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Assessment of heavy metal contamination of groundwater in Sikandra forest area of Agra district, U.P. (India)

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Abstract

Heavy metal contamination of groundwater in Sikandra forest Area of Agra district, U.P. (India) was assessed using Flame Atomic Absorption Spectrometry (AAS). Finding revealed that the concentration of heavy metals in the groundwater within the study area ranged from 0.026 to 0.077 mg/L for Pb, 0.016 to 0.046 mg/L for Cd, 0.241 to 0.979 mg/L for Cu, 0.452 to 1.021 mg/L for Mn, 0.005 to 0.052 mg/L for Ni and 0.430 1.036 mg/L for Zn. Findings also showed that Pb, Cd and Mn Concentrations exceeded the World Health Organization's guidelines for drinking-water quality in 25%, 40% and 5% of groundwater samples examined respectively. In view of degree of groundwater contamination in Sikandra forest area of Agra district by Pb and Cd. The study suggest an urgent need for remediation and regular monitoring of the groundwater in Sikandra forest area of Agra district.

Keywords: contamination, groundwater, hand-dug wells, heavy metals, Agra

Introduction

Groundwater is the water located beneath the earth's surface. It constitutes about 95% of global freshwater and it is an important source of drinking water in many regions of the world. The popular belief among the general public that groundwater, unlike surface water is immune to chemical contamination has been disproved by the findings of several investigations which indicated that groundwater is also susceptible to contamination by both organic and inorganic contaminants [1-5]. Although contamination of groundwater could occur by natural processes. Such as geological weathering and dissolution of numerous minerals beneath the earth's surface, the natural concentrations of these contaminants in groundwater are generally low. Nevertheless. Contamination of groundwater by anthropogenic sources such as from agricultural wastewaters. Domestic sewages, mining activities and industrial effluents has been shown to adversely affect the quality of groundwater in many parts of the World [6-8].

Metal contaminants to human health and the environment involves concerns that are different from those associated with organic chemicals. Unlike organic pollutants such as petroleum hydrocarbon and detergent which may visibly build up in the environment, Metals may accumulate to toxic levels without being noticed in the environment. Further more organic chemicals are generally broken down over time in the environment but metals are not and can easily be accumulated and concentrated in living systems. In recent times the exposure of human population to drinking water contaminated with toxic metals has concern among Scientists as well as the general public. This is mainly due to an ever increasing awareness of the negative roles that these toxic metals play in human health. The negative health effects of heavy metals to human beings are well documented in literature [9-12].

Agra is an ancient town and popularly known as Taj city of Uttar Pradesh (India) and has a population about 15.9 Lac and spread area of 121 km [13]. The people of Agra district are depend mainly on ground water for drinking and other domestic purpose. In view of the vulnerability of ground water to toxic metal contamination and the health risk associated which these toxic metals. It is pertinent to assess the extent at which the ground water in Sikandra, Agra has been contaminated with major heavy metals including, lead, cadmium, copper, manganese, nickel and zinc complexes [14-15].

Materials and Methods

The groundwater samples from boreholes and hand-dug wells were randomly collected from twenty sampling location in Sikandra forest area of Agra district of Uttar Pradesh (India). The samples were preserved by adding 0.2% HNO_3 to bring the pH below 2.00 before transporting them to the laboratory [16]. The samples were then digested using acid digestion procedure for total recoverable metals as previously described.

Stock solution containing 1000 mg/L of Pb^{2+}, Cd^{2+}, Cu^{2+}, Mn^{2+}, Ni^{2+} and Zn^{2+} were prepared using analytical grade of $Pb(NO_3)_2$, $Cd(NO_3)_2$, $4H_2O$, $Cu(NO_3)_2$, $3H_2O$, $Mn(NO_3)_2$, $4H_2O$, $Ni(NO_3)_2$, $6H_2O$ and $Zn(NO_3)_2$, $6H_2O$. The working standard solutions with concentrations ranging from 0.05-1.00mg/L for Pb^{2+}, 0.10-1.00 mg/L for Cd^{2+}, 0.10-6.00 mg/L for Cu^{2+}, 0.10-2.00 mg/L for Mn^{2+}, 0.10-1.00 mg/L for Ni^{2+} and 0.10-6.00 mg/L for Zn^{2+} were prepared from the stock solutions as described elsewhere. The standard solutions were later used for external standard calibration [17].

The analytical procedure employed in this study was validated by carrying out a recovery study. This was accomplished by determining the concentrations of Lead, Ladmium, Copper, Manganese, Nickel and Zinc in some of the groundwater samples before and after spiking each of the samples with a predetermined amount of Pb^{2+}, Cd^{2+}, Cu^{2+}, Mn^{2+}, Ni^{2+} and Zn^{2+} [18]. The guideline offered by the International Atomic Energy Agency on the validation of analytical method using recovery study was adopted [19]. The analytical techniques were carried out for the absorbance value of all standard and test solutions were determined in triplicate using MODEL 210 VGP Flame Atomic Absorption Spectrophotometer (AAS).

All statistical analysis were performed with the aid of Microsoft Excel Model 2007. The concentration of heavy metals are reported as mean (±standard deviation) of triplicate determinations Regression analyses were carried out on the result of external standard calibration using least-squares method and the concentrations of heavy metals in each samples were obtained from the resulting equations. The mean concentrations of heavy metals in all the samples were statistically compared with the World Health Organization's guidelines for drinking-water quality using t-test at $\alpha = 0.10$ [20].

Results and Discussion

The results of regression analyses and recovery studies are shown in Table-1. The high values 09DMK PS402 6R1Z4 of coefficients of determination (R^2=0.999 for all metals or R^2=0.998 for Mn) obtained in the regression analyses indicate that there were strong relationship between the concentrations of standard solutions and the absorbance values. The R^2 value of 0.998 for Mn indicates that 99.8% of the variation in Flame Atomic Absorption Spectrophotometer (AAS) signals can be explained by the linear model for Mn while the R^2 values of 0.999 for the remaining heavy metals indicate that 99.9% of the variations in AAS signals can be explained by the linear models for Pb^{2+}, Cd^{2+}, Cu^{2+}, Ni^{2+} and Zn^{2+} [21]. The average present recoveries indicate values ranging from 81.13% for Cd to 97.00% for Zn which are comparable with the levels of accuracy reported in literature [22-23].

Table 1: Coefficient of determinations and average percent recoveries of spiked groundwater samples in Sikandra, Agra (U.P.)

Heavy Metal	R^2 (Coefficients of determination)	% Mean Recovery
Pb	0.999	94.97
Cd	0.999	81.13
Cu	0.999	93.21
Mn	0.998	90.14
Ni	0.999	87.41
Zn	0.999	97.00

Concentrations of heavy metals in all the 20 groundwater samples collected in Sikandra, Forest area of Agra ranged from 0.028 to 0.078 mg/L for Pb 0.018 to 0.044 mg/L for Cd, and 0.241 to 0.979 mg/L for Cu are shown in Table-2. Similarly, the concentration of Mn, Ni and Zn ranged from 0.452-1.02 mg/L, 0.005- 0.005- 052 mg/L and 0.430-1.036 mg/L respectively.

Table 2: Concentrations of heavy metals in groundwater samples from Sikandra, Agra district U.P. (India).

Sample	Pb (mg/L)	Cd (mg/L)	Cu (mg/L)	Mn (mg/L)	Ni (mg/L)	Zn (mg/L)
S_1	0.057±0.033	0.038±0.007*	0.651±0.158	0.852±0.133	0.005±0.003	0.430±0.139
S_2	0.057±0.016	0.040±0.010	0.504±0.124	0.452±0.244	0.025±0.014	0.551±0.160
S_3	0.053±0.028	0.032±0.009	0.057±0.033	0.057±0.033	0.057±0.033	0.057±0.033
S_4	0.060±0.012*	0.027±0.005*	0.733±0.098	0.575±0.162	0.030±0.108	0.809±0.120
S_5	0.042±0.018	0.036±0.005*	0.651±0.320	0.514±0.270	0.014±0.003	0.824±0.146
S_6	0.053±0.018	0.041±0.009*	0.438±0.049	0.683±0.184	0.022±0.007	0.566±0.114
S_7	0.042±0.021	0.030±0.015	0.356±0.173	0.652±0.096	0.028±0.016	0.057±0.033
S_8	0.057±0.033	0.057±0.033	0.057±0.033	0.057±0.033	0.057±0.033	0.581±0.208
S_9	0.042±0.011	0.036±0.008*	0.487±0.098	0.560±0.096	0.025±0.006	0.703±0.205
S_{10}	0.046±0.034	0.018±0.008	0.339±0.197	0.683±0.231	0.032±0.009	0.536±0.091
S_{11}	0.071±0.006*	0.029±0.014	0.307±0.0173	0.006±0.710	0.018±0.012	0.733±0.250
S_{12}	0.042±0.039	0.040±0.003*	0.339±0.130	0.822±0.092*	0.022±0.004	0.884±0.184
S_{13}	0.049±0.006*	0.038±0.015	0.241±0.130	1.021±0.672	0.052±0.028	0.794±0.160
S_{14}	0.053±0.128	0.036±0.014	0.438±0.130	0.914±0.394	0.051±0.011	0.900±0.091
S_{15}	0.067±0.012*	0.044±0.007*	0.372±0.124	0.575±0.175	0.024±0.008	0.824±0.069
S_{16}	0.078±0.027	0.043±0.011	0.569±0.124	0.683±0.211	0.037±0.020	0.036±0.536
S_{17}	0.039±0.006*	0.041±0.012	0.405±0.205	0.975±0.208	0.033±0.009	0.794±0.335
S_{18}	0.042±0.019	0.030±0.012	0.569±0.102	0.057±0.033	0.057±0.033	0.854±0.253
S_{19}	0.056±0.033	0.036±0.008*	0.454±0.075	0.545±0.231	0.030±0.006	0.839±0.052
S_{20}	0.028±0.012	0.41±0.012	0.979±0.177	0.498±0.166	0.028±0.006	0.054±0.157
WHO guideline	0.010	0.003	2.000	0.400	0.070	5.000

*Values marked with asterisks are concentrations that were significantly greater than WHO guidelines for drinking water quality at $p < 0.01$

None of the samples contains Cu, Ni and Zn in concentrations above the WHO maximum permissible levels of 2 mg/L, 0.07 mg/L and 5 mg/L respectively. However, concentrations of Pb in samples S_4, S_{11}, S_{13}, S_{15} and S_{17} exceeds the WHO maximum permissible level of 0.01 mg/L. The data also indicate that samples S_1, S_4, S_5, S_6, S_9, S_{12}, S_{15} and S_{19} contain Cd Concentrations in excess of the 0.003 mg/L maximum permissible level recommended by World Health Organization (WHO). Only sample S12 contains Mn concentrations in excess of the WHO guideline of 0.4 mg/L. Percentages of groundwater samples within Sikandra forest area of Agra district U.P. (India) that contain heavy metal contaminants In excess of WHO guidelines for drinking water quality correspond to 25% for Pb, 40% for Cd and 5% for Mn. The findings presented in this study agree with the reports of similar studies conducted in Sikandra Forest area of Agra district (U.P.), elsewhere which indicate that groundwater resources are being increasingly contaminated by heavy metals beyond WHO guidelines for drinking- water quality [24-26]. Since no mining and industrial activities take place in the study area, the source of heavy metal contamination of the groundwater in Forest area of Sikandara, Agra, (U.P.) may be attributed to weathering and dissolution of minerals in the underground formation. The results generated in this study indicate that some of the groundwater samples contained lead and cadmium concentrations above the World Health Organization's guidelines for drinking-water quality. In view of the magnitude of contamination of groundwater in Forest area of Sikandra, Agra district of Uattar Pradesh (India) by Pb and Cd and the health risk associated with drinking water contaminated with these toxic metals, it is recommended that remediation and regular monitoring program be set up for groundwater system in the Agra town.

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