International Journal of Advanced Research in Botany
Volume 8, Issue 1, 2024, PP 14-18
ISSN 2455-4316 (Online)
https://doi.org/10.20431/2453-4316.0801002
www.arcjournals.org

Characterization of Heavy Metal Contamination in the Soils of Riyadh

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Abstract

The objective of this study is to quantify the heavy metal content in the soil samples collected from different areas of Riyadh. Six soil samples were randomly collected across the Riyadh city and analyzed for cadmium (Cd), nickel (Ni) and lead (Pb) by using Atomic Absorption Spectrophotometer (AAS). When the data were subjected to international standard, heavy metals in the studied area surpassed the threshold limit. The content of the heavy metals in all the collected soil samples found decreased in the order of Pb>Ni>Cd. The soil sample collected from Khashman Al-aan area in Riyadh showed maximum Lead (Pb) contamination followed by Nickel (Ni) and Cadmium (Cd). Soil samples collected from Al-Janadriyah, Al-Hayer, Al Amran, and DirAiyahareas showed moderate contamination of heavy metals within the permissible limits in the order of Pb> Ni> Cd. Whereas the soil sample collected from ArRimayah area of Riyadh found least polluted in terms of heavy metal contamination.

Keywords: *AAS; Cadmium; Heavy metals; Lead; Nickel*

1. INTRODUCTION

Soil is an essential, energetic, ever-changing component of the ecosystem. In recent years soil pollution has significantly augmented as a result of increased anthropogenic activities. Industrialization, wastewater management, application of agrochemicals, automobile emissions, all were recognized as main causes of atmospheric metallic burden (Yusuf *et al*. 2015). Heavy metals are considered as the most common environmental pollutants in the biosphere (Papafilippaki *et al*. 2008). Reportedly more than five million sites around the world are contaminated by heavy metals (Liu *et al*. 2018). Therefore, in order to study the soil heavy metal pollution several studies have been conducted all around the world (Li *et al*. 2016, Alshahri and El- Taher 2018).

The harmful impacts of heavy metals on natural and biochemical properties of soil are well reported. Heavy metals can affect the soil quality i.e., clay contents, ionic balance and pH. (Speira *et al*. 1999).Accumulation of heavy metals such as cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), zinc (Zn), copper (Cu), chromium(Cr), and nickel (Ni) in soils is known to be associated with industrial discharge such as combustion of fossil fuel and ore processing (Sun *et al*. 2014). Moreover, application of chemical fertilizers, pesticides, and fungicides are also considered as the leading sources of Cd, Zn and Cu deposition in agronomic soil (Pan *et al*. 2016). Due to high stability and toxicity heavy metals available in soil can easily make a route to ecological chain, becoming a major threat to food, water and even human health. (Chabukdhara and Nema, 2013). Heavy metals, accumulated in the soil enter the human body by inhalation of soil dust, dermal contact and through soil ingestion (Ciarkowska 2018; Alshahri and El-Taher 2018). Excessive exposure of heavy metals can lead to serious diseases related to blood heart, kidney and bones. (Jarup 2003). Reportedly prolonged Lead (Pb) and Arsenic (As) exposure can damage the nervous system, kidney dysfunction, dermal lesion, skin cancer, and hypertension (Qing *et al*. 2015, Krishna and Mohan 2016; Ciarkowska2018). Due to their toxic nature and non-reversible characters heavy metals, such as Cr, As Cd, Hg, Pb, Cu, Zn, and Ni, have been listed as major pollutants by the United States Environmental Protection Agency (US EPA) which created the attention around the globe. (Chen *et al*. 2015; US EPA 2001).

As there is not much data available concerning the soil heavy metal content in Riyadh (Saudi Arabia), with the above background the objective of this study is to study the content of heavy metals such as cadmium (Cd), nickel (Ni) and lead (Pb) in soil samples collected from different areas of Riyadh by using Atomic Absorption Spectrophotometer (AAS).

2. Materials And Methods

2.1. Collection of Soil Samples

All the soil samples were collected in the month of October. The sampling site was ArRimayah, Al Janadriyyah, Al-Hayer, Al Amran, Dir Aiyah and Khashm Al Aan of Riyadh city. (Kingdom of Saudi Arabia). All the soil sample were collected at 18cm depth from the sampling sites. Soil samples were carefully mixed and transferred into the clean and labeled polythene bag for further laboratory analysis.

2.2. Determination of Soil pH

pH of soil was determined in 1:1 soil water suspension by using pH mete Model-S210-Seven Compact, Mettler Toledo, U.S.A.). The pH meter was calibrated by pH 7.0 4.0 and 9.2 buffer solutions. 20g of dried soil samples were weighed into 100 mL beaker and mixed with 50ml of double distilled water. The suspension of each soil sample was stirred well with a glass rod for 30 minutes and allowed to stand for 1 hour. pH reading of soil samples was taken by immersing the electrode of the pH meter into the partially settled slurry and the pH value was recorded from the digital display of the pH meter.

2.3. Digestion of Soil Sample

For the digestion of the soil samples 1g of the oven dried finely ground sample was weighed using a weighing balance and transferred in a 250ml of glass beaker. Soil samples were added with 5ml of concentrated HNO_3, 15ml of H_2SO_4 and 0.3ml of $HClO_4$. The obtained slurry was digested in a digester till a dense white fume appeared. 15 minutes after complete ingestion and cooling the solution was diluted with distilled water. The digested solution was filtered through Whattman filter paper into a volumetric flask and further analysis.

2.4. Heavy Metal Analysis

Analysis of the heavy metals like cadmium (Cd), lead (Pb) and Nickel (Ni) were done by using AAS-Atomic Absorption Spectrophotometer. The data obtained was subjected to one way analysis of variance (ANOVA) to show the variations in concentration of heavy metals.

3. Results And Discussion

Soil pH data collected from different areas of Riyadh are presented in the Fig 1. Soil pH impacts the progressions of soil formation and development. It plays a significant role in determining which shrubs grasses or trees will dominate the land under natural environmental condition. Soil samples collected from ArRimayah (7.7) Al Janadriyyah (7.6), Al-Hayer (7.6), Al Amran (7.8) with the recorded pH, showed that the soil is mildly Alkaine. Whereas the samples collected from Dir Aiyah (8.5) and Khashm Al Aan (8.6) exhibited strongly alkaline nature. Soil pH affects the accessibility of mineral nutrients to the plants. Alkaline pH of the soil decreases the micronutrients (particularly Zn, Fe, Cu and Mn) solubility. Availability of most of the essential nutrients are highest, within the pH range of 6.5 –7.5. It is reported by Brady and Weil (1999) that neutral to alkaline pH in semi-arid soil can be due to little rainfall, causing no percolation of alkaline compounds, thus making the soil of the region too alkaline.

In our study, heavy metals in soil samples collected from different areas of Riyadh revealed the variation in the amount of lead, nickel and cadmium. The concentration of heavy metals in the examined soil samples were recorded in the following order Pb> Ni> Cd graphically presented in Fig.1. Among the observed heavy metals, concentration of Pb was recorded higher than the thresh hold values in all the soil samples except the ArRimayah area. According to the Agency for toxic substances and disease registry (ATSDR) lead is placed second among the top 20 hazardous elements. The maximum concentration of Pb (228mg/kg) was recorded in Khashm Al Aan area which surpassed the permissible limit whereas the minimum Pb concentration (57mg/kg) was observed in ArRimayah area of Riyadh (Fig.2). The higher amount of lead in all the examined area could be correlated with the wide use of lead products in storage batteries, anthropogenic activities such as combustion of leaded gasoline. It is

reported that excessive exposure of Pb can cause metabolic disorders affects the renal system and neuro-physical deficits in children (Gu *et al*.2016).

Table 1. *Threshold and permissible limits for heavy metals in soils. (UNEP 2013)*

Elements	Threshold limit (mg/kg)	Permissible limit (mg/kg)
Cadmium (Cd)	1.0	10.0
Lead (Pb)	60.0	200.0
Nickel (Ni)	5.0	100.0

Ni is listed as potential carcinogen by the International Agency for Research on Cancer. (Chaney *et al*. 1997). In recent years, due to its inimitable physicochemical properties nickel (Ni) has been expansively used in several consumable products such as paints iron-based alloys, catalysts, and batteries. (Iram *et al*. 2009). Reportedly, the main sources of nickel are the sewage sludge when dispersed on land can elevate the level of nickel in soils. (Aslam *et al*.2013). The Ni content of soils in the studied area ranged from 34.9 to 81.9 mg/kg. (Fig.2).The maximum amount of Nickel was observed in Al-Amran region, while the minimum Ni concentration 34.9kg/mg was recorded in soil sample of Al-Janadriyyah which lies under permissible limit. (Table 1). However, it is reported that higher content of Ni causes lung cancer (Rattan *et al*. 2005).

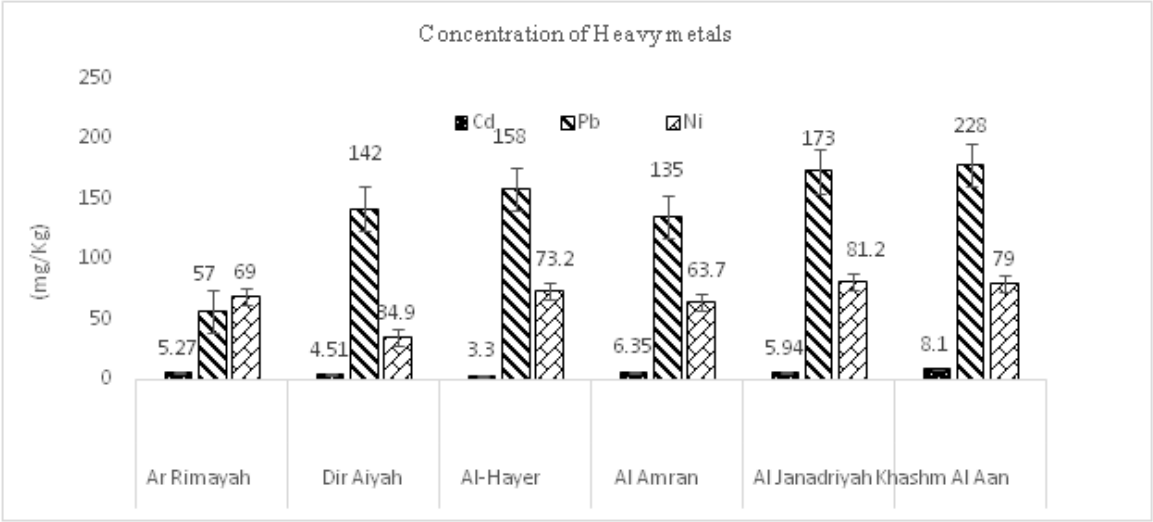

Fig 1. *Heavy metal (Cd, Pb, Ni) concentration of soil samples collected from different areas of Riyadh. Data represent mean of three replicates. Vertical bars indicate ±S.E.*

Table 2. *The concentration of heavy metals in the soil (mg/kg) samples collected from different areas of Riyadh*

Elements	ArRimayah	Al Janadriyah	Al-Hayer	Al Amran	Dir Aiyah	Khashm Al Aan
Cd	5.27	4.51	3.30	6.355	.94	8.10
Pb	57.0	142.0	158.0	135.0	173.0	228.0
Ni	69.0	34.9	73.2	81.2	63.7	79.0

Cadmium is a non-essential highly toxic metal to plants and animals, with a long biological half-life of about 20 years. (Zorrig *et al*. 2019). The Cd content in the studied area showed the variation in concentration ranging from 3.3mg/kg to 8.1mg/kg. The highest Cd concentration was observed in Khashm Al Aan (8.10 mg/kg) followed by Al Amran (6.35 mg/kg). The lowest (3.30 mg/kg) Cd concentration was observed in Al Hayer area of Riyadh. (Fig.2). The observed Cd Concentration in all the studied was more than threshold value but found less than permissible limits. Reports suggest that chronic consumption of Cd can lead to serious health hazards, such as bone damage, kidney dysfunction and even cancers (Xu *et al*. 2018; Zhao *et al*. 2017).

4. CONCLUSION

Identification and quantification of heavy metals in the soil is important for deterrence and reduction of soil pollution. With this aim accumulation of Pb, Ni and Cd were investigated in the soil samples from different areas of Riyadh and compared with the threshold values and permissible limits. The results

showed higher accumulation of Pb in all the studied areas followed by Ni and Cd. Pb mostly originated from vehicle emissions and coal combustion deposition, whereas Ni deposition is closely related to the anthropogenic activities. Crucial measures are required to control the increasing limits of Pb accumulation in the soil in the studied areas. The data can be used further for the research on soil heavy metal pollution in Riyadh.

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Citation: *Faheema Khan et al. Characterization of Heavy Metal Contamination in the Soils of Riyadh. International Journal of Advanced Research in Botany. 2024; 8(1):14-18. DOI: http://dx.doi.org/10.20431/2453-4316.0801002.*

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