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Advances in Applied Science Research, 2011, 2 (3):186-190

ISSN: 0976-8610
CODEN (USA): AASRFC

Environmental radioactivity: A case study of Punjab, India

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ABSTRACT

The natural radioactivity present in our environment is a major health hazard for human populations. Many health related malignancies in humans have been attributed to the exposure to natural radioactivity. It is in this context that a series of surveys were undertaken in different areas of Punjab state of India to assess the levels of natural radioactivity in air, soil and drinking water. In the present paper we report the results of measurements of dissolved radon in drinking water in some areas of the state along with the summary of results of earlier surveys so as to present a holistic picture of radioactive environment in the state of Punjab, India. The inhalation dose rate and radioactivity in soil and water samples has been found to be within permissible limits.

Keywords : Radiation, dose, RAD7, radon, uranium.

INTRODUCTION

Human beings are being continuously exposed to ionizing radiations. The main source of these ionising radiations are the radioactive elements present in the earth's crust i.e uranium and thorium. Radon and its isotopes, being gaseous elements have a very special place among all radioactive elements. Radon and its isotopes along with their progeny account for more that 50% of the total annual effective dose to humans [1]. It is a well established fact radon, when present in high concentrations is a causative agent of lung cancer [2-4]. A case control study from Sweden also indicates radon as a important risk factor for lung cancer in general population [5]. Studies relating radon to other cancer such as kidney and malignant melanoma have also been reported [6]. In the light of these facts a large no. of radon surveys have been reported from various parts of the world [7-9]. In India also, some local surveys have been carried out in different parts of the country, but not much data was available for the state of Punjab. With this in view, a comprehensive survey was undertaken under the Department of Atomic Energy (DAE) project to measure air borne distribution of radon and thoron. Simultaneously we carried out the measurements for distribution of radioactivity in soil. The complement the above data,

the present survey of drinking water was undertaken. Also, some recent reports have appeared in local newspapers about increasing number of cases of cancer and genetic deformities in newly born babies. In this context the present data can be useful in ascertaining the exact cause of these diseases.

The state of Punjab lies in northern plains of India. The area forms a part of Indo-Gangetic alluvial plane and is more or less flat. All of the area is covered by Indo-Gangetic alluvium. The lithology of the area is not uniform. The state is poor as regards mineral wealth and no large scale mineralization of any kind has been reported.

MATERIALS AND METHODS

Experimental technique

While the plastic detector LR-115 was used to measure radon in air and gamma spectrometry was used to analyse the soil samples, the solid state alpha detector based RAD7 (Durridge Co. USA) has been used to measure the concentration of dissolved radon in water. The RAD7 is a continuous radon monitor based on the alpha spectrometry technique. It uses a solid state semiconductor detector that directly converts an alpha radiation to electrical signal. Its accessory RAD H_2O is used to measure the radon in water over a wide range of concentration. It is a portable and battery operated instrument and measurement is fast and accurate. The RAD H_2O uses a standard, pre-calibrated degassing system and which give a direct reading of the radon concentration in the water sample, itself. The method is, in fact, a special case of the grab sampling. A schematic diagram of RAD H_2O is shown in figure 1.

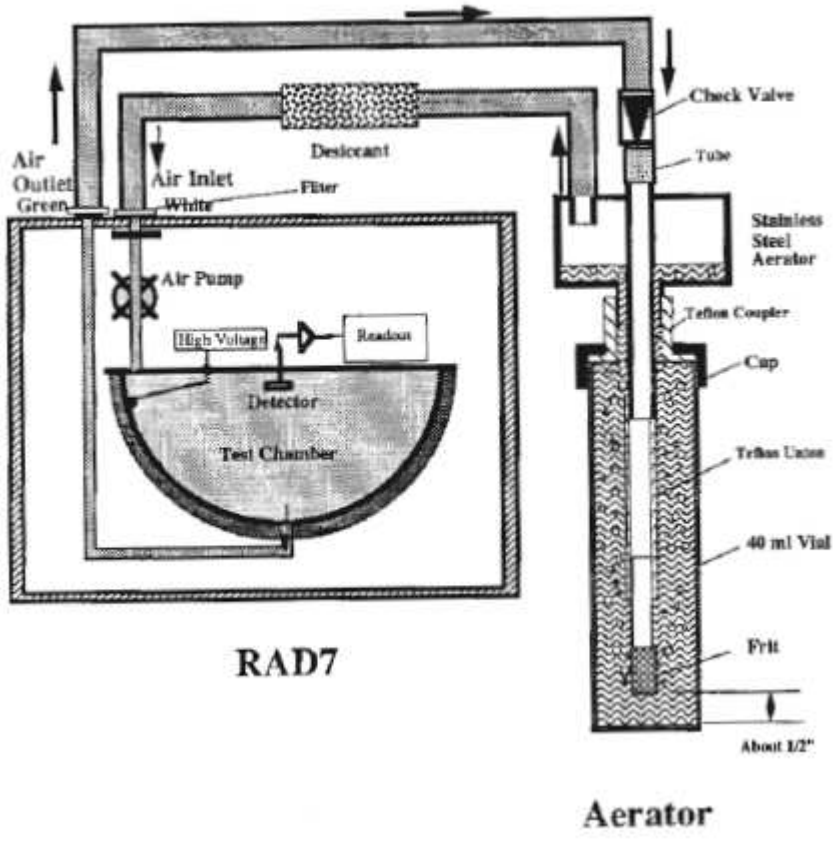

Fig. 1.

The RAD-H_2O method employs a closed loop aeration scheme in which the air is re circulates through the water sample collected in vial and the radon is continuously extracted until a state of equilibrium develops. The RAD-H_2O system reaches this state of equilibrium within about 5 minutes, after which no more radon can be extracted from the water. The extracted radon is pumped in the test chamber the detector measures the radon concentration.

The representative water samples were collected from the study areas in 250 ml vials using the standard technique, taking care that the collected water samples is not exposed to atmospheric air before sealing. After making the measurements, the measured values were corrected to account for the time gap between the collection of the sample and analysis.

RESULTS AND DISCUSSION

The results of measurements of radon in water in are summarized in table 1. A total of 52 water samples from four districts were analysed. The concentration of radon in drinking water in Jalandhar district varies from a minimum value of 1226 Bq/m^3 to a maximum value of 7240 Bq/m^3 with average of 3323 Bq/m^3. In Amritsar district the value varies from a minimum of 2069 Bq/m^3 to a maximum of 6340 Bq/m^3 with an average value of 3789 Bq/m^3. In Bathinda district minimum value of radon in drinking water is found to be 1418 Bq/m^3 while the maximum value is 11044 Bq/m^3 with an average of 4233 Bq/m^3. For Gurdaspur district, the minimum value is 5190 Bq/m^3 while the maximum is 8220 Bq/m^3 with an average value of 7210 Bq/m^3. Among all the district covered under this survey, the maximum average value is for Bathinda district while the highest value in a sample has also been measured from Bathinda district. The maximum limit of concentration of radon in water proposed by US Environmental Protection Agency (USEPA) is 11000 Bq/m^3 which corresponds to a life time cancer risk of about 1 in 10^4 [10]. So only for one sample from Bathinda District, the measured value crosses the maximum limit of EPA while for all other samples, the measured values are less than the maximum limit. The major risk of radon dissolved in water comes from its contribution to indoor to indoor air. It is estimated that for every 10000 pCi/l of radon in water, about 1 pCi/l is released into air [11].

The results of the survey, conducted earlier, to assess the quality of indoor air for its radon/ thoron contents have been summarized in table no. 2. It is fairly established that contribution of indoor thoron to inhalation dose is significant despite its short half life. Also it is established that radioactive progenies of radon and thoron are major contributors to total inhalation dose. So the present survey was the first large scale survey to be conducted in the state of Punjab to simultaneously measure levels of radon, thoron and their equilibrium factors in dwellings. Data for each dwellings was collected for a period of one year in form of quarterly cycles. For the district of Amritsar, the concentration of radon varies from a minimum value of 8.9 Bq/m^3 to a maximum value of 35.4 Bq/$m^3$with an average value of 19.2 Bq/m^3. The concentration of thoron varies from a minimum value of 1.9 Bq/m^3 to a maximum value of 35.0 Bq/m^3 with an average value of 9.5 Bq/m^3. The variation of equilibrium factor for radon is from a minimum of 0.05 to a maximum of 0.53 with an average value of 0.35. Similarly the equilibrium factor for thoron varies from a minimum value of 0.01 to a maximum value of 0.24 with an average of 0.14. Inhalation dose rate varies from a minimum of 0.01 µSv/h to a maximum of 0.29 µSv/h with an average of 0.11 µSv/h.

For the district of Bathinda, the variation of radon is from a minimum value of 11.7 Bq/m^3 to a maximum value of 43.5 Bq/$m^3$with an average value of 23.9 Bq/m^3. The concentration of thoron varies from a minimum value of 2.3 Bq/m^3 to a maximum value of 46.7 Bq/m^3 with an average

value of 17.5 Bq/m^3. The variation of equilibrium factor for radon is from a minimum of 0.07 to a maximum of 0.52 with an average value of 0.30. Similarly the equilibrium factor for thoron varies from a minimum value of 0.01 to a maximum value of 0.23 with an average of 0.10. Inhalation dose rate varies from a minimum of 0.03 µSv/h to a maximum of 0.16 µSv/h with an average of 0.08 µSv/h.

For Gurdaspur district, the variation of radon is from a minimum value of 8.8 Bq/m^3 to a maximum value of 42.8 Bq/$m^3$with an average value of 19.9 Bq/m^3. The concentration of thoron varies from a minimum value of 1.4 Bq/m^3 to a maximum value of 19.6 Bq/m^3 with an average value of 10.1 Bq/m^3. The variation of equilibrium factor for radon is from a minimum of 0.17 to a maximum of 0.53 with an average value of 0.40. Similarly the equilibrium factor for thoron varies from a minimum value of 0.02 to a maximum value of 0.24 with an average of 0.15. Inhalation dose rate varies from a minimum of 0.02 µSv/h to a maximum of 0.45 µSv/h with an average of 0.11 µSv/h.

From the values reported above, it is clear that the concentration of radon, thoron and dose rate for all the dwellings are well below the permissible limits prescribed by International Commission on Radiological Protection. ICRP recommends an action level of 200 Bq/m^3 for radon and annual effective dose of 3-10 mSv [12].

The results of measurements of natural radioactivity of soil in three districts are summarized in table 3. Comparing these values with the data for other parts of the world, the activity concentrations of ^{226}Ra and ^{40}K are lower than the values reported while the activity concentration of ^{232}Th is comparable with the world wide data [13][14][15]. From the table it is clear that Radium equivalent activity (Ra_{eq}) activity is maximum for Amritsar district and minimum for Bathinda district. The values of radium equivalent activity in all districts are less than the acceptable safe limit of 370 Bq/Kg [16].

Table 1. Concentration of radon in drinking water in various districts

Name of District	No. of Samples	Minimum Value (Bq/m^3)	Maximum Value (Bq/m^3)	Average (Bq/m^3)
Jalandhar	16	1226	7240	3323
Amritsar	15	2069	6340	3789
Bathinda	14	1418	11044	4233
Gurdaspur	12	5190	8220	7210

Table 2. Radon/thoron concentration levels, equilibrium factors and dose rates in dwellings in various districts

Name of District	No. of Samples	Radon (Bq/m^3) Min. Max. Average	Thoron (Bq/m^3) Min. Max. Average	F_R Min. Max. Average	F_T Min. Max. Average	D (µSv/h) Min. Max. Average
Amritsar	19	8.9 35.4 19.2	1.9 35.0 9.5	0.05 0.53 0.35	0.01 0.24 0.14	0.01 0.29 0.11
Bathinda	09	11.7 43.5 23.9	2.3 46.7 17.5	0.07 0.52 0.30	0.01 0.23 0.10	0.03 0.16 0.08
Gurdaspur	25	8.8 42.8 19.9	1.4 19.6 10.1	0.17 0.53 0.40	0.02 0.24 0.15	0.02 0.45 0.11

** Data for Jalandhar district was not available*
F_R – Equilibrium factor for radon, F_T – Equilibrium factor for thoron,
D – Inhalation dose rate

Table 3. Natural radioactivity levels in soils of various districts

Name of District	Concentration (Bq/kg)			Ra_{eq} activity (Bq/kg)
	^{226}Ra	^{232}Th	^{40}K	
Amritsar	68.8	88.7	157.1	207.8
Bathinda	21.0	39.0	74.7	82.5
Gurdaspur	53.8	80.0	145.3	177.9

** Data for Jalandhar district was not available*

CONCLUSION

The values of natural radioactivity measured in air, soil and water in various districts covered in the present survey is within the permissible limits prescribed by regulatory bodies. Regarding the increased number of cancer cases being reported from Bathinda and adjoining areas, detailed and more extensive surveys need to be carried out and role of other toxic elements and pesticides need to be probed.

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