

Evaluation of Heavy Metals in Drinking Water Resources in Urban and Rural Areas of Hamadan Province in 2016

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ABSTRACT

Introduction: Drinking water should be free of any chemical contaminants. One of the important aspects of drinking water pollution is presence of heavy metals that can be hazardous for consumer's health. This study was carried out to determine the concentration of heavy metals in urban and rural drinking water networks of Hamadan province in 2016.

Materials and Methods: This study was a descriptive cross-sectional study. In order to investigate the concentration of heavy metals in drinking water resources of the province, a total of 60 samples (38 rural and 22 urban samples) from water distribution networks was taken based on standard methods. After transferring the samples to the laboratory, the elements were measured by polarography and the results were analyzed using Excel software.

Results: The heavy metals average concentration of Hg, As, Cr (total), Cu, Pb, Cd and Zn in all samples was 0.565, 6.733, 2.045, 11.637, 2.636, 0.031 and 282.596 $\mu\text{g.L}^{-1}$ respectively. Only 1.67% of samples were contaminated with mercury, 3.33% were contaminated with lead and 8.33% samples were contaminated with arsenic.

Conclusion: The results showed that the average concentration of heavy metals measured in all samples of Hamadan province was lower than the maximum allowed in the national and international standards. Apart from the worrying situation of arsenic amount in samples of a small number of villages, it can be concluded that the status of drinking water sources in terms of heavy metals contamination is favorable in Hamadan province, but annually control of arsenic is strongly recommended.

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Introduction

The release and diffusion of toxic substances in the environment can have adverse effects on humans and other living organisms. The increased production and consumption of heavy metals over the past few decades has resulted in significant amounts of them entered in to aquatic and terrestrial environments. Due to the lack of biological degradation of heavy metals in ecological systems

and the occurrence of various destructive effects, it is necessary to pay special attention to them¹.

The term of heavy metals is basically a group of elements with a specific gravity greater than 6 g/cm^3 or an atomic mass of 50. According to this definition, there are more than 50 elements that can be classified as heavy metals, 17 of which are the most common and, at the same time, the most toxic elements. The toxicity of these elements

depends on factors such as the type of metal and its biological role in the life cycle¹⁻³.

These elements can enter the body through the food cycle, the most important of which is contaminated water, and cause chemical poisoning. The origin of heavy metals entering water can be urban wastewater, industrial waste, old urban pipelines, and so on. Urban population growth and the development of various industries are one of the main factors contributing to the increase of pollutants, especially heavy metals, in our drinking water^{4, 5}. Heavy metals can enter water sources from natural ways such as rainfall, soil erosion and dissolution of soluble salts^{5,6}.

The most common metals in human toxicity are lead, mercury, arsenic and cadmium. Other heavy metals such as copper, zinc and chromium are needed in trace amounts for the body, but these elements can cause poisoning at high levels. Heavy metals, by creating various mechanisms, cause the lack of balance in living organisms, especially human beings, and create a wide range of complications and disorders. These complications and disorders have been observed in all organs in which various factors, including the type of metal and its biological role, are involved. The most important disorders and complications of these can be carcinogenicity, effects on the central and peripheral nervous system, effects on the skin, effects on the blood system, effects on the cardiovascular system, damage to the kidneys and accumulation in Tissues¹⁻³.

Drinking water should be free of any chemical and microbial contaminants. One of the important aspects of drinking water pollution is presence of heavy metals that can be hazardous for consumer's health. Since, heavy metals can enter to water sources through environmental pollutants as well as the corrosion of pipe materials, the concentration of these elements should be continuously monitored and controlled in drinking water⁷. This study was carried out to determine the concentration of heavy metals (mercury, arsenic, chromium, copper, lead, cadmium and zinc) in urban and rural drinking water sources of Hamadan province in 2016.

There are various instrumental methods for measuring the concentration of heavy metals in water samples, including spectrophotometry, flame atomic absorption (FAAS) or graphite furnace (GFAAS), inductively coupled plasma (ICP) And electrochemical methods such as polarography, each of which has its own characteristics⁸. In this study, heavy metals of arsenic, mercury, zinc, cadmium, lead, copper and chromium (total) were measured and determined by polarographic method and with polarograph instrument and the results were compared with national standards and World Health Organization (WHO) guidelines^{7,9}.

Hamadan province is located in the west of the country with an area of 19,493 square kilometers. Hamadan province reaches north to the provinces of Zanjan and Qazvin, south to Lorestan province, east to Central province, and west to Kermanshah province and part of Kurdistan province¹⁰.

Hamadan province (34.7982°N, 48.5146°E) has 9 counties with names Hamadan, Malayer, Kabudarahang, Razan, Famenin, Tuyserkan, Nahavand, Asadabad and Bahar. Hamadan is the most populated county in the province and its center is Hamadan, the capital of the province. According to the latest statistics, the number of villages in the province of Hamadan is 1071 villages. Malayer county with 207 villages has the highest number of villages in between 9 counties of the province. Nahavand, Kabudarahang, Razan, Hamadan, Tuyserkan, Asadabad, Bahar and Famenin counties have 169, 127, 124, 109, 107, 97, 68 and 63 villages respectively¹¹.

Materials and Methods

This study was a descriptive cross-sectional study. In order to investigate the concentration of heavy metals of mercury, arsenic, chromium, copper, lead, cadmium and zinc in drinking water networks of urban and rural areas of the Hamadan province which includes 9 counties (Hamedan, Malayer, Bahar, Nahavand, Asadabad, Tuyserkan, Razan, Famenin and Kabodarahang), the cities, plus the villages of each city, a total of 60 samples from

water distribution networks of urban and rural areas was taken based on standard methods.

After transferring the samples to the Pesticides and Heavy Metals Analysis Unit of the Western Water and Wastewater Reference Laboratory (affiliated to the Vice-chancellor for Health, Hamadan University of Medical Sciences, Hamadan, Iran), the intended elements were measured by polarographic method and using a Voltmeter / Polarograph instrument (model 797 VA Computrace, made in Swiss by Metrohm, 2012) according to the company's guidelines and existing standards, and the results were analyzed using Excel software (Ver. 2007) ^{8, 12-15}.

Sampling method in this study was nonprobability sampling and kind of quotient sampling ¹⁶. Based on the number of urban water sources and reservoirs, as well as the number of urban areas in each county separately, a total of 22 urban water samples were prepared, so that all urban water reservoirs were covered. Based on statistical analyzes and according to the laboratory capacity, from each county (except Hamadan) 4 rural water samples from villages with distribution network and 6 samples from Hamedan county, a total of 38 rural water samples were collected and analyzed.

Due to the high cost of the tests and also the high number of heavy metals measured per sample in this study (7 cases per sample) and due to the high number of villages in the province and because of the analysis of the samples were costly and time-consuming, there was no possibility to evaluate and analyze water samples of all villages. So water samples of a limited number of villages (suspected villages or with a history of contamination) were evaluate and analyzed.

Sampling was carried out in summer and on July 2016 by experienced environmental health experts based on the announced timetable. It can be said that the quality of the samples in terms of collection time represents the average quality of the dry period of the water year and the results can be a very good

assessment of the status of heavy metals in drinking water resources of urban and rural areas of the Hamadan province.

Ethical issues

This article was approved by the Ethical Committee (ethical code; Ref: 202) of the Vice-chancellor for Research and Technology, Hamadan University of Medical Sciences.

Results

For each sample, 7 heavy metals including arsenic, mercury, zinc, cadmium, lead, copper and chromium (total), and a total of 420 analyzes, were measured and determined. The results of the analysis of 60 drinking water samples of urban and rural areas from the 9 counties of Hamadan province, with the maximum amount of heavy elements allowed in the national standard of Iran and the WHO guidelines, in the tables 1 and 2 are reflected separately.

The heavy metals average concentration of mercury, arsenic, chromium (total), copper, lead, cadmium and zinc in all samples was 0.565, 6.733, 2.045, 11.637, 2.636, 0.031 and 282.596 mg/L respectively. The concentrations of chromium, copper, cadmium and zinc in all samples were much lower than the maximum allowed in the national standard and the WHO guidelines. The results showed that 86.67 percent of the total samples are allowed samples wick did not have any heavy metals studied in this research or had in concentrations lower than the maximum allowed in the national standard and the WHO guidelines. There were 13.33 percent impermissible samples wick had heavy metals at concentrations higher than the maximum allowed in the national standard and WHO. From 13.33 percent of the impermissible samples, 1.67 percent were mercury-contaminated samples (1 urban sample), 3.33 percent were lead-contaminated samples (1 urban sample and 1 rural sample) and 8.33 percent were arsenic-contaminated (5 rural samples). Contamination of samples with other parameters (chromium, copper, cadmium and zinc) was not observed (tables 1-2).

Table 1: The number of urban and rural samples and the number of unacceptable parameters in each county

| County name | Number of urban samples | Number of urban unacceptable parameters | Number of rural samples | Number of rural unacceptable parameters |
|--------------|-------------------------|---|-------------------------|---|
| Asadabad | 2 | 0 | 4 | 1 ^b |
| Bahar | 2 | 0 | 4 | 0 |
| Tuysarkan | 2 | 0 | 4 | 0 |
| Razan | 2 | 0 | 4 | 0 |
| Famenin | 2 | 0 | 4 | 0 |
| Kabodarahang | 2 | 1 ^a | 4 | 3 ^c |
| Malayer | 2 | 0 | 4 | 1 ^c |
| Nahavand | 2 | 0 | 4 | 1 ^c |
| Hamedan | 6 | 1 ^b | 6 | 0 |

^a Contaminated with mercury.

^b Contaminated with lead.

^c Contaminated with arsenic.

Table 2: The mean and maximum values of the studied heavy metals and their limit values in drinking water, in terms of mg/L (ppb)

| Heavy metals | Mean | Maximum | allowed Maximum | | Total number of unacceptable samples |
|--------------|---------|----------|-------------------|----------------|--------------------------------------|
| | | | National standard | WHO guidelines | |
| Mercury | 0.565 | 6.469 | 6 | 6 | 1 (1.67%) |
| Arsenic | 6.733 | 233.427 | 10 | 10 | 5 (8.33%) |
| Chromium | 2.045 | 11.937 | 50* | 50* | 0 |
| Copper | 11.637 | 285.523 | 2000 | 2000 | 0 |
| Lead | 2.636 | 40.155 | 10 | 10 | 2 (3.33%) |
| Cadmium | 0.031 | 0.186 | 3 | 3 | 0 |
| Zinc | 282.596 | 3635.386 | --- | --- | 0 |

*The values are for total chromium.

Discussion

Due to the importance of heavy metals in water resources especially in drinking water, the concentration of these elements should be continuously monitored and controlled in drinking water. For this purpose, in the present study, drinking water networks of Hamadan province in urban and rural areas were evaluated and measured in terms of heavy metals of arsenic, mercury, zinc, cadmium, lead, copper and chromium. In order to determine the samples contaminated with heavy metals, the obtained concentration of heavy metals was compared with the recommended maximum values in national and international standards.

The results showed that the average concentration of heavy metals (mercury, arsenic, chromium, copper, lead, cadmium and zinc) in all samples of Hamedan province is lower than the

maximum allowed in the national and the WHO standards. From the 22 urban samples, only one sample was contaminated with mercury and one sample contaminated with lead, and all other parameters lacked the values or were much lower than the national standard and the WHO limit values. Contamination of only one urban sample to lead can be due to the use of lead pipes and fittings in a relatively old water distribution network in some parts of the Hamedan city. Contamination of only one other urban sample to mercury can be due to possibility of industrial wastewater diffusion into the groundwater resources of the Kabodarahang city. From 38 rural samples, only one sample was contaminated with lead and 5 samples contaminated with arsenic and no contamination with other studied metals was observed. Contamination of the drinking water of these villages to arsenic and lead can be due to

the geological structures and characteristics of the studied areas.

In a study by Rahmani and et al. in order to the non-cancerous risk assessment of heavy metals on drinking water sources in Hamadan in 2014, 41.46 percent of samples had a lead concentration higher than the WHO and the national standard. Also, chromium and zinc were below the standard limits¹⁷. According to the study of Karimpour and Shariat in 1994, the mean and standard deviation of lead, cadmium and chromium in Hamedan drinking water network were 0.514 (0.281), 0.118 (0.169) and 0.107 (0.105) mg/L¹⁸. In the present study, only 3.33 percent of the samples had a lead concentration higher than the standard limit, and the concentration of chromium, zinc and cadmium in all samples was much lower than the national and international standards. The difference in the results can be explained so that the time interval between previous studies with this study is high and due to changes in the urban texture and replacement and renewal of water distribution network pipes (PVC pipes instead of lead pipes), some elements had a difference in concentration between the present study and the past ones.

Conclusion

Apart from the worrying situation of arsenic amount in samples of a small number of villages, it can be concluded that the status of drinking water sources in terms of heavy metal contamination is favorable in Hamadan province. As it is known, among the rural samples, contamination with arsenic is the most common contamination, of which 3 cases were in the villages of the Kaboudarahang county and the other 2 cases were in the villages of the Malayer and Nahavand counties. A rural sample in Asadabad county has also been contaminated with lead. Due to the lack of polluting industries near the studied villages, contamination of the drinking water of these villages to arsenic and lead can be due to the geological structures and characteristics of the studied areas.

Also, the results of this study showed that the polarographic method is used to measure heavy metals such as mercury, arsenic, chromium,

copper, lead, cadmium and zinc in drinking water. Therefore, the polarographic method can be used to measure heavy metals in drinking water in other laboratories as well.

It is worth noting that in the survey carried out by the investigator, no studies have been done to determine the amount of heavy metals in drinking water in rural areas of Hamedan province. This study is the first study in this field which is the main advantage of this research than to other similar studies. It is hoped that the results of this study will be the criteria for the main policies of the drinking water supply of Hamedan province, including the provincial water safety program, as well as for other researchers to investigate the concentration of heavy metals in other provinces of the country. In this regard, more and better comparisons can be made in Iran.

Due to the presence of excess quantities of the standards for arsenic, lead and mercury in a limited number of samples, to prevent contamination of other water resources of the province and reduce the health effects of heavy metals, the followings were suggested;

1- Annual monitoring and control of heavy metals (especially arsenic, mercury and lead that have a history of contamination) by supplier and supervisor organizations of drinking water in urban drinking water networks, and in particular in rural areas that are less frequently considered, is strongly recommended.

2- Avoiding unchecked groundwater in order to reduce the effects of heavy elements, and implementing educational and promotional programs by relevant organizations.

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Conflict of interests

No conflict of interest has been stated by the authors.

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