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Soil Quality As Affected By Long Term Irrigation With Raw Wastewater

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ABSTRACT

There is consensus in the research community on the effect of irrigation with treated wastewater on soil properties and the accumulation of heavy metals in the soil. Studies that show the effect of irrigation with untreated wastewater(RWW)and evaluation health risk Index of heavy metals accumulation are very important and limited studies. This research was conducted in Palestine to examine the soil quality as affected by long-term irrigation with raw wastewater. A total of 44 soil, plant and water samples were randomly taken from Wadi al-Far'a; a region with a long history of RWW irrigation. The samples comprised 14 composite surface soil samples, 20 edible parts equally representing from two vegetable crops zucchini (Pepo gourd) and eggplant (Solanummelongena), and 10 irrigation water samples. All samples were collected according to the standard methods during the period May-September 2020 and were chemically and physically analyzed. The results showed that soils irrigated with RWW over the long term contained significantly higher concentrations of soil salinity, heavy metals, soil organic matter, and Nutrients available(N, p, and k. mg/L) compared to fields irrigated with fresh water. Heavy metal levels in water and soil samples were within the permissible limits, except for Cd concentration. Opposite behavior was seen for soil pH which decreased from 7.82 to 7.22, and 7.51, for RWW and Rain fed irrigation (Rf) respectively. The findings for determining the level of human exposure to heavy metals by using the Health Risk Index (HRI) for heavy metals accumulationin eggplant and zucchini crops were within the safe limits (<1). The presence of RWW nutrients within standards levels can increase land productivity, reduce fertilizer needs, and subsequently, cut down costs of the entire agricultural process. Our findings are critical for decision-makers in the Palestinian administration and other nations who are developing a plan for using Raw wastewater in irrigation for long-term agricultural management.

Keywords: Raw wastewater irrigation; Soil property; Heavy metal accumulation; Salinity;Organic matter

INTRODUCTION

Due to industrial development and increasing population growth, water resources are steadily decreasing all over the world and the problem is exacerbated in developing countries in particular, Unless these societies adopt a policy of reuse and reduce pollution to maintain the sustainability of the development of their societies. The use of low-quality water resources is considered a solution to agricultural irrigation, which includes the largest global consumption of water. The use of wastewater for irrigation without risk assessments and management can pose a significant risk to water and soil quality, and ultimately to human health. It has been proposed to use treated wastewater for irrigation in agriculture as an alternative water source due to the increasing scarcity of fresh water in arid and semi-arid regions of the world. However, the inability to treat wastewater and build appropriate plants calls for more studies and researches to assess the current situation and suggest appropriate solutions (Craddock et al., 2019). Wastewater reuse policy for agricultural irrigation saves the amount of freshwater that must be extracted from water resources. Thus, it reduces the amount of attrition due to the ever-increasing population, a huge amount of domestic sewage is produced in cities, but the indiscriminate disposal of this water is a cause of pollution to the air, soil, and groundwater supplies (Rezapour et al., 2021). In general, wastewater irrigation enriches the soil with vital macro and micronutrients, including nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), iron (Fe), manganese(Mn), copper (Cu)and others, as a result of its composition. Wastewater may have a high organic matter content; as a result, wastewater could be a sustainable and beneficial supply of organic matter for soils and can encourage plant development. It is believed that the quality of irrigation water has a clear impact on the properties and quality of the soil in addition to its impact on human health. (Razzaghi et al., 2015). Palestine is among the countries that are exposed to the problem of increasing water shortage, but here as a result of the theft of Palestinian water by the Israeli occupation in favor of the settlers (Human Rights Watch. 2010), the occupation measures and the lack of treatment plants called for the need to reuse raw wastewater in agricultural irrigation. Water shortage In Wadi Al-Far'a (in the West Bank) it is compensated by reusing raw sewage water, which calls for the need for more studies on the impact of this type of irrigation water on soil quality and the future of agriculture. As a result of receiving large quantities of domestic, industrial, and agricultural wastewater, Wastewater usually contains high amounts of phytonutrients and thus reduces the need for costly inorganic fertilizers and enhances soil fertility and crop production (Phogat et al.,2020). The practice of reusing wastewater in agriculture is a traditional way to counteract overflow pressure on freshwater resources (Elgallal et al., 2016). Regardless of the benefits, the use of wastewater It may have negative effects on the physical and chemical properties of the soil, and eventually on Crops therefore, the use of wastewater in agriculture can lead to soil salinization Sodium ions increase relative to other cations - and heavy metals build up in soil and crops, causing potential long-term health risks, soit depends on the constituents levels of wastewater and the treatments applied as well as the inherent soil Properties (Lottermoser, 2011). In Palestine, there is poorback ground information in concept of application of untreated wastewater irrigation (RWW compared with freshwater sources. Thus, there is an urgent need to understand the potential environmental impacts of this practice. The widely applied solution is based on this problem to retain heavy metals below the permissible limits in soil and agricultural crops. The aim of this study is to trace the effects of raw wastewater irrigation on soil fertility and quality to protect it from pollution and degradation. The outcome ofthese study can provide basic information on developing soil fertility and decrease health risk index due to mineral deposits in plants, which are usefulin achieving sustainable agricultural management.

MATERIALS AND METHODS

Study Area

WadiAl-Far'ais located in the northeastern part of the West Bank and extends from the foothills of the Nablus Mountains down to Jordan Valley escarpments overlooking the Jordan River topographic details can be found in Google Maps, (2021). During the period May-September, 2020, a field experiment was conducted in Wadi Al-Far'a which descends eastward down to the Jordan Valley floor. Weather in the study area is hot, especially during Summertime, and semiarid with rain falls mainly during the period December-March.The Wadiarea is some 340 $km^2$of which about 33.9 $km^2$are used in agriculture (7.9 $km^2$are rainfed and some 26.0 km^2 are irrigated).Agricultural land comprises olive and almonds orchards, vineyards, cereals,and vegetable fields mainly eggplant, zucchini, and cucumbers all are considered the main resource supporting the living of about 95,000 Palestinian citizens (PCBS, 019, 2000).

WadiAl-Far'a enjoys one of the major groundwater aquifers in the Israeli-occupied West Bank as there are70 wells, 62 of which are devoted to irrigation, and only 8 wells are employed in domestic supply. In addition, 13 fresh-water springs are producing 3.8-38.3 MCM/year (Shadeed, 2005).TheWadi hosts different industries and small businesses including pharmaceutics, food, detergent, painting, insecticides, olive presses, and stone saws, all of them discharge their effluents into the local sewer system, eventually empties in the Wadi without any kind of treatment. Therefore, the raw wastewater (RWW) quality varies along its pathway, especially increases in heavy metals concentration, but its load with organic matter decreases due to the natural aeration (Abboushi, 2013; Duraidi, 2015).

Collecting Samples

Fifteen representative composite surface soil samples were collected randomly from soil profile depth (0-20 cm) using an auger in summer 2020. collecting samples from two different types fed by different irrigation sources, 10 soil samples from fields after irrigated with RWW, 4 soil samples from fields after irrigated with rain-fed water, and one soil sample collected before irrigated and planting to determine the initial characteristics of soil properties as in Table 1. Fewer soil samples were collected from the field irrigated with Rain fed water because it was looking more homogeneous and smallness of the field than the field irrigated with Raw wastewater. Samples were renamed and placed in plastic containers. Then, soil samples were transported quickly to laboratories for standard analysis. Eight composite water samples were gathered from a RWW irrigation canal from the point where it entered the field until harvest, (1 L each sample every two weeks).Two composite water samples obtained from the reservoir with the goal of collecting rainfall. The water samples were collected in 1.5 L polyethylene bottles kept cool by preserving in ice, and transferred to the laboratory. A total of 20 vegetable samples were collected randomly and taken equally by hands from the two fields with deferent water irrigation sources, each field planted with the two vegetable crops (Zucchini and Eggplant).

Analytical Methods

Fifteen grams of soil Samples were air-dried at room temperature and crushed with a porcelain mortar and a pestle. The samples were sieved by 2 mm sieves.Forsoil physical properties, The soil particle size distribution was determined by the hydrometer method in ICARDA (Estefan et al., 2013). The soil texture is classified as fine sandy clay soil(Sandy55%, Silt 15%, and Clay 45%).For soil chemical propertieswas measuredaccording to ICARDA method (Estefan et al., 2013):The soil pH was estimated by a pH meter in the saturation paste (1:1 suspension). In the same suspension, electrical conductivity was also measured using a conductivity meter. Sodium and Potassium were determined in theextract of the saturated paste using flame photometry.The measurement of the available soil heavy metals content-Soil microelements-(Cd,Pb,Ni, Mn, and Fe) were determined usingAtomic Absorption Spectrophotometer. The presence of phosphorus wasdetermined using a Spectrometer. EDTA,titration method was used for calcium and magnesiumdetermination. Total nitrogenwas determined using the Kjeldahl method. Organic matter (OM) was measured, Cations exchange capacity (CEC) was measured according to the ammonium acetate method.

Prior to the application of either wastewater or rain fed water into the irrigation system, it was screened and passed through filtration media (gravel-sand media filter and disk filter) to remove the suspended materials. Sewage water is screened to remove all large objects like cans, rags, sticks etc.Samples from municipal wastewater were collected two times during the study period, in presowing and after harvesting field crops toanalyzing in the laboratory for their physic-chemical parameters Table 1.

The collected vegetable samples were washed at the lab using distilled water to remove the attached dust particles on the samples. Then, the vegetable samples were sliced into smaller pieces. To increase the accuracy level, random vegetable pieces were selected and taken and dried in the oven with a temperature of 65-100 °C, for 48 hours. The samples then will be ready for acid digestion after drying them in the oven. For the process of acid digestion, the Microwave Digestion System was used for the digestion process due to its high speed, precision, and high sensitivity. The method of digestion was given by the machine itself. Each sample of the vegetable samples ware weighted at 0.5 grams, and then 50 ml of 65% pure nitric acid (HNO_3) was added to each sample to create a mixture. Then the mixture was digested until the transparent solution was achieved. After the cooling down of the digested vegetable samples, the samples were filtered through Whitman filter paper number 42 and diluted to 50 ml with distilled water.The levels of concentration of heavy metals (Mn, Fe, Ni, Pb, and Cd) in the filtrate were determined by using Inductively Couples Plasma Mass Spectrometry (ICP-MS). Inductively Couples Plasma Mass Spectrometry is an analytical technique that is used for elemental determinations.The food chain is used to determine the level of human exposure to heavy metals.For potential human health risks duo exposure for heavy metals used, a Health Risk Index (HRI) which statically calculated by both daily mineral intake (DIM) and oral reference dose (RFD).as the equations: HRI= DIM/ RFD. DIM = C. metal x C. factor x D. food intake / B. Average. The standard factors are (C. factor=0.085), (D. food intake= 0.345), (B.

Average =55.90). The coefficient (TF) is soil-to-plant transfer, which explains the transport of pollutants from soil to plants, is an essential component of human exposure to heavy metals through the food chain. , TF = C. Plant / C. Soil. Plant and Soil represent the heavy metal concentration in the edible part of vegetables and soils, respectively.

Statistical Analysis

Statistical analyses were performed regarding the effects of irrigation with raw wastewater and Rainfed water using the Statistical Package (SPSS). The comparison of the two sites was performed using a t-test, One-way ANOVA. This was applied to assess the significant difference between heavy metal concentrations in vegetables irrigated by wastewater and Rainfed water. As the ICP-MS provides the concentration in parts per billion (ppb), there is a need to demonstrate a path of mathematical calculations that includes conversion between the units of the concentrations of the chosen heavy metals. international standers of the WHO, the soil and vegetable results have been converted into mg/kg, while water results have been converted into parts per million (ppm, mg/ L).

RESULTS AND DISCUSSION

Characteristics of theRaw wastewater, and Rain fed water

Soil characteristics of the experimental field prior to the study are chemically analyzed to check for the soil properties changing by deferent irrigation water resources types, The results of the analysis indicate that the pH and salinity of the soil are suitable for most agricultural crops. The levels of heavy metals concentrations came within the permissible limits according to the International standards. Water irrigation characteristics determine the plant quality and quantity. RWW effluent was slightly acidic, with a pH of 6.48 and the salinity was 0.98 dS m-1, on average. The problem appears when approximately 160,000 m3 /month of Raw wastewater flow into an open channel that runs for about 30 kilometers between agricultural lands(PCBS, 2019 b).

, there is an urgent need to investigate the potential effects on soil fertility and public health. Table 1 illustrates the chemical analysis for two water irrigation resources, the concentrations values of heavy metals for rain-fed water were less than the detection level, and this indicates that there is no pollution to this source of water, these results are in agreement with thoseof(Angin et al., 2012;Razzaghi et al., 2015).

Table 1: Average values of chemical characteristics of raw wastewater and rain-fed irrigation water (Mean, SD).

Parameter	RWW	Rain fed Water
pH	6.48±0.01	7.31±0.01
EC, dS m^{-1}	0.98±0.04	0.35±0.02
Total N(mg/L)	169.52±1.00	12.02±1.00
HCO_3(mg /L)	320.24± 5.00	110.72±5.00
CO_3(mg /L)	0.62±0.02	0.18±0.02
Cl(mg /L)	309.45±5.00	102.56±5.00
Nutrients Cations (me /L)		
Ca	7.81±0.01	2.13±0.01
Mg	6.12±0.01	1.15±0.01
Na	15.44±0.01	2.11±0.01
K	1.35±0.01	0.32±0.01
Tp	0.53±0.01	0.11±0.01
Micronutrients (mg /L)		
Mn	0.07±0.01	BDL
Cd	0.03±0.01	BDL
Ni	0.14±0.01	BDL
Pb	0.65±0.01	BDL.
Fe	9.83±0.08	2.13±0.08

Soil Physical and Chemical Highlights

The experimental soil was classified as fine sandy clay soil (sandy 55%, silt 15%, and clay 45%). The sewage wastewater irrigation applied for a season had no significant effect on type soil in terms of the soil physical properties. The pH of the pre-sowing soil was found to be normal (7.82) which is most desirable in agricultural soil. In the field irrigated with sewage water, the pH of soil extract was found to be slightly decreased from 7.8 to 7.22 after harvesting. The significant decrease in the pH level is a very important factor influencing the bioavailability of macro and micronutrients in the soil solution, and its effect on the transport of heavy metals from soil to plants. Heavy metal mobility increased with decreased soil pH. The tendency of the soil salinity rises from 0.74 to 1.02 dS m-1 in case of rain-fed water and 2.55 dS m-1 in case of RWW irrigation. The organic carbon of sewage irrigation increased from 3.52% to 6.25%, This indicates that sewage irrigation helps to improve the soil fertility situation after the harvest of eggplants and zucchini crops. The organic carbon content in sewage water resources is enhanced more than rain-fed water irrigation. as presented in Table 2, and this is possible due to the incorporation of organic matter through sewage. The significant difference in organic carbon was observed in the soils irrigated with sewage water to that of rain-fed water. Studies show increased wastewater reuse boosts soil fertility and these findings are in agreement with thoseof (Santos et al., 2018; Mustafa et al., 2014; Angin et al., 2012), Because the addition of wastewater to soil particles will increase the high soil particles bonding, which leads to increase absorption, improved soil composition, and increased nutrients necessary for plants growth. As a result, increasing the organic matter and nitrogen content for the soil.For available N, P, and K, the effect of irrigation water on soil fertility status after harvest of eggplant and zucchini crops is shown to be significant. Table 2 recorded significantly higher available nutrients N, P, and K as compared to crops irrigated with rain-fed water. This indicates that sewage water irrigation provides the essential nutrients to the crops as well as improves fertility levels of soil as reported by Assouline (2016). But in conversely, excess nitrogen and phosphorous in irrigation water over limited can cause algal blooms and eutrophication. The concentrations of interchangeable cations, (Ca, Mg, Na, and K) were also higher in the RWW irrigated soil than in rain-fed soil.

The finding showed increasing micronutrients content, as recorded after harvest of eggplant and zucchini crop as in Table 3. The increasing due to irrigation with sewage water in all the crops types. The DTPA (Diethylene thiamine pent acetic acid) extractable metals consisting of Fe, Mn, Pb, Ni, and Cd, after harvesting found to be slightly higher than that of rain-fed water, however, it is with normal limited safe. The findings conformed to the earlier studies reported by Chen et al. (2016). Heavy metals in wastewater are a source of worry, as their accumulation in wastewater irrigated soil, their subsequent transport to plants, and eventual absorption into food chainsso its agreement with finding of (Chen et al., 2016). Low levels of heavy metals, maybe because the farmers used an effective irrigation system and the effluent contains low suspension solidsthese results are in agreement with theseof (Razzaghi et al., 2015), but in comparison with soils Rain fed type, the results showed an increase four times in heavy metals concentration as shown in Table 2. And its agreement with finding of(Elgallal et al., 2016).

Table 3: Average values for selected chemical parameters for the investigated soil field profiles (0-20 cm) under various water irrigation resources (Mean, SD).

Parameter	Pre-sowing Soils	Rain fed- Soils	RWW-Irrigated Soils
pH	7.82 ± 0.35	7.51±0.12	7.22±0.14
EC, dS m^{-1}	0.74 ± 0.12	1.02±0.01	2.55±0.03
O.M. (%)	3.52 ± 0.45	4.52±0.16	6.25±0.12
CEC (cmol(+)/kg)	18.22±2.42	20.04±2.01	28.34±2.12
Cations Nutrients (me \L)			
Na (me/L)	1.22±0.01	2.10±0.10	16.20±1.00
K (me/L)	2.04±0.01	2.40±0.10	8.40±1.00
Ca (me/L)	5.02±0.05	8.40±1.03	12.70±1.12
Mg (me/L)	4.42 ±0.05	7.50±1.01	9.30±1.06
Micronutrients (mg/L)			
Cd (mg/L)	0.12±0.01	0.21±0.01	0.90±0.01
Ni (mg/L)	0.11±0.01	0.17±0.01	0.88±0.01
Pb (mg/L)	0.65±0.05	0.70±0.02	3.40±0.02
Fe (mg/L)	35.23±5.04	45.08±3.05	67.02±2.04
Mn (mg/L)	1.12±0.03	1.20±0.01	2.81±0.03
Available nutrients			
Available N (mg/L)	77.81±5.06	95.25±5.06	135.24±5.43
Available p (mg/L)	7.05±1.02	8.26±1.06	12.61±1.04
Available k (mg/L)	110.05±5.04	120.47±5.06	155.76±4.04

Health Risk Index

A one-way ANOVA statistical analysis test was subjected to evaluate if heavy metal concentrations varied significantly depending on the metals type and irrigation sources (Rainfed water and RWW). Results of one-way ANOVA show that variation in the heavy metal concentration was significant due to treatment in Cd and Pb, the remaining all elements were non-significant. The variation in heavy metal concentration in vegetables of the same site may be described as the differences in their morphology and physiology for heavy metal uptakethese results are in agreement with these results of, (Awala, 2015).For (Ni, Mn, and Fe), the significance was 0.75, 0.38, and 0.98 (> 0.05), while for (Pb and Cd) the significance was 0.001 and 0.004 < 0.05 respectively. A t-test was used on all assessed soil samples to see if there were statistically significant variations in average heavy metal concentrations when irrigation was done using rain-fed water versus raw wastewater irrigation. As a result of the study's findings, it was discovered that the results revealed a value of t = 1.02 and a significance of 0.34 (>5%), indicating that no statistically significant differences exist. Cadmium (Cd) was also found to be below detection thresholds in most samples, as shown in Table 3. This depicts link between soil concentration and plant concentration for soil transfer factors (TF), with the results revealing that zucchini samples had a higher (TF) proportion than eggplant samples for all heavy metals examined. This means that eggplant is less likely to be contaminated with trace metals because it is still a safe limit. Zucchini samples have a higher value for all heavy meatal selected than eggplant duo to have a higher daily minerals intake (DIM) value for detecting the health index risk. Table 3 also includes the calculated heavy metal transfer coefficients from soil to crops. The average TFs were (0.05). The computed transport parameters for heavy metals transfer from soil to vegetables are shown also in Table 3. For all selected heavy metals, average TFs ranged from (0.01 low value to 3.55 high values)these results are in agreement with those of(Jolly et al., 2013; Zhou et al., 2017)

Table 3: The average concentration for heavy metals (mg/L), Transfer factor (TF) for soil-plant, and oral references dose for heavy metals in Zucchini plant and Eggplant.

Items Names*	Mn		Fe		Ni		Pb		Cd	
	Avg.	TF	Avg.	TF	Avg.	TF	Avg.	TF	Avg.	TF
Zucchini (RWW)	1.28	3.55	80.46	0.15	0.51	1.64	1.05	0.20	0.01	0.05
Zucchini (Rain fed)	0.10	2.1	65.40	0.06	0.10	0.92	0.01	0.01	0.001	0.02
Eggplant (RWW)	2.49	1.36	70.78	0.13	0.30	0.97	2.06	0.24	0.01	0.05
Eggplant(Rain fed)	0.23	1.15	58.70	0.03	0.10	0.64	0.05	0.01	0.001	0.02
Mean	1.05		68.8		0.25		0.79		0.022	
T-test	NS		NS		NS		S		S	

(P=0.05)	0.38	0.98	0.98	0.005	0.002
RFD	1.40×10^{-1}	7.10×10^{-1}	2.00×10^{-2}	4.00×10^{-3}	1.00×10^{-3}
DIM zucchini	6.70×10^{-4}	4.10×10^{-2}	2.60×10^{-4}	0.26×10^{-4}	0.05×10^{-4}
DIM Eggplant	2.50×10^{-4}	3.60×10^{-2}	1.56×10^{-4}	0.31×10^{-4}	0.05×10^{-4}
HRI zucchini	4.78×10^{-3}	0.58×10^{-1}	1.32×10^{-2}	0.07×10^{-1}	0.05×10^{-1}
HRI Eggplant	1.78×10^{-3}	0.51×10^{-1}	0.78×10^{-2}	0.08×10^{-1}	0.05×10^{-1}

Notes :

*DIM = C metal X C factor X D food intake / Bw. Average.

*(C. Factor = 0.085), (D. Food intake = 0.345). (B. Average = 55.9)

*TF = C. Plant / C. Soil

*HRI = DIM/ RFD

*Plant and soil represent the heavy metal concentration in the edible part of vegetables and soils, respectively.

Temperature, Humidity, Organic matter, PH, and Nutrient availability all influence heavy metal absorption and accumulation in plant tissues. Organic matter, on the other hand, has been shown to boost manganese (Mn), nickel (Ni), iron (Fe), lead (Pb), and cadmium (Cd) absorption in eggplant and zucchini plants (Amin, 2018; Zhou et al., 2017). Locally, few studies focusing on assessing heavy metal contamination in soil and vegetables (AbouAuda et al., 2011;Nejem et al., 2009), However, information about the health risks of these pollutants is limited or not available. Soil-to-crop transport factor (TF) is a human exposure factor to minerals through the food chain. As in Table 3, the results from the present study and earlier findings(Jolly et al., 2013) demonstrated that plants grown on irrigated soils by wastewater are contaminated with heavy metals and pose a health concern.The results indicate based on the calculation of both DIM and HRI for humans as shown in Table 3, the reference dose (RFD) values - indicative of the daily exposure of individuals to toxins or pollutants - For Mn, Fe, Ni, Pb, and Cd are 1.40×10^{-1}, 7.00×10^{-1}, 2.00×10^{-2}, 4.00×10^{-3}, and 1.00×10^{-3} mg/kg on the first day, respectively. When HRI exceeds one, there is concern about potential health effects (Zhong et al., 2017). The Health Risk Index in our study had an (HRI < 1), indicating that few risks Exist. However, there is still a risk of increased absorption of heavy metals from food crops in the future. According to Rabiul et al. (2020), the consumption of vegetables cultivated in wastewater-irrigated areas in Saudi Arabia poses a significant risk. Also, keep in mind that adults have greater impact thane children, lead and cadmium are highly dangerous minerals for people, and earlier study has shown that the food chain is the primary route for lead transmission from the environment to humans, (Decharat and Pan-in, 2020; Elgallal et al., 2016). This part indicates that the current study is important from the point of view of human health because it attempts to determine the level of pollution by showing the path of human exposure to heavy metals in food crops.

CONCLUSION

Irrigation with raw wastewater in the long term affects the physical and chemical properties of the soil, Compared to soils irrigated with non-wastewater, the results showed an apparent decrease in the pH and an increase in the level of organic matter, CEC, and micro and macro elements but still under the admissible limits recommended by the FAO. Soil degradation in semiarid environments needs mitigation to conserve non-renewable resources, Irrigation with raw wastewater can be used as an organic fertilizer to improve the physical and chemical properties of the soil as a potential source of nutrients. Wastewater has a high nutritional value that may improve plant growth, reduce fertilizer application rates, and increase the productivity of soils with poor fertility. One of the disadvantages of irrigation with raw wastewater is the accumulation of non-moving heavy metals in the soil, Therefore, more research should be done on heavy metal pollution to determine the residual effects of wastewater before its use in land reclamation and as fertilizers, as well as computing the health risk index to determine the health status of the use. In summary, these results show minimal risk indicators, food crops with low levels of heavy metals in our study area, and minimal health risks to the local population, humans, and animals. Consequently, precautionary instructions will be considered to maintain low levels of heavy metal pollution. Based on the case study and the results, remediation techniques along with management plans are needed in the study area to achieve improved soil properties. To increase soil productivity, the following steps are recommended: construction of integrated wastewater treatment plants in the east of Nablus; control of industrial activities (pretreatment); periodic maintenance of the existent wastewater treatment plants to maintain efficiency; control of unplanned urban sprawl to avoid increasing demand for available water resources.

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