Iran Red Crescent Med J. 2016 February; 18(2): e18631. doi: 10.5812/ircmj.18631
Published online 2016 February 20. **Research Article**

Evaluating the Density of Toxic Elements in the Respiratory Organs of Rosemary (*Rosmarinus officinalis* L.) Herbal Medicine Grown in the Isfahan and Shahr-e-Kurd Regions

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Received 2014 March 1; **Revised** 2014 September 8; **Accepted** 2015 November 10.

Abstract

Background: The amount of effective ingredient production in plants is influenced by various climatic and environmental factors such as quality of water resources, soil quality, air quality, and the level of environmental pollutants.
Objectives: In this research, we seek to study and analyze the qualitative effects of heavy metals on the respiratory organ of rosemary. Further, we will compare the results to the permitted levels in various ecological regions.
Materials and Methods: Rosemary leaves were collected from four regions: Isfahan, Foulad Shahr, Zoub Ahan, and Shahr-e-Kurd. Samples were placed in an atomic absorption device, after they had been dried, in order to measure the density of lead, mercury, cadmium, arsenic, zinc, and sulfur.
Results: A significant difference, as much as $P < 0.01$, was observed between the levels of sulfur, cadmium, lead, mercury, arsenic, and zinc in various regions. The densities of lead, arsenic, mercury, and cadmium in the respiratory organs of rosemary were much less than the permitted level. Although the density of cadmium in the region of Foulad Shahr was close to the critical level (due to the presence of the Isfahan steel company), the main problem was with the elements of zinc and sulfur. The densities of zinc in Shahr-e-Kurd, Zoub Ahan, and Isfahan were far more than the permitted levels. The densities of sulfur in Zoub Ahan, Foulad Shahr, and Isfahan were far more than the permitted level, while this density was quite within the permitted range in Shahr-e-Kurd, which is noteworthy.
Conclusions: Planting rosemary in polluted areas to clean the air and using this plant in clan areas for medical products seems quite appropriate.

Keywords: Heavy Metals, Rosemary, Pollutants, Isfahan

1. Background

The global trend in recent years has mostly been towards the use of herbal medicines and away from their chemical counterparts. For this reason, it is necessary to pay greater attention to herbal medicines. One of the major problems in this area is our lack of information about the various medical characteristics of the plants in nature.

Rosemary or *Rosmarinus officinalis* L. belongs to the plant family of *Lamiaceae*, which is a perennial herb characterized by ascending branches (which may grow as tall as two meters) and thin leaves without a sharp or needlelike point. The leaves and flowering shoot are considered to be the medical organs of the plant. This plant is observed in most areas of Iran. The major worldwide producers of this plant are northern African countries, such as Morocco and Tunisia, southern European states such as France and Italy, and America. The production rate of the effective ingredients in rosemary, as well as other plants, is influenced by various climatic and environmental factors such as the quality of water resources, soil and air quality, and the level of pollutants in the region (1).

Environmental pollutants and their destructive effects on ecosystems are no secret to anybody. If not controlled appropriately, the activities of the Isfahan steel factory, like any other industrial plant, may have negative effects on the soil, environmental health, and human and plant health (2).

Air pollution is also an important environmental problem. Hydrocarbons are substances that pollute air. As per the statement of the joint society of air pollution and control engineers, the presence of one or many pollutants in the open air depends on the level, duration, and characteristics of the pollutant that are dangerous for the lives of humans, animals, and plants, and cause harm to stuff and facilities of life (2).

The pollution of soils with heavy metals is a serious and expanding problem. Diffusion of toxic metals, as a result of human activities, pollutes the soil. The level of pollution in such soils is either above the natural limit or will reach critical levels soon (3).

Various studies have been conducted worldwide regarding soil and plant pollution with heavy metals, especially pollution caused by watering soil and plants with urban and industrial wastewater or wastewater sludge (4, 5). Environmental systems have a limited capacity for the absorption of pollutants, and if pollutants gather continuously the ability of the soil to be a receptive environment is reduced significantly or is completely demolished (6).

Due to the toxic and carcinogenic effects of metals, such as zinc, arsenic, lead, cadmium, and mercury, assessment and control of their density in plant tissue and compounds (especially medicinal herbs, which are usually used to produce chemical medicines or directly used to treat patients) is particularly important (7).

Rosemary is one of the most important and valuable medicinal herbs. The capability of this plant for development in Isfahan and Shahr-e-Kurd (which have an increased possibility of pollution due to the presence of iron and steel factories in the region) has pushed many researchers to study the role of environmental pollutants, such as soil and air pollutants, on rosemary's ecological performance in various environments (1).

2. Objectives

Thus, the present research was conducted to study the density of toxic elements, such as lead, mercury, cadmium, arsenic, and zinc, in the respiratory organs of rosemary planted in Isfahan and Shahr-e-Kurd.

3. Materials and Methods

3.1. Sampling

The respiratory organs of rosemary were collected from four different ecological regions in September of 2013. These regions included the northeastern area of Bagh Ghadir in Isfahan, Foulad Shahr, the Isfahan steel factory and Shahr-e-Kurd. After the rosemary leaves were collected from the four different areas and dried in the shade, they were ground and sent to the laboratory to study and analyze the heavy elements and metals.

3.2. Evaluating the Density of Heavy Elements and Metals

After the plant samples were dried, 0.5 grams of each sample was burnt in a 550°C furnace. The burnt plant samples were then placed in test tubes and 6 mL of nitric acid was added. The samples were exposed to room temperature for 24 hours and then exposed to 150°C temperature for one hour. After the test tubes were completely cooled, 2 mL of perchloric acid was added to each tube, and the contents of the tubes were exposed to 215°C for 2 hours. In the end, when each test tube was completely cooled, 10 mL of 90°C distilled water was added, the contents of each tube were filtered through Whatman paper, and their volume was reduced to 25 milliliters. To measure the levels of sulfur, cadmium, lead, mercury, arsenic, and zinc in the laboratory, an atomic absorption spectrophotometer (AAS) was used.

3.3. Statistical Analysis of the Results

Variance analysis was done using Minitab software, version 16 and average comparisons were conducted through the Duncan test in the level of 5%.

4. Results

The present research was conducted in order to measure the density of toxic metals in the respiratory organ of rosemary grown in Isfahan. Table 1 represents the results of variance analysis of the elements in rosemary leaves of various regions. Based on these results, a significant statistical difference was observed ($P < 0.01$) between the levels of sulfur, cadmium, lead, mercury, arsenic, and zinc in different areas.

4.1. Zinc and Sulphur Elements

A comparison of the averages (Figure 1) shows that the level of zinc in various regions is significantly above the critical level. There was also a significant difference between various regions in terms of sulfur and the level in Foulad Shahr was increased significantly, by five times, as compared to the level recorded in Shahr-e-Kurd (Figure 1). A significant difference was also observed between the level of sulfur in Zoub Ahan, Isfahan and Foulad Shahr.

4.2. Cadmium Element

A comparison of the averages (Figure 3) shows that the level of cadmium in various regions is significantly below the critical level. There was also a significant difference between various regions in terms of cadmium, and the level in Foulad Shahr was increased significantly, by four times, as compared to the level recorded in Shahr-e-Kurd.

A comparison of the averages (Figure 2) shows that the level of zinc in Foulad Shahr is significantly less than the critical level. There was also a significant difference between areas in terms of zinc, and its level in Shahr-e-Kurd was increased significantly, by four times, as compared with Foulad Shahr.

4.3. Lead Element

A comparison of the averages (Figure 4) shows that the level of lead in various regions is significantly below the permitted level. There was also a significant difference between various regions in terms of lead, and the level in Foulad Shahr was increased significantly, by three times, as compared to the level recorded in Isfahan. A significant difference was also observed between the level of lead in Zoub Ahan and Shahr-e-Kurd.

4.4. Mercury Element

A comparison of the averages (Figure 5) shows that the level of mercury in various regions is significantly below the permitted level. Concerning the regions studied, a significant difference was observed between Foulad Shahr and other regions in terms of the level of mercury.

4.5. Arsenic Element

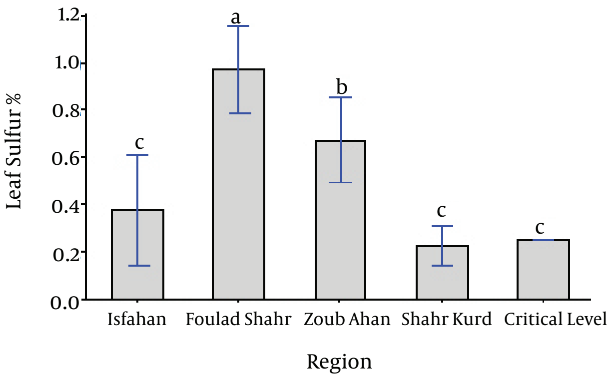
A comparison of the averages (Figure 6) shows that the level of arsenic in various regions is significantly below the permitted level. There was also a significant difference between various regions in terms of lead, and the level in Foulad Shahr was increased significantly, by two times, as compared to the level recorded in Shahr-e-Kurd.

Table 1. Results of Variance Analysis of the Elements That Exist in Rosemary Leaves in Various Regions

Source of changes	Elements															
	df	N	P	MSK	Ca	Mg	S	Zn	Mn	Fe	Cd	MSNi	Pb	Hg	As	Cu
Regions	3	0.54[a]	0.003[b]	0.215[a]	0.118[a]	0.007[b]	0.33[a]	2072[a]	465.5[a]	6818[a]	5.64[a]	0.012[a]	22.2[a]	0.003[a]	0.104[a]	18[a]
Error	8	0.01	0.002	0.014	0.006	0.003	0.005	19.5	37.2	14.7	0.02	0.002	0.02	0.0001	0.007	0.25

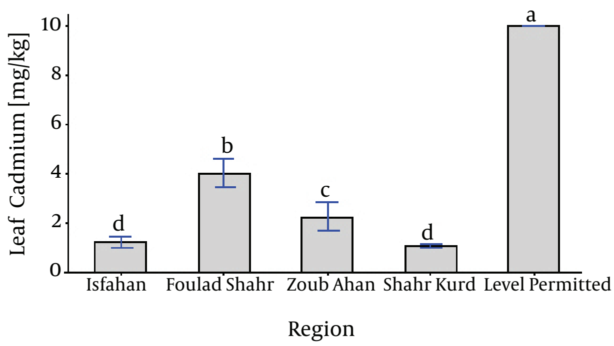
[a]No significant difference.
[b]A significant difference in the possibility level (1%).

Figure 1. Changes in Leaf Sulfur Density in Various Areas of Sampling With Their Critical Level in Plants



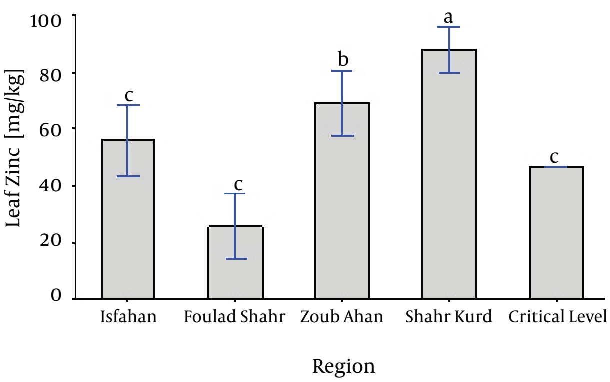
Similar letters represent cases where there was no statistical difference, at the level of 1%.

Figure 3. Comparison of Changes in Leaf Cadmium Density in Various Areas of Sampling With Their Permitted Level in Plants



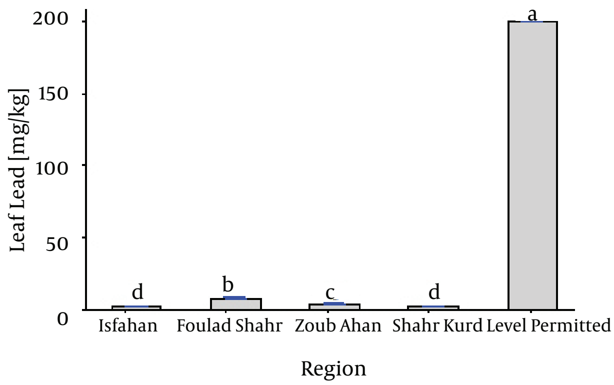
Similar letters represent cases where there is no statistical difference, at the level of 1%.

Figure 2. Comparison of Changes in Leaf Zinc Density in Various Areas of Sampling With Their Critical Level in Plants



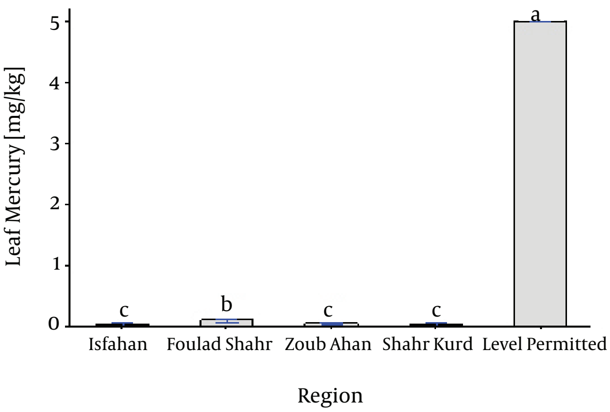
Similar letters represent cases where there was no statistical difference, at the level of 1%.

Figure 4. Comparison of Changes in Leaf Lead Density in Various Areas of Sampling With Their Permitted Level in Plants



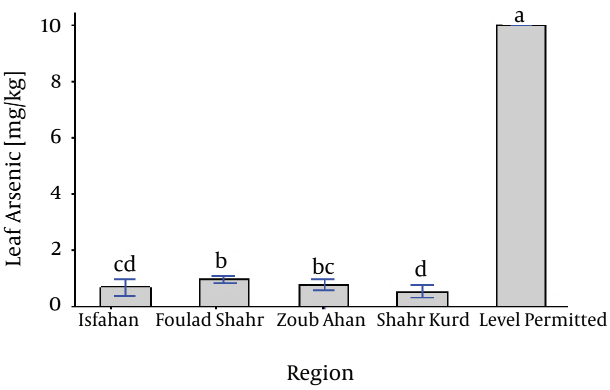
Similar letters represent cases where there is no statistical difference, at the level of 1%.

Figure 5. Comparison of Changes in Leaf Mercury Density in Various Areas of Sampling With Their Permitted Level in Plants



Similar letters represent cases where there is no statistical difference in the Duncan test, at the level of 1%.

Figure 6. Comparison of Changes in Leaf Arsenic Density in Various Areas of Sampling With Their Permitted Level in Plants



Similar letters represent cases where there is no statistical difference in the Duncan test, at the level of 1%.

5. Discussion

The results of the present study conducted in Isfahan (which is one of the richest areas of Iran in terms of natural and artificial habitats for medicinal herbs, and is also the site of the Mobarakeh steel factory and the Zoub Ahan factory, which are the biggest industrial complexes in Iran) showed that the respiratory organ of rosemary planted in those areas was polluted by heavy elements and toxic metals such as sulfur, cadmium, lead, mercury, arsenic, and zinc. Rosemary has been able to act as a refinery, storing some heavy elements and metals that exist in the air and soil of the region and filtering them. These results indicate that rosemary can be potentially used for filtering water and soil for heavy and toxic metals. On the other hand, peasants and other people who plant and harvest medicinal herbs, or those who use medicinal herbs to produce therapeutic medicines and compounds, should bear this point in mind, that rosemary that has been grown in the vicinity of factories and industrial complexes should not be used freshly and directly. In other words, the high capacity of rosemary to store and absorb toxic elements and heavy metals from soil, water, and even air will increase the density of such elements in the respiratory organ of the plant and restrict the fresh use of the plant for therapeutic purposes.

Based on the results of our study, if rosemary is utilized to produce medical products through distillation, no traces of heavy metals will be observed in the essence. Thus, planting rosemary in the areas polluted by these elements will probably not cause a problem, although the density of cadmium in Foulad Shahr is close to the critical level (due to the presence of the Isfahan Zoub Ahan factory). However, the major problem is found with zinc and sulfur. The density of zinc in Shahr-e-Kurd, Zoub Ahan, and Isfahan was far above the level permitted, and the density of sulfur in Zoub Ahan, Foulad Shahr, and Isfahan was far more than the level permitted. The density of sulfur in Shahr-e-Kurd was close to the level permitted, which might be a significant issue.

A few scattered studies have been done regarding this issue in other countries. Davazdah Emami et al. geochemically and environmentally analyzed heavy metals in the soils produced by the s Gorgan schists (8). The results of their study indicated that the soil of this area was heavily polluted by chromium, nickel, cobalt, arsenic, and copper, and further, the plants in this area played a major role in storing these materials.

In a study conducted in Slovakia, Faiz et al. studied the pollution of plants and soil by heavy metals. The results of this study showed cadmium, lead, chromium, and mercury to be the elements traced in the respiratory organs of plants (9). The aforementioned author concluded that planting medical and non-medical plants in the vicinity of factories and industrial complexes will result in the elements getting inside them. He concluded that consuming these plants might be harmful to humans, which is in line with the results of this study. Results similar to our research were also reported by another study (10). They reported the level of lead, cadmium, and arsenic in the respiratory organs of the plants planted in polluted soils to be highly significant. Similar results have also been reported in other studies (11, 12).

Another study was conducted to compare five plant species in terms of their ability to tolerate toxic levels of lead (Pb) and accumulate lead in shoots and roots. Plants were grown outdoors under natural daylight in artificial soil media (perlite: vermiculite) containing 0 or 500 µg/mL of lead. Results indicated that the five plant species tested exhibited differing sensitivities to toxic levels of lead. Based on the magnitudes of reduction in leaf area and dry tissue biomass, radish was the most sensitive, while black mustard was the most tolerant to lead. Among the five species evaluated, sunflower had the greatest ability to accumulate lead in the roots, but it translocated the least amount to its (13). Experiments were also conducted to evaluate the suitability of some plants as phytoextraction species. Tall fescue (*Festuca arundinacea Schreb. cv. Spirit*) can tolerate and accumulate significant amounts of lead (Pb) in its shoots when grown in Pb-amended sand. Results revealed that tall fescue was relatively tolerant to moderate levels of Pb, as shown by non-significant differences in root and shoot biomass among treatments. Root Pb concentration increased with increasing levels of soil-applied Pb. Further increases in root Pb concentrations were attributed to chelate amendments (14). Concerning the phytoremediation of heavy metals, factors such as plant tolerance against heavy metals, plant root system, the ability to transfer elements from their underground organs to their respiratory organs (transfer factor), quick growth rate, and biomass above the plant must be taken into consideration. The reduced capacity of white mulberry, poplar, and certain types of sunflower for filtering heavy metals, as compared with rosemary (the present study), has been proven in various studies (15).

Generally, the results attained through the present study confirm the existence of heavy and toxic metals in the respiratory organs of rosemary planted in Isfahan. It also revealed the high effects of this plant in filtering metals. The high filtering capacity of rosemary, especially for zinc and sulfur, is also noticeable. Zinc and sulfur are usually in the air and in soils located close to steel and iron sites, as well as factories. Planting rosemary in such places will enable us to use their high capacity for filtering such factors out of soil and air. The other advantage of rosemary, as compared with other plants. is that the heavy metals gathered in the respiratory organs of other plants return to the soil as they lose their leaves in autumn, but such a thing is not seen in rosemary. The other point to note here is that rosemary that is grown in the vicinity of large factories and industrial complexes should not be used freshly and directly for medical purposes.

The present study proved, for the first time, that direct use or brewing of the respiratory organ of rosemary planted in the vicinity of big industries is never recommended as heavy metals in the air and soil, such as zinc and sulfur, are stored in it. On the other hand, using this plant due to its high potential for filtering heavy metals can be an appropriate solution to reduce the environmental pollution in the vicinity of big industries and factories. According to our results, this plant has the greatest ability to absorb zinc, sulfur, and cadmium. Furthermore, heavy and toxic elements such as lead, mercury, and arsenic are stored in the respiratory organ of this plant. The authors recommend planting rosemary in polluted areas in order to filter the air. Rosemary may also be planted in clean areas so that it may be used in medical products.

Acknowledgments

The authors wish to extend their gratitude to Dr. Farhad Safarpoor Dehkordi and all the hardworking staff of Chahar Mahal Bakhtiari province soil lab, especially engineer Farzan.

Footnote

Authors' Contribution: Maryam Jalalian: writing and revise; Mehrdad Ataie Kachoie: supervision, writing, and editing; Rasoul Ghorbali: supervision, study concept, and study design.

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