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Assessment of Long-Term Cultivation on Soil Properties and Heavy Metal Levels in Greenhouse

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تقييم الزراعة طويلة الامد على خصائص التربة ومستويات المعادن الثقيلة في تربة الدفيئة مقابل التربة غير المزروعة

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Abstract:
This study was conducted to assess the effect of long-term cultivation on physicochemical characteristics such as pH, organic matter (OM), electrical conductivity (EC), cation exchange capacity (CEC), and concentration of heavy metals (HMs) Cr, Cu, Cd, Mn, Zn, Ni, Fe, and Pb in greenhouse (GH) soils compared to uncultivated soils. Soil samples were collected from depths of 0 - 10, 10 - 20, 20 – 30, 30 - 40, 40 - 50, 50 - 60 cm. The findings indicate that the physicochemical properties of soil samples have experienced minor alterations compared to uncultivated soils. These changes are attributed to long-term agricultural practices and the application of chemical fertilizers. The heavy metal contents (Ni, Cr, Mn, Cu, Cd, Pb, Fe, and Zn) in greenhouse soils demonstrate that all levels are well below the maximum permissible limits. However, there is a significant accumulation of Cu, Cd, Mn, and Zn in greenhouse soils compared to uncultivated soils. The heavy metal pollution index (HPI) for various soil depths clearly shows moderate pollution levels in the greenhouse soils ($1 < P \leq 3$). Moreover, the HPI value consistently decreases as soil depth increases. The Geoaccumulation index (Igeo) indicates that the greenhouse soils are either uncontaminated or only moderately contaminated, with manganese (Mn) exhibiting an Igeo value of 0.357. Soil pH demonstrates a strong negative correlation with various soil properties and several heavy metal samples from the greenhouse. Furthermore, there is a strong positive correlation between the physicochemical characteristics and most heavy metals found in the greenhouse soils. This decisive positive correlation among the soil samples confirms that they share a common source of pollution. In contrast, the observed strong negative correlations point to diverse origins and sources of pollution loads.

Keywords: Greenhouse, physicochemical, correlation, pollution index, geo-accumulation index. Contaminated, Uncontaminated.

الملخص
أجريت هذه الدراسة لتقييم تأثير الزراعة طويلة الأمد على الخصائص الفيزيائية والكيميائية مثل الرقم الهيدروجيني، والمواد العضوية (OM)، والتوصيل الكهربائي (EC)، والقدرة على التبادل الكاتيوني (CEC)، وتركيز المعادن الثقيلة (HMs) Cr، Cu والكادميوم والمنغنيز والزنك والنيكل والحديد والرصاص في تربة البيوت المحمية (GH) مقارنة بالتربة غير المزروعة. تم جمع 36 عينة تربة من كل موقع على عمق ستة (0-60) سم لهذا الغرض. أظهرت النتائج أن الخصائص الفيزيائية والكيميائية لعينات التربة قد تغيرت قليلاً مقارنة بالتربة غير المزروعة نتيجة للزراعة الطويلة الأمد واستخدام الأسمدة الكيماوية. كانت محتويات المعادن الثقيلة المقاسة (الكروم والنحاس والكادميوم والمنغنيز والزنك والنيكل والحديد والرصاص) التي تم تحليلها في تربة الدفيئة أقل من الحدود القصوى المسموح بها. ومع ذلك، فقد تراكم بعضها (النحاس، الكادميوم، المنغنيز، الزنك) في الترب الدفيئة مقارنة بالتربة غير المزروعة. يدل مؤشر التلوث بالمعادن الثقيلة (HPI) لأعماق التربة في منطقة الدراسة على

وجود تلوث متوسط للتربة الدفيئة ($1 < 3 \geq P$). تتناقص قيمة HPI مع زيادة عمق التربة. أظهرت نتائج مؤشر التراكم الجغرافي (Igeo) أن تربة الدفيئة كانت غير ملوثة أو ملوثة بدرجة متوسطة بـ 0.357) Mn Igeo). ارتبط الرقم الهيدروجيني للتربة ارتباطًا قويًا وسلبيًا بخصائص التربة وبعض عينات المعادن الثقيلة المأخوذة من الدفيئة، في حين ارتبط سلبيًا مع OM لعينات التربة الزراعية المفتوحة. وكان هناك ارتباط موجب قوي واضح بين الخصائص الفيزيائية والكيميائية ومعظم العناصر الثقيلة في التربة المحمية وأقل ارتباطاً بينها في عينات التربة الزراعية المفتوحة. إن الارتباط الإيجابي القوي في عينات التربة يعد مؤشرا على أن لها مصدر مشترك للتلوث، في حين أن الارتباط السلبي القوي الذي لوحظ هو سمة لأصول ومصادر مختلفة لحمل التلوث.

الكلمات المفتاحية: الدفيئة، الفيزيوكيميائية، الارتباط، مؤشر التلوث، مؤشر التراكم الجغرافي ملوثة، غير ملوثة.

Introduction

Soil is one of the three essential components of our planet and is a fundamental resource that supports all life. Its quality is marked by significant spatiotemporal variability in its biological, physical, and chemical properties, which can result from both natural processes and human activities [1 – 4]. Soil is an important compartment in our ecological system, its receiving heavy metals coming from many different sources and simultaneously acts as a buffer to control the movement of these elements to other compartments, many pollutant elements can be remaining a long time in soil [5-8]. Soil contamination with heavy metals (HMs) is a serious environmental problem. The heavy use of agrochemicals in greenhouse farming leads to these toxic metals building up in the soil. This pollution not only affects greenhouse soils but also harms nearby areas. The contamination impacts local ecosystems, plant health, and food safety. The excessive use of fertilizers, pesticides, and metal-rich chemicals, along with the addition of organic matter, can lead to soil and environmental pollution in greenhouses [9,10]. In undisturbed soils, heavy metals originate mainly from parent materials and consistently maintain stable concentrations [11-13]. In greenhouses, large amounts of chemical fertilizers, organic fertilizers, and pesticides are used instead of those typically applied to arable fields to achieve higher yields. However, these practices can result in the accumulation of heavy metals, increased salinity, pesticide residues, and soil degradation due to acidification [4, 5]. Phosphate fertilizers significantly contribute to the accumulation of heavy metals, such as zinc (Zn), copper (Cu), and cadmium (Cd), in agricultural soils. This issue is exacerbated by the excessive use of nitrogen fertilizers, which can increase cadmium (Cd) and lead (Pb) levels in crops. The accumulation of these toxic elements raises concerns about soil health, food safety, and the long-term sustainability of agriculture [14-19]. Natural and human activities are the main sources of heavy metals in soils. In recent decades, human inputs have surpassed natural sources, which typically arise from soil formation processes. Additionally, sewage sludge and fertilizers contribute significantly to the presence of heavy metals in the environment, and the nature of these human sources has become increasingly complex [20-22]. The use of large quantities of fertilizers and pesticides in greenhouse vegetable production without proper strategies has resulted in significant consequences. One major issue is the accumulation of heavy metals in soil-vegetable systems under greenhouse conditions, which poses serious health risks for human consumption [10,11]. The levels of cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) in greenhouse vegetable soils can reach twice the normal background values due to highly intensive cultivation and multiple cropping. This practice not only contributes to the accumulation of excessive heavy metals in the soil but also leads to a decline in soil quality, resulting in issues such as soil salinization, soil acidification, and nutrient imbalances [23,24]. Greenhouse soils frequently contain high levels of heavy metal contamination, particularly cadmium (Cd), which originates from pesticides and fertilizers applied in large quantities each year [2]. If not properly managed, the long-term use of greenhouse agricultural practices can increase the mobility of these heavy metal residues [25]. Recent reports reveal that around ten million hectares of agricultural land in China are contaminated with cadmium (Cd), a toxic heavy metal that threatens food safety and consumer health [11]. The accumulation of heavy metals, especially in greenhouse environments, is a major factor in declining soil quality. As these contaminants seep into the soil, they compromise the health of vegetables, raising concerns about agricultural productivity and food safety [12]. Heavy metals, including lead (Pb), copper (Cu), chromium (Cr), zinc (Zn), nickel (Ni), cadmium (Cd), and others, are present in low concentrations in the soil environment to maintain an optimal ecological balance [26]. The concentration of these metals largely depends on the composition of the parent material. Metals are primarily introduced into agricultural soils through the use of agrochemicals, biosolids, manure, and compost amendments, which significantly increase the levels of cadmium (Cd), copper (Cu), and zinc (Zn) in the soil [16]. Since 1998, an intensive greenhouse production system in the Jordan Valley, Jordan, has significantly affected soil health. This method has increased electrical conductivity in both topsoil and subsoil, contrasting sharply with uncultivated soil [26]. Excessive use of organic and mineral fertilizers has led to a buildup of salts, raising sustainability concerns. Additionally, chloride levels have risen, bacterial counts have declined, and both total nitrogen and nitrate (NO3) nitrogen levels have decreased, creating a complex agricultural landscape [27]. Greenhouse vegetable production has been prevalent in Turkey since the 1970s, focusing primarily on tomatoes, cucumbers, peppers, and eggplants. This type of production accounts for approximately 96% of the total greenhouse output [28-31]. In Zilfi province in the Kingdom of Saudi Arabia, soil samples from greenhouses revealed high concentrations of heavy metals such as chromium (Cr), cadmium (Cd), and lead (Pb), all of which exceeded WHO standards [31,32]. This study aimed to evaluate the

concentration of heavy metals and the physicochemical properties of greenhouse soils after long-term cultivation; therefore, we assessed (1) the accumulation of eight heavy metals in soils of greenhouse and open field agriculture in the Alshatti agriculture project after long-term cultivation with vegetables; (2) the changes that might be happening in some physicochemical properties of the two study area soils; and (3) the determination of a possible relationship among elements and between soil properties and elemental concentration.
The introduction should be typed in Times New Roman with font size 10. Author can select Normal style setting from Styles of this template. The simplest way is to replace (copy-paste) the content with your own material. In this section, highlight the importance of topic, making general statements about the topic and presenting an overview on current research on the subject. Your introduction should clearly identify the subject area of interest.

Material and methods

Study Area

The soil samples were collected from some farms of Alshati agricultural project, the study area is located in southwest Libya, between latitudes 23° and 28.5° North and longitudes 10° and 16° East, at an elevation of approximately 400 meters above sea level (Fig 1). The project aims to cultivate a variety of vegetables and fruits for human consumption and forage for animal feed. The region faces harsh environmental conditions, with winter temperatures averaging around 7°C and summer temperatures soaring up to 45°C. To address these challenges, the farms utilize a sprinkler irrigation system that draws water from artesian wells, providing essential hydration for the predominantly sandy soil [33,34].

Figure 1: Map of Libya, elucidating the study area; *Study area.

Collection of Samples

Soil samples

The study area was divided into six sectors towards the field slope; six soil samples were collected four times in 2023. A soil auger was used to collect soil samples. About 1000 g of soil was collected in polyethene bags from each sector labelled and transferred to the laboratory. Soil samples were homogenized, air-dried to constant weight, sieved through a 2mm sieve, and stored in a dry place for further investigation.

Samples of Fertilizers

The most fertilizers mostly used are Urea (46%) and Diammonium phosphate (DAP) for fertilization, therefore about 1.0 kg of urea and 1.0 kg of diammonium phosphate fertilizers were taken to the laboratory for chemical analysis.

Physicochemical analysis

Soil pH, Electrical Conductivity (EC), Cation Exchange Capacity (CEC), Soil texture and Organic matter (OM) were measured as mentioned by [35].

Assessment of HMs in soil and chemical fertilizer samples

About 1.0g of dried sieved soil were digested in about 15ml of aqua-regia (HCl: HNO_3 = 3:1) for approximately 4-5 hrs. using a hotplate, maintaining a heating temperature of about 110°C. the digest was filtered through filter paper (Whatman no. 42) into a 50 ml volumetric flask and made to the mark with deionized water. The concentration of HMs was determined by the Atomic Absorption spectrophotometer (NOVA-A400). (procedure and reference needed). The irrigation water was also tested for its heavy metals content as described by [22,36]. Analysis of heavy metals was carried out in triplicates by using NOVA-A400 Atomic Absorption Spectrophotometer (AAS). Blanks containing only distilled water were prepared and processed in the same manner along with all types of samples. heavy metals were also determined in the chemical fertilizers, di-ammonium phosphate (DAP) and urea (46%) used for fertilization as mentioned by [37,38]. 5g sample of fertilizer was placed in a 150ml beaker and digestion was performed in a hotplate at 80°C with 40 ml of 5% (v/v) HNO3, then filtered through Whatman 42 filter paper and transferred into a 50ml volumetric flask (volume was made up with 5% nitric acid).

Pollution degree

Pollution Load Index (PLI)

Pollution Load Index is used to calculate and compare total metal load in different soil depths and sampling locations greenhouse using the equation given by [39].

$$HPI = \frac{1}{n}\prod_{i=1}^{n} Cf_i \tag{1}$$

Cf is the concentration factor used to ascertain the levels of soil contamination. It represents the ratio of the concentration of heavy metal in the soil sample (Cm) to the background value (Cb). It can be calculated by the equation given by [40].

$$Cf = \frac{Cm}{Cb} \tag{2}$$

The *PLI* of each element is classified as either low ($PLI \leq 1$) middle ($1 < PLI \leq 3$) or high ($PLI > 3$).

Geochemical Index (I*geo*).

Geochemical index (I*geo*) was calculated as mentioned by [40,41], this method widely used for the assessment of contamination degree by comparing the levels of heavy metals obtained to background levels originally used with bottom sediments, it can also be applied to the assessment of soil contamination. As shown in the equation below:

$$Igeo = log\left(\frac{Cn}{Bn * 1.5}\right) \tag{3}$$

Where *Cn* is the measured concentration of the element in the enriched samples, *Bn* is the background or pristine value of the element, and the constant 1.5 is introduced to minimize the effect of possible variations in the background values, which may be attributed to lithologic variation. The method assesses the degree of metal pollution in terms of seven enrichment classes (Table 1) based on the increasing values of the index.

Table 1: Index of Geoaccumulation (*Igeo*) for contaminated levels in the soil

***Igeo* value**	**Contamination level**	***Igeo* class**
0	Uncontaminated	0
0-1	Uncontaminated to moderately contaminated	1
1-2	Moderately contaminated	2
2-3	Moderately to strongly contaminated	3
3-4	Strongly contaminated	4
4-5	Strongly to extremely contaminated	5
>5	Extremely contaminated	6

Statistical analysis

Statistical analysis of the data was performed using the SPSS 16 software package, Pearson correlation significance was computed among various physicochemical parameters and heavy metals concentrations in soil at 0.95 and 0.01 confidence levels ($P<0.05$ and $P<0.01$) using one-way analysis of variance (ANOVA)

Results and discussion

Assessment of physicochemical properties in soil depths

The studied physicochemical properties assessed at different soil's depths, table 2. Mean pH values of soil samples in greenhouse are generally increased with increasing soil depths, whereas in uncultivated soils its decrease with increasing depths, these results are consistent with [42,43]. pH of soil samples of greenhouse decreased compared to uncultivated soils. The decrease in pH of greenhouse soils is attributed to the addition of fertilizers which lead to nitrification and acidification processes stimulated by the continuous application of fertilizers and releasing of H^+ by roots [28]. The content of OM in GH and uncultivated soils decreased with the increase in soil depth. Also, EC follows this trend. The mean values of CEC of soil samples of greenhouse were decreased with depths, whereas in uncultivated soil samples its values were decreased in second and third depths and increased in fourth, fifth and sixth depths.

Table 2: Physicochemical properties of soil samples of greenhouse and uncultivated at different soil depths.

Param	**N= 36**	**Soil depth (cm)**					
		0-10	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**
pH	GH	6.95±0.17	7.12±0.14	7.28±0.13	7.40±0.09	7.51±0.06	7.62±0.07
		6.55 -7.34	6.80 -7.45	6.98 -7.61	7.22 -7.65	7.38 -7.68	7.48-7.80
	Unculti	8.22	8.20	8.22	8.20	8.00	8.01
OM	GH	2.56±0.08	1.77±0.09	1.11±0.11	0.88±0.07	0.64±0.04	0.62±0.06
		2.35-2.70	1.65-2.03	0.88-1.38	0.73-1.08	0.53-0.70	0.53-0.81
	Unculti.	1.80	0.80	0.80	0.80	0.80	0.60
EC	GH	0.34±0.03	0.30±0.0	0.23±0.01	0.20±0.01	0.19±0.01	0.19±0.01
		0.30-0.42	0.24-0.36	0.21-0.26	0.18-0.22	0.17-0.22	0.017-0.20
	Unculti.	17.97	0.83	0.83	0.83	1.81	2.04
CEC	GH	9.42±0.90	8.59±1.19	6.69±0.94	5.65±0.71	5.16±0.50	4.59±0.56
		7.85-11.60	6.67-12.02	5.38-9.45	4.33-7.60	4.57-6.65	3.83-6.27
	Unculti.	5.80	2.70	3.60	6.30	6.80	5.80

Assessment of concentration of heavy metals at soil depths

Table 3. presents the mean concentrations of Cr, Cu, Cd, Mn, Zn, Ni, Fe and Pb in greenhouse and in uncultivated soil samples in depths of, 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60 cm. The mean concentration of Cr in GH was 27.75±5.94, 27.18±5.5, 27.11±5.8, 27.11±5.65, 26.49±5.62 and 26.96±5.38 $mg.kg^{-1}$ in the depths respectively. The results show that there is no big difference of the Cr concentration in all soil depths of the greenhouse and uncultivated soil sites. These results are consistent with the results reports by [44,45] Cu concentration in soil samples of greenhouse was, 0.70±0.41, 0.46±0.26, 0.47± 0.27, 0.37±0.25, 0.42±0.25 and 0.42±0.26 $mg.kg^{-1}$. Whereas uncultivated soil samples Cu was not detected. We attribute the existence of Cu in greenhouse soils to the use of chemical fertilizers. It had been reported that chemical fertilizers such as diammonium phosphate and NPK contains trace elements as an impurity [23,30]. The Mean concentration of Cd in soils of greenhouse was, 3.53±1.27, 2.31±224, 2.40 ±1.83, 2.16 ±0.77, 3.37±2.02 and 3.82±1.97 $mg.kg^{-1}$, Cd was not detected in uncultivated soil samples. Substantial amounts of Cd had been detected in phosphate fertilizers used in Jordan [46-48], therefore we believe that its accumulation in soils of greenhouse and OF soils is a result of chemical fertilization [23,30]. Mn was also assessed in examined soil samples, comparing with others its content is very low [49,50]. In our study its mean concentration in greenhouse soils were 61.81±3.57, 41.00±7.84, 19.95±4.67, 12.08±3.92, 10.83±3.66 and 10.0±3.71 $mg.kg^{-1}$, whereas in uncultivated soils 17.90, 15.50, 11.20, 10.66, 12.94 and 12.88 $mg.kg^{-1}$, respectively in soil depths. It's obvious that Mn concentration is decreasing with increasing soil depth in greenhouse and uncultivated soils, Mn concentration is higher in greenhouse than in uncultivated soils. The mean concentration Zn in soil samples of in greenhouse soils were ranged between 0.89 ± 0.28 - 10.22 ± 2.34 $mg.kg^{-1}$, whereas Zn has not detected in uncultivated soil samples. These results are similar to the results reported [4,33,34]. We attribute the existence of Zn in greenhouse soils to its present in DAP used for fertilizations. In general Zn concentration in all soil samples were below the permissible limits (table 5). It is obviously clear that concentration of Zn decreasing with increasing of soil depth, this result consistent with the results of [51,52].

Ni was also measured in the soil samples of greenhouse, its concentration was ranged between 8.32 ± 1.59 -9.21 ± 1.80, 10.13±4.85 -11.05 ± 4.52 $mg.kg^{-1}$ dwt respectively, while in uncultivated soil its value ranged between 6.35 - 8.05 $mg.kg^{-1}$ dwt. Ni concentration was not decreased dramatically as soil depth increased. The mean concentration of Ni in soil samples were below the permissible limits [53,54]. Our findings were similar to the results reported by [29,33,55,56]. Iron is the most predominant among essential metals in soil, its content in soil samples was higher than other HMs studied, it ranged between 464.17± 45.98 - 725.39 ± 31.19, 197.64 ± 62.51-373.86 ±72.06 and 516.00 - 886.00 $mg.kg^{-1}$ dwt in greenhouse soils. High content of Fe was reported in many studies, for example, 15,274 $mg.kg^{-1}$ in the Segura river valley Alicante, Spain [32], 16,916 $mg.kg^{-1}$.dwt in European Mediterranean region [35,57]. 5692 $mg.kg^{-1}$ in agriculture soils of Amristar, Punjab, India [58]. It had been mentioned that accumulation of high concentration of Fe could be a result of the long-time irrigation with wastewater and continuous use of inorganic fertilizers in respective of agricultural fields [58,59]. Pb is one of the most dangerous pollutant elements in the nature, agricultural soils usually contain a wide range of Pb, its concentration in soils depends on several factors such as the parent rock materials, pedogenic processes and the anthropogenic input from the surrounding environment [37,60]. In our study Pb was not detected, that is because there is no source of Pb such as factors or heavy traffic close to the site, farms are also irrigated with uncontaminated water.

Table 3: concentration of heavy metals (mg.kg^{-1} dwt) in different greenhouse and uncultivated soil depths, N=36

Elem.	sites	Soil depths (cm)						*Pl
		0-10	10-20	20-30	30-40	40-50	50-60	
Cr	GH	27.75 ± 5.94	27.18 ±5.5	27.11±5.8	27.11±5.65	26.49 ± 5.62	26.96 ± 5.38	70-100
		10.10 - 35.04	10.58- 33.84	9.81-34.81	10.38 - 34.63	9.81 - 34.20	10.93 - 34.14	
	Unculti.	29.43	26.82	28.27	27.58	26.87	25.56	
Cu	GH	0.70 ±0.41	0.46 ±0.26	0.47 ± 0.27	0.37 ± 0.25	0.42 ± 0.25	0.42±0.26	20-30
		ND -1.46	ND - 0.96	ND - 0.99	ND -1.08	ND - 1.01	ND -1.03	
	Unculti.	ND	ND	ND	ND	ND	ND	
Cd	GH	3.53 ± 1.27	2.31 ± 2.24	2.40 ± 1.83	2.16 ±0.77	3.37 ± 2.02	3.82 ± 1.97	0.2-1.0
		ND - 6.01	ND - 9.02	ND - 7.74	ND - 3.40	ND - 8.05	ND - 8.55	
	Unculti.	ND	ND	ND	ND	ND	ND	
Mn	GH	61.81 ± 3.57	41.00 ± 7.84	19.95 ± 4.67	12.08 ± 3.92	10.83 ± 3.66	10.0 ± 3.71	-
		52.53 - 69.73	21.00 - 59.34	7.00 - 28.45	2.54 - 20.91	2.28 - 17.66	0.46 -16.85	
	Unculti.	17.90	15.50	11.20	10.66	12.94	12.88	
Zn	GH	10.22 ± 2.34	6.02 ± 1.84	1.89 ± 0.53	2.01 ± 0.54	1.34 ± 0.47	0.89 ± 0.28	50
		7.74 - 17.25	2.60 - 11.07	0.42 - 2.96	0.43 - 2.86	0.00 - 2.10	0.08 - 1.35	
	Unculti.	ND	ND	ND	ND	ND	ND	
Ni	GH	9.21 ± 1.80	8.84 ± 1.63	8.32 ± 1.59	8.79 ± 2.14	9.12 ± 2.37	8.96 ± 2.38	50
		6.74 - 14.44	6.27 - 13.46	5.92 - 12.93	5.70 - 15.01	5.72 - 16.07	5.67-16.02	
	Unculti.	7.15	8.05	6.70	6.84	6.35	6.45	
Fe	GH	725.4±31.19	694.4±50.40	561.0±35.16	486.0 ± 41.50	464 ± 45.98	479.0±46.09	50,000
		640.8-788.3	556.3-779.8	488.1-656.12	423.4 - 603.9	411.5 -601.3	396.1-606.7	
	Unculti.	886.00	758.00	635.00	516.00	520.00	592.00	
Pb	GH	ND	ND	ND	ND	ND	ND	10-30
	Unculti.	ND	ND	ND	ND	ND	ND	

*Pl = permissible limit of metals content in agriculture soil [38]

Determination of HMS in chemical fertilizer samples

To identified the source of soil contamination, HMs were also assessed in the irrigation water and used chemical fertilizers. Table 4, shows that concentration of measured HMs was very low comparing to the Canadian Standards limits [39,61, 64].

Table 4: Concentration of HMs (mg.kg^{-1}) in DAP and Urea

Fertilizers	Elements							
	Cr	Cd	Ni	Pb	Zn	Cu	Mn	Fe
DAP	3.3	1.15	2.6	ND	33.0	0.8	ND	6.4
Urea	0.14	ND	0.23	ND	0.2	ND	ND	1.9
Canadian STD*	-	20	180	500	1850	-	-	-

ND = Not Detected; (-) * Canadian Standard Limits

Contamination degree

The contamination degree was measured in two ways, Contamination factor (CF) and Heavy Metal Pollution Index (HPI). The total concentration of measured HMs and Pollution Load Index values of GH soil samples at different depths are presented in Table 5. HPI values of Cr, Cu, Cd, Mn, Zn and Ni in GH soil depths (0-10, 10-20, 20-30, 30-40, 40-50 and 50-60) cm respectively, were up by 1.0 and fell within the (1<PL≤3) category, which means that their presence in the study area fell between low and high pollutants in the soil. The results show that the concentration of HMs was decreased as soil depth increased, HM accumulation in greenhouse soils can be caused by elevated fertilization, pesticides, sewage irrigation and agriculture practices. our results are similar to the results reported by [40,41,65].

Table 5: Total concentration and heavy metal pollution index in greenhouse soil samples.

Soil depths (cm)	Elements							PLI
	Cr	Cu	Cd	Mn	Zn	Ni	Fe	
0-10	0.941	ND	ND	3.453	ND	1.288	0.819	1.361
10-20	1.014	ND	ND	2.645	ND	1.098	0.916	1.283
20-30	0.959	ND	ND	1.871	ND	1.242	0.884	1.185
30-40	0.983	ND	ND	1.133	ND	1.285	0.942	1.078
40-50	1.018	ND	ND	0.837	ND	1.436	0.893	1.022
50-60	1.067	ND	ND	0.776	ND	1.389	0.809	0.982

Geochemical Index (I*geo*)

Igeo values and contamination levels of different metals in soil samples of greenhouse are given in Table 6. The results of Igeo analysis indicates that soils samples of greenhouse were only uncontaminated/moderately contaminated with Mn (Igeo value = 0.357), while it is uncontaminated with the other metals. Contamination of greenhouse soils with Mn reflects the mass use of agrochemicals of farmers. Contamination of greenhouse soils comparing to the arable soils were also reported by [4]. Our results are similar to the results reported by [42,44, 66]

Table 6: Geoaccumulation index (I*geo*) values of the greenhouse soils.

Element	I*geo* Value	Contamination level
Cr	-0.602	Uncontaminated
Cu	0.0	Uncontaminated
Cd	0.0	Uncontaminated
Mn	0.357	Uncontaminated/moderately contaminated
Zn	0.0	Uncontaminated
Ni	-0.227	Uncontaminated
Fe	-0.731	Uncontaminated

Statistical analysis

One of the commonly used methods for statistical analysis is correlation, which used for analyzing similarities between paired data, it is widely used in trace metal database analyses. [2,67]. We used this method to ascertain the sources of heavy metals in soils of greenhouse in Alshatti agricultural project. Table 7 represents the results of correlation analysis between some soil property parameters and the heavy metal concentrations. There was high significant positive correlation (p>0.01) between EC, CEC, Mn, Zn, Fe and OM were r= (0.919, 0.800, 0.922, 0.807 and 0.713) respectively, between Ni and Cu (r=0.617), Zn, Fe and Mn (r=0.838 and 0.635 respectively) and between Fe and Zn (r=0.69) greenhouse soils. CEC and Mn (r=0.677) Cr and Ni (r=0.672). significantly positive correlation level at (p>0.05) between CEC and Fe (r=0.414). Cr and Ni (r=0.479). Zn, Fe and Cu (r=0.419 and r=0.447) respectively in greenhouse soils. High negative correlation at ((p>0.01) was also observed between OM, EC, Mn, Zn, and pH (r= -0.726, -0.680, -0.803 and -0.524 respectively), and at (p>0.05) level negative correlation was between CEC, Fe and pH (r= -0.433 and -0.508 respectively) in greenhouse soils. High negative correlation was also occurred at (p>0.01) between Fe and pH (r=-0.696), Cr and EC (r=-0.528) and between Cd and Cu (r=0.538), whereas at (p>0.05) level negative correlation observed between OM, Cr and pH (r=-0.419, r=-0.437 respectively), Cu, Zn and Cr (r= -0.424, r= -0.431 respectively). Positive correlation among heavy metals may suggest that they share a similar origin [2,68-70]. It was reported that Zn, Cd, Pb and Zn were common anthropogenic elements in the urban environment, its significant correlations indicate that they may have originated from common source [45,71,72]. Positive and negative correlation between soil properties and heavy metals were reported by others and our results are similar to them [29,33,35,46].

Table 7: Correlation matrix between soil properties and heavy metals of greenhouse soils. (n=24)

	pH	OM	EC	CEC	Cr	Cu	Cd	Mn	Zn	Ni	Fe
pH	1										
OM	-.726-**	1									
EC	-.680-**	.919**	1								
CEC	-.433-*	.800**	.790**	1							
Cr	.459*	.074	.120	.214	1						
Cu	.012	.052	-.116-	-.068-	-.299-	1					
Cd	.262	.082	.134	.408*	.344	-.046-	1				
Mn	-.803-**	.922**	.888**	.762**	-.173-	.064	.064	1			
Zn	-.751-**	.807**	.695**	.562**	-.300-	.419*	.099	.838**	1		
Ni	.524**	-.051-	-.126-	.041	.479*	. 617**	.365	-.207-	.004	1	
Fe	-.508-*	.713**	.623**	.414*	.102	.447*	-.131-	.635**	.679**	.350	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

This study aimed to evaluated the soil properties and the concentration of some heavy metals in the soils of greenhouse farms compared to uncultivated soils as a reference, after long-term of cultivation. Our results indicated that soil pH tend to become more acidic, comparing to uncultivated soils. The cultivation increased values of OM and CEC comparing to soils of uncultivated soils. Whereas EC of greenhouse soils is less than EC of uncultivated soils. Our results were also indicated that excessive and long-term fertilization with chemical fertilizers that contain high heavy metals levels lead to accumulation of Cu, Cd, Zn and Mn in greenhouse comparing to uncultivated soils. Therefore, we recommended that rational fertilization program and reductions in the concentrations of chemical fertilizers must be used to maintain a safe concentration of heavy metals in greenhouse soils. In general, the levels of heavy metals in all of soil samples were within the permissible concentration limits set by WHO/FAO 2001. Data also show positive significant correlation between OM and EC, CEC, Mn, Zn and Fe.

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