Short Communication:

Determination of Cadmium Levels in Agricultural Soils of Some Regions in Syria

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Abstract: *Soil pollution with heavy metals has become a serious global threat, largely due to anthropogenic activities, and cadmium (Cd) is one of the most toxic known heavy metals. This study aimed to assess cadmium levels in several agricultural soils in several Syrian regions. Soil samples were taken from six agricultural lands, prepared, and processed to determine the total content of cadmium using a graphite furnace atomic absorption spectrometry. The results showed that the values of cadmium concentration ranged between 0.60 and 1.48 ppm in the studied soil samples, exceeding the permissible limit in some areas. Cadmium values were higher in farmland soils near industrial facilities than those far from them .This study indicates the spread of Cd contamination throughout the study area, significantly near the industrial activities; thus, it may impact local agricultural production safety and human health.*

Keywords: *cadmium; contamination; agricultural soil; atomic absorption spectrometry*

INTRODUCTION

Soil pollution with heavy metals has become a serious global threat to the ecosystem and food security [1]. This may occur mainly due to anthropogenic activities resulting from rapid development in agriculture and industry, urbanization, and increment growth of the population [1-2]. These anthropogenic activities, such as mining and processing of metal ores, burning of fossil fuels, using fertilizers, including sewage sludge and pesticides, transport, and many other industrial processes, have caused an accumulation of heavy metals in soil and in plants [1-3]. This makes its impact on the safety of agricultural products a significant concern [4].

Heavy metals are toxic and non-degradable, and their presence in soil persists long after being released into the environment [5-7]. They can result in potential health risks to human beings and ecosystems through direct ingestion or contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal-human), drinking of contaminated groundwater, reduction in food quality, and reduction in land usability for agricultural production [5-6]. In addition, Heavy metal contamination in soil has a combined worldwide economic impact estimated to be more than US$10 billion per year [1].

Cadmium (Cd) is one of the heavy metals known widely and the most toxic [4,8]. Cadmium is used in Ni/Cd batteries, anticorrosive coatings for metals, pigments, polyvinyl chloride (PVC) stabilizers, and alloys and electronic compounds. Cd is also an impurity in several products, including phosphate fertilizers, detergents, and refined petroleum products [4-9]. The application of agricultural inputs containing Cd, such as fertilizers, pesticides, and biosolids (sewage sludge), the disposal of industrial wastes, or the deposition of atmospheric contaminants increases the total concentration of Cd in soils [5-9].

Exposure to Cd can cause various deleterious effects on cellular molecules, mainly due to oxidant–antioxidant imbalance [1]. Moreover, Cd has been implicated in the pathogenesis of many cancers, itai–itai disease, and cardiovascular diseases, inducing nephrotoxicity and osteotoxicity and impairing the function of the immune system [1,8].

Evaluating the contamination of cultivated soil with heavy metals can help judge whether the soil meets the standard and whether the pollution will threaten human health and the ecological environment. In addition, it may provide a scientific basis for determining the heavy metals whose control needs to be a priority and managing the potential health risks.

Owing to the hazard of Cd, the presence of several anthropogenic activities that can release Cd into the environment near some cultivated lands, and the toxic effects that may result on human health and the environment, this study aimed to determine the concentration of Cd in several agricultural soils in Syria and to assess the extent of their contamination due to the spread of the metal pollution from waste dumpsites to these agricultural areas.

■ EXPERIMENTAL SECTION

Materials

The materials used in this study were concentrated nitric acid (Sigma-Aldrich), and concentrated hydrochloric acid (Sigma-Aldrich).

Instrumentation

The digestion was done in Anton Paar-Multiwave 3000 microwave (Scientific Instruments), and the Cd concentration was measured using graphite furnace atomic absorption spectrometry (GF-AAS ZEEnit 700 P, Analytik Jena AG, Germany). Soil pH was measured by a pH meter (Boeco, BT-600, Germany).

Procedure

Study area

Six typical agricultural soils in Damascus and Homs were selected as the study areas. Deir Ali is a small town in southern Syria administratively subordinate to the Damascus countryside. Ibn Al-Nafees region is located in the north of Damascus and contains orchards, including those of Abu Jarash. Al-Mleha is a town in the Ghouta area of Damascus countryside, west of Jaramana. Qattinah is a village in central Syria, located south of Homs. Tall al-Shawr is a village located in the southwest of Homs. Finally, Hassia is an industrial city 40 km from Homs, as shown in Fig. 1.

Collection and treatment of soil samples

The top surface soil samples (0–25 cm deep) were collected randomly from the agricultural lands in self-locking polyethylene bags and transported to the laboratory. After collection, pebbles, and twigs were

Fig 1. Location map of the sampling points in the study area

removed. The samples were air-dried at room temperature, grounded, homogenized, and sieved through a 2 mm stainless steel sieve. Finally, fine powder was stored until analysis.

Sample preparation and analysis

Sixty soil samples were processed to assess the total concentration of Cd. To estimate the whole content of Cd, a 0.6 g dried soil sample was digested with acid mixture of concentrated nitric acid and concentrated hydrochloric acid (5 mL HNO_3 + 1 mL HCl) in the microwave digestion system for 15 min according to the US EPA method 3051A (the protocol followed in the laboratories of the Ministry of Local Administration and Environment), where it was put in heat and pressure resistant Teflon tube. The digested samples were then filtered through the filter paper.

The extracts of soil samples were digitized and ready to be read in graphite furnace atomic absorption spectrometry. The metal standards were prepared from a stock solution of 1000 ppm by successive dilutions to get the following solution concentrations of Cd (0, 0.2, 0.5, 1 ppm). All measurements were made in triplicates. Soil pH was conveniently measured in (1/2.5) soil/water suspensions using a pH meter.

Statistical analysis

Descriptive statistics, including maximum, minimum, mean, and standard deviation were calculated. Regression coefficients and ANOVA were used to identify the relationship between soil pH and Cd concentration.

RESULTS AND DISCUSSION

The pH is a main factor in assessing the mobility and retention of heavy metals in soils [10]. The range of pH values was from 1.3 to 8.1, indicating that the soil in the study areas was strongly acidic and slightly alkaline, Table 1. Changes in pH seem to be one of the most important factors affecting heavy metal content in soil. Soil acidity increases the absorption of heavy metals, while the alkalinity of the soil may reduce the retention of heavy metals. In other words, lower soil pH will increase the activity of heavy metal ions and enhance bioavailability [10-11]. Table 2 shows the study of the relationship between soil pH and Cd metal concentration by applying a regression coefficient ($P > 0.05$). So, this study found no linear correlation between pH soil and Cd content, Fig. 2. Although Cd is one of the most mobile heavy metals in the environment, this may be attributed to the physicochemical properties of soil and the surrounding anthropogenic activities that can affect the soil pH [12-13].

Table 1. Results of soil pH

Region	pH
Deir Ali	1.6
Ibn Al-Nafees Orchards	1.3–1.6
Al-Mleha	7.9–8.0
Tall Al-Shawr	7.7–7.9
Qattinah	7.3–7.5
Hassia	7.8–8.1

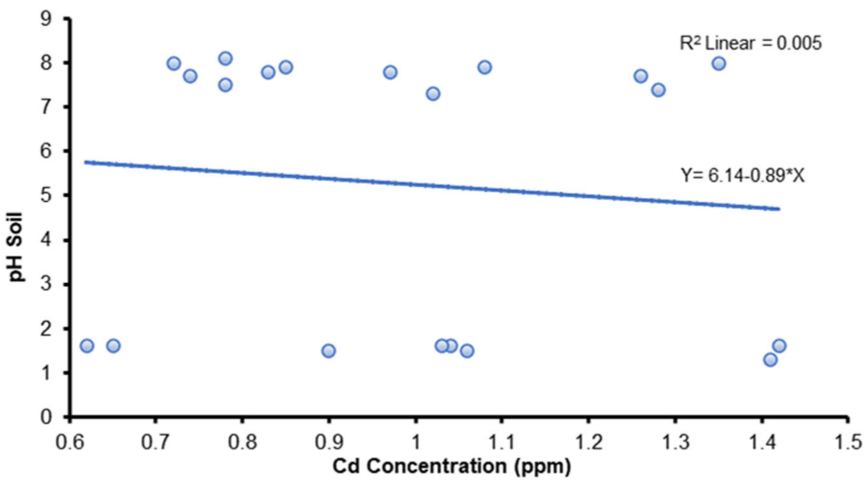

Fig 2. Correlation between pH and Cd concentration

Table 2. Regression coefficient and ANOVA results of pH with Cd concentration

Regression:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.067[a]	.005	-.051	3.21173

Predictors: (Constant), Cd Concentration

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.848	1	.848	.082	.778[b]
	Residual	185.674	18	10.315		
	Total	186.522	19			

a. Dependent Variable: pH

b. Predictors: (Constant), Cd Concentration

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.141	3.123		1.967	.065
	Cd Concentration	-.889	3.099	-.067	-.287	.778

a. Dependent Variable: pH

The statistical tables showed (P > 0.05), So there is no linear correlation between soil pH and Cd concentration.

There is a growing environmental concern about Cd being one of the most ecotoxic metals, exhibiting highly adverse effects on soil health, biological activity, plant metabolism, and the health of humans and animals [14-15]. It is worth noting that the permissible limit of Cd, according to the Syrian standard, is 1 ppm.

The measurement results showed that the values of Cd concentration ranged between 0.60 and 1.48 ppm in the studied soil samples, and the highest measured value for Cd was in sample No. (7), which was taken from the orchards of Abu Jarash in the Damascus Ibn al-Nafees area, while the Cd's lowest value was in sample No. (3), which was taken from the workers' housing for Deir Ali thermal station in Damascus countryside. Descriptive statistical characteristics of the soil Cd content are shown in Table 3 according to each area.

The results found that the highest value of the average Cd concentration was for the samples of Ibn Al-Nafees orchards, where the values exceeded 1 ppm in most points. In comparison, it was more dispersed in both Qattinah and Hassia Industrial City despite exceeding the value of 1 ppm at some points, then Tall Al-Shawr, and finally the Deir Ali thermal station and Al-Mleha, Fig. 3.

Table 3. Descriptive statistics of the soil cadmium content according to each area

	Sample number	Minimum value	Maximum value	Mean	Standard deviation	Median
Deir Ali	9	0.60	1.09	0.77	0.21	0.66
Ibn Al-Nafees Orchards	15	0.85	1.48	1.13	0.19	1.07
Al-Mleha	6	0.67	0.94	0.78	0.09	0.77
Tall Al-Shawr	12	0.66	1.33	0.98	0.22	0.94
Qattinah	6	0.74	1.47	1.03	0.31	0.94
Hassia	12	0.71	1.41	1.03	0.22	1.00

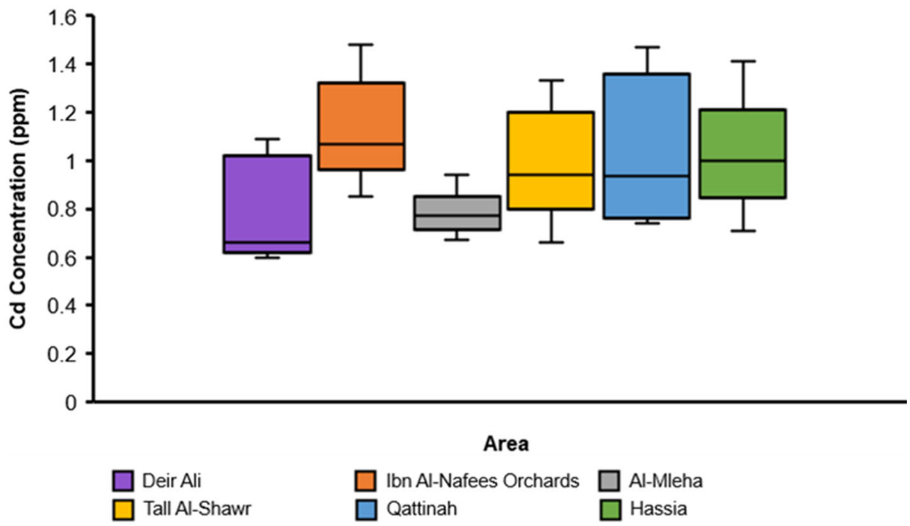

Fig 3. Quartile distribution of cadmium in the soil samples

Cd in Ibn Al-Nafees orchards may be attributed to the widespread use of cadmium in various industries near this area, such as battery production, tanning, and dyeing. This was consistent with the study of Amouei et al. [16] and Sor et al. [17], where the levels of metals, including Cd, are higher in industrial lands or near them than that in remote lands due to industrial human activities. Cd content in the samples of Abu Jarash orchards exceeded the upper acceptable limit as a result of the use of phosphate fertilizers and irrigation with polluted Yazid River water that directly exposed the soil to this metal, and this was supported by the study conducted by Maas et al. [18], where the percentage of Cd pollution was low, due to the non-use of phosphate fertilizers contaminated with it.

There was also observed dispersion in the values obtained in both the Qattinah and Hassia industrial areas, and the difference may be attributed to the presence of Cd in the samples of agricultural lands near the industrial facilities with higher concentrations than the samples of agricultural lands far from them. It must be pointed out that the population living in places close to sources of Cd pollution is exposed to severe damage, as chronic exposure to Cd leads to anemia, insomnia, high pressure, and renal disorders, as indicated by Rahman et al. and Yang et al. [19-20].

The agricultural lands in the Tall al-Shawr area were irrigated with a stream contaminated with the residues of the fertilizer factory near this area, and the cultivation of vegetables like potatoes, cabbage, and sugar beet mainly prevails. Due to cadmium, metal has a high mobility in the soil, which makes it easy to pick up by plants. Therefore, it is recommended rainfed agriculture only in such areas.

In the Deir Ali region, the results were almost in agreement with the results of Kelmendi et al. [21], which showed elevated concentrations of Cd in the studied soils. The current study concluded that Cd contamination exceeded the permissible limits due to the proximity of the agricultural lands from which the samples were taken to the power plant, which was evident in this study in Sample No. (2) taken from agricultural land located at the drainage outlet of Deir Ali station. Since Cd reaches the atmosphere as a passive product of coal combustion processes in power plants, it settles in soil or water sources and then living organisms with toxic effects.

This study also found that Cd content was within the natural limits in Mleha samples due to the absence of industrial facilities surrounding the area, in addition to irrigating agricultural lands with pure well water. According to the governorates, the current study displayed that Cd value is higher than 1 ppm in each of the governorates of Damascus and Homs, while it is the lowest in Damascus countryside, with less dispersion, as shown in Fig. 4. This may be due to the multiplicity and

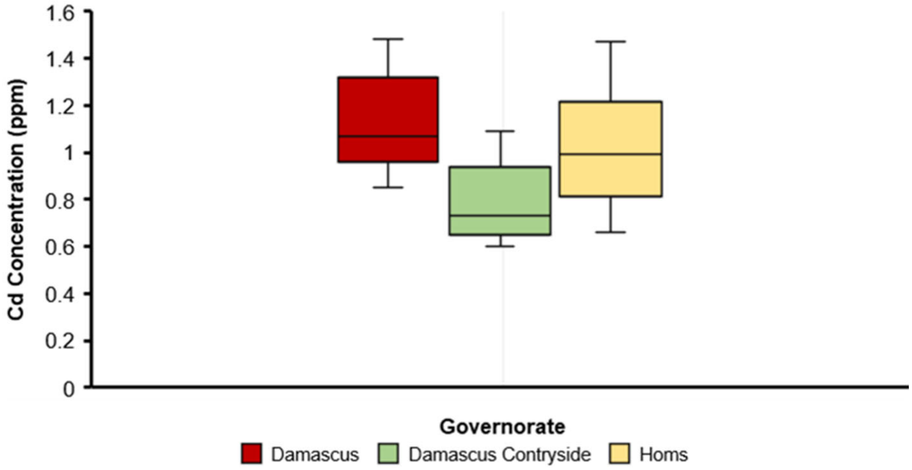

Fig 4. Quartile distribution of cadmium in the soil samples according to governorate

proximity of the sources of pollution to agricultural lands in Damascus and Homs than it is in the countryside of Damascus.

CONCLUSION

The results revealed that elevated concentrations of Cd were found in almost all the soil samples, indicating that the surrounding industrial activities greatly affect the soil in the contaminated areas. This may contribute to the pollution of water sources and the transformation of Cd from soil to vegetables and, consequently, human health risks. Thus, the present study provides a scientific basis for preventing and controlling soil heavy metal pollution to ensure local agricultural production safety and health risk management. However, further Research is required to assess the heavy metals in farmland soils, especially near industrial areas.

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AUTHOR CONTRIBUTIONS

Ranim Ibrahim conceived and designed the experiments, collected the samples, performed the experiments, analyzed and interpreted the data, and wrote the paper. Sophie Barguil was the supervisor, also conceived and designed the experiments, contributed to interpreting the data, and reviewed the paper. Sondos Hesenow contributed to conceiving and designing the experiments, analyzing and interpreting the data, and writing and reviewing the paper.

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