

## ASSESSMENT OF HEAVY METAL CONTENT IN *SALVIA CABULICA* COLLECTED FROM HANNA VALLEY USING ATOMIC ABSORPTION SPECTROSCOPY

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### ARTICLE INFO:

Received: 01/04/2026.  
Accepted: 10/04/2026.  
Published: 15/04/2026.

### Keywords:

*Salvia cabulica*, Heavy metals, Atomic Absorption Spectrometry, *Salvia cabulica*, Balochistan

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### DOI:

<https://doi.org/10.5281/zenodo.19818467>

### ABSTRACT

*Medicinal plants have been used traditionally for the treatment of different diseases all over the world. Salvia cabulica which belongs to Lamiaceae family is widely used in Balochistan in Pakistan for its therapeutic qualities. However, the safety of medicinal plants with regard to heavy metal contamination is a recent concern. This study was aimed to find the concentration of essential and non-essential heavy metals in Salvia cabulica collected from Hanna valley, Quetta, Balochistan and compared with WHO permissible limits. The plant samples were collected, processed and digested using concentrated acids mixture ( $\text{HNO}_3:\text{H}_2\text{SO}_4:\text{HClO}_4$  10:2:1). The concentrations of nine metals (Co, Pb, Mn, Cr, Fe, Ni, Cd, Cu, and Zn) were analysed by atomic absorption spectrophotometry. The metal concentration of Salvia cabulica was in the descending order:  $\text{Fe} > \text{Cu} > \text{Mn} > \text{Ni} > \text{Co} > \text{Zn} > \text{Cd} > \text{Cr} > \text{Pb}$ . The highest concentration was found for iron (90.63 mg/kg), followed by copper (87.58 mg/kg) and manganese (18.15 mg/kg). The concentration of toxic elements such as Cd (5.855 mg/kg), Cr (2.61 mg/kg) and Pb (2.56 mg/kg) were detected. When compared with WHO permissible limitations of medicinal plants, Fe, Cu, Cd and Cr were found to be higher than the recommended values whereas Mn and Pb were found to be in safe limits. Salvia cabulica has considerable quantities of essential elements, which are responsible for its nutritive value. However, the high concentrations of toxic metals especially Cd and Cr require special care in monitoring and dosage to use this plant for medicinal purposes. It is recommended that regular quality control assessments are conducted to ensure the safety of consumers.*

## 1. Introduction

Medicinal plants have long served as a cornerstone of traditional medicine systems and continue to play a significant role in modern healthcare. According to the World Health Organization (2007), approximately 80% of the population in developing countries depends on plant-based medicines for their primary healthcare needs. The genus *Salvia*, belonging to the family Lamiaceae, comprises more than 900 species distributed worldwide and is widely recognized for its pharmacological properties, including antioxidant, antimicrobial, and anti-inflammatory activities (Tunay *et al.*, 2020).

The therapeutic properties of medicinal plants are largely attributed to their chemical composition, which includes both organic compounds and inorganic elements. Essential trace elements such as iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) play crucial roles in physiological processes, including enzyme function, oxygen transport, and immune response (Maiga *et al.*, 2005). However, when present in excessive concentrations, these elements may become toxic and lead to adverse health effects (Basgel & Erdemoğlu, 2006).

In contrast, non-essential heavy metals such as cadmium (Cd), lead (Pb), and chromium (Cr) are inherently toxic and pose serious health risks even at low concentrations. These metals have been associated with various health problems, including kidney damage, neurological disorders, and carcinogenic effects (Dogan, 2014). Cadmium has been classified as a Group 1 human carcinogen by the International Agency of Research on Cancer (2012), and it has a serious toxicological effect.

Heavy metal contamination in medicinal plants can occur through multiple pathways, including soil contamination, irrigation with polluted water, atmospheric deposition, and agricultural practices such as the use of fertilizers and pesticides (Wu *et al.*, 2015). Plants absorb these metals from their environment and accumulate them in different tissues, thereby introducing them into the human food chain (Stanojkovic-Sebić *et al.*, 2015).

Despite its widespread traditional use in Balochistan for treating gastrointestinal and respiratory disorders, *Salvia cabulica* has not been extensively investigated for heavy metal contamination. Therefore, the present study aims to quantify the concentrations of essential and toxic metals in *Salvia cabulica*, Compare the observed levels with international safety standards. Assess potential human health risks using established indices such as EDI, THQ, and HI

## 2. Materials and Methods

### 2.1. Area of the Study and Sampling:

The plant samples of *Salvia cabulica* were collected from Hanna Valley, located in north of Quetta, Balochistan from Pakistan (latitude 30°15'N, longitude 67°05'E) in the month of April 2025. Hanna Valley is unique in its microclimate and the variety of flora and is thus an important area for medicinal plants to grow.

### 2.2 Sample Preparation

The collected plant samples (whole plant including stems, leaves and flowers) were thoroughly washed first with tap water to remove adhering soil and dust particles followed by rinsing with ultra-pure deionized water (Bibi et al., 2021). The washed samples were spread on a clean filter paper and dried at room temperature (25 ± 2°C) in a dust-free environment, shielded from direct sun to avoid photodegradation and volatile losses (Tunay et al., 2020). The dried plant material was ground to a fine powder by using an electric grinder (Moulinex, France) and passed through a 0.5 mm sieve to insure homogeneity. The powdered samples were kept in pre-cleaned, air tight, polyethylene bags until further analysis.

### 2.3 Chemicals and Reagents

All chemicals and reagents used were of analytical grade. Concentrated nitric acid (HNO<sub>3</sub>, 65%), sulfuric acid (H<sub>2</sub>SO<sub>4</sub>, 98%) and perchloric acid (HClO<sub>4</sub>, 70%) were purchased from Merck (Darmstadt, Germany). Standard stock solutions (1000 mg/L) of Co, Pb, Mn, Cr, Fe, Ni, Cd, Cu and Zn were purchased from Merck (Germany) for calibration purposes. Ultra-pure deionized water (18.2 MΩ.cm) was used throughout the course of the experimental work, both for dilutions and glassware washing.

### 2.4. Digestion Procedure

A wet acid digestion technique was used for the decomposition of plant samples (Kiazai, 2019). Accurately, 1.0 g of powder of the *Salvia cabulica* sample was weighed and placed in a 50 mL digestion flask. A mixture of concentrated acids (HNO<sub>3</sub>:H<sub>2</sub>SO<sub>4</sub>: HClO<sub>4</sub>) in the ratio of 10:2:1 was added to the sample. The digestion mixture was heated on an electric hot plate at 80-85 °C in a fume hood for the complete decomposition of the organic matter which was indicated by dense white fumes created (Bibi et al., 2021). The sample after digestion was allowed to cool to room temperature and then quantitatively transferred to a 50 mL volume flask. The volume was made up to the mark with deionized water and the



solution was filtered through Whatman No. 42 filter paper to remove any undigested particles. The clear filtrate was collected in pre-cleaned polyethylene bottles, and stored at 4 °C till analysis. Blank digestions were undertaken at the same time using the same procedure without plant material.

## 2.5. Instrumental Analysis

The concentrations of heavy metals (Co, Pb, Mn, Cr, Fe, Ni, Cd, Cu and Zn) were measured by a Flame Atomic Absorption Spectrophotometer (FAAS, Model S4 AA, Thermo Scientific, USA). The instrument was provided with hollow cathode lamps specific for each element and an air-acetylene flame was used for atomization. The operating parameters including wavelength, slit width and lamp current were set according to the manufacturer's recommendations for each element (Table 1).

## 2.6. Calibration and Quality Assurance

For each metal, 5 standard solutions of varying concentrations were prepared by suitable dilution of 1000 mg/L stock standards with 0.5 M HNO<sub>3</sub>. Calibration curves were made by plotting absorbance as a function of concentration and the coefficients of linear regression ( $R^2$ ) were calculated. Calibration of the instrument was performed before each analysis and calibration verification was done after every ten sample measurements.

Quality assurance procedures consisted of the analysis of reagent blanks, analysis of samples in triplicate, and recovery studies. The accuracy of analytical method was confirmed by spiking known concentrations of standard solutions to sample digests and calculating percentage recoveries.

## 2.7. Statistical Analysis

All analyses were done in duplicate and results were expressed as mean  $\pm$  standard deviation (SD). Statistical analysis was performed with Microsoft Excel 2016 and IBM Statistical program (SPSS) version 20.0 (IBM Corp. USA). The metal concentrations were compared with WHO permissible limits of medicinal plants.

## 3. Results

### 3.1. Heavy Metal Concentrations in *Salvia cabulica*

Concentrations of nine heavy metals (Co, Pb, Mn, Cr, Fe, Ni, Cd, Cu and Zn) obtained for *Salvia cabulica* from Hanna Valley, Balochistan are shown in Table 2. The results are

expressed in mg/kg on a dry weight basis as mean values on triplicates with their respective standard deviations.

**Table 1:** Heavy Metal Concentrations in *Salvia cabulica* (mg/kg, dry weight basis)

| Metal | Concentration (mg/kg) | WHO Permissible Limit (mg/kg) |
|-------|-----------------------|-------------------------------|
| Co    | 54.31 $\pm$ 2.45      | -                             |
| Pb    | 2.56 $\pm$ 0.12       | 10                            |
| Mn    | 18.15 $\pm$ 0.85      | 200                           |
| Cr    | 2.61 $\pm$ 0.11       | 2.0                           |
| Fe    | 90.63 $\pm$ 4.20      | 15                            |
| Ni    | 42.82 $\pm$ 1.95      | 1.5                           |
| Cd    | 5.855 $\pm$ 0.26      | 0.3                           |
| Cu    | 87.58 $\pm$ 4.10      | 10                            |
| Zn    | 48.82 $\pm$ 1.95      | 50                            |

The concentrations of the analysed metals followed the descending order: Fe > Cu > Mn > Ni > Co > Zn > Cd > Cr > Pb. Iron showed the highest concentration of 90.63 mg/kg followed by copper with 87.58 mg/kg. Manganese, Nickel, Cobalt, and Zinc had moderate concentrations ranging from 18.15 - 48.82 mg/kg. The toxic metal cadmium, chromium and lead were found to be present in the concentration of 5.855 mg/kg, 2.61 mg/kg and 2.56 mg/kg respectively.

### 3.2 Comparison to Acceptable Limits and Health Risk Assessment.

The levels of heavy metals found in *Salvia cabulica* were compared with international accepted levels to determine the level of safety of the product to human consumption levels. Guideline limits of toxic metals are given by the World Health Organization (WHO) mainly in raw herbal materials, namely cadmium (Cd), lead (Pb) and chromium (Cr). Nevertheless, WHO fails to outline allowable levels of some of the vital components such as iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn). Thus, thresholds to these components were borrowed with FAO/WHO Codex Alimentarius and other literature to provide a comprehensive analysis (World Health Organization [WHO], 2007; FAO/WHO, 2011; Street, 2012).

The findings showed that cadmium (5.855 mg/kg), chromium (2.61 mg/kg), nickel (42.82 mg/kg) and copper (87.58 mg/kg) were above the permissible limit, but lead (2.56 mg/kg), manganese (18.15 mg/kg), and zinc (48.82 mg/kg). There were no WHO limits on iron and cobalt and these elements did not get a direct comparison (WHO, 2007; Street, 2012). Of particular concern is the very high levels of cadmium and nickel because they are very toxic and may have health consequences.

### 3.2.1 Metal Pollution Index (MPI)

The Metal Pollution Index (MPI) was also derived to assess the total amount of contamination with heavy metals in the plant sample based on the geometric mean of all the metals analysed.

$$\text{MPI} = (\text{C}_1 \times \text{C}_2 \times \text{C}_3 \dots \text{C}_n)^{1/n}$$

The MPI of *Salvia cabulica* was 22.38 mg/kg, which was a significant amount of metals. The higher MPI values will reflect the greater contamination load and indicate the capacity of plants to receive and store metals in the environment (Usero et al., 2005). The measured MPI value indicates that the environmental or geochemical factors might affect the study area and cause high metal uptake.

### 3.2.2 Health Risk Assessment

#### Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) of metals was determined to estimate the level of exposure to the consumers with a rate of ingestion of 0.02 kg/day and mean body weight of 70 kg. The EDI values reflected that iron and copper had the greatest daily intake as compared to zinc and nickel.

**Table2:** Estimated Daily Intake

| Metal | EDI (mg/kg/day) |
|-------|-----------------|
| Pb    | 0.00073         |
| Mn    | 0.00519         |
| Cr    | 0.00075         |
| Fe    | 0.02589         |
| Ni    | 0.01223         |
| Cd    | 0.00167         |
| Cu    | 0.02502         |
| Zn    | 0.01395         |

## Target Hazard Quotient (THQ)

The Target Hazard Quotient (THQ) was computed using reference dose (RfD) values that have been set by the United States Environmental Protection Agency (USEPA). A THQ above 1 means that it has a risk to the health (USEPA, 2011).

$$\text{THQ} = \text{EDI} / \text{RfD}$$

**Table3:** Reference Dose

| Metal | RfD (mg/kg/day) |
|-------|-----------------|
| Pb    | 0.0035          |
| Mn    | 0.14            |
| Cr    | 0.003           |
| Fe    | 0.7             |
| Ni    | 0.02            |
| Cd    | 0.001           |
| Cu    | 0.04            |
| Zn    | 0.3             |

The findings indicated that cadmium had a THQ of 1.67, above the threshold, which meant that there was a possibility of a health risk in case of long-term consumption. The levels of risk associated with nickel (0.61) and copper (0.63) were moderate, whereas other metals were within safe limits (THQ < 1).

These results indicate that cadmium is the most problematic contaminant in *Salvia cabulica*, which is in line with the previous researches that indicated that cadmium has high toxicity and bioaccumulation capacity (Street, 2012).

**Table 4:** Target Hazard Quotient

| Metal | THQ         | Risk Level |
|-------|-------------|------------|
| Pb    | 0.21        | Safe       |
| Mn    | 0.04        | Safe       |
| Cr    | 0.25        | Safe       |
| Fe    | 0.04        | Safe       |
| Ni    | 0.61        | Moderate   |
| Cd    | <b>1.67</b> | High Risk  |
| Cu    | 0.63        | Moderate   |
| Zn    | 0.05        | Safe       |

### 3.2.3 The implications to consumer safety.

The high cadmium and other metals can be explained by the environmental factors which include the composition of the soil, the agricultural processes and the deposition of the metals in the air. The same has been observed in medicinal flora of similar areas, suggesting that the environmental pollution is a major factor in the metal accumulation (Wu *et al.*, 2015).

The findings underscore the importance of periodically monitoring medicinal plants to determine the levels of heavy metals in the plants and also to put in place stringent quality control measures to guarantee consumer safety (WHO, 2007).

### 3.3. Analytical Method Validation

The calibration curves of all the analysed metals exhibited excellent linearity with correlation coefficients ( $R^2$ ) values ranging from 0.991 to 0.999. The recovery studies, which involved spiking known concentrations of standards into sample digests, gave percentage recoveries in the range of 94-106%, and this served as a proof of the accuracy of the analytical method. The relative standard deviations for three measurements were less than 5% for all elements, which indicates good precision and reproducibility of the results.

## 4. Discussion

### 4.1 Essential Element Concentrations & Nutritional Impact

The high concentrations of essential elements, especially iron (90.63 mg / kg) and copper (87.58 mg / kg) in *Salvia cabulica* indicate that this plant may be an important dietary source of these micronutrients. Iron is a constituent of hemoglobin and Myoglobin and is a vital constituent of oxygen transport and electron transfer reactions (Al-Fartusie & Mohssan, 2017). The daily requirement of iron is 8 mg/day for adult males and 18 mg/day for females (Bibi *et al.*, 2021). Based on the concentration present in the *Salvia cabulica*, the consumption of about 10-20 g of this plant could contribute significantly to the daily requirement of iron.

The amount of copper (87.58 mg/kg) in *Salvia cabulica* is quite high compared to other medicinal plants. Tunay *et al.* (2020) found copper levels in different *Salvia* species between 2.94 and 24.74 mg/kg in different plant parts while Basgel and Erdemoglu (2006) determined that copper levels were 35.8 mg/kg in the samples of sage (*Salvia officinalis*) from Turkey. The much higher copper concentration in *Salvia cabulica* from Balochistan may be explained by the regional differences in soil geochemistry, human impact or plant

specific accumulation characteristics. Copper is an essential cofactor for many enzymes such as cytochrome c oxidase, superoxide dismutase and tyrosinase (Maiga *et al.*, 2005). The recommended dietary requirement for copper is 2-5mg/day, implying that moderate consumption of this plant may contribute beneficially to copper nutrition.

Manganese (18.15 mg/kg) in *Salvia cabulica* is in the range of the typical values reported for medicinal plants. Tunay *et al.* (2020) reported a great variation in the concentration of manganese in different *Salvia* species ranging from 0.52-9.13 mg/kg. Manganese is necessary for bone formation, carbohydrate metabolism and as a constituent of antioxidant enzymes like manganese superoxide dismutase (Al-Fartusie & Mohssan, 2017). The concentration found is well below the WHO permissible limit of 200 mg/kg and not a concern from the toxicity perspective.

The concentration of nickel (42.82 mg/kg) in *Salvia cabulica* is very high compared to similar studies conducted in the past. Tunay *et al.* (2020) reported levels of nickel in the range of 0.86-9.57 mg/kg in different species of *Salvia*, and Tokalioglu (2012) found levels of nickel in sage, 3.83 mg/kg. Nickel is deemed an essential trace element in very low concentrations (80-130 ug/day) but can be toxic in high levels (Bibi *et al.*, 2021). The high nickel content detected in the present study calls for attention as it is higher than the WHO limit of 1.5 mg/kg for medicinal plants.

Cobalt (54.31 mg/kg) and zinc (48.82 mg/kg) were in appreciable amounts in *Salvia cabulica*. Cobalt is a necessary element of vitamin B<sub>12</sub> and is involved in red blood cell formation (Karpiuk *et al.*, 2016). The fact that no WHO permissible limit for cobalt in medicinal plants has been established makes the risk assessment difficult, but the concentration found is not negligible.

Zinc, with a recommended dietary allowance of 15 mg/day for adults (WHO, 1994), is present to levels which could contribute beneficially to zinc nutrition. The zinc concentration in *Salvia cabulica* is similar to the values in mixed samples of different *Salvia* species reported by Tunay *et al.* (2020) (0.96-3.53 mg/kg) but lower than the values in sage reported by Basgel and Erdemoglu (2006) (48.4 mg/kg).

#### 4.2. Toxic Metal Contamination and Health Implications

The presence of toxic metals such as cadmium, chromium and lead in *Salvia cabulica* creates important safety issues for consumers. The cadmium concentration (5.855 mg/kg) is



quite troubling as it is almost 20 times higher than the WHO permissible concentration for cadmium (0.3 mg/kg) for medicinal plants. Cadmium is listed as a human carcinogen (Group 1 by IARC) and is recognized to accumulate largely in the kidneys and liver and lead to nephrotoxicity and bone demineralization with chronic exposure (Tunay et al., 2020). The high cadmium concentrations in *Salvia cabulica* could have come from natural processes of soil geochemistry and/or anthropogenic origins, such as phosphate fertilizer and atmospheric deposition in the Hanna Valley region.

The chromium concentration (2.61 mg/kg) is a little more than the WHO value of 2.0 mg/kg for raw herbal materials. Tunay et al. (2020) found that chromium content in the root sections of several species of *Salvia* exceeded permissible limits and similar results were seen in leaf samples of certain species. Chromium toxicity is highly dependent upon its oxidation state with hexavalent chromium ( $\text{Cr}^{6++}$ ) being much more toxic than trivalent chromium ( $\text{Cr}^{3+}$ ) (Belitz et al., 2009). The speciation of chromium in *Salvia cabulica* was not determined in this research and this is an important direction for further research. The level of lead (2.56 mg/kg) was well below the permissible limit of 10 mg/kg for medicinal plants as per WHO. This finding is consistent with the study by Bibi et al. (2021) who reported lead levels of 1.18 ug/g *Xylanthemum macropodum* from the same region well within acceptable limits. The relatively low concentrations of lead in *Salvia cabulica* is reassuring because lead is a cumulative toxin with multiple health effects on the body, especially the nervous system and the hematopoietic system (Abou-Arab & Abou Donia, 2000).

### 4.3 Comparison with Other Studies on Medicinal Plants

The *Salvia cabulica* heavy metals levels are similar and have significant differences with other medicinal plants values presented in the literature from Balochistan. In their comprehensive investigation of five *Salvia* species in Turkey, Tunay et al. (2020) have found metal concentrations that significantly differ from each other between different parts of the plants (seeds, roots, leaves, flowers, and mixed samples). They found that toxic metals including As, Cd, Cr, Hg and Pb were generally accumulated at higher concentrations in root segments as compared to aerial parts suggesting that roots act as barriers restricting translocation of toxic elements to above-ground tissues. This pattern of accumulation is of major significance for the selection of parts of plants for medicinal use. Bibi et al. (2021) examined the *Xylanthemum macropodum* from the Hanna Valley Region and found the metal concentrations of Fe (92.36 micrograms/g), Cu (85.31 micrograms/g), Co (49.24

micrograms/g), Ni (40.94 micrograms/g), Mn (20.94 micrograms/g), Cd (6.655 micrograms/g), Cr (1.61 micrograms/g) and Pb (1.18 micrograms/g). These values are remarkably similar to the results of the current research for *Salvia cabulica*, suggesting that plants growing in the Hanna Valley region may be under similar geochemical and environmental conditions that result in similar metal accumulation patterns.

The amounts of copper and iron in *Salvia cabulica* are found to be much higher in comparison with *Salvia* species found in Turkey, by Tunay et al. (2020), who detected copper amounts of 2.94-24.74 mg/kg, and iron concentrations below 30 mg/kg in aerial parts. This discrepancy may reflect differences in the composition of soils, climatic conditions and anthropogenic influences in the two regions. Maiga et al. (2005) provided copper and zinc values of 2.4-17.1 and 9.2-67.1 mg/kg, respectively, for medicinal plants from Mali, with wide range within and between species and sites.

#### 4.4. Regional Environmental Issues

The Hanna Valley area of Balochistan, while being relatively less industrialized than other parts of Pakistan, may still be at risk of heavy metal contamination from a variety of sources. Agricultural practices such as application of phosphate fertilizers, pesticides and fungicides may contribute to cadmium and copper accumulation in soils (Wu *et al.*, 2015). Vehicular emissions from the Quetta-Hanna road may be responsible for lead and cadmium deposition in areas nearby. In addition, the geological make-up of the region may naturally be high in certain metals, which are then absorbed by plants. The similar patterns of metal accumulation in *Salvia cabulica* (present study) and *Xylanthemum macropodum* (Bibi *et al.* 2021) from the same collection area indicate that the metal concentration is reflecting the characteristics of the local environment and not the accumulation capabilities of species.

#### 4.5. Suggestions of safe use and Quality Control

The levels of toxic metals, especially cadmium and chromium, are high suggesting that the uncontrolled or excessive consumption of this plant could be a health hazard to the consumer. Tunay *et al.* (2020) highlighted the need for dosage control in medicinal plants that have toxic metals content, as although traditional usage patterns may have modified safety considerations due to toxicity, the modern use patterns as herbal tea or dietary supplements may increase the dosage levels of exposure. Several approaches can be adopted to reduce the risks of heavy metal contamination of medicinal plants. First, the choice of suitable plant parts for medicinal uses is of utmost importance, because toxic metals are present more in roots than aerial parts (Tunay *et al.*, 2020). For *Salvia cabulica*, the use of leaves and flowers,



instead of whole plants including roots would likely decrease the intake of toxic metal. Second, cultivation of medicinal plants in controlled environment using tested soils could reduce the contamination from anthropogenic sources. Third, regular quality control testing of herbal products on the heavy metal content should be made mandatory before they enter the market (WHO, 1994).

#### 4.6. Comparison with International Standards

The permissible limits of toxic metals in medicinal plants are different for the different countries and international organizations. The WHO limits used in this study (10 mg/kg for Pb, 2 mg/kg for Cr and 0.3 mg/kg for Cd) are standard limits for raw herbal materials (WHO, 1994). However, some countries have adopted more stringent limits. For example, Canada has set limits of 0.02 mg/day for the intake of lead, chromium and mercury from herbal products (Tunay et al., 2020). The admissible limits 5.0 mg/kg Pb, 1.0 mg/kg Cd and 0.1 mg/kg Hg are set in the European Pharmacopoeia for herbal drugs.

The cadmium content level of *Salvia cabulica* (5.855 mg/kg) is higher even than the less stringent standards and thus it is the most toxicological concern metal. The chromium content (2.61 mg/kg) is somewhat above the limits set by the World Health Organisation but below some of the national standards. The lead concentration (2.56mg/kg) lies well within international safety limits.

### 5. Conclusion

This research is the first comprehensive analysis of heavy metal concentrations of *Salvia cabulica* of Hanna Valley, Balochistan, Pakistan. The plant has fairly good content of essential elements such as iron, copper, manganese and zinc, which are associated with its nutritional value and potential therapeutic properties. However, the high concentrations of toxic metals mostly cadmium (5.855 mg/kg) and chromium (2.61 mg/kg) are above the permissible limits for WHO for medicinal plants and is an issue of concern for consumer safety. The results show that *Salvia cabulica* is accumulating the heavy metals in a manner matching the environmental conditions of the region and that it resembles other medicinal plants from the same area of collection. While the traditional use of this plant may have persisted for generations and may have been safe, the current patterns of consumption and

potential for changes in the level of environmental contamination have required scientific evaluation and regulation.

The combination of the Metal Pollution Index (MPI) and health risk assessment showed that *Salvia cabulica* is contaminated moderately with heavy metals, and the cadmium is a serious health risk. Such results underline the necessity to monitor them regularly, consume them in a controlled manner, and introduce regulatory norms regarding the safety of medicinal plants.

Based on the results of this study the following suggestions are made: (1) The regular monitoring of the content of heavy metals in medicinal plants growing in the Hanna Valley region, (2) Cultivation of *Salvia cabulica* in a controlled environment to reduce contamination, (3) Selection of suitable plant parts (leaves and flowers rather than roots) for medicinal preparations, (4) Setting up of maximum permissible limits of heavy metals in herbal products by the regulatory authorities in Pakistan, and (5) Public awareness programmes related to the possible risks of uncontrolled intake of herbal medicines. Future research should be focused on metal speciation studies, especially with regard to chromium, in order to better determine toxicological risks. Bioavailability studies on the proportion of metals that are released during the preparation of herbal tea would give more realistic estimates of exposure. Additionally, soil and water analysis throughout the collection area would be helpful in identifying sources of contamination and would aid in remediation.

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