±1.05	297.33±3.18	36.53*
Co_3^{-2}		0.37±0.01	0.44±0.02	8.24*
HCO_3^{-1}		0.33±0.02	0.42±0.03	6.28*
Cl^{-1}		1.09±0.14	2.24±0.18	32.2**
SO_4^{-2}		0.01±0.002	0.02±0.004	0.44
Ca^{++}	mg g^{-1}	34.09 ± 1.80	39.78 ± 2.98	19.5*
Mg^{++}		14.23 ± 2.25	15.34 ± 1.88	3.45
K^{+}		2.15±0.18	4.5±0.036	14.25**
N		0.03±0.008	0.08±0.01	9.12**
P		14.5±0.3	19.42±1.85	75.62**
Fe		118.0±109.4	157.7±130.3	11.0***
Co		17.4±1.32	20.9±1.15	62.9**
Pb		53.6±24.52	60.2±3.23	28.7**
Cd	mg kg^{-1}	26.8±1.34	30.8±2.05	53.3**
Cu		3.46±0.22	6.11±0.51	25.9**
Mn		123.3±11.95	125.6±11.20	20.0
Zn		110.9±1.51	129.2±1.05	1.02

*, **, ***significant differences at P<0.05, 0.01, 0.001

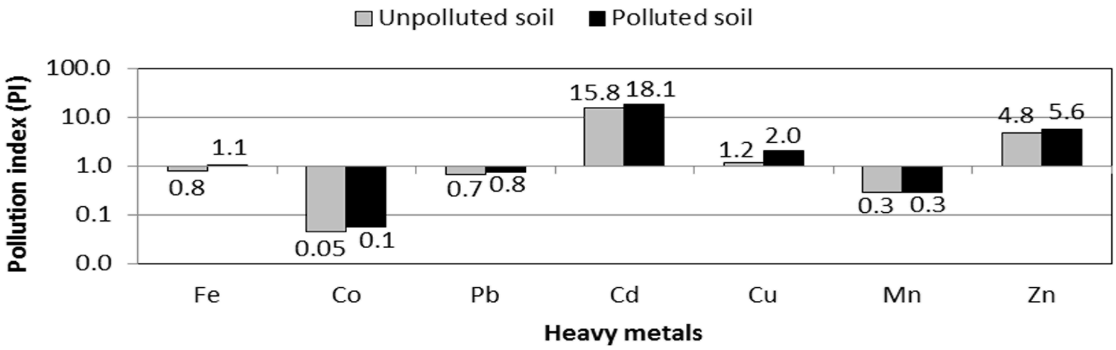


Fig. 3. Pollution index of heavy metals in soils irrigated with canal and drainage water

Growth traits of Arachis hypogea

Table 3 shows the significant variation in growth traits between *Arachis hypogea* plants irrigated with canal water and drainage water. Irrigation with drainage water reduced root length, shoot length, root dry biomass, shoot dry biomass, number of branches, and plant & leaf area (cm^{-2}) by 35.0%, 14.1%, 25.0%, 42.9%, 35.4%, and 53.24%, respectively. In addition, irrigation with drainage water significantly decreased the leaf area from 46.1 to 30.1cm^{-2}, a reduction of 53.2%.

Yield traits of Arachis hypogea

High significant variations at P< 0.01 and 0.001 were recorded in the yield traits and productivity between *Archis hypogia* crops irrigated from the Sharkawia canal and Shibin drain (Table 4). Irrigation with wastewater from the Shibin drain decreased the number of pods per plant from 113.33 ± 24.55 to 54.0 ± 12.72 g $plant^{-1}$ and the pod dry weight per plant from 166.7 ± 22.4 to 83.3 g $plant^{-1}$ ± 10.6, corresponding to reductions of 52.4% and 50.0%, respectively. In addition, drainage water decreased the number of seeds per plant from 98.33 ± 18.43 to 46.67 ± 10.28 g $plant^{-1}$ and the weight of seeds per plant from 98.33 ± 18.43 to 46.67 ± 10.28 g $plant^{-1}$, corresponding to reductions of 52.1% and 52.5 %, respectively.

TABLE 3. Growth traits of *Arachis hypogea* plants irrigated with canal and drainage water

Irrigation water	Length (cm)		Dry weight (g plant^{-1})		No. of branch/ plant	Leaf area (cm^{-2})
	Root	Shoot	Root	Shoot		
Canal	20.0±1.8	90.0±3.6	6.7±2.9	373.3±16.8	27.3±4.2	46.1±1.5
Drainage	13.0±2.7	77.3±2.5	5.0±4.4	213.3±8.6	17.7±2.5	30.1±2.1
Reduction (%)	35.0	14.1	25.0	42.9	35.4	53.24
T-value	**14.34***	**24.89****	**0.31**	**35.5****	**18.0****	**82.70****

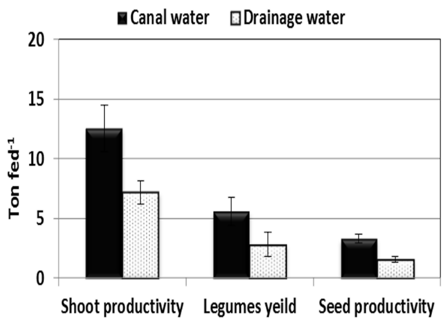
*,**significant difference at P<0.05, 0.01

TABLE 4. Yield traits of *Arachis hypogea* crop irrigated with canal and drainage water

Irrigation water	No. of pods/plant	No. of seeds/plant	Pods dry wt./ plant (g)	Wt. of seeds/plant (g)
Canal	113.3±24.6	156.7±25.5	166.7±22.4	98.3±18.4
Drainage	54.0±12.7	75.0±13.4	83.3±10.6	46.7±10.3
Reduction %	**52.4**	**52.1**	**50.0**	**52.5**
T-value	42.2***	54.3**	57.2**	76.9**

,*significant difference at P<0.01, 0.001

Figure 4 indicates that the productivity of the *Archis hypogia* crop is significantly reduced due to irrigation with drainage water, with P < 0.01. shoot dry biomass productivity was reduced from 12.54 ± 1.92 ton fed^{-1} to 7.17 ± 1.01 ton fed^{-1}, corresponding to a reduction of 42.9%. Pod and seed productivity decreased from 5.60 ± 1.15 ton fed^{-1} to 1.80 ± 1.03 ton fed^{-1} (50.0% reduction) and from 3.30 ± 0.38 ton fed^{-1} to 1.57 ± 0.21 ton fed^{-1} (52.5% reduction), respectively.



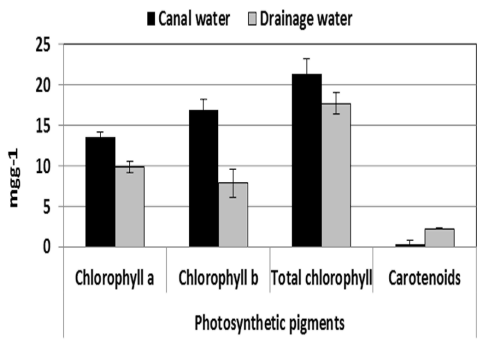
F-value 35.5** 57.2** 73.1**

**significant difference at P<0.01

Fig. 4. Productivity of *Arachis hypogea* crop irrigated with canal and drainage water

Photosynthetic pigments

The photosynthetic pigments of *A. hypogea* leaves were significantly affected by irrigation with drainage water at P< 0.01 and 0.001. Chlorophyll *a* and chlorophyll *b* decreased from 13.51 ± 0.62mg g^{-1} and 16.86 ± 3.29mg g^{-1} (leaves irrigated with canal water) to 9.85 ± 1.72mg g^{-1} and 7.87 ± 2.76mg g^{-1} (leaves irrigated with drainage water), respectively. In contrast, carotenoids increased from 0.37 ± 0.42mg g^{-1} in leaves of plants irrigated with canal water to 2.27 ± 0.11mg g^{-1} in plants irrigated with drainage water (Fig. 5).



F-value 12.09** 13.13*** 35.24** 57.71**

**significant difference at P<0.05, 0.01

Fig. 5. Photosynthetic pigments of *Arachis hypogea* crop irrigated with canal and drainage water

Mineral nutrients

Irrigation with drainage water significantly (at P< 0.05, 0.01, 0.001) decreased the content of NPK in peanut plants but increased the content of Ca and Mg. The highest values of N (4.5 ± 0.28mg g^{-1} dry weight) and P (0.22 ± 0.02mg g^{-1} dry weight were recorded in seeds of plants irrigated with canal water but these values decreased to 2.07 ± 0.16 and 0.21 ± 0.01mg g^{-1}dry weight, respectively in plants irrigated with drainage water. Irrigation with drainage water caused significantly high values of Ca (108.50± 9.86mg g^{-1} dry weight) in peanut shoots when compared to those irrigated with canal water. No significant variation in Mg content was observed between plants irrigated with canal and drainage water (Table 5).

TABLE 5. Inorganic nutrients content of *Arachis hypogea* crop irrigated with canal and drainage water

	Inorganic nutrients (mg g^{-1})														
	N			P			K			Ca			Mg		
	Root	Shoot	Seeds	Root	Shoot	Seeds	Root	Shoot	Seeds	Root	Shoot	Seeds	Root	Shoot	Seeds
Canal water	2.05 ± 0.18	1.75 ± 0.06	4.5 ± 0.28	0.19 ± 0.01	0.19 ± 0.01	0.22 ± 0.02	1.68 ± 0.11	2.04 ± 0.20	1.05 ± 0.11	30.14 ± 2.45	47.75 ± 4.15	17.81 ± 0.78	5.09 ± 0.48	5.48 ± 0.40	4.81 ± 0.34
Drainage water	1.43 ± 0.087	1.02 ± 0.01	2.07 ± 0.16	0.11 ± 0.01	0.12 ± 0.008	0.21 ± 0.01	1.15 ± 0.07	1.42 ± 0.08	0.42 ± 0.025	55.21 ± 4.56	108.50 ± 9.86	31.03 ± 2.46	6.41 ± 0.53	6.77 ± 0.59	4.84 ± 0.38
T-value	7.52*	6.57*	9.65*	27.8***	45.4***	1.82	12.43**	16.25**	11.32**	48.6**	104.2***	75.6**	2.44	3.17	0.44

*, **, ***significant difference at P< 0.05, 0.01, 0.001

Organic nutrients content

Irrigation with drainage water significantly reduced the total carbohydrates (NFE) and crude protein (CP) but have no significant effect on the crude fats (EE) and crude fibers (CF) compared to those of plants irrigated with canal water (Table 6). Where, the NFE, CP and EE were decreased with reduction percentage 36.7, 54.1 and 4.2 %, respectively, but non-significantly increased the content of the CF with 28.8%. On the other hand, irrigation with was drainage water significantly increased the total soluble carbohydrates (TSS) form 3.20±0.25% (for plants irrigated canal water) to 4.50±0.28%.

Nutritive value

The estimation of peanut seedsnutritive value, when irrigated with canal and drainage water, revealed highly significant variation (at P < 0.01 and 0.001) in all variables (Table 7). Irrigation with drainage water decreased the DCP by 62.4% but increased the TDN from 71.9% ± 5.84% to 81.7%± 4.56%. Furthermore, digestible, metabolized, and net energy were reduced by 21.74%, 21.74%, and 20.01%, respectively.

Heavy metals

Figure 6 shows significant variation in all heavy metals, except Co and Cd, between *Arachis hypogea* plants (roots, shoots, and seeds) irrigated with canal water compared with those irrigated with drainage water. Fe, Cu, and Mn significantly increased in organs (roots, shoots, seeds) of *Arachis hypogea* plants irrigated with drainage water when compared to those irrigated with canal water. There was a significantly high Fe content in plant roots irrigated with canal water (1851.0mg kg^{-1} dry wt.), but in plants irrigated with drainage water, the shoots recorded the highest Fe content (2526.0mg kg^{-1} dry wt.). Mn was recorded at its high value in the plant shoots when irrigated with canal water (169mg kg^{-1} dry wt) but in the seeds of plants irrigated with drainage water (283.5mg kg^{-1} dry wt.). The irrigation with drainage water decreased the content of Zn in roots, shoots, and seeds from 455.5 to 211.5, 443.5 to 341.5, and 590.5 to 382.5 283.5mg kg^{-1} dry wt, respectively. Peanut plants irrigated with canal and drainage water showed a high content of Cu in roots (266.5 and 275.0mg g^{-1} dry wt.). Roots and seeds of the plants irrigated with canal water showed a lower content of Pb than those of plants irrigated with drainage water.

TABLE 6. Organic nutrients content of *Arachis hypogea* seeds irrigated with canal and drainage water. Where total carbohydrates (NFE), Total soluble salts (TSS), crude protein (CP), crude fates (EE) and crude fibers (CF)

Water resources	Organic nutrients content (%)				
	NFE	TSS	CP	EE	CF
Canal water	18.4±1.5	3.20±0.25	28.1±2.7	38.4±3.0	4.1±0.78
Drainage water	11.7±1.3	4.50±0.28	12.9±1.1	36.8±2.8	5.2±0.42
T-value	45.68**	16.44**	14.6**	4.52	1.25

*, **, ***significant difference at P< 0.05, 0.01, 0.001

TABLE 7. Nutritive value of *Arachis hypogea* seeds irrigated with canal and drainage water

Water resources	Nutritive value				
	DCP	TDN	DE	ME	GE
	%			(Kcal kg^{-1})	
Canal water	22.6±3.24	71.9±5.84	4.6±0.36	2.3±0.18	619.3±34.52
Drainage water	8.5±0.75	81.7±4.56	3.6±0.28	1.8±0.09	495.4±28.3
T-value	85.2***	28.3**	9.4**	6.3**	187.2***

*, **, ***significant difference at P< 0.05, 0.01, 0.001

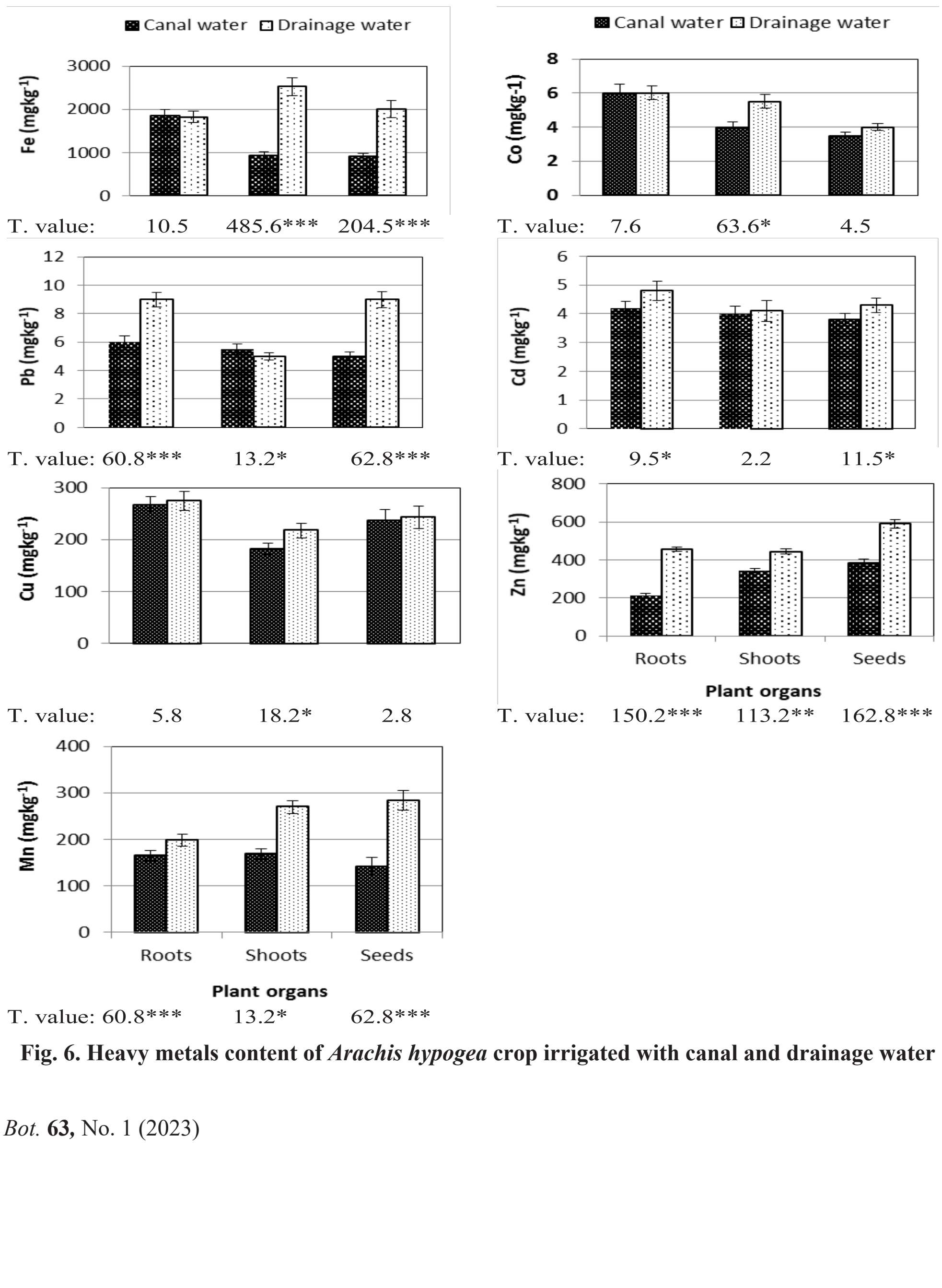


Fig. 6. Heavy metals content of *Arachis hypogea* crop irrigated with canal and drainage water

Bioaccumulation (BAF) and translocation factors (TF) of heavy metals

Table 8 showed that *A. hypogea* plants had high tendency to accumulate high contents of Cu, Mn and Zn and low tendency for Fe, Co, Pb and Cd under irrigation with canal and drainage water. The BAF of Fe recorded critical value (0.98) under irrigation with drainage water and the TF of it from root to shoot was higher than the unit (1.39) under irrigation with drainage water. On the other hand, the BAF of Co, Pb and Cd is very low than the unit ranged between 0.13 and 0.26. It was noticed that the plants irrigated with drainage water had TF from shoots to seeds more than the unit; 1.80 for Pb and 1.05 for Cd. The BAF of heavy metals Cu, Mn and Zn in the whole plant is more than the unit and increased under irrigated with drainage water than canal water, where the BAF was increased from 3.71 to 6.98 for Cu, 6.80 to 9.79 for Mn and 25.56 to 41.72 for Zn. The TF of Cu, Mn and Zn from soil to roots and from shoots to seeds was higher than the unit.

Daily intake and health risk index (HRI) of heavy metals

Table 9 shows that consuming peanut seeds irrigated with drainage water increased the daily intake of heavy metals, except for Co and Cd. From Table 10, Co had HRI values of less than the unit in the *Arachis hypogea* seeds irrigated with canal and drainage water (0.05 for each). In the seeds of *Arachis hypogea* plants irrigated with canal water, Pb, Mn, and Fe had low HRI (less than the unit, 0.66, 0.53, and 0.68, respectively, for adults) but for seeds of plants irrigated with drainage water, the HRI of Pb, Mn, and Fe was more than the unit (1.18, 1.06, and 1.50 for adults and 1.36, 2.47, and 1.19 for children, respectively). Cd and Cu had an HRI of more than the unit for plant seeds irrigated with canal and drainage water. Zn recorded HRI greater than one 1 in plant seeds irrigated with drainage water (1.03) but an HRI < 1 in plant seeds irrigated with canal water (0.67).

Discussion

Water scarcity is a major problem facing farmers, driving them to irrigate crops with wastewater. Irrigation with wastewater has a long history that spans centuries and has operated better in developed countries than in the developing world (Zhang & Shen, 2017). Wastewater has been used in date orchards for over 400 years; however, most farmers are not aware of wastewater benefits or environmental risks, they are only interested in maximizing crop yields (Reed et al., 1995).

TABLE 8. Bioaccumulation and translocation factors of heavy metals for *Arachis hypogea* crop irrigated with canal and drainage water

HM	WS	$BAF_{plant/soil}$	$TF_{R/Soil}$	$TF_{Sh/R}$	$TF_{Seed/Sh}$
Fe	Canal	0.58	0.87	0.50	0.97
	Drainage	0.98	0.84	1.39	0.79
Co	Canal	0.26	0.35	0.67	0.88
	Drainage	0.25	0.29	0.92	0.73
Pb	Canal	0.14	0.16	0.92	0.91
	Drainage	0.13	0.15	0.56	1.80
Cd	Canal	0.15	0.16	0.95	0.95
	Drainage	0.14	0.16	0.85	1.05
Cu	Canal	3.71	4.34	0.68	1.31
	Drainage	6.98	7.80	0.78	1.17
Mn	Canal	6.80	7.07	1.02	0.84
	Drainage	9.79	7.75	1.36	1.05
Zn	Canal	25.56	17.34	0.97	1.12
	Drainage	41.72	38.28	1.61	1.33

TABLE 9. Daily intake of metals (mg day^{-1}) by adults and children for individual heavy metals in *Arachis hypogea* seeds irrigated with canal and drainage water

Heavy metal	Daily intake of metals (mg day^{-1})			
	Adult		Children	
	Canal water	Drainage water	Canal water	Drainage water
Fe	0.474	1.052	0.545	1.209
Co	0.002	0.002	0.002	0.002
Pb	0.003	0.005	0.003	0.005
Cd	0.002	0.002	0.002	0.002
Cu	0.128	1.052	0.143	0.147
Mn	0.074	0.149	0.086	0.171
Zn	0.201	0.310	0.231	0.356

TABLE 10. Health risk index (HRI) of heavy metals for adults and children via intake of heavy metals in *Arachis hypogea* seeds irrigated with canal and drainage water

Heavy metal	Health risk index (HRI) of heavy metals			
	Adult		Children	
	Canal water	Drainage water	Canal water	Drainage water
Fe	0.68	1.50	0.78	1.73
Co	0.05	0.05	0.05	0.06
Pb	0.66	1.18	0.75	1.36
Cd	2.10	2.15	2.41	2.47
Cu	2.63	3.19	3.58	3.67
Mn	0.53	1.06	0.61	1.22
Zn	0.67	1.03	0.77	1.19

Water analysis in this work indicates that the pH of canal and drainage irrigation water is alkaline. This result is in agreement with Fathi & Kobbia (2000) and Khalifa (2014). They returned their results to increase the photosynthetic activity of phytoplankton or may be to chemical composition of irrigation water. The increase in pH value of the El-Sharkawia Canal water may be due to increased photosynthetic activities and the growth of aquatic plants, where due to photosynthesis, the plant consumes CO_2 and decreases the bicarbonate concentration (Shakweer, 2006; Yousry et al., 2009; Ezzat et al., 2012). In this work, low pH values were recorded in the wastewater of the Shibin drain. Ravindra & Kaushik (2003) recorded similar results for the Yamuna River and attributed the downstream lowering in pH to the increasing effluent from the industries and sewage of Delhi. The rise of the EC values results from the increase in TDS (Kumar & Bahadur, 2009) and high concentrations of inorganic and organic contents in domestic and agricultural wastewater (Ahmed, 2007). In the present study, the data shows that the EC of drainage water was approximately three-fold greater than that of canal water. The increase in EC values in the Shibin drain may be caused by an increase in land runoff. Domestic and industrial wastewater and agricultural effluents discharged in the lowered values of water result in raising the dissolved salts and suspended particles, increasing the potential to convey EC (Ahmed, 2012). These results agreed with the findings of El-Sayed (2008), Abdo & El-Nasharity (2010), and Abdo et al. (2012). The low EC value in the El-Sharkawia canal can be attributed to the uptake of soluble salts by phytoplankton (Saad et al., 2011), and the sedimentation of the suspended solids with ionic salts resulted in a decrease of chemical elements (Marshall & Falconcer, 1973).

A higher DO value was recorded in canal water than in drainage water, possibly because of an increase in the photosynthetic rate caused by phytoplankton that release large amounts of oxygen to the aquatic ecosystems (Talling, 1976). A low DO value was reported in the Shibin drain, a direct effect of the discharged effluents being heavily loaded with organic and inorganic waste (El-Degwy, 2016). This returns to consuming oxygen by aerobic microorganisms so that they can decompose organic matter into inorganic products. In contrast to the DO values, the Shebben drain contained high values of BOD and COD, which may be due to the presence of a high bacterial load in the water and thus, a higher rate of organic matter decomposition (Sanap et al., 2006). This organic matter is discharged into water from domestic sewage and agricultural effluents. The current findings are similar to those of Goher et al. (2014), who mention that BOD in the Ismailia Canal ranged from 0.3 to 7.18mg/L. COD values are always greater than BOD values (Patel & Parikh, 2013).

The concentration of carbonates anion (CO_3^{2-}) was observed to be lower than bicarbonate anions (HCO_3^-) concentration that can be attributed to the respiration of the aquatic plants and decomposition of the dead phytoplanktons leading to release CO_2 which dissolved in water asHCO_3^- (El Bouraie et al., 2011). In the current study, the increase of bicarbonate concentration in Shibin drain may be attributed to the bacterial decomposition of the organic substances which are discharged into the canal from domestic and agricultural wastes, where bicarbonate and ammonia are the final product as mentioned by Weimer & Lee (1973). On the other hand, El-Sharkawia canal had lower bicarbonate concentration than that recorded in Shibin drain may be attributed to uptake CO_2 from bicarbonates by phytoplanktons populations and as CO_2-H_2O reaction during the photosynthetic process (Klein, 1973). The values of bicarbonates in the two types of irrigation water (342 and 200 mg/L) were in the range that reported by Boyd (1990) which is 40-400mg/L, who reported that bicarbonate of water should be in this range.

The results herein show that another physical and chemical variables recorded higher values in the drainage wastewater than in canal water. These results are in agreement with the findings of Galal et al. (2018). The drainage water of the Shibin drain had high concentrations of heavy metals; these are toxic for crops, butchery animals, and humans if their concentrations are more than the allowable limits (WHO, 2006). Present findings recorded higher concentrations of heavy metals (Fe, Cd, Cu, Mn, and Zn) in the Sharkawia canal than the permissible concentrations reported by the Egyptian Ministry of Water Resources and Irrigation. The concentration of heavy metals in the Shibin drain was also higher than the permissible concentrations, except for Pb, which had a critical PI (US-EPA, 1982; Allen, 1989; Cal/EPA, 2010; FAO, 2011; Chiroma et al., 2014, Khan et al., 2020). These results agree with El-Degwy (2016), who revealed that the El-Sharkawia canal had high concentrations of heavy metals, above permissible concentrations, due to agricultural runoff, domestic sewage effluents, and the wastes of the Shibin El-Qanater water plant.

Soil is a dynamic environment with complex interactions taking place between its biotic and abiotic components. The soil components and properties identify the function of soil in different locations, a concept called "soil quality" (Gurjar et al., 2017; Tian et al., 2022). The irrigation water quality certainly affects the physical and chemical characteristics of soil. Our results indicate that soil irrigated with drainage water had lower pH but higher EC than soil irrigated with canal water. These results are in accordance with Alghobar et al. (2014) who reported that irrigation with sewage wastewater reduced soil pH, which may be attributed to the high content of organic materials, decomposed by microorganisms to organic acids. The pH of soil is a significant variable that controls the partitioning of metals between the soil phases. It influences the adsorption/desorption of the soil metals, in addition to the biogeochemical cycle between soil and plant (Shahid et al., 2012). Furthermore, pH is the major factor that affects the adsorption and mobility of heavy metals in the soil (Shahid et al., 2018).

Continuous irrigating soil with drainage wastewater resulted in high accumulation of total dissolved solids (TDS) and enhances its conductivity. Also, Mohammad & Mazahreh (2003) recorded higher conductivity of soil irrigated with wastewater than soil irrigated with unpolluted water. In addition, Foda et al. (2020) found that long term irrigation with controlled drainage water and recycled water (Phogat et al., 2020) increased soil salinity.

Significant amounts of cations are added to soils Irrigated with wastewater, as well as chlorides, bicarbonates, phosphates and sulfates, salts (Alghobar & Suresha, 2015; Connor, 2017). It is known that irrigation with wastewater alters the cations concentrations in the soil, which effects on metal/nutrient balance between soil phases; solid and aqueous (Murtaza et al., 2010; Khalid et al., 2017). Where, the impact based on concentrations of cations in the used wastewater.

Irrigation with drainage water elevates total heavy metal concentrations in soils. The results of the present study show that soils irrigated with canal water had heavy metals in permissible concentrations (Cal/EPA, 2010), with the exception of Cd, Cu, and Zn. This agrees with the results of El-Degwy (2016). Soil irrigated with drainage water had concentrations of Fe, Cd, Cu, and Zn that exceeded safe ranges. Galal et al. (2018) obtained similar results for cabbage soil irrigated with industrial polluted water in the El-Teppen region.

Soils are the direct pathway for plants contamination with heavy metals through roots absorption. Plants irrigated with wastewater may uptake and accumulate the heavy metals more than maximum allowable concentrations with severe public health implications (Hussain et al., 2013; Khalid, 2017). Excessive heavy metals exposure can enhance the production of reactive oxygen species (ROS) which may led to changes in the plant cell cycles and division, and chromosomal abnormalities (Shahid et al. 2014; Shamshad et al., 2018). As well as overproduction of ROS+ cause protein oxidation, lipid peroxidation, and genotoxicity. The obtained results showed that excess of heavy metals concentration in the soil represents the main factor caused reduction in the growth traits of *A. hypogea*. Additionally, peanut productivity significantly reduced in soils irrigated with drainage water. Where pods, seeds and straw biomass productivity were reduced with reduction percentage 50, 52.5 and 42.9%, respectively. In agreement with the current results, Hussain et al. (2013) recorded reduction in lettuce leaves number and circumference of turnip tuberous roots irrigated with industrial wastewater. Reduction in the plant growth and yield traits represents the common symptoms to heavy metals stress as reported by Hadi et al. (2014), Galal et al. (2017a, b), Farahat et al. (2017), Galal et al. (2018) and Tauqeer et al. (2022). This reduction may be attributed to inhibition in the biosynthesis of photosynthetic pigments and their activity and/or nutrients insufficiency (Chauhan & Joshi, 2010; Nagajyoti et al., 2010). Also, Sun et al. (2016) explained decreasing in the growth of plants irrigated with wastewater by decreasing the photosynthesis rate causing reduction in biosynthesis of carbohydrates and deformation in leaves phloem vessels which inhibit the translocation of nutrients to seeds. In addition, Foda et al. (2020), El-Khallal et al. (2016) and Phogat et al. (2020) recorded reduction in plant growth parameters and yield indices as a result to controlled irrigation with drainage water and attributed this reduction to accumulative salinity in the root zone of salt-sensitive crops. In this respect, the growth and productivity of peanut plants is sensitive to high salinity and contamination with Cu, Mn and Zn.

A reduction of chlorophyll (*a* and *b*) occurs due to irrigation with drainage water. Increased concentrations of Cu, Zn, and Cd in the soil decrease the chlorophyll content in various plants (Aggarwal et al., 2012). Decreasing in photosynthesis pigments is may be returns to inhibition in reductive steps in the biosynthetic pathways of the photosynthesis pigments (De Filippis, 1994). Carotenoids increased in plant leaves irrigated with drainage water as a result of heavy metal stress. In addition to the structural function of carotenoids in the photosynthetic antenna and the reaction center, they play a significant role in protecting the photosynthetic system from oxidative damage through scavenging ROS (You & Chan, 2015).

Metabolic products (proteins, lipids, and carbohydrates) are the major organic nutrients and the main source of energy for human activities (Lupton et al., 2002). The NFE, TSS, EE, and CF in peanut seeds irrigated with canal water in the present study were less than those recorded by USDA (2005), USDA (2018), and Settaluri et al. (2012). Irrigation using wastewater reduced NFE, CP, EE, and CF, but the TSS was increased to act as organic osmoregulation against oxidative stress, resulting in an accumulation and translocation of heavy metals from soil to roots, then finally to plant seeds. The GE of peanut seeds(619.3 kcal) irrigated with canal water was greater than that recorded by USDA (2018) at 587.00kcal, Ingale & Shrivastava (2011) at 567.00kcal, and Settaluri et al. (2012) at 585kcal. Irrigation with drainage water reduced the GE stored in the peanut seeds to lower than the standard GE recorded by USDA (2005) and USDA (2018).

Present study detected low concentration of Fe, Mg, Ca and P in peanut plants irrigated with canal water were in contrast to high concentrations of all heavy metal in organs of the plants irrigated with drainage water. reported that the absorption and translocation of plant nutrients like Fe, Mg, P and Ca depended on Zn concentration in soil (Cayton, 1985; Guo et al., 2022). They reported, Zn was antagonist to Cu at its site of primary absorption, contrast to its action on Fe, P, Ca and Mg. Zinc overlapped at loading site of roots and decreased the rate of absorption or translocation of the essential nutrients to plants, consequently it leads to mineral imbalances (Chaney, 1975; Chaudhry, 1977). Metal phyto-toxicity leads to inhibition of enzyme activities; disturbed mineral nutrition; water imbalance; change in hormonal status, and alteration in membrane permeability (Ernst, 1998; Seregin & Ivaniov, 2001) that can be affected uptake of macronutrient by plants. Irrigation with drainage wastewater caused disturbance in the investigated heavy metals distribution in plant organs. The present results indicated that under irrigation with drainage wastewater, peanut plants tend to translocate heavy metals to seeds. Bioaccumulation additional heavy metals in the plant seeds effects on the nutritional value of the seeds as well as the health of consumers as they transferred to the food chain (Opaluwa et al., 2012).

Peanut plants had high potency to bio-accumulate Cu, Mn, and Zn with BAF differed according to concentrations of the metals in the soil, where metals increased more with drainage wastewater irrigation than with canal water. In addition, peanut plants translocated the heavy metals from shoots to seeds with TF ranging from critical values for Fe, Co, and Pb to more than the unit for Cd, Cu, Mn, and Zn. These results were in agreement with Galal et al. (2018), who found in a cabbage crop that the BFs of Pb, Cd, Fe, Mn, and Co were more than the unit, and that the TF in polluted plants was more than the unit for Pb, Cu, and Ni.

Drainage water irrigation had significantly negative impacts on total carbohydrates contents, crude protein, lipids of contaminated peanut plants. Reduction in the organic nutrients attributed to excessive accumulation of toxic metals (Mn, Zn Cu, Co, Pb and Cd,) which may inhibit carbohydrates synthesis through destroying the ROS production and the photosynthetic electron transport chain (Sandalio et al., 2001). In addition, heavy metals can replace Mg in chlorophyll molecules, so it alters chlorophyll function (Kowalewska et al., 1987). Similarly, Chaffei et al. (2004) reported that high concentration of Cd in plant tissues can significantly changes the physiological processes that caused low carbohydrates metabolism. In addition, Irrigation by drainage water could reduce significantly the protein synthesis because of physiological changes in plants. Also, High heavy metals concentrations may inhibit protein metabolism by changing the physiological functions and biosynthetic activities (Sandalio et al., 2001). Where heavy metals can be interacted with DNA and proteins producing oxidative agents cause damages to plant molecules (Leonard et al., 2004). Similarly, high concentrations of heavy metals suppress protein biosynthesis by altering the pigment–lipoprotein complex accumulation in photosystems I and II (Wang et al., 2009), and effect ribulose-1,5-bisphosphate carboxylase/oxygenase enzymes (Krantev et al., 2008). Also, Leschber (1991) and Wild et al. (1991) found that some organic substances may be toxic to rhizobia and thus inhibit nodulation due to high application rates of wastewater which may significantly limit microbial activity including rhizobia resulting in depression of nodulation and consequently, inhibition of legume plant growth depending on symbiotically nitrogen fixation. In contrast, the total soluble sugars increased in peanut plants irrigated with drainage water. Moreover, the present results and those of Abdel Latef et al. (2020) and Galal et al. (2021) recorded increase in total soluble sugars content (TSS) in plant tissues exposed to salt stress of the polluted conditions. Where, TSS is an organic osmoregulation agent help plants in conserving water balance through maintaining turgor pressure and osmotic stress resistance.

Heavy-metal-induced oxidative stress can cause chloroplast deterioration and lipid peroxidation (Khanna-Chopra, 2012), which affects the nutritional status of polluted plants. High Cd concentrations in plant tissues cause lipid peroxidation (Monteiro et al., 2004), which results in metal-induced lipoxygenase activity and consequently, the deposition of metal ions and changing enzymatic activities (Wildner & Henkel, 1979). HRI has been adopted to evaluate the risks of hazardous materials in foods (Asgari & Cornelis, 2015). According to USEPA (2012), an HRI greater than the unit is not safe for human health. In this study, Cu and Cd in seeds of peanut plants those irrigated by canal water have HRI values greater than one. Those irrigated with drainage water had higher HRI values (>1) for Fe, Mn, Zn, Cu, Pb, and Cd. High Cd accumulation causes plants to be unfit for human consumption. Foods with excess concentrations of Cd cause bone fracture, diarrhea, intense vomiting, stomach pains, reproductive failure, damage to the central nervous system, and cancer (Roosens et al., 2003). Moreover, excess Cd can cause incorrect hemoglobin biosynthesis, renaland tumor infection, raised blood pressure, and disorders of the reproductive system (Pourrut et al., 2011, 2013).

Conclusion

The results herein show that using wastewater in peanut irrigation results in the deterioration of soil properties and a decrease in crop productivity (>50%). Drainage water irrigation had a negative effect on pod productivity, seed productivity, and biomass productivity. In peanut plants irrigated with drainage water, chlorophyll *a* and *b* were reduced through wastewater irrigation but carotenoids were increased as a result of heavy metal stress. Carotenoids play an important role in protecting the photosynthetic system, which works as a defense mechanism against oxidative injury by scavenging reactive oxygen species. High metal concentrations affect photosynthesis activities, which in turn inhibit carbohydrate & protein synthesis, lipid content and energy of polluted plants. Peanut plants irrigated with Sharkawia canal water and Al Sharqawia drain wastewater will be damaging to human health if the polluted seeds or their products are consumed. The HRI values of Fe, Mn, Zn, Cu, Pb, and Cd in polluted peanut plants and those of Cu and Cd in unpolluted plants were higher than the unit. The present study indicates that the water of the Al Sharqawia canal or the Shibin drain is not suitable for irrigating peanut crops, which will need treatment to remove excess toxic metals, especially Pb, Cd, and Cu.

Conflicts of interest: The authors declare no conflict of interest.

Authors' contributions: Conceptualization, Zienab, A. Abdelgawad; data curation, writing—original draft, formal analysis, Asmaa A. Ahmed; investigation, Zienab, A. Abdelgawad and Seliem M. Madbouly; software, Asmaa A. Ahmed; supervision, validation, Mona N. abd El-Wahed and Zienab, A. Abdelgawad. All authors have read and agreed to the published version of the manuscript.

Ethics approval: Not applicable.

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أثار الري بمياه الصرف غير المعالجة على إنتاجية الفول السوداني (*Arachis hypogea*) وصحة الإنسان

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يلجأ المزارعون إلى استخدام مياه الصرف في الري وذلك بسبب ندرة المياه. يهدف هذا العمل إلى دراسة آثار الري بمياه الصرف على الاقتصاد الزراعي وصحة الإنسان. تم جمع عينات من مياه الري من مصرف شبين وقناة الشرقاوية، ومن التربة المروية منهما وتم تحليل الخصائص الفيزيائية والكيميائية لمياه الصرف، ومياه القناة، والتربة الملوثة، والتربة غير الملوثة. كذلك تم تقييم الصفات الخضرية والإنتاجية لنباتات الفول السوداني بما في ذلك محتواها من المغذيات المعدنية ومنتجات التمثيل الغذائي الأولية ومحتوى العناصر الثقيلة .

أدى الري بمياه الصرف الصحي إلى انخفاض إنتاجية القرون والبذور والكتلة الحيوية، بنسبة انخفاض بلغت 50٪ و 52.5٪ و 42.9٪ على التوالي. كذلك انخفض محتوي كلوروفيل أ وكلوروفيل ب بينما زاد محتوي الكاروتين.

انخفض محتوى الكربوهيدرات والبروتين الخام والدهون ومحتوى الطاقة الخام والطاقة الاجمالية وذلك نتيجة الري بمياه الصرف ،بينما زادت تركيزات العناصر الثقيلة، وتحديداً الحديد، المنجنيز،الزنك، الكوبالت، النحاس، الرصاص والكادميوم.

سجلت بذور نباتات الفول السوداني تراكم للمعادن الثقيلة وتخزين للزنك، المنحنيز، النحاس، الرصاص والكادميوم، مما يثبت خطورتها على صحة الإنسان. يؤثر الري بمياه الصرف سلباً علي الاقتصاد العام ورفاهية الإنسان؛ لذلك، توصي هذه الدراسة بسن التشريعات التي تحظر الري بمياه الصرف غير المعالج ومنع التخلص من مياه الصرف المنزلية والصناعية والزراعية في قنوات الري.