Heavy metals accumulation by *Vicia faba* L and *Pisum sativum* L plants grown in contaminated soil

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Abstract

This study was conducted in agricultural fields near the city of Al-Marj. Al-Marj area is located on the southern coast of the Mediterranean Sea in the province of Cyrenaica. Many vegetables and fruits grow in these agricultural fields, and the domestic and industrial wastewater streams pass through them, and the study aimed to determine the quantity of heavy metals (Cd, Ni, and Pb) in leguminous plants beans (*Vicia faba* L) and peas (*Pisum sativum* L) growing in soil contaminated with domestic and industrial wastewater. All the experiments were conducted at the Al-Bariqa company laboratory in Tripoli, Libya. Samples of some grown vegetables, i.e., beans (*Vicia faba* L) and peas (*Pisum sativum* L), were collected from seven different locations in the agricultural fields. For metal analysis, only the pods of in two studied plants samples were used. Three replicates were taken from plant samples. The study results showed that pods of studied plants in different locations contained heavy metals with different concentrations within the normal levels of toxicity except cadmium. The concentration of cadmium was over then (0.1) ppm., which was applied by (WHO).

**Keywords:** Heavy metals, accumulation, *Vicia faba*, *Pisum sativum*, contaminated soil, leguminous.
المحلية والصناعية. أجريت جميع التجارب في مختبر شركة البريقة في طرابلس، ليبيا. تم جمع عينات من بعض الخضروات المزروعة، أي الفاصوليا (Vicia faba L) والبازلاء (Pisum sativum L)، من سبعة مواقع مختلفة في الحقول الزراعية. لتحليل المعادن الثقيلة في النباتات المدروسة، تم استخدام القرون فقط وأخذت ثلاثة تكرارات متماثلة من عينات النباتات. أظهرت نتائج الدراسة أن قرون النباتات المدروسة في مواقع مختلفة تحتوي على معادن ثقيلة بتركيزات مختلفة ضمن المستويات الطبيعية للمسمى، ما عدا الكادميوم كان تركيزه قد تجاوز (1.0 جزء في الدليون) ظاً على بعض الأشخاص المسموح بهم من قبل منظمة الصحة العالمية.

الكلمات المفتاحية: معادن ثقيلة، تربة ملوثة، قرون.
1. **Introduction**

Rapid urbanization and industrialization with improper environmental planning often lead to the discharge of industrial and sewage effluents into the environment. Industrial or municipal wastewater is mostly used for the irrigation of crops, mainly in a periurban ecosystems, due to its easy availability, disposal problems, and scarcity of freshwater. Irrigation with wastewater is known to contribute significantly to the heavy metals content of soil[9]. Heavy metals have become serious stressors in the environment, representing a significant risk for humans via food chains, water, and air pollution. Therefore, it is important to reduce the concentration of heavy metals in the environment. Also, Soil contamination with toxic chemicals may occur as a result of improper agricultural operations, and the use of contaminated irrigation water and adding liquid and solid waste as well as air pollutants. Concern has been expressed concerning to the accumulation of toxic heavy metals such as cadmium(Cd), Nickl (Ni), and lead (Pb) and their impact on both human health and the environment [15]. Wastewater contains substantial amounts of toxic heavy metals, which create problems [13]. Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination but also affect food quality and safety [23]. Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops[20]. Vegetables take up heavy metals and accumulate them in their edible and inedible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants[3]. several serious health problems can develop as a result of excessive uptake of dietary heavy metals. This study was conducted in agricultural fields near the city of Al-Marj. Al-Marj area is located on the southern coast of the Mediterranean Sea in the province of Cyrenaica[24]. The Astronomical site extends between latitudes 33° and 31°N and longitudes 20.30°-21.30°E. Many vegetables and fruits grow in these agricultural fields, and the domestic and industrial wastewater streams pass through them, and therefore the study aimed was to determine the quantity of heavy metals(Cd, Ni, and Pb) in leguminous plants beans( *Vicia faba* L) and peas (*Pisum sativum* L) growing in soil contaminated with domestic and industrial wastewater.
2. Materials and methods

2.1. Plant and soil samples

All the experiments were conducted at the Al-Bariqa company laboratory in Tripoli, Libya. Samples of some grown vegetables, i.e., beans (Vicia faba L) and peas (Pisum sativum L), were collected from seven different locations in the agricultural fields. For metal analysis, only the edible parts (pods) of vegetable samples were used. Three replicates were taken from plant samples at the studied locations, (about 63 samples for each plant). Soil samples were collected from the same studied locations and taken from deep (0–30 cm).

2.2. Heavy metal analyses

Heavy metal determination (Cd, Ni, and Pb) in soil and plant samples was done according to[16]. Soil samples were sieved and oven-dried at 60 C for five days. A soil sample (2 g) was digested in 12.5 ml of HNO3 (4 M) for 12 h at 80 C, after cooling to room temperature the digest was brought to 25 ml with deionized distilled water. The aqueous solutions were filtered through Whatman filter paper no. 42. Samples were serially diluted and analyzed for heavy metal concentration using an atomic absorption spectrophotometer (Perkin–Elmer 1100 B, USA. Plant samples were washed thoroughly with deionized water oven-dried at 70 C for 24 hours, and ground to powder, which (0.5 g) was digested according to[16]. Heavy metal analysis was done as described above.

2.3. Data analysis

The experiments were designed and analyzed statistically using Excel 2007 and SPSS (windows 13) and Duncan’s New Multiple Range Test for comparing between plants studied samples and their content of heavy metals.[7,8].

2. Results and Discussion

At least three different sources of contamination are responsible for pollution in agricultural soils in AL-marj plain, namely agricultural, industrial, and municipal (sewage) effluents, coming through several drains from the AL-Marj city directions. Heavy metals are the most dangerous contaminants since they are persistent and accumulate in soil and plant tissues through mechanisms, namely bioconcentration.
Heavy Metal concentration in soil

The mean concentrations of Cd, Ni, and Pb in soils are shown in Table 1. The highest concentrations of Pb and Cd were observed in the study area. The trend of occurrence of heavy metals concentration in soils revealed; Pb<Cd<Ni These values are higher in soil samples compared to the pods of the studied plants. The reason might be due to their weak adsorptive nature in the soil[ 21]. The highest value (22.35 ppm) of Cd was recorded in the fourth location, while, location 6 showed the lowest value (1.59 ppm), and The maximum concentrations of Ni were observed for location 4 (9.20 ppm), while the first location attained the minimum Ni concentration (0.56 ppm). Generally, location 3acquired the highest Pb concentration (40.06 ppm).On the other hand, the lowest Pb concentration (5.75 ppm) was recorded in location 7.

WHO[29] and Council of the European Communities. [10] guidelines show that soils concentrations studied heavy metals within the prescribed limits except Cd. Heavy metals may accumulate in the soil as the result of the long-time application of industrial and wastewater within the range of permissible concentration levels. This indicates that the heavy metal concentration in soil is due to the discharge of wastewater from industrial, municipal, and domestic activities in the Al-Marj city. Heavy metal pollution is mainly the result of human activities such as agriculture, mining, construction, and industrial processes (Chiras, 2001; Singh et al., 2004). Pesticides and fertilizers are known to be the main sources of heavy metal pollution in agricultural areas (Whitney, 1998; KabataPendas and Pendias, 2001).

**Table 1.** Average concentration (± SD) of the studied heavy metals in the soil samples (ppm ) collected from the studied locations.

<table>
<thead>
<tr>
<th>Locations</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cd</td>
</tr>
<tr>
<td>1</td>
<td>9.22± 0.40</td>
</tr>
<tr>
<td>2</td>
<td>4.94± 0.62</td>
</tr>
<tr>
<td>3</td>
<td>11.60± 0.55</td>
</tr>
</tbody>
</table>
Heavy Metal concentration in the plants

The chemical analysis (for the pods) of two cultivated plant species were collected from the studied area was carried out.

Cadmium (Cd) in plants

Cadmium (Cd) content in the pods of two studied plant species is shown in Table 2. The data show that the Cd contents in the pods differed among the two species, also indicating their different capacities for Cd uptake. Content of Cd was higher in *Vicia faba* (2.89 ppm at seventh location) in its pods whereas in the *Pisum sativum* was (2.80 ppm at fifth location) (Fig. 1). These differences in cadmium concentrations may be due to the difference in the sources of cadmium. The environmental pollution of these locations, as the seventh location is affected by pollutants resulting from household waste, oil change stations, and agricultural waste, while the Fifthly location is affected by domestic, and industrial wastewater pollutants. The relationship between cadmium concentrations in the two studied plants was related to the locations they were taken from. This relationship shows the extent of the pollution of the environment of the studied locations with cadmium, especially the soil as a medium for plant growth. These results are consistent with the results obtained by [2] the soil content of Cadmium higher than that of plant parts. Cadmium levels in pods of two studied plants grown in the studied locations can be arranged descending as follows: *Vicia faba*: 7 > 4 > 5 > 3 > 2 > 1 > 6 whereas, *Pisum sativum* 5 > 4 > 3 > 1 > 7 > 2 > 6. Cadmium is a non-essential element for plants, but it deserves attention and study because it is. It accumulates in plant tissues in large quantities that lead to toxicity in humans through eating it. Crops and vegetables in quantities that may be dangerous to his health [11]. Plant toxicity occurs in
legumes when their tissues contain cadmium in the range of (5-30 ppm) [17]. When comparing cadmium levels in pods of two studied plants with the levels mentioned above, we find that it did not reach the limits of toxicity for plants. That compare Cadmium levels in legumes (Table 2) within the permissible limits specified in 1992 by the World Health Organization [25] and amounting to (1.0) ppm by weight of dry matter of crops. Legumes reach us to the extent that they exceeded the permissible level and in all the studied sites. The reason for this is due to the increased environmental pollution in these sites with cadmium because they are close to the sources of cadmium pollution, and these results are in agreement with the findings [4]. Because factories and public roads Chemical and organic fertilizers, city waste and sewage are also sources of cadmium pollution. About atmospheric deposits in industrial areas [6].

Table 2. Average contents of Cd in the pods of the studied plant species (ppm) collected from the studied locations.

<table>
<thead>
<tr>
<th>Studied plant species</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><em>Pisum sativum L</em></td>
<td>2.17c</td>
</tr>
<tr>
<td><em>Vicia faba L</em></td>
<td>1.46b</td>
</tr>
</tbody>
</table>

*Averages with similar letters in the horizontal bars do not differ significantly at the 5% probability level according to Duncan's Polynomial Test.*

Fig.1. Content of Cd in the pods of the studied plant species (ppm) collected from the studied locations.
Nickl (Ni) in plants:

The results in (Table 3) showed that the levels of nickel were high in the pods of the *Vicia faba* plant in the fourth location, where the concentration of nickel reached (1.55 ppm) while the level of nickel was higher in the *Pisum sativum* plant in the seventh position (1.30 ppm). The data show that the Ni contents in the pods differed among two species (Fig2). The reason for this may be due to the difference in the environmental pollution of these locations with nickel due to the increase of waste and residues in the soil, and this is agreement with [22]. The addition of wastes and residues rich in heavy and toxic metals, including nickel, led to an increase in the soil and plant content of these metals. Nick levels in pods of two studied plants grown in the studied locations can be arranged descending as follows: *Vicia faba* : 4>7>5>3>1>6>2 whereas, *Pisum sativum* 7>4>3>1>2>5>6. The plant’s nickel content is between (0.1-5) ppm of dry matter and high concentrations. Also, high concentrations of nickel have toxic effects on plants [6]. Nickel toxicity occurs in plants growing in soils to which large amounts of nickel are added by fertilizers to the soil in the form of waste or sewage waste [27]. It was found that the toxicity levels of nickel ranged from (10-100 ppm) [5]. When comparing the levels of nickel in the pods of *Vicia faba* and *Pisum sativum* with the levels of toxicity mentioned above, it was found that the levels of nickel in the pods of the two studied plants are within the normal limits for nickel.

**Table 3.** Average contents of Ni in the pods of the studied plant species (ppm) collected from the studied locations.

<table>
<thead>
<tr>
<th>Studied plant species</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><em>Pisum sativum</em> L</td>
<td>0.70d</td>
</tr>
<tr>
<td><em>Vicia faba</em> L</td>
<td>0.56b</td>
</tr>
</tbody>
</table>

*Averages with similar letters in the horizontal bars do not differ significantly at the 5% probability level according to Duncan’s Polynomial Test*
Fig. 2. content of Ni in the pods of the studied plant species (ppm) collected from the studied locations

**Lead (Pb) in plants:**

The content of plants of lead is not related to its content in the soil, in contrast to the case of other heavy metals (cadmium, and nickel), increased lead content in plants may be to the aerobic deposition of this element, which is caused by traffic congestion. More than the soil factor and the remnants added to it that contain heavy metals, including lead [1]. The genetic factor may affect the content of the plant more than the influence of the soil factor. This is confirmed by [30] and these results agree with the results mentioned in Table (4). Levels of lead were high in the pods of the *Vicia faba* plant in the fourth location, where the concentration of nickel reached (7.08 ppm) while the level of lead was higher in the *Pisum sativum* plant in the third locations (6.41 ppm). (Fig. 3).

**Table 4.** Average contents of Pb in the pods of the studied plant species (ppm) collected from the studied locations.

<table>
<thead>
<tr>
<th>Studied plant species</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><em>Pisum sativum</em> L</td>
<td>3.11a</td>
</tr>
<tr>
<td><em>Vicia faba</em> L</td>
<td>4.99d</td>
</tr>
</tbody>
</table>
Averages with similar letters in the horizontal bars do not differ significantly at the 5% probability level according to Duncan's Polynomial Test.

Fig. 3: Content of Pb in the pods of the studied plant species (ppm) collected from the studied locations.

The reason for this is that the fields in which these plants were planted are close to transportation areas and traffic roads. Lead contamination depends on several factors, including distance from the external road, nature of vegetation surfaces, duration of pollution, traffic density and wind direction [19]. Lead levels in pods of two studied plants (Vicia faba and Pisum sativum) with the levels of toxicity mentioned above, were found to be lower than the toxicity limits because they are lower out of (30 ppm) [17].

When comparing the levels of lead in the pods of Vicia faba and Pisum sativum, the toxic effect of lead in the pods of each of the two studied plants was higher than the toxicity limits because they are lower out of (30 ppm) [17].

Adding fertilizers plays an important role in accumulation of heavy metals in plants. The plants planted in the seventh and sixth locations were affected by the remnants of residential areas, sewage effluents and used irrigation water, and these results are consistent with [2]. The plants planted in the seventh and sixth locations were affected by the remnants of residential areas, sewage effluents and used irrigation water, and these results are consistent with [2].
tissues. It is also add organic plant fertilizers to sandy soils led to an increase in cadmium, nickel and lead in Grains, as adding natural fertilizers to the soil with its heavy metals may lead to an increase in accumulation of heavy metals in different parts of the plant. Also, the accumulation of heavy metals may reach Limits of toxicity to humans and animals through the food chain [4]. Increased levels of lead in pods of two studied plants grown in close to roads The passage of means of transport, it indicates that one of the important factors that affect the accumulation of pollutants in Plants is the increase in closeness to the source of pollution as well as the length of time of exposure to pollution.
References


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