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EFFECT OF HEAVY METAL CONTAMINATION IN DRINKING WATER IN CORRELATION WITH PHYSICO-CHEMICAL PROPERTIES: A CASE STUDY OF NORTHERN RAJASTHAN, INDIA

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ABSTRACT

In the present communication, high resolution inductively coupled plasma mass spectroscopy (HR-ICP-MS) technique has been used to analysis the concentration of various heavy metals (Cr, Fe, Cu, Zn, As, Se, Cd, Pb and Th) in 10 drinking water samples collected from the diverse locations from different depths of Bikaner district of Northern Rajasthan, India. The water samples were taken from hand pumps and tube wells. The measured concentrations of Cr, Fe, Cu, Zn, As, Se, Cd, Pb and Th varies from 4 to 48 $\mu g\ l^{-1}$, 84 to 401 $\mu g\ l^{-1}$, 1 to 3 $\mu g\ l^{-1}$, 10 to 88 $\mu g\ l^{-1}$, 1 to 7 $\mu g\ l^{-1}$, 3 to 23 $\mu g\ l^{-1}$, 0.2 to 4 $\mu g\ l^{-1}$, 3 to 32 $\mu g\ l^{-1}$ and 1 to 2 $\mu g\ l^{-1}$ with the mean value of 15 $\mu g\ l^{-1}$, 153 $\mu g\ l^{-1}$, 2 $\mu g\ l^{-1}$, 37 $\mu g\ l^{-1}$, 3 $\mu g\ l^{-1}$, 10 $\mu g\ l^{-1}$, 1 $\mu g\ l^{-1}$, 10 $\mu g\ l^{-1}$ and 1 $\mu g\ l^{-1}$, respectively. The heavy metals have been studied for their health hazards and the concentration is correlated with recommended safe limits as suggested by various protection agencies. Moreover, significant correlation has been observed among the physico-chemical properties of water and heavy metal concentration. The results revel that drinking water contaminated with heavy metals is prone to radiological and chemical threats for inhabitants.

Keywords: Health Hazards, HR-ICP-MS, Physico-Chemical properties, Protection Agencies and Radiological and Chemical Risk.

I. INTRODUCTION

In the 20th century obtaining drinking water has become a serious problem due to the ground water is contaminated by the addition of toxic substance. A number of studies have been conducted in the whole world to determine the concentration of heavy metals in water samples [1-5]. Among heavy metals Zn, As, Cu, Cd and Pb are present throughout the earth crust and are much toxic than other metals. The previous studies reveal that intake of these metals may result chronic damage. From the health point of view the intake of large amount of Zinc can cause anaemia. The intake of Cadmium by food and water can injure the renal, pulmonary, skeletal, testicular and nervous system. Excess of Lead in the human body may lead to cause headache, irritability, abdominal pain and various symptoms related to the nervous system. Large consumption of Arsenic via water may lead to gastrointestinal symptoms, severe disturbances of the cardiovascular and central nervous systems, and eventually death. Large intake of Copper may cause stomach and intestinal distress such as nausea, vomiting, diarrhea and stomach cramps.

In our recent investigation, the activity concentration of natural radionuclides in the soil samples of Bikaner district of Northern Rajasthan, India was found to be higher than MCL [6]. The concentration of natural radionuclides in soil and water is proportional to heavy metal concentration at particular place. In the target region the main sources of drinking water is mainly tube well. The water obtained from the tube well may be unsafe for drinking purposes and very harmful from the health point of view. Hence measurement of heavy metal concentration in water sample of Bikaner district of Northern Rajasthan, India assumes significance. Such study will be helpful in determination whether the water of this district can be used for drinking purpose without posing any health hazard to the inhabitants. However literature survey shows no attempt has been made towards the measurement of heavy metal concentration in water of Bikaner district of Northern Rajasthan, India. In the present study, heavy metal concentration in water from Bikaner district of Marwar region of Northern Rajasthan, India has been investigated systematically.

II. GEOLOGY OF THE AREA

Rajasthan is located in North West of India. It lies between 23°30´ and 30°11´ north latitude and 69°29´ and 78°17´ east longitude. Figure 1 shows the geographic location of Rajasthan in India, as well as the location of the sampling sites.

Bikaner district is located in the North Western part of Rajasthan. It is bounded between 27°11´ and 29°03´ North latitude and 71°54´ and 74°12´ East longitude. In North it is bounded by Sriganganagar and Hanumangarh districts, in East by Chum, in South by Jodhpur and Nagaur districts and West partly by Jaisalmer districts and partly by Pakistan. Like Nagaur district it is also a part of Thar Desert. The soil of Bikaner district is predominantly light texture, weak structure and well drained. The minerals commonly found in this district are lignite, gypsum, clay and limestone.

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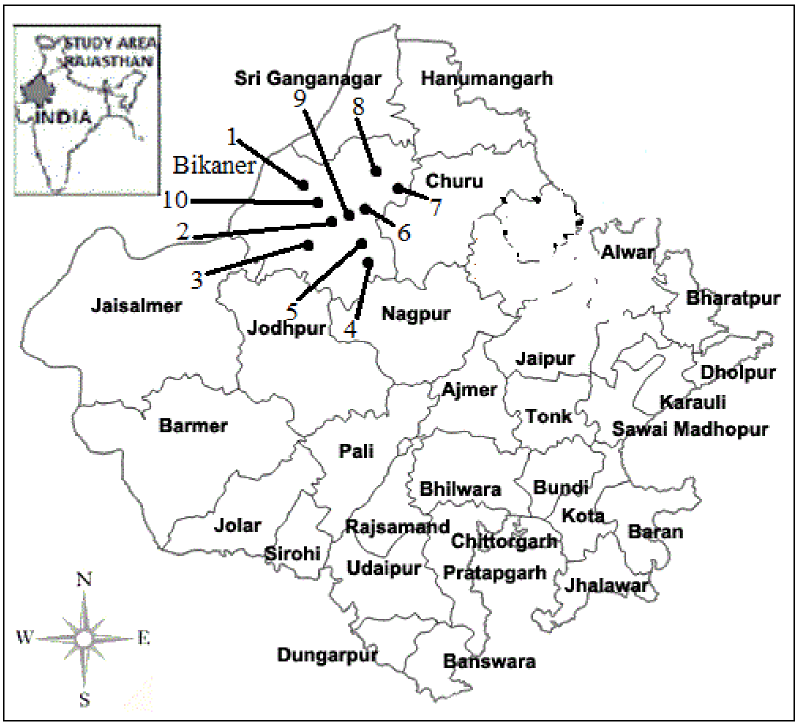

Fig. 1 The map showing the sample locations of Bikaner District

III. MATERIALS AND METHODS

3.1 Sample Collection and Preparation

In order to measure the heavy metal concentration, 10 drinking water samples were collected from the various different locations of Bikaner district of Rajasthan, India on random bases. The samples were collected from tube wells at the various depths. In order to get fresh water, the tube wells were pumped for at least 10 minutes before the samples were taken. 100 ml of water sample was taken from each location and there after filtered by using Whatman filter paper No. 1.

3.2 Physico-Chemical Analysis

Half of the filter water for each sample was used for physico-chemical analysis namely pH, conductance and total dissolved solids (TDS) by using pH/EC bench top meter using standard procedures (ALPHA, 1985).

3.3 HR-ICP-MS Analysis

The heavy metal analysis in half of the water samples was carried out by using high resolution inductively coupled plasma mass spectroscopy (HR-ICP-MS) (Perkin-Elmer Sciex Elan DRC II) technique at National Geophysical Research Institute (NGRI), Hyderabad, India. For heavy metal analysis, NIST 1640a (National Institute of Standards and Technology) was used as a calibration standard and NIST 1643e was used as a reference material. HR-ICP-MS technique takes only 2 to 6 minutes for the analysis of each sample and has excellent precision of about 5% relative standard deviation (RSD). It is a full Multi-elemental technique over a mass range of 3-238 a.m.u. The detail analytical procedure of this method is described by Balaram [7].

IV. RESULTS AND DISCUSSION

The data for various heavy metal concentration (Cr, Fe, Cu, Zn, As, Se, Cd, Pb and Th) in 10 drinking water samples collected from the different locations at different depths of Bikaner district of Northern Rajasthan, India are tabulated in

Table1. The concentration of different heavy mates in groundwater samples from some areas of Bikaner District.

Sr. No.	Sample Location (Village)	Source	Depth (feet)	$^{52}Cr_{24}$	$^{57}Fe_{26}$	$^{63}Cu_{29}$	$^{66}Zn_{30}$	$^{75}As_{33}$	$^{77}Se_{34}$	$^{111}Cd_{48}$	$^{208}Pb_{82}$	$^{232}Th_{90}$
	Bikaner											
1	Pugal	Tube well	400	13	92	2	67	7	8	1.0	14	1
2	Naal	Tube well	375	48	85	3	11	3	17	0.2	4	2
3	Kolayat ji	Tube well	700	7	210	1	10	1	4	0.2	3	1
4	Nokha	Tube well	740	11	84	2	17	2	8	4.0	32	1
5	Deshnok	Tube well	650	9	164	2	20	3	7	0.3	3	1
6	Shri. Dungargarh	Tube well	350	5	130	1	58	2	3	0.2	5	1
7	Kaloo	Tube well	250	27	401	3	88	5	17	1.0	14	2
8	Lunkaransar	Tube well	700	4	100	2	32	3	7	1.9	17	2
9	Bikaner	Tube well	150	23	184	2	40	2	23	0.4	6	1
10	Jaimalsar	Tube well	300	7	84	1	29	1	10	0.8	3	2
	Range		**150-740**	**4-48**	**84-401**	**1-3**	**10-88**	**1-7**	**3-23**	**0.2-4**	**3-32**	**1-3**
	Average		**462**	**15**	**153**	**2**	**37**	**3**	**10**	**1**	**10**	**1**

table1. From which it can be seen that the heavy metal concentration in drinking water samples varies from 4 to 48 μg l^{-1} (Cr), 84 to 401 μg l^{-1} (Fe), 1 to 3 μg l^{-1} (Cu), 10 to 88 μg l^{-1} (Zn), 1 to 7 μg l^{-1} (As), 3 to 23 μg l^{-1} (Se), 0.2 to 4 μg l^{-1} (Cd), 3 to 32 μg l^{-1} (Pb) and 1 to 2 μg l^{-1} (Th) with the mean value of 15 μg l^{-1}, 153 μg l^{-1}, 2 μg l^{-1}, 37 μg l^{-1}, 3 μg l^{-1}, 10 μg l^{-1}, 1 μg l^{-1}, 10 μg $l^{-1}$and 1 μg l^{-1}, respectively. Various protection agencies have recommended the different permissible limits of concentration of heavy metal in drinking water for inhabitants.

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The US Environmental Protection Agency (USEPA, 2011) has recommended 1300 µg l^{-1}, 5 µg l^{-1}, 50 µg l^{-1}, 10 µg l^{-1}, 100 µg l^{-1}, 300 µg l^{-1}, 5000 µg l^{-1} and 15 µg l^{-1} of Cu, Cd, Se, As, Cr, Fe, Zn and Pb respectively in drinking water as a permissible limit. [8]. The concentration of heavy metals in all the investigated drinking water samples lies within the safe limit approved by USEPA. Moreover the safe limits of heavy metal concentration of Cu, Cd, Se, As, Cr, Fe, Zn and Pb in drinking water samples are 1000 µg l^{-1}, 5 µg l^{-1}, 10 µg l^{-1}, 50 µg l^{-1}, 50 µg l^{-1}, 300 µg l^{-1}, 5000 µg l^{-1} and 5 µg l^{-1}, respectively as set by WHO (2008) [9]. The observed values of the concentration of all the heavy metals in our investigated water samples are well below the allowed maximum contamination limit as approved by USEPA except (S4, Lead concentration 32 µg l^{-1} and S8 Lead concentration 17 µg l^{-1}. The concentration of iron in all drinking water samples is found to be higher than the safe limit as recommended by WHO and USEPA except sample S7 (Iron concentration 401 µg l^{-1}). The content of Se in 30% drinking water samples has been found to be higher than the permissible limit as recommended by WHO (S2, selenium concentration 17 µg l^{-1}; S7, selenium concentration 17 µg l^{-1}; S9, selenium concentration 23 µg l^{-1}) . The measured value of lead in 50% water samples is found to be higher than the safe limit as set by WHO expect (S1, lead concentration 14 µg l^{-1}; S4, lead concentration 32 µg l^{-1}; S7, lead concentration 14 µg l^{-1}; S8, lead concentration 17 µg l^{-1} and S9, lead concentration 6 µg l^{-1}). The high concentration of heavy metal has been found in Bikaner district may be due to the geological structure of the district and intensive mining of red marble in this district. Moreover high concentration of heavy metals in drinking water samples may be due to the use of minerals such as lignite, gypsum, clay and limestone which contains high concentration of heavy metals in this district. The concentration of Zn and Cu in present water samples are higher where as Cd and Pb are lower than the reported values for Amritsar district of Punjab [1].

Table 2. Physico-Chemical properties at various locations in Bikaner district of Northern region of Rajasthan.

Sr. No	Sample Location (Village)	TDS (mg l^{-1})	Conductance $m\Omega^{-1}$	pH
	Bikaner			
1	Pugal	430	1.11	7.81
2	Naal	875	2.79	7.52
3	Kolayat ji	315	1.11	7.03
4	Nokha	700	1.75	7.27
5	Deshnok	400	1.21	7.26
6	Shri. Dungargarh	375	2.69	7.37
7	Kaloo	835	2.72	7.68
8	Lunkaransar	672.5	1.66	7.92
9	Bikaner	725	1.68	7.97
10	Jaimalsar	1075	2.1	7.51
	Range	**315-1075**	**1.11-2.79**	**7.03-7.97**
	Average	**640.25**	**1.88**	**7.53**

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From table 2 it is clear that TDS in drinking water samples ranges from 315 to 1075 mg l^{-1} with the mean value of 640.25 mg l^{-1}. The value of TDS in all water samples were found well below than the recommended permissible limit 1000 mg l^{-1} as set by WHO (2008) except (Jaimalsar TDS value 1075 mg l^{-1}. A good positive correlation of Se, Cu and Cr with TDS has been found.

The conductance of drinking water samples ranges from 1.11 to 2.79 mΩ^{-1} with mean value of 1.88 mΩ^{-1} as shown in table 2. The measure value of conductance in 4 water samples were found more than the recommended MCL of 2 mΩ^{-1} as given by WHO (1971) [10]. High values of TDS and conductance may be due to the heavy metals dissolved in investigated water samples.

From table 2 it is clearly seen that the pH of drinking water samples ranges from 7.03 to 7.97 with the mean value of 7.53. pH values of all the drinking water samples were found to be below the permissible limit of 7-8.5 as recommended by WHO (1971) except (Lunkaransar, pH value 7.92 and Bikaner, pH value 7.97). Hence the drinking water samples from these regions are unsafe for drinking purpose.

V. CONCLUSION

The measured concentration of heavy metals in water samples from the some selected regions of Rajasthan are higher than the safe limit recommended by WHO (2011) and USEPA (2011). The conductance of 40% and TDS in one water samples has been found more than the recommended safe limit as given by WHO and a good positive correlation between the concentration of Se, Cu and Cr with TDS in studied water samples has been observed. Except one sampling site the observed pH value in all drinking water samples are found within the MCL limit as approved by WHO. The overall result shows that heavy metal concentration in six drinking water samples cross the MCL as recommended by various protection agencies and therefore unsafe for drinking purposes which is harmful for health point of view.

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