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A Comprehensive Assessment of Heavy Metal Contamination and Their Correlation in Groundwater Samples Collected from Kota District of Northern Rajasthan, India

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ABSTRACT

In the present communication, assessment of various heavy metal (U, Cu, Fe, Co, Zn, Pb, Ni, Cd, As and Al) concentrations in 20 drinking water samples collected from the diverse locations from different divisions of Kota district of Rajasthan, India has been carried out by using LED Fluorimetry and atomic absorption spectroscopy (AAS) technique. The water samples were taken from hand pumps, open wells and tube wells. The measured concentrations of U, Cu, Fe, Co, Zn, Pb, Cd, As, Ni and Al varies from 1.6 to 12.7ppb, 0.003 to 0.033ppm, 0.0 to 0.037ppm, 0.083 to 0.118ppm, 0.123 to 0.143ppm, 0.003 to 0.051ppm, ND, ND, 0.0 to 0.118ppm and ND with the mean value of 5.41ppb, 0.018ppm, 0.013ppm, 0.101ppm, 0.132ppm, 0.017ppm, ND, ND, 0.076ppm and ND, respectively. The heavy metals have been studied for their health hazards and the concentration is correlated with uranium and recommended safe limits as suggested by various protection agencies. According to WHO, USEPA and BIS recommended limit the heavy metal concentrations of all investigated water samples lies below than the permissible limit except for Al, Co and Pb. Moreover, significant weak positive and negative correlation has been observed Uranium with heavy metal concentration. The results revel that drinking water contaminated with heavy metals is prone to radiological and chemical threats for inhabitants. A large population is using groundwater as drinking purposes; hence they are at the high risk of heavy metal toxicity. Therefore, continuous monitoring of heavy metals in ground water must be ensured to aware the consumers to mitigate the health related problems occurred from heavy metals.

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 substances.[1] A number of studies have been conducted in the whole world to determine the concentration of heavy metals in water, soil, leachate solution samples.[2-4] Among heavy metals Zn, As, Cu, Cd and Pb are present throughout the earth crust and are much toxic than other metals.[4-7] Toxic heavy metals in different components of the environment are a severe threat to civilization.[8] Sources may include mining and smelting of ores, electroplating operations, fungicides and pesticides, sewage and sludge from treatment plant etc.[8-12] There are hundreds of sources of heavy metal pollution including industrial waste dumping, burning of fossil fuel, chlor-alkali industries, pulp and paper industries etc.[13-17] These metals may enter into the human body through food, water, air or absorption through the skin when they come in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial or residential settings. Industrial exposure accounts for a common route of exposure for adults.[18-24] Chambal Fertilizers is a well known name for manufacturing fine-grade fertilizers which aid in enhancing the agricultural turnover of the state.[25-27] Soil quality and fertility is largely influenced by controlling factors like climate, soil topography whereas soil erosion is a serious problem for productive agricultural land.[28-30] Through awareness we can maintain proper yield and economy of the production. For this region the present study has been undertaken which could be helpful in assessing the quality of the soil of the area.[31-35] From the health point of view Zinc toxicity can occur in both acute and chronic forms and acute heath effect of high intake of zinc includes vomiting, nausea, abdominal cramps, loss of appetite, headaches and diarrhea.[36-38] Chronic exposure to arsenic in drinking water can cause cancer in the kidney, bladder, lungs and skin.[39-40] The previous studies reveal that intake of these metals may result chronic damage.[41] The intake of Cadmium by food and water can injure the renal, pulmonary, skeletal, testicular and nervous system.[42] Chronic exposure of the lead causes depression, loss of short-term memory or concentration, nausea, fatigue, abdominal pain, headaches, problems with sleep, stupor, anemia and slurred speech. Excess of Lead in the human body may lead to cause headaches, irritability, abdominal pain and various symptoms related to the nervous system.[43-44] Large consumption of Arsenic via water may lead to gastrointestinal symptoms, severe disturbances of the cardiovascular and central nervous systems, and eventually death.[45-50] Large intake of Copper may cause stomach and intestinal distress such as nausea, vomiting, diarrhea and stomach cramps.[51-55] In the present study, assessment of heavy metal concentration and correlation with uranium in water from Kota district of hadoti region of Northern Rajasthan, India has been investigated systematically.

MATERIALS AND METHODS

Study Area

Kota is the third largest city of Rajasthan with an area of 5217 km^2. It is bounded in the north by Bundi, in the east by Baran, in the south by Jhalawar and in the west by Chittorgarh district. Kota is education city of Rajasthan. It is famous for the preparation of IIT-JEE as well as medical exams. Chambal Fertilizers is a well-known name for manufacturing fine grade fertilizers which aid in enhancing the agricultural turnover of the state.

Estimation of Uranium in samples

Uranium analysis was done in LED fluorimeter LF-2 (Quantalase Enterprises Pvt. Ltd., India). Calibrate the fluorimeter with four uranium standards to check the instrument performance and the linear dynamic range. One uranium standard of 500 ppb can be prepared; each time 50 microliter can be added to 5 ml ultrapure water and 0.5 ml buffer, to avoid the error in the preparation of lower ppb level standards. Also, the ppb level standards require fresh preparation before analysis. If the TDS level is low (less than 1500 ppm) in clear drinking water samples, then the water sample can be directly analyzed for uranium using a fluorimeter, no chemical processing is required. Take 5 ml of water sample in a cleaned and dry suprasil quarts cuvette, add 0.5 ml of buffer (fluorescence enhancing agent that is 5 % sodium pyrophosphate solution, pH is almost 7 adjusted using phosphoric acid). Record the fluorescence response of the sample only, in terms of counts, minimum 4 repetitions. Add 50 microliter of 500 ppb uranium standard onto the cuvette that contains the sample and buffer, record the fluorescence response of the first standard added (amount of standard additions depends on the sample fluorescence counts). Again add 50 microliters of 500 ppb uranium standard onto the cuvette and record the fluorescence response. Uranium level in the sample can be analyzed using standard addition method using excel sheet, to avoid matrix effect.

Method of Heavy Metal Analysis

Heavy metals concentrations (Cu, Zn, Co, Ni, Cd, As, Fe, Pb and Al) in groundwater samples were measured using Atomic Absorption Spectrophotometer (thermo scientific iCE 3000 Series) with a precision better than 5%. Atomic Absorption Spectrometer (AAS) is an instrument for estimating the ingestion of follow components introduce in water by estimating the radiation consumed by the compound component of intrigue. This is finished by investigation the spectra created when the sample is energized by radiation. It depends on the Beer-Lambert law standard in which atomic absorption technique measures the vitality as photons of light that are consumed by the sample. A detector measures the wavelengths of light transmitted by the sample, and compares them to the wavelengths which originally passed through the sample. A signal processor then integrates the changes in wavelength absorbed, which appear in the readout as peaks of energy absorption at discrete wavelengths.

RESULTS AND DISCUSSION

The uranium concentration in Kota district ranged from 1.6ppb (village simliya) to 12.7ppb (village dara) the mean, median, mode; standard deviation value was ppb, 5.41ppb, 4.85ppb, 2.6ppb and 3.14ppb in the study area. However, chemical effects may occur after the uptake of large amounts of uranium and these can cause health effects such as kidney disease. Table1 depicts the spatial concentration of different heavy metals in groundwater samples from some areas of some divisions of Kota district. Table 2 shows correlation coefficients and the nature of correlation for uranium measurements with different heavy metals in groundwater samples in the study area. The concentration of copper in water samples of study area ranged from 0.003ppm to 0.0.033ppm. All the water samples were within permissible limit. Copper has been used in agriculture as a fertilizer and in the management of plant diseases. Organic agriculture is very dependent on copper as a fungicide. The range of zinc concentration is from 0.123ppm to 0.143ppm. All water samples were within desirable limit and permissible limits of zinc. Zinc is not detected in some water samples in the study area. Zinc is an essential element and is generally considered to be non-toxic below 5 mg/l. High concentrations (150mg/l or more) may result in vomiting, electrolyte imbalance, nausea, abdominal pain, lethargic conditions and lack of the muscular co-ordination [28]. Most of the iron in soil is found in silicate minerals or iron oxides and hydroxides, forms that are not readily available for plant use. The concentration of iron in water samples in area ranged from 0.0ppm to 0.037ppm. All the water samples were within permissible limit. The concentration of lead in study area varied between 0.003ppm to 0.051ppm. All the samples were within permissible limits. Lead is naturally present in all soils and generally occurs in the range of 15 to 40 parts lead per million parts of soil (ppm), or 15 to 40 milligrams lead per kilogram of soil (mg/kg) [(29-30)]. During monsoon season lead compounds and other compounds leached to the ground water and long time contact of water supply with pipes made of lead causes occurrence of lead in tap water. Instead, this element, along with other elements, such as aluminum (Al), selenium (Se), silicon (Si), sodium (Na), and titanium (Ti), has been considered as a beneficial element for plant growth [(33-34)]. The concentration of cobalt in study area varied between 0.083ppm to 0.118ppm in the study area. All the samples were within permissible limits. Cobalt is an essential nutrient for prokaryotes, human beings, and other mammals but has not been considered an essential micronutrient for plants. The concentration of nickel in the study area ranged from 0.0ppm to 0.118ppm in water samples. Aluminum is present in soils in a variety of forms and bound to the soil constituents, particularly clay particles and organic matter. Aluminum, arsenic and cadmium are not detected in all groundwater samples in the study area. Uranium weak positive correlated with heavy metals viz. Pb, Co that means possibility of same origin of source of pollution and weak negative correlated with heavy metals viz. Cu, Fe, Ni that means no similar source of heavy metals pollution.

Table 1. The spatial concentration of different heavy metals in groundwater samples from some areas of some division of Kota district.

S.No.	Sample Location (Village)	Division	Depth (Feet)	U (ppb)	Cu (mg/l)	Zn (mg/l)	Fe (mg/l)	Pb (mg/l)	Co (mg/l)	Al (mg/l)	Cd (mg/l)	As (mg/l)	Ni (mg/l)
1	Borawas	Ladpura	440	3.8	0.0154	0.1431	0.0198	ND	0.1015	ND	ND	ND	0.1057
2	Mandana	Ladpura	350	2.06	0.0078	ND	0.0097	0.0065	0.1047	ND	ND	ND	0.087
3	Umedpura	Ladpura	300	3.3	0.0337	0.1311	0.0076	0.003	0.1048	ND	ND	ND	0.0925
4	Gopalpura	Ladpura	500	2.6	0.0159	ND	0.0028	0.0081	0.1057	ND	ND	ND	0.0969
5	kalyakheri	Ladpura	750	5.2	ND	ND	0.0036	ND	0.087	ND	ND	ND	0.1063
6	Dara	sangod	250	12.7	ND	ND	0.0094	ND	0.0925	ND	ND	ND	0.0924
7	Rajpura	sangod	230	7.1	ND	ND	0.0041	ND	0.0969	ND	ND	ND	0.0832
8	Bhaluhera	sangod	300	6.1	0.0231	ND	0.0055	0.0094	0.1043	ND	ND	ND	0.0939
9	Rupahera	sangod	140	8.5	ND	0.1308	0.0043	0.0191	0.1058	ND	ND	ND	0.1187
10	Laxmipura	sangod	160	5.3	ND	0.1369	0.001	ND	0.1002	ND	ND	ND	0.087
11	Gadesh ganj	Pipalda	300	3.6	0.03	ND	0.0066	ND	0.1063	ND	ND	ND	0.0925
12	Itava	Pipalda	460	4.5	0.0268	ND	0.033	ND	0.0924	ND	ND	ND	0.0969
13	Pipalda	Pipalda	500	11.2	ND	ND	0.0006	0.0298	0.0832	ND	ND	ND	0.1043
14	Ron	Pipalda	432	7.1	0.002	ND	0.0206	ND	0.0939	ND	ND	ND	0.1058
15	Sanavda	Pipalda	400	2.6		ND	0.0235	0.0512	0.1187	ND	ND	ND	0.1002
16	Gadepan	Digod	500	9.4	0.0133	0.1232	0.0196	ND	0.1032	ND	ND	ND	0.001
17	Simliya	Digod	130	1.6	ND		0.02	ND	0.1043	ND	ND	ND	0.0066
18	Polai kala	Digod	400	1.9	ND	ND	0.0286	ND	0.098	ND	ND	ND	0.033
19	Bargu	Digod	360	3.4	0.0173	0.1301	0.0372	0.0147	0.107	ND	ND	ND	0.0006
20	Tehlala	Digod	400	6.4	ND	ND	0.0113	ND	0.1136	ND	ND	ND	0.0206

Table 2 shows correlation coefficients and the nature of correlation for uranium measurements with different heavy metals in groundwater samples in the study area

S.No.	Heavy Metals	Correlation Coefficient	Nature of Correlation
1	Cu	-0.27	weak negative correlation
2	Zn	0	no correlation
3	Fe	-0.17	weak negative correlation
4	Pb	0.28	weak positive correlation
5	Co	0.17	weak positive correlation
6	Al	0	no correlation
7	Cd	0	no correlation
8	As	0	no correlation
9	Ni	-0.28	weak negative correlation

CONCLUSION

The results of this investigation showed presence of heavy metals and correlated in groundwater samples collected from Kota district of hadoti region. All samples have resulted in U, Cu, Zn, Fe, As, Cd and Al under the permissible limits by BIS/WHO except of some samples of Co, Pb, and Ni in the study area. A weak positive correlation has been observed between Uranium and Pb, Co but there is weak negative correlation between uranium and Cu, Zn, Fe, Cd, As, Ni which may be due to the different origins of both the metals in the area water and soil. Uranium is mostly from the natural earth crust while Pb is through vehicular activities. It appears instructive to regularly monitor water and soil quality to determine alterations in uranium and heavy metals in water of Kota district of hadoti region in Rajasthan for a unique variation with time. Since, lead, cobalt, nickel have not found in higher values, a detailed work of monitoring of trace elements in water may be carried out in future. It is recommended on the basis of the analytical results that to mitigate the entry of heavy metals and other toxic elements in the food chain, the municipal and industrial waste must not be drained into the rivers and other areas such as farmlands without the prior treatment. Use of synthetic chemicals like fertilizer, pesticides and growth hormones etc. must be avoided and shall be replaced by bio-fertilizer at all levels of agriculture. Study of heavy metals in water and soil are further important as metals play a significant role in providing the catalytic pathway for various environmental reactions. The chemistry of uranium is important to understand the leaching from solid soil surface to the aqueous phase. The results of present investigation may be used as baseline for further research on uranium, toxic heavy metals in the soils and leaching of uranium from soil to ground water in Rajasthan. The overall result shows that heavy metal concentration in some drinking water samples cross the MCL as recommended by various protection agencies and therefore unsafe for drinking purposes which is harmful for a health point of view.

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