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Measurements of Natural Radioactivity in Some Water and Soil Samples of Punjab State, India

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Key Words

Nuclear track · Uranium · Radon · Chemical etching · Lexan

Abstract

In the present investigation a nuclear track-etch technique using Solid State Nuclear Track Detectors was used to estimate the trace uranium concentration in water and soil samples collected from different sources and locations of the Amritsar and Bathinda cities of Punjab. The uranium concentration in the water samples collected from Amritsar was found to vary from 3.17 to 4.19 $\mu g \cdot L^{-1}$ and in the Bathinda city it varied between 4.28 and 16.48 $\mu g \cdot L^{-1}$. A lake sample, collected from the NFL water works site in Bathinda city had a uranium content of only 1.21 $\mu g \cdot L^{-1}$ which was several times lower than those samples collected from hand-pumps and tube-wells from this area. The uranium concentration in soil samples of Amritsar city was found to vary from 0.61 to 1.27 ppm. In addition, soil samples from other cities of the Punjab were analysed using the Gamma-spectroscopic technique to determine ^{226}Ra, ^{232}Th and ^{40}K concentrations in soil. The average values of the concentration of these elements was found to be 43.9, 55.9 and 101.7 $Bq \cdot kg^{-1}$ respectively.

Introduction

Uranium and thorium (^{232}Th) are two naturally occurring radioactive elements in the general environment and these isotopes are the heaviest naturally occurring radio-nuclides. Along with their radioactive decay products, they are transferred to water and plants from soil and then to humans through ingestion routes. Uranium is the heaviest naturally occurring element and is commonly present in water and soil in trace quantities. In general, it is difficult to analyse directly such small quantities of uranium in water by routine chemical means. However, the fission track registration technique is easier, less expensive and equally accurate compared to many other existing methods [1]. The determination of uranium content is of considerable interest to geologists, oceanographers, nuclear scientists and health physicists for various reasons, viz. searching for new fuel in sea water, developing new techniques for uranium prospecting in the case of river water and also,

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collecting information for public health services in the case of mineral and tap water. Knowledge of uranium levels in water and soil samples is also important for environmental studies, viz. ecological changes brought about by uranium due to its absorption in plants and also for the assessment of its oral toxicity and effects on the human kidney [2–4]. From the health hazard point of view, there is a concern for radioactive nuclides entering the human body mainly through food and water, which contain trace quantities of uranium. In India, estimations of uranium concentration in water and soil samples have been carried out by many workers [5–9] with the aim of either hydrogeochemical prospecting for uranium or for health risk assessments.

Methods

Uranium Estimation in Water Using a Particle Track Etch Technique

The particle track etch technique has been used for uranium estimation in water samples [10]. In this technique, a drop (0.05 cc) of water was dried on a Lexan® (polycarbonate resin) detector disc. The residue left behind was covered with another Lexan detector of the same size and the two were irradiated with a known dose of thermal neutrons from a nuclear reactor. The induced fission tracks caused by ^{235}U were revealed in the Lexan disc after etching with 6.25 N NaOH at 60°C for 25 min. The track density was counted using an optical microscope and the uranium concentration (C) was determined using the formula

$$C = TM/(VGNsfE)$$

where T is the total number of tracks formed; M is the atomic weight of the uranium isotope ^{238}U; V is the volume of one drop (cc); G is the the geometry factor; N is the Avagadro number (6.023×10^{23}); s is the fission cross section (4.2×10^{-24} cm^2); f is the total thermal neutron dose of 2×10^{15}(nvt); E is the the etching efficiency factor for Lexan plastic.

Uranium Estimation in Soil Using the Homogenised Fission-track Technique

For uranium estimation in soil, the Homogenised Fission-track Technique was used [11]. In this method, an accurately weighed powder sample of the material was mixed homogeneously with uranium-free methyl cellulose powder as a binding material in the ratio of 1:2 by weight. From 150 mg of this mixture a thin pellet of about 1 mm thickness and 1.3 cm diameter was made using a pellet-making machine in our Solid State Nuclear Track Detector (SSNTD) laboratory. Pellets of standard glass of known uranium concentration were also made in an exactly similar manner. Each of these pellets were sandwiched between a pair of plastic track detectors (Lexan). All the pelleted samples and the standard were enclosed in an aluminium can and sent to the [Baba Atomic Research Centre] BARC for irradiation with the known thermal neutron dose. After irradiation, the Lexan detectors were etched as before and scanned. A comparison of induced fission track density which was recorded in unknown and standard pellets gave the uranium content in the sample, determined by the relation:

$$C_{un}(U) = C_{st}(U) \cdot \rho_{un}/\rho_{st}$$

where $C_{un}(U)$ is the uranium concentration in an unknown sample; $C_{st}(U)$ is the uranium concentration in a standard sample; ρ_{un} is the track density in an unknown sample; ρ_{st} is the track density in a standard sample.

Results and Discussion

The values of the uranium concentrations in the water samples collected from different locations in the cities of Amritsar and Bathinda are reported in Table 1. It can be seen that the uranium content in the drinking water samples varies from source to source and also with location. It was also observed that the water samples collected from the hand pumps and the tube wells, situated around the thermal power plant of Bathinda city, showed higher concentrations of uranium compared to the water samples collected from Amritsar city. The water samples Bl–B6, which were collected from Bathinda city and the surrounding villages, showed much higher uranium content varying from 4.28 ± 0.07 to $16.61 \pm 0.13\ \mu g \cdot L^{-1}$, compared to the water samples from Amritsar city which varied between 3.18 ± 0.06 and $4.19 \pm 0.06\ \mu g \cdot L^{-1}$. The tube-well water samples B3 and B4 collected from Bathinda city showed much higher concentrations at 15.91 ± 0.12 and $16.61 \pm 0.13\ \mu g \cdot L^{-1}$ respectively, as compared to the tube-well samples Al–A3 from Amritsar city which

Table 1. Uranium concentration in water samples of Amritsar and Bathinda cities using particle track etch technique

Sample No.	Location	Depth (ft)	Water-source	U – conc. ($\mu g \cdot L^{-1}$)
AMRITSAR				
A1	Jallianwala Bagh	80	Tubewell	3.54 ± 0.06*
A2	Tarn – Taran Road	100	Tubewell	3.77 ± 0.06*
A3	University Campus	250	Tubewell	3.18 ± 0.06*
A4	Chehharta Sahib	40	Handpump	4.19 ± 0.06*
BATHINDA				
B1′	NFL water works	–	Lake	1.21 ± 0.03*
B3	Thermal-Kachi, Colony	200	Tubewell	15.91 ± 0.12*
B4	Thermal-Pucka, Colony	275	Tubewell	16.61 ± 0.13*
B1	Adarsh Nagar, NFL road	30	Handpump	4.28 ± 0.07*
B2	Thermal-Kachi, Colony	30	Handpump	9.92 ± 0.10*
B5	Ramana village	30	Handpump	9.75 ± 0.10*
B6	Joga Nand village	120	Handpump	5.65 ± 0.07*

*Statistical counting error – 1σ; Volume of water taken – 0.05 cc (1 drop) (1 cc of water contains 20 drops).

Table 2. Estimated uranium concentration in soil samples of different locations of Amritsar city using track etch technique

Sample No.	Sample Location	Depth (cm)	Average Track Density Per Graticule	Uranium Content (ppm)
A1	Jallianwala Bagh	30	1.56	0.71 ± 0.02*
A2	Tarn-Taran Road	30	1.79	0.81 ± 0.02*
A3	Dashmesh Avenue, G.T. Road	30	2.79	1.27 ± 0.03*
A4	Chheharta Sahib	30	1.32	0.61 ± 0.02*
A5	University Campus	30	2.32	1.05 ± 0.02*

*Statistical counting error = 1σ.

varied from 3.18 ± 0.06 to $3.77 \pm 0.06\ \mu g \cdot L^{-1}$. The water sample collected from the lake of the NFL water works (B1′) in Bathinda city showed the lowest uranium content of only $1.21 \pm 0.03\ \mu g \cdot L^{-1}$, which might be due to the fact that canal water flows into the lake to maintain its level.

The results of the fission-track analysis for the uranium concentration of soil samples collected from different parts of Amritsar city are tabulated in Table 2. The uranium concentration in these samples were found to vary from 0.61 to 1.27 ppm. The low levels of uranium found in these samples were considered quite normal, as it is well known that the level of this trace element in soils in general is less than 2 ppm. So, no large amount of uranium was observed in the soil samples collected from Amritsar city. In fact, the observed values of uranium content in these soil samples were very much lower than those reported for soil samples collected from the uranium mineralised zones of Himachal Pradesh which have a high background of natural radioactivity. Virk [9] has reported quite high uranium concentrations in some soil samples from the Samurkalan and Ramada villages of Hamirpur district, Himachal Pradesh at 116.1 and 117.9 ppm, respectively, showing the high uranium content in the sediments of the zones where these villages are situated. The very low levels found in the soil samples of Amritsar city reflect the fact that no uranium occurrences have been reported in or around Amritsar or indeed in the Punjab state even though this is adjacent to Himachal Pradesh.

Measurements of the concentrations of the natural radio-nuclides ^{226}Ra, ^{232}Th and ^{40}K in soil samples from different cites of Punjab using the Gamma-spectroscopic technique are summarised in Table 3. ^{226}Ra is a product from the radioactive decay of ^{238}U while ^{232}Th and ^{40}K, like ^{238}U, are natural isotopes at the top of their decay series. The average values of the concentration of these elements were found to be 43.9, 55.9 and 101.7 $Bq \cdot kg^{-1}$, respectively. Though the samples were collected from

Table 3. Natural radioactivity levels in the soils of Punjab state.

S. No.	Location (District)	Concentration (Bg/kg)			Ra_{eq} Activity ($Bq \cdot kg^{-1}$)
		^{226}Ra	^{232}Th	^{40}K	
1.	Patiala	34.7	10.6	59.6	54.4
2.	Bathinda	18.6	36.3	68.0	75.7
3.	Bathinda	23.4	41.7	81.4	89.3
4.	Sangrur	46.8	79.5	133.0	170.7
5.	Sangrur	28.8	30.1	79.1	77.9
6.	Moga	34.6	BDL	48.8	38.4*
7.	Moga	45.9	11.6	95.1	69.8
8.	Hoshiarpur	49.1	68.1	86.7	153.2
9.	Amritsar	68.9	94.2	154.1	215.5
10.	Amritsar	68.7	83.2	160.1	200.0
11.	Gurdaspur	59.0	73.9	104.6	172.7
12.	Gurdaspur	48.5	86.0	150.0	183.0
	Average	**43.9**	**55.9**	**101.7**	**125.1**

BDL – below detection limit; * taking ^{232}Th to be zero.

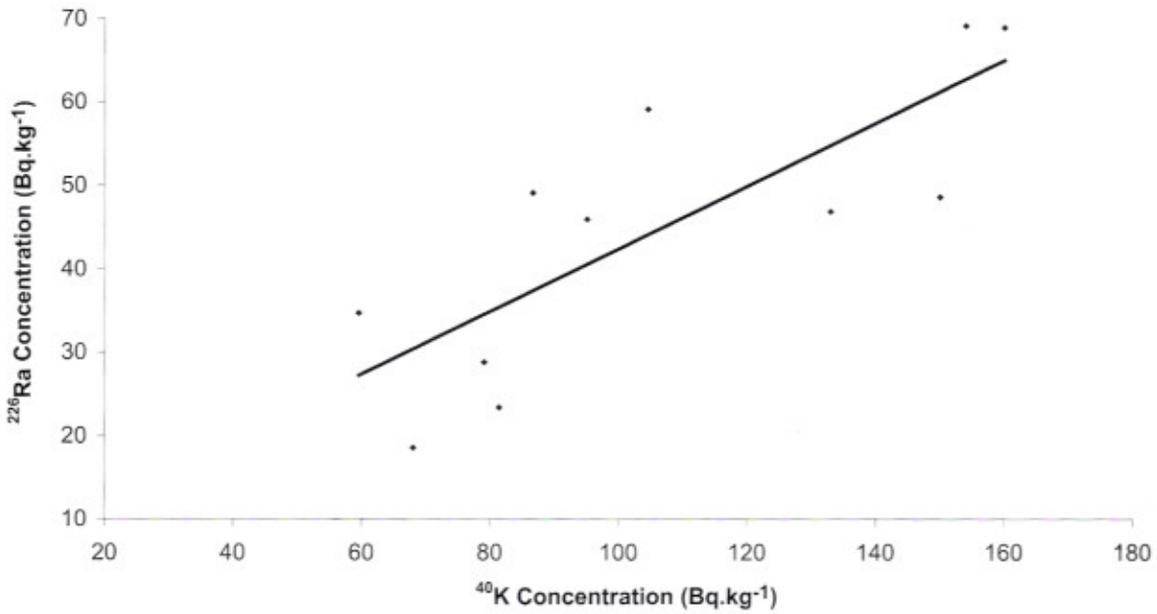

Fig. 1. Correlations between ^{226}Ra and ^{40}K concentration in soil.

about forty locations in the state, only a few could be analysed as the gamma spectrometry system was not available at our place of work and we had to depend for the analysis on borrowed time at the Defence laboratory, Jodhpur. The concentration of ^{226}Ra in the state varies from a minimum value of $18.6\,Bq \cdot kg^{-1}$ in Bathinda district to a maximum value of $68.9\,Bq \cdot kg^{-1}$ in Amritsar district. Similarly, the ^{232}Th concentration varied from a minimum of $10.6\,Bq \cdot kg^{-1}$ for Patiala district to a maximum of $94.2\,Bq \cdot kg^{-1}$ for Amritsar district. In one of the samples from Moga district, the ^{232}Th activity was found to be below the lower detection limit of the system. The activity concentration of ^{40}K varied from $48.8\,Bq \cdot kg^{-1}$ for Moga district to $160.1\,Bq \cdot kg^{-1}$ for Amritsar district. A study of the correlation between the concentrations of ^{226}Ra and ^{40}K and ^{232}Th and ^{40}K, shows reasonably good correlation in both cases (Figures 1 and 2). The correlation coefficient between the concentrations of ^{226}Ra and ^{40}K was calculated to be 0.80 while that between the concentration of ^{232}Th and

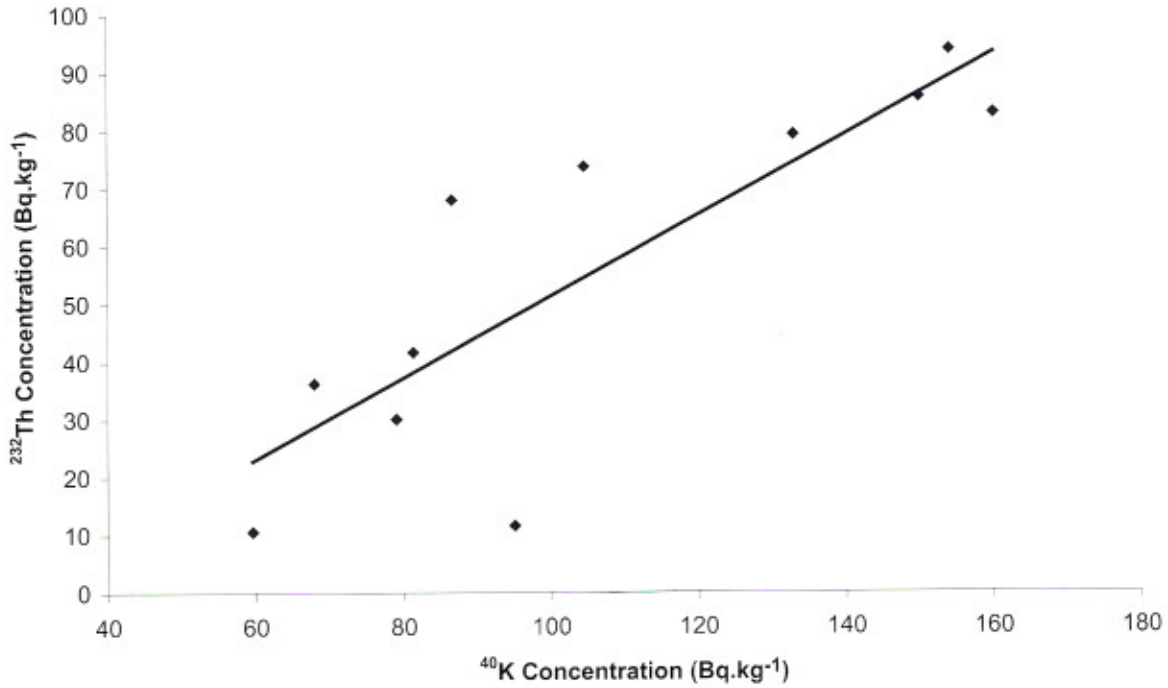

Fig. 2. Correlation between ^{232}Th and ^{40}K concentrations in soil.

^{40}K was 0.84. However, for any conclusive evidence for the correlation between these quantities, a larger number of samples needs to be studied. When comparing the specific radio-activities of soil from different districts of Punjab, the value of specific radioactivity was found to be highest for Amritsar district with two samples from this district reporting the values of 200 and 215.5 Bq · kg^{-1}, whereas the lowest value of 38.4 Bq · kg^{-1} was for one sample from Moga district in which the concentration of ^{232}Th was found to be less than the lower detection limit of the system.

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