STM JOURNALS

Research & Reviews: Journal of
Ecology

ISSN: 2278-2230
Volume 13, Issue 2, 2024
May–August
DOI (Journal): 10.37591/RRJoE

https://journals.stmjournals.com/rrjoe

Review RRJoE

# A Study of Environmental Pollution in Some Areas of the City of Najaf for Some Heavy Metals

Salwa Hamza Hussein Al-hassnawy[1,*], Furqan Saddam Salman Al-abbasi[2]

***Abstract***

*Pollution is one of the most important problems that people face at present, and the problem of soil pollution is the most serious, due to its relationship to human health and other organisms. Soil sample collection areas in the city of Najaf were chosen based on several factors, including traffic, industrial and urban activities, and population density. Soil samples were taken at a depth level ranging between 0 and 15 cm from the soil surface and toothed leaves of a plant. Dodonaea viscosa for each site to estimate some heavy metals, including lead, Pb, cadmium, Cd, and copper, Cu, starting from October 2020 to March 2022. D. viscosa was selected in the current study for being a plant. Mostly present near the streets of the holy city of Najaf, as it is one of the evergreen trees. The soil of the industrial neighborhood site recorded the highest rate of lead at 92.25 ppm and the lowest rate at 26.25 ppm in the soil of the Albu Madi control site. As for copper, it recorded natural rates, reaching its highest rate of 11.07 parts per million in the soil of the industrial district site. As for the D. viscosa plant, lead and cadmium recorded their highest rates in the industrial district site, 0.56 and 78 ppm, respectively, and their lowest rates were 0.04 and 1.22, respectively, in the Albu Madi control site. This indicates that the increased concentrations of these heavy elements In the soil, increased their absorption from the soil and thus increased their concentrations in the leaves of the D. viscosa plant, and all study sites showed that it was clean and free from pollution, as estimated by the anthropogenic factor (AF) for each element and the pollution index (PI) for all study sites.*

**Keywords:** Soil pollution, plant, *Dodonaea viscosa*, heavy elements, cadmium, contamination, evidence

## INTRODUCTION

The presence of heavy metals in the soil at high concentrations is a clear indicator of soil contamination. Rapid industrial growth, population, and transportation systems have contributed to increasing levels of pollution in regions that include heavy elements in dust. The danger of heavy metals is concentrated in their survival in the soil for a long period of time without decomposing or undergoing any chemical changes [1, 2], they are considered one of the most dangerous substances thrown into the soil, as they not only affect plant growth as a result of their presence in agricultural soils but also lead to contamination of grains and fruits that are eaten by humans. As the human attempt to reduce pollution is not sufficient to stop pollution, it is not sufficient to make the necessary improvements. Traffic activity is one of the largest industrial pollutants that causes chemical pollution of the soil in terms of organic compounds and heavy elements, and the concentration of these pollutants decreases [3–6]. The greater the distance from the main road. Pollution particularly affects plants outwardly, where leaf necrosis can be observed as well as the early fall of leaves and flowers. There may be a halt in plant growth and a

*Author for Correspondence
Salwa Hamza Hussein Al-hassnawy
E-mail: salaw-hanm@gmail.com

[1]Assistant Professor, Department of Biology, College of Education for Girls, Kufa University, Iraq.
[2]Assistant. Professor, Department of Biology, College of Education for Girls, Kufa University, Iraq.

Received Date: May 23, 2024
Accepted Date: July 12, 2024
Published Date: July 20, 2024

**Citation:** Salwa Hamza Hussein Al-hassnawy, Furqan Saddam Salman Al-abbasi. A Study of Environmental Pollution in Some Areas of the City of Najaf for Some Heavy Metals. Research & Reviews: Journal of Ecology. 2024; 13(2): 14–23p.

© STM Journals 2024. All Rights Reserved 

delay in fruit ripening, which affects productivity and quality [7]. The negative effects of pollution on plants center on three important levels, starting with leaf tissue damage with the evolution of necrosis patterns, yellowing or discoloration of the plant, and finally noticeable changes in growth and early loss of flowers, indicating that the concentration of Cu and Pb in plants growing in polluted soils was ten times higher than their concentration in plants growing in unpolluted areas. Their presence at high levels in the atmospheric air and soil and under special conditions leads to an increase in the plant content of the two elements at concentrations that may be dangerous to human and animal health, as an increase in the levels of heavy metal elements in the plant nutrient medium may stimulate or inhibit the absorption and distribution of mineral elements necessary for plant growth. The plant uptake of heavy metals depends on several factors related to the soil and the plant, such as the parent material of the soil, the quality of the dominant minerals in it, and the total and available levels of heavy metals, which are among the most important soil factors that affect the plant's uptake of these minerals [5–8].

## MATERIALS AND METHODS

### Sample Collection

The areas for collecting soil samples and *D. viscosa* leaves were selected in the city of Najaf, depending on factors such as traffic, industrial and urban activities, and population density. Based on this, the city of Najaf was divided into three industrial areas represented by the industrial district, traffic represented by the location of the Albu Madi control, and residential represented by the Al-Ghadeer district. The samples were collected between October 2020 and March 2022. A special form containing the sample number and the name of the site was prepared for each sample, as shown in Table 1.

### Scientific Classification of *Dodonaea viscosa*

*Kingdom:* Plantae
*Clade:* Tracheophytes
*Clade:* Angiosperms
*Clade:* Eudicots
*Clade:* Rosids
*Order:* Sapindales
*Family:* Sapindaceae
*Genus: Dodonaea*
*Species: D. viscosa*

### Soil Samples

The digestion method was used to determine the concentrations of the studied heavy metals in the soils of the study sites, according to the method described by ICARDA (2021). Soil samples were collected from a depth of 0-15 cm below the soil surface. Laboratory and dried by exposing them [9–12] to sunlight, placed in an electric oven at a temperature of 60 °C for an hour, ground, passed through a 2 mm sieve, and collected in plastic containers until the digestion process of soil samples was carried out using solutions including dissolving 1.97 grams of diethylene triamine penta acetic

**Table 1.** Sites for collecting soil and *D. viscosa* samples in the holy city of Najaf.

| Sample collection site | The site | Site description | Number the site |
|---|---|---|---|
| An industrial area that includes auto repair shops, oil change shops, the lubricating mill, Tikrit test ground for affiliated cars The Traffic Directorate of Al-Najaf Al-Ashraf Governorate. | Industrial District | Industrial area | The first |
| A residential area only that is close to the Directorate of Environment of Al-Najaf Al-Ashraf. | Al-Ghadeer district | Residential area | The second |
| Albu Madi traffic area includes shops, schools, and residential houses. | Location traffic area Albo Madi | Traffic area | The third |

© STM Journals 2024. All Rights Reserved 

acid and 1.1 g of CaC12 in distilled water. Then 14.92 grams of Triethanolamine was dissolved in distilled water, the two solutions were mixed, and the volume was completed to a liter of distilled water. Ten grams of dry soil was taken and pre-sifted, and 20 ml of the two solutions were added to it and shaken for two hours using a shaking device [9–11]. The solution uses Whatman No. 42 filter paper). The filtrate was used to measure the concentrations of the elements using a flame atomic absorption device AA240FS at the North Gas Company in Kirkuk.

**Plant Samples**

The digestion method was used to determine the concentrations of the studied heavy metals in the leaves of *D. viscosa* plants according to the method described by ICARDA (2021). The aged leaves of *D. viscosa* plants were collected, placed in polyethylene bags, transported to the laboratory, dried in an electric oven at a temperature of 60°C for an hour, ground, and collected in plastic containers until the digestion of the *D. viscosa* samples using some solutions. The digestion solution was prepared by adding (500) ml of $HClO_3$ acid to [1] liter of concentrated nitric acid $HNO_3$, 1 g of the crushed dry plant was taken and put in the digestion tube, 10 ml of the digestion solution was added to it, and the solution was left for a whole day [12–15] After that, the digestion tubes were placed in the digestion system at a temperature of 150°C, and the digestion process was stopped 30 min after the appearance of 3HCI acid vapors inside the tube. We removed the tubes from the device, left the solution to cool, completed the volume of the digested solution with distilled water to 100 ml, mixed well, and left it for a short time. We confirmed the heavy metal readings using a sequential atomic absorption device (AA 240 FS).

**Evaluation of Degree of Pollution**

To estimate the degree of heavy metal contamination in the study areas, some quantitative indices were used to clarify the concentration status and to facilitate comparison between the variables measured in the study and among these indicators [16].

*Single-factor index analysis or anthropogenic factor (AF):* refers to the degree of pollution resulting from the ratio of the rate of the concerned element measured in the soil to the value of the natural element in the soil or taken from an area that is geochemically similar to the polluted soil but in an unpolluted area. This is expressed by the following equation: AF = cm/Bm.

*Where Cm:* Measured concentration of metal in soil

*Bm:* Background measured concentration of metal in soil Bm was either taken from the natural ratios in previous studies or from a geochemically similar area but not polluted; in the current study, it was taken from previous studies [17, 18].

**Estimating the Degree of Pollution by Multi-element Contamination Called the Pollution Index (PI)**

It is also called the enrichment index (EI), and it is considered the best way to estimate the degree of pollution because pollution with heavy elements in the surface environment (surface environment of the soil) is the result of pollution with more problematic pollutants; however, there are different types of PI used by researchers, but the basic principles are the same [19, 20].

In this study, soil PI was calculated using the sum of the average concentration ratio of each element to the allowable (critical) limit. In this study, the following equation includes three elements:

PI = Σ (metal concentration in soil/permissible level for metal) / number of metals.

A value greater than 1 indicates that the metal concentrations are above permissible (critical) levels.

© STM Journals 2024. All Rights Reserved 

## RESULTS AND DISCUSSION

### Soil Content of Pb

Table 2 shows the soil Pb values recorded during the study period, showing the highest and lowest values depending on the date of sampling and sampling locations. In the current study, lead recorded the highest value of 118 parts per million at the industrial district site in January of the winter season, and the lowest value was 23 parts per million at the control site of Albu Madi in November of the autumn season. Pb pollution depends on several factors, including the distance on both sides of the road, the nature of vegetation surfaces, the period of exposure to pollution, traffic density, and wind direction (Hannah *et al.*, 2019). In addition to the increase in the number of cars, which is considered one of the most important sources of lead pollution, there is a car driving test yard of the Traffic Directorate of Al-Najaf Al-Ashraf near that site. Compared to other results, it is higher than the results obtained to study environmental lead pollution in the city of Baquba and its environs, which had rates of 63.41 parts per million and less than the results of lead concentration Pb for the soil of the industrial zone in Baiji in a study, which ranged between 156.43 and 184.85 parts per million [21–25]. The results are shown in Table 2.

### Pb Content of Plant Lead

The Pb content in plants is not related to its content in the soil, in contrast to other heavy metals (cobalt, nickel, and cadmium). Perhaps the reason for the increase in the content of Pb in plants is the air precipitation of this element resulting from traffic congestion rather than the soil factor and what is added to it. Residues containing heavy metals, including Pb The relatively high levels of heavy elements, including Pb, in the leaves of the study plant at the industrial district site, maybe because these elements pass through the pores through surface precipitation from rainwater and dust. In addition to the process of taking them from the soil through bio-absorption through the root, as these elements are found on the surfaces of plants in a dissolved form, this indicates that heavy metals permeate into the plant through the leaves and roots. Plants transfer larger amounts of minerals to their leaves than to fruits or seeds. It is clear from Table 3 that the average concentrations of Pb [26–29] and Pb in the leaves of *D. viscosa* at the industrial district site were 3.03 parts per million. The average concentration of Pb in the plant leaves of the Al-Ghadeer district was 2.31 parts per million.

**Table 2.** Pb values for soil samples (parts per million ppm) in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 27 | 32 | 85 | October |
| 23 | 35 | 93 | November |
| 33 | 53 | 113 | December |
| 36 | 49 | 118 | January |
| 34 | 29 | 77 | February |
| 26 | 38 | 81 | March |
| 29.83 | 39.33 | 94.5 | The average |

**Table 3.** Lead values for *D. viscosa* parts per million ppm samples in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 1.2 | 1.7 | 1.7 | October |
| 0.8 | 1.9 | 3.2 | November |
| 1.6 | 2 | 3.5 | December |
| 1.8 | 2.6 | 3.3 | January |
| 1.3 | 2.5 | 3.6 | February |
| 1.2 | 3.2 | 2.9 | March |
| 1.31 | 2.31 | 3.03 | The average |

© STM Journals 2024. All Rights Reserved 

For the Albu Madi control site, the average Pb was 1.31 parts per million. In general, the concentration of Pb in the study plant was within permissible limits, which ranged between 1 and 3 parts per million (Table 3).

**Soil Content of Cadmium Cd**

Cadmium is a highly toxic metal whose presence and transport in soil depend on the physical, chemical, and mineral properties of the soil. Natural levels of Cd in the environment are generally low, but the activities of civilizational development have contributed to increasing these levels, including smelting and mining of zinc, using sewage waste as agricultural fertilizer, increasing engine emissions (car exhaust smoke), fuel combustion products extracted from the ground, and the use of phosphate fertilizers and industrial production processes, and is consumed in the manufacture of dyes, electroplating, batteries, and the composition of glass and ceramics.

In the current study, the highest concentration of Cd was recorded in the soil of the industrial district in October, when it reached 1.6 parts per million, while the lowest concentration was recorded in the soil of the Albu Madi control in March, and it reached 0.02 parts per million, as shown in Table 4, the current study proved that the Cd element, according to these sites, is a pollutant for the soil of the industrial district and Al-Ghadeer District [30–33]. The reason for the high concentrations of cadmium in these sites is attributed to soil contamination with this element as a result of a large number of industrial uses of this element, such as its entry into rechargeable batteries, lubricating oils, and motor lubrication fluid, its emission from poor fuel when burning, and the friction of car tires. When comparing the results of this study with those of other studies, it turns out that the results of the current study are higher. The dust near the electric power station in Baiji ranged from 1.10 to 1.91 ppm, and less than the results, which ranged between 3.7 and 10.4 ppm for the soil of the industrial zone in Baiji [34–37]. The results are shown in Table 4.

**Plant Content of Cadmium Cd**

Plants are the most important in their uses as an indicator for evaluating total concentrations and the movement of minerals in the soil. The concentrations of elements in the plant parts indicate their total concentrations in the soil. To understand the behavior of plants exposed to excessive concentrations of these elements, parts of these plants must be analyzed. Cadmium is a non-essential element for animals and plants; however, it enters the human body through the food chain, and 99% of cadmium combines with the solid phase of some soils as it binds with organic matter, forming organic-mineral complexes, and thus its readiness for plants decreases. The cadmium element in the current study plant recorded its highest concentration in the industrial district in October, when it reached 0.8 parts per million, while the lowest concentration was recorded in the control site of Albu Madi in February and reached 0.01 parts per million, as shown in Table 5. The high concentrations of Cd at the industrial district site indicate soil contamination with this element as a result of the ability of Cd to replace cations such as Ca and Mg in the soil and thus become easily absorbed by plants [38]. The results are shown in Table 5.

**Table 4.** Cadmium values for soil samples (parts per million ppm) in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 0.08 | 1.2 | 1.6 | October |
| 0.05 | 0.9 | 1.3 | November |
| 0.07 | 0.3 | 1.1 | December |
| 0.04 | 0.4 | 0.7 | January |
| 0.06 | 0.5 | 0.5 | February |
| 0.02 | 0.6 | 0.9 | March |
| 0.30 | 0.65 | 1.01 | The average |

© STM Journals 2024. All Rights Reserved 

**Table 5.** Cadmium values for (*D. viscosa* parts per million ppm) samples in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 0.06 | 0.3 | 0.8 | October |
| 0.05 | 0.2 | 0.7 | November |
| 0.02 | 0.1 | 0.4 | December |
| 0.03 | 0.3 | 0.3 | January |
| 0.02 | 0.2 | 0.5 | February |
| 0.04 | 0.4 | 0.4 | March |
| 0.03 | 0.25 | 0.51 | The average |

### Soil Content of Cu

Copper is present in small quantities in the soil and owing to the entry of copper into the structural composition of the rocks, the total soil content of this element varies according to the nature of the parent material. Copper is present in the atmosphere at concentrations ranging from 0-5 to 3 in most urban areas. Table 6 below shows the copper values recorded during the study period, showing the highest and lowest values depending on the sampling date and location. Copper in the soils of the current study recorded the highest value of 4.2 ppm in the industrial district site in January of the winter season, and the lowest value was 0.5 ppm in the Albu Madi site in December of the winter season, so the high values of copper in the soils of some sites The study may refer to the deposited copper resulting from the corrosion of motors and brake linings of cars and the introduction of these elements with car emissions as well as the connecting and connecting parts made of iron, aluminum, and copper in cars and the element is also found on the sides of roads with high traffic density in contrast to This is the decrease in copper values in the Albu Madi site, as it is a low-crowded site due to the lack of vehicle momentum [39]. The results are presented in Table 6.

### The Plant Content of Cu

Plants require copper as an essential micronutrient for the normal growth and development of its organs, and when the element is not available in the appropriate quantities, some symptoms appear on the plants, most of which are in the young leaves and reproductive organs; generally, the increase or decrease in the content of copper and its availability for the plant in the soil causes disorders in plant growth and development through its effect on important physiological processes, especially the processes of electron transfer for photosynthesis, which suffer changes when copper deficiency or its compounds, and when its concentrations are excessively increased within plant tissues (Inmaculada) indicated that the concentration of each of copper and lead in plants growing in polluted soils, their concentration was ten times higher than in plants growing in unpolluted areas. Table 7 shows that the highest value of copper in *D. viscosa* plant was 44.3 parts per million in the Al-Ghadeer neighborhood site in January of the winter season, and the lowest value was 19 parts per million in the Albu Madi site in January of the winter. The reason for the difference in copper concentrations in the *D. viscosa* plant between the study sites is due to the deposition of copper in the soil according to the location of the soil, and according to the physical and chemical properties, it is characterized by, which is

**Table 6.** Copper values for soil samples (parts per million ppm) in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 0.9 | 2.2 | 2.3 | October |
| 0.7 | 1.5 | 3.4 | November |
| 0.5 | 1.4 | 3.7 | December |
| 0.8 | 1.8 | 4.2 | January |
| 0.7 | 1.2 | 3.2 | February |
| 0.8 | 0.9 | 2.6 | March |
| 0.73 | 1.5 | 3.23 | The average |

© STM Journals 2024. All Rights Reserved

**Table 7.** Copper values for (*D. viscosa* parts per million ppm) samples in the study sites.

| The location of Albu Madi control | Al-Ghadeer neighborhood | The industrial district | Location/ month |
|---|---|---|---|
| 23.5 | 41.4 | 24.4 | October |
| 20.5 | 40 | 25 | November |
| 19.9 | 42.5 | 25.7 | December |
| 19 | 44.3 | 27.4 | January |
| 19.5 | 40.5 | 28.3 | February |
| 20.6 | 39.8 | 31.5 | March |
| 20.5 | 41.41 | 37.05 | The average |

reflected in the difference in copper concentrations within plant tissues between study sites. The results of the current study agree with the results of the previous study, as it recorded copper concentration values *for D. viscosa* between 12.3 and 57.3 ppm. The high absorption of plants is one of the important factors used in phytoremediation processes [39, 40]. The results are shown in Table 7.

**Evaluation of Degree of Pollution**

The indices or indicators used to estimate heavy metal contamination are the anthropogenic factor (AF) or single-factor index. Pollution index (PI) or EI: The degree of pollution can be determined by the AF factor, depending on what is shown in Table 8.

1 <(AF) indicates that the metal concentrations are above permissible levels, and any other increase is considered a human source or a natural geological source. In the current study, Table 8 shows the levels of heavy elements resulting from human sources at the stations. > It was concluded that Pb, Cd, and Cu were the most added elements to the soil from human sources, that is, the AF of the elements lead and cadmium for the two sites, Al-Sinai District and Al-Zuhur, was greater than 1. From the previous data, we conclude that lead and cadmium are among the hazardous polluting metals in the two sites of Al-Sinai District and Al-Ghadeer Especially the lead element, as this element has high levels in them and therefore is closest to the population and industrial activity and the traffic density of gasoline cars, which contains lead tetroxide, then the levels of this element decrease in the Albu Madi site farthest from the industrial activities. The pollution index method, or the method of estimating the degree of multiple pollution (it does not only take pollution with one element, but also the quality of the pollution index for the environment depending on all the elements, i.e., reflects the degree of pollution resulting from different pollutants (heavy elements) in the current results of the pollution index, as shown in Table 8, it is noted that the PI for all the study sites is less than 1, which indicates that all the study sites are free of pollution and agree to assess the pollution with heavy elements of the surface soils of the Hawija region, southwest of Kirkuk, as he indicated that it is considered from pollution-free to slightly polluted places [40, 41]. The results are shown in Table 8.

**Table 8.** Mean concentrations of heavy metals, human factor AF for each element, and pollution index (PI) for all study sites.

| Heavy elements | Pb | Cu | Cd |
|---|---|---|---|
| Industrial live concentration rate | 94.5 | 3.23 | 1.01 |
| AF | 6.15 | 6.46 | 0.05 |
| IP | *Clean 0.332* | | |
| Al-Ghadeer district | 39.33 | 1.5 | 0.65 |
| AF | 2.622 | 3 | 0.03 |
| IP | *Clean 0.155* | | |
| Albu Madi control site | 29.83 | 0.73 | 0.30 |
| AF | 1.98 | 1.46 | 0.01 |
| IP | *Clean 0.074* | | |
| The normal rate of the element | 15 | 0.5 | 20 |
| allowed rate | 100 | 3 | 100 |

© STM Journals 2024. All Rights Reserved 

## CONCLUSIONS

The soils and plants of the study area, *D. viscosa*, in the industrial neighborhood and Al-Ghadeer neighborhood, were characterized by higher concentrations of the heavy elements Pb and Cd than the other elements. Cu, but the concentrations of heavy elements were within permissible limits. There is no polluting effect of a single element on the pollution of the other element; that is, there is a single potential for pollution for each element in the studied environmental systems. It was found that the study plant could accumulate high quantities of heavy elements, especially Pb and Cd, making it one of the preferred species for use in phytoremediation phytotherapy. The Al-Ghadeer neighborhood, especially the Pb component, is a result of the transport medium. The PI results showed that all study sites were pollution-free.

### Conflict of Interest

The authors declare no conflict of interest.

## REFERENCES

1. Abdel-Sabour MF, Aly RO. Bioremediation of heavy metal contaminated soils in dry lead: case studies. In: Inyang HI, Stotmeister U, editors. Bioremediation of contaminated soils. New York (USA): Marcel Dekker, Inc.; 2000.
2. Adriano DC. Trace elements in terrestrial environments: biogeochemistry, bioavailability, and risks of metals. 2nd ed. Volume I. New York (USA): Springer; 2001.
3. Adamu CI, Nganje TN. Heavy metal contamination of surface soil in relationship to land use patterns: a case study of Benue State, Nigeria. Mater Sci Appl. 2010;1:127–34. DOI: 10.4236/msa.2010.13021.
4. Alabama and Auburn Universities. Air pollution damage to plants. Alabama Cooperative Extension System, ANR-913; 2016.
5. Ali HA. Heavy metals concentrations in surface soils of the Haweja area southwestern of Kirkuk, Iraq. Kirkuk Univ J Sci Stud. 2007;2:35–48. DOI: 10.32894/kujss.2007.43434.
6. Alloway BJ. Cadmium. In: Alloway BJ, editor. Heavy metals in soils. London: Blackie Corp; 1995. p. 122–51.
7. American Galvanizers Association (AGA). Hot-dip galvanized steel’s contribution to zinc levels in the soil environment; 2013. Available from: www.galvanizeit.org.
8. Auburn AL. Heavy metal soil contamination. Soil Quality – Urban Technical Note No. 3. United States Department of Agriculture; 2000.
9. Caselles J, Collige G, Zornoza P. Evaluation of trace element pollution from vehicle emission in Petunia points. [Journal title missing]. 2001.
10. Chon HT, Ahn JS, Jung MC. Heavy metal contamination in the vicinity of some base-metal mines in Korea: a review. Geosyst Eng. 1998;1:74–83. DOI: 10.1080/12269328.1998.10541128.
11. Christensen TH, Huang PM. Solid phase cadmium and the reaction of aqueous cadmium with soil surfaces. In: McLaughlin M, Singh BR, editors. Cadmium in soil and plants. Dordrecht: Kluwer Academic Publishers; 1999. p. 1–9.
12. Dampare SB, Ameyaw Y, Adotey DK, Osae S, Serfor-Armah Y, Nyarko BJB, Adomako D. Seasonal trend of potentially toxic trace elements in soils supporting medicinal plants in the Eastern Region of Ghana. Water Air Soil Pollut. 2006;169:185–206. DOI: 10.1007/s11270-006-2381-z.
13. FAO of the United Nations (FAO). Trace elements in soils and agriculture. Food and Agriculture Organization Soils Bulletin 17; 1972.
14. Mathe-Gaspar G. Heavy metal uptake by radish varieties. In: Anton A, editor. Proceedings of the 7th Hungarian Congress on Plant Physiology. Volume 46; 2002. p. 113–4.
15. Gholami A, Mojiri A, Amini H. Investigation of the air pollution tolerance index (APTI) using some plant species in Ahvaz region. J Anim Plant Sci. 2016;26:475–80.
16. Shayler H, Bride MM, Harrison E. Sources and impacts of contaminants in soils. Cornell Waste Management Institute; 2019.

© STM Journals 2024. All Rights Reserved 

17. Hiroyuki H, Eriko A, Mitsuo CH. Estimate of cadmium concentration in brown rice. In: Proceedings of the 17th World Congress of Soil Science; 1992. p. 1–5.
18. Hong-gui D, Teng-feng G, Ming-hui L, Xu D. Comprehensive assessment model on heavy metal pollution in soil. Int J Electrochem Sci. 2012;7:5286–96. DOI: 10.1016/S1452-3981(23)19621-0.
19. Hill MK. Understanding environmental pollution. Cambridge: Cambridge University Press; 2010.
20. ICARDA. Soil and plant analysis laboratory manual. 2nd ed. International Center for Agriculture Research in the Dry Areas (ICARDA) and the National Agriculture Research Center (NARC); 2021.
21. Sabah R, Al-Kazazz AF, Al-Ameri SAH. Investigation on glucose and levels of Zn and Cu in sera of Iraqi males addicted to methamphetamine or tramadol. J Adv Sci Eng Technol. 2020;3:52–63. DOI: 10.32441/jaset.03.02.06.
22. Yruela I. Copper in plants. Braz J Plant Physiol. 2005;17:145–56. DOI: 10.1590/S1677-04202005000100012.
23. Kabata-Pendias A, Pendias H. Trace elements in soils and plants. 3rd ed. Boca Raton (FL): CRC Press; 2001.
24. Marchiol L, Assolari S, Sacco P, Zerbi G. Phytoextraction of heavy metals by canola (Brassica napus) and radish (Raphanus sativus) grown on multicontaminated soil. Environ Pollut. 2004;132:21–7. DOI: 10.1016/j.envpol.2004.04.001.
25. Eswari L, Bharathi RV, Jayshree N. Preliminary phytochemical screening and heavy metal analysis of leaf extracts of Ziziphus oenoplia (L) Mill. Gard. Int J Pharm Sci Drug Res. 2013;5:38–40. ISSN 0975-248X.
26. Li YM, Chaney R, Brewer E, Roseberg R, Angle JS, Baker AJM, Reeves R, Nelkin J. Development of a technology for commercial phytoextraction of nickel: economic and technical considerations. Plant Soil. 2013;249:107.e115.
27. Maruyama N, Munegumi T. Cicada shells as chemical education resources to study functional groups and environmental cycles. World J Chem Educ. 2023;11:127–33. DOI: 10.12691/wjce-11-4-1.
28. Dhuha Raheem AA, Zainab Abd AM. Biosynthesis, characterization, antioxidant and antihemolysis activity of silver nanoparticles (AgNPs) produced using Cynophyta alga extract (Spirulina platensis). Alharf. 2023;Issue: November.
29. Jian L, Qingru Q, Jian C, et al. Assessment on pollution of heavy metals and metalloid in soil along road. J Environ Health. 2020;17:284–6.
30. Mahmood A, Jwad SM. Development and preparation of ciprofloxacin drug derivatives for treatment of microbial contamination in hospitals and environment. Indian J Forensic Med Toxicol. 2020;14:1115–22.
31. Malan HL, Farrant JM. Effects of the metal pollutants cadmium and nickel on soybean seed development. Seed Sci Res. 1998;8:445–53. DOI: 10.1017/S0960258500004414.
32. Manno E, Varrica D, Dongarrà G. Metal distribution in road dust samples collected in an urban area close to a petrochemical plant at Gela, Sicily. Atmos Environ. 2006;40:5929–41. DOI: 10.1016/j.atmosenv.2006.05.020.
33. Murphy AP, Coudert M, Barker J. Plants as biomarkers for monitoring heavy metal contaminants on landfill sites using sequential extraction and inductively coupled plasma atomic emission spectrophotometry (ICP-AES). J Environ Monit. 2000;2:621–7. DOI: 10.1039/b005594h.
34. Aydın E, Turhan GM. Exploring primary school teachers’ pedagogical content knowledge in science classes based on PCK model. J Pedagog Res. 2023;7:70–99. DOI: 10.33902/JPR.202318964.
35. Muh A, Asriadi AM, Hadi S, Istiyono E. Trend research mapping of differentiated instruction: a bibliometric analysis. J Pedagog Res. 2023;7:194–210. DOI: 10.33902/JPR.202320544.
36. Preeti, Tripathi S. Ziziphus jujuba: A phytopharmacological review. Int J Res Dev Pharm Life Sci. 2014;3:959–66. ISSN: 2278-0238.
37. Calduell RL. Effects of air pollution on vegetation. Prog Agric Ariz. 2016.
38. Sánchez-Camazano M, Sánchez-Martín MJ, Lorenzo LF. The content and distribution of cadmium in soils as influenced by the soil properties. Sci Total Environ. 1994;156:183–90. DOI: 10.1016/0048-9697(94)90185-6.

© STM Journals 2024. All Rights Reserved

39. Shrebsky EC, Taballdi LA, Pereira LB, Rauber R, Maldaner J, Carrgnelutti D, Goncalves JF, Castro GY, Shetinger MRC, Nicoloso FT. Effect of cadmium on growth, micronutrient concentration, and δ-aminolevulinic acid dehydratase and phosphatase activities in plants of Pfaffia glomerata. Braz J Plant Physiol. 2008;20(4):1–12.
40. Winther M, Slentø E. Heavy metal emissions for Danish road transport. NERI Technical Report No. 780. Aarhus University, Denmark; 2010. Available from: www.dmu.dk/Pub/FR780.pdf.
41. Yadav DV, Jain R, Rai RK. Impact of heavy metals on sugarcane. In: Soil heavy metals. Soil Biology, vol. 19. 2010;339–67. DOI: 10.1007/978-3-642-02436-8_16.

© STM Journals 2024. All Rights Reserved 