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Uranium concentration in drinking water samples using the SSNTDs

Harmanjit Singh*, Joga Singh, Surinder Singh and B S Bajwa

Department of Physics, Guru Nanak Dev University,
Amritsar-143 005, Punjab, India

E-mail : harman_edu@rediffmail.com

Abstract : Uranium concentrations in the drinking water samples collected mainly from hand pumps along the Amritsar to Bathinda track are presented. Uranium concentration values in these samples show a wide range of variation depending upon different factors like source, location, depth and local geology *etc.* The observed uranium content in water samples has been found to be varying from 0.9 ± 0.08 to 63 ± 0.21 ppb and even the radon activity in ground water observed in our earlier survey carried out in this area has been found to be increasing from Amritsar towards Bathinda. The higher values were observed from the ground water samples particularly of the areas falling in belt from Zira to Maur towards the Haryana border. The values observed at certain locations are found to be higher than the highest recommended value of 15 ppb [1]. The high uranium concentration observed particularly in certain areas along this track can be attributed due to interaction of ground water with the soil formation of this region and the local subsurface geology of the region.

Keywords : Water, uranium, geology, sources.

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1. Introduction

Uranium often is grouped into a broader classification of contaminants particularly for drinking water, known as the radionuclides. The most common radionuclides found in drinking water include uranium, radon and radium. Uranium is a naturally occurring, radioactive mineral present in certain types of rocks and soils. Water passing through and over rock and soil formations dissolves many compounds and minerals, including uranium and as such varying amounts of it are present in almost all the water sources. Thus, uranium contamination of groundwater comes from the aquifer from which the water is pumped. Also, uranium in groundwater does not move appreciably, so high uranium

* Corresponding Author

levels are associated with the rocks and soils through which a water source is drilled. Uranium contamination can also result from human activities. It can be released into the environment from various activities such as the use of phosphate fertilizers, mining, and combustion from coal and other fuels. Drinking water containing uranium can cause adverse health effects. As a result of non-biodegradable nature, the heavy metals including uranium accumulate in vital human organs and exert progressively growing toxic actions [2]. Most notably, long-term ingestion of uranium and some other heavy metals may increase the risk of kidney damage, cancer and cardiovascular diseases [3,4], whereas the experimental evidence suggests that the respiratory and reproductive systems are also affected by uranium exposure [5]. Public community water supplies must comply with the maximum contaminated limits (MCL) recommended by various National and International agencies like 15 ppb [1], 30 ppb [6], 9 ppb [5] *etc.*

The natural weathering of rocks such as granite dissolves the natural uranium, which goes into ground water. Once getting in to water, uranium does not transfer into the air. Leaching and illuviation are the chemical and physical processes, respectively, by which mineral matter and dissolved solutes are moved downward through the soil profile and get concentrated in discrete zones. Radionuclides can be removed from or concentrated in particular soil horizons by these processes, depending on the pH, dissolved oxygen content, and presence and availability of humic and fluvic acids and other ions in solution. Thus these radioactive contaminants, depending on their chemical properties, may accumulate in drinking water sources at levels of concern. Water systems which are vulnerable to this type of contamination are required to undergo extensive monitoring for radioactive contamination to ensure that their drinking water is safe. The estimation of uranium in water may also be significant for the hydro geochemical prospection for uranium, for health risk assessments and also for mitigation processes.

Keeping in view the above mentioned factors, an attempt has been made to evaluate the uranium content in some drinking water samples. Uranium measurements in ground water have been carried out globally in the recent past [7–11]. In the present study we have employed solid-state nuclear track detectors (SSNTDs) for the microanalysis of uranium content in environmental samples taken from some areas of Punjab state, India. For checking any positive or negative correlation with environmental factors, uranium content of above samples is compared with the factors like local geology, terrestrial radioactivity, source depth, location *etc.*

2. Experimental techniques

For the present study, the uranium content in the drinking water samples has been determined using the fission track registration technique developed by Fleischer and Lovett [12] and recently revised by Ilic and Durrani [13]. In this technique a drop of water of known volume was dried on a circular lexan disk in a dust free atmosphere. A non-volatile

constituent of the water was left over the lexan disk in the form of a thin film. It was then covered with another lexan disk to make it a pair. All such pairs were then packed in an aluminium capsule and irradiated with thermal neutrons in the IC-1 position of the CIRUS Reactor at BARC, Trombay, Mumbai. A blank lexan disk was also irradiated along with the sample disks in order to calculate the background. After irradiation the lexan detectors were etched in 6.25 N NaOH at 70 °C for 25 min. The whole area of the droplet was manually scanned with an optical microscope at a magnification of 400*x*. The uranium concentration *C* (in μg l^{-1}) was determined using the formula [12] :

$$C = (TM)/(VG\sigma N\phi E)$$

where *N* is the Avogadro's number (6.023×10^{23}); *T*, the total number of tracks formed; *V,* the volume of 1 drop (ml); *M*, the atomic weight of uranium isotope ^{238}U; *G* the geometry factor (assumed unity); ϕ, the total thermal neutron dose 2×10^{15} (nvt); σ the fission reaction cross section (4.2×10^{24}) and *E*, the etching efficiency factors, taken as unity for lexan plastic.

3. Results and discussion

The results for uranium estimation in the wide range of drinking water samples collected from different locations belonging to Amritsar, Tarn-Taran, Ferozpur, Faridkot and Bathinda districts of Punjab state, India are reported in Table 1.

The uranium concentration varies from 1.4 ± 0.03 μg l^{-1} in village Naushera Pannuan (Tarn-Taran District) to 42.8 ± 0.27 μg l^{-1} in village Budhlada (Bathinda District), while the average uranium content for the whole belt which has been studied in this investigation (from Balachak (Amritsar) to Budhlada (Bathinda) towards Haryana border) approximates 17.4 μg l^{-1}. The health and environmental protection agencies have recommended safe limit of uranium in drinking water for human beings. United States EPA [6] has recommended 30 μg l^{-1} of uranium in water as safe limit, whereas WHO [1] has recently recommended 15 μg l^{-1} of uranium in water as the safe limit for drinking purpose. However, UNSCEAR [5] recommended safe limit as 9 μg l^{-1} and ICRP [14] has recommended the safe limit as 1.9 μg l^{-1}. These levels are set to represent a concentration that does not result in any significant risk to health over the lifetime drinking of water. Public community water supplies must comply with the maximum contaminated limits (MCL) recommended by these various National and International agencies. The results from present survey reveal that in about 14% of water samples from Amritsar to Bathinda belt of Punjab area, the concentration of uranium lies below the recommended safe limit of 9 μg l^{-1} [5], whereas 86% drinking water samples have shown higher uranium content. The measured uranium content in 59% water samples is below the recommended level of WHO [1] with 41% of the total water samples above this limit (15 ppb). However, when compared with EPA [6] recommended level of 30 μg l^{-1}, the results reveal that, for 82% of all the analyzed samples from the study area, the uranium values are shown below the safe limit while

18% of the total are above this permissible limit. On the other hand, the recorded uranium concentrations in all the water samples from different locations belonging to Amritsar, Tarn-Taran, Ferozpur, Faridkot and Bathinda districts of Punjab are observed to show a wide variation in their values, which may be due to the different sub-soil activities, different source depths *etc.* but no direct correlation has been found from the present data. In general, most drinking water sources have radioactive contaminants at levels that are low enough to be considered a public health concern. However, some parts of the state have, on average, elevated levels of uranium content in ground water compared to the reccomended average values. The water samples collected from hand pumps of villages Budhlada, Bajakhana, Morh, Kot-Fateh and Bathinda city observed to have quite higher concentrations of uranium (upto 42 $\mu g\ l^{-1}$). All these locations fall in Bathinda District situated between 29°33/ and 30°36/ north latitude and 74°38/ and 75°46/ east latitude. The

Table 1. Uranium concentration in water samples in different villages of Tarn-Taran, Amritsar, Ferozepur, Faridkot and Bathinda districts of Punjab state, India.

Sl. No.	Location	Source	Uranium concentration ($\mu g\ l^{-1}$)	Depth (fts.)
1	Budhlada	Hand Pump	42.8 ± 0.27[a]	50
2	Bajakhana	Hand Pump	31.4 ± 0.17	70
3	Morh	Hand Pump	30.1 ± 0.14	65
4	Kot-Fateh	Hand Pump	37.7 ± 0.23	55
5	Bhikhi	Hand Pump	18.4 ± 0.08	60
6	Bathinda	Hand Pump	29.5 ± 0.10	55
7	Faridkot	Hand Pump	16.8 ± 0.07	80
8	Zira	Hand Pump	17.0 ± 0.12	105
9	Tindwan	Hand Pump	23.5 ± 0.14	135
10	Killi Bodla	Hand Pump	12.8 ± 0.10	112
11	Makhu	Hand Pump	13.7± 0.09	140
12	Behak Pachharian	Hand Pump	12.9 ± 0.09	130
13	Harike	Hand Pump	11.4 ± 0.09	65
14	Marhana	Hand Pump	11.1 ± 0.09	80
15	Khara	Hand Pump	10.0 ± 0.08	65
16	Ruri Wala	Hand Pump	8.4 ± 0.08	65
17	Sarhali	Hand Pump	10.8 ± 0.09	80
18	Thathia M.	Hand Pump	9.7 ± 0.09	200
19	N. Pannuan	Hand Pump	1.4 ± 0.03	60
20	Tarn-Taran	Hand Pump	8.7 ± 0.08	70
21	Doburji	Hand Pump	9.6 ± 0.09	75
22	Balachak	Hand Pump	15.9 ± 0.11	120

[a]Statistical counting error : $\sigma = \pm(1/\sqrt{N})$ × uranium content, where N is number of tracks.

gelogical structure of this region is alluvium and the main soils are coarse sandy loam-to-loam, grey or red desert soils. A general trend of growing uranium content in the water samples, particularly from village Makhu to village Budhlada towards Tusham ring complex, Haryana, has been observed, whereas no regular trend and correlation has been observed for the remaining locations. The higher uranium content in ground water samples of Bathinda region may be attributed to the radioactive rich granitic rock formations of Tusham Hills, Bhiwani district of the neighboring state of Haryana, India. It has been reported by Kochher that the bad rocks of Tusham ring complex are underlying the alluvium layer and these deepen towards the Malwa region of Punjab and their effect can be seen upto village Tindwan (near Teh. Zira) where strangely higher uranium content in ground water has been observed (Table 1). In general, this contamination originates naturally and has affected subterranean waters. Also higher than acceptable levels of natural uranium (> 20 $\mu g\ l^{-1}$) in drinking water can be present anywhere where rock formations are enriched in uranium [1]. But the whole area needs further investigation using sophisticated analytical techniques to pin point exactly the reasons for higher uranium concentrations observed in the ground water samples of some particular locations along the studied area. Further Fission track registration technique using nuclear track detectors is found to be reliable and it affords the means for concentration in a large variety of soil-, rocks-, water- *etc.* samples.

4. Conclusion

In general, most drinking water sources have radioactive contaminants at levels that are low enough to be considered a public health concern. However, some parts of the state have, on average, elevated levels of uranium content in ground water compared to the recomended average values. The higher uranium content in ground water samples of Bathinda region may be attributed to the radioactive rich granitic rock formations of Tusham Hills (Bhiwani) of the neighboring state Haryana, India. But the whole area needs further investigation using sophisticated analytical techniques to pin point the exact reasons for higher uranium concentrations observed in some particular locations along the studied area. Further, Fission track registration technique using nuclear track detectors is found to be reliable and it affords the means for concentration in a large variety of soil-, rocks-, water- *etc.* samples.

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