Radon monitoring in groundwater of some areas of Himachal Pradesh and Punjab states, India

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Radon measurements have been carried out in groundwater of Himachal Pradesh and Punjab states, India. Radon concentration values in potable water show a wide range of variation from source to source and from place to place. Generally, radon concentration values in thermal springs groundwater have been found to be higher than the values from other sources.

Introduction

Radiation is a natural part of the environment in which we live. All people receive exposure from naturally occurring radioactivity in soil, water, air and food. The largest fraction of the natural radiation exposure we receive comes from a radioactive gas, radon. Radon monitoring has become a global phenomenon due to its health hazard. More than 55% radiation dose delivered to human kind on this globe from all natural sources is due to radon alone. Radon is emitted from uranium, a naturally occurring mineral in rocks and soil; thus, radon is present virtually everywhere on the earth, but particularly over land. Although it cannot be detected by a person's senses, radon and its radioactive by-products are a health concern because they can cause lung cancer when inhaled over long durations.

Radon gas is continuously generated within the rock strata as an intermediate decay product of the U/Th radioactive series and its emanation is a well understood phenomenon. Its migration from the earth's crust to atmosphere is a complex phenomenon studied by various authors.[1–3] During recent years, radon monitoring has become a global phenomenon due to its health hazard inside the dwellings.[4–6] Radon measurements have been carried out in soil-gas, groundwater and even in the air by our group.[7–11]

Most of the radon that enters a building comes directly from soil that is in contact with or beneath the basement or foundation. Radon is also found in well water and will enter a home whenever this water is used. In many situations such as showering, washing clothes, and flushing toilets, radon is released from the water and mixes with the indoor air. Thus, radon from water contributes to the total inhalation risk associated with radon in indoor air. In addition to this, drinking water contains dissolved radon and the radiation emitted by radon and its radioactive decay products is exposed to sensitive cells in the stomach as well as other organs once it is absorbed into the bloodstream. Approximately half of the drinking water in the India comes from ground water that is tapped by wells. Underground, this water often moves through rock containing natural uranium that releases radon to the water. Water from wells normally has much higher concentrations of radon than does surface water such as lakes and streams.

Radon gas is partially soluble in water in the sense that the gas is transported through water in the house. The mole fraction solubility of radon in water is 2.3×10^{-4} at 15 °C and it is produced mainly by leaching of hexavalent uranium present in traces. The solubility co-efficient of radon in water is 0.254 at 20 °C and its variation with temperature is given by the following equation:[12]

$$\alpha = 0.1057 \pm 0.405 \exp(-0.0502t)$$

where t is water temperature in °C. The solubility of radon increases with pressure and decreases with temperature like most other gases. When the groundwater is pumped out into the storage facility, the dissolved gases in water dissipate and escape into the air under atmospheric pressure. Meteorological parameters have influence on the emanation of radon in the soil and groundwater. The temperature, pressure and wind velocity have positive correlation with radon while humidity and rainfall have negative correlation.[13,14]

Although radon in drinking water does not pose a direct health risk,[15] the main concern is that the levels of radon in indoor air of dwellings can be enhanced partially by radon derived from water supply.[16] High radon concentration has been reported[17] in river waters of Garhwal and Siwalik Himalayas and underground waters of the Doon valley.[18] Extremely high uranium content was reported[19] in groundwater of Bathinda district in the Punjab state. The purpose of this study is to investigate the radon levels of groundwater being used for drinking as potable water and to determine the health hazards, if any, to the population groups of Himachal Pradesh and Punjab states, India.

Experimental technique

Radon monitoring was carried out in the soil-gas and groundwater by scintillometry, using silver-activated zinc sulfide phosphor, ZnS (Ag), as the scintillation material. In the case of radon estimation in water by scintillometry, water samples were collected at ambient temperature and pressure from different sources in the Gurdaspur and Bathinda districts of the Punjab state. An Alpha Scintillometer (GBH 2002) with Lucas cell assembly supplied by International Environmental Consulting, Germany, was used to record alpha counts from one litre of water over an interval of 10 min. Radon gas emanated from radium present in the water or dissolved in it was sucked by a pump connected to a radon bubbler with an extraction efficiency of more than 90%. The electronic digital counter records the alpha counts and radon concentration in water is measured by using the calibration constant (10 counts = 1 Bq l^{-1}). The detection limit for the Lucas cells used in Alpha Scintillometer is 0.02 Bq l^{-1}.

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Geology of areas

The district of Kullu forms a transitional zone between the Lesser and Greater Himalayas and presents a typical rugged mountainous terrain with moderate to high relief. The district is known for its hot springs, especially at Kasol, Manikaran and Vashisth.[20] The rock types found in the district are phyllite, slate, quartzite limestone, schists and granites and have been classified on the basis of their physical characteristics and mode, and period of formation. The tourmaline granites, one of the type, are inferred to occur as intrusive and are the probable source of high radioactivity in areas where these rocks occur and many hot springs are seen around. Radioactive minerals occur in the massive quartzite near Chhinjra and Jari in the Parbati Thela in the Garsah valley.

Una and Hamirpur districts lie in the middle and lower Siwaliks. The upper part of the lower Siwalik and middle Siwalik formation in Himachal Pradesh is comprised of hard grey to greenish sandstone and interbedded intraformational clay conglomerates which carry an unoxidised greying mudstone, shale and siltstone fragments and carbonaceous and sulfide materials.[21] The sandstones are of sub greywacke type and carry numerous rock fragments. They are feldsparic and micaceous and have a calcite cement.

The Kangra district lies in Siwalik–Lesser Himalayan zone and its topography is defined by a series of almost parallel hill ranges separated by longitudinal valleys. The rock types commonly seen in the district are shale, clay and sandstones of Siwalik group, green shales and fossil rich limestones of Subathu formation, gneissic and granitic rocks of Dhauladhar group, slates, phyllites, schists and limestones of Salooni formation, quartzite, phyllite and limestone of Manjir formation and older rocks comprising slate, schist, quartzites, basic lava flows, salt, marl and dolomites belonging to Jutogh, Sundernagar and Shali formations. The valleys are filled with alluvial sand, silt and boulders of recent age.

The district of Bathinda is located in the southern part of the Punjab. The area also forms a part of the Indo-Gangetic alluvial plains. The alluvium is comprised of clay mixed with kankar, sandy clay and sand. Physiographically, the district of Gurdaspur has the low lying rugged hills of outer Himalaya and a large span of Indo-Gangetic alluvial tract. The oldest rocks met within the district belong to the lower, middle and upper Siwalik formations. The lower Siwaliks are characterised by grey to light grey micaceous, fine to medium grained sandstone interbedded with reddish brown clays and reddish brown (ferruginous) sandstones occasionally with pseudo-conglomerates containing pebbles of calcareous clay and shale. The middle Siwaliks comprise reddish brown, grey, medium grained soft sandstones interbedded with red, orange and yellow clays and sandstones occasionally with pseudo-conglomerates containing pebbles of calcareous clay and shale. The upper Siwaliks are represented by Pinjor sand rock, boulder conglomerates interbedded with siltstone and clays. Foundry sand (moulding and core sand) deposits are reported from Batala area. Limestone occurs in Pathankot area as boulders and pebbles mixed with other rocks.[20]

Results and discussion

Groundwater is the major source of drinking water in the Himachal Pradesh. The commonly used sources are thermal springs, natural springs (bauli) hand-pumps, wells and tap water supply schemes. There are a number of thermal springs located in the Parbati valley along the Parbati River and Kullu valley along the Beas River in the Kullu district. The Parbati River is a tributary of the River Beas. Some of these hot springs are known since historical times as famous pilgrimage centres, especially the ones at Manikaran and Vashish near Manali.

Radon concentrations from different water sources of districts of Himachal Pradesh were measured by an on the spot survey using Alpha Scintillometer and are summarized in Table 1. Radon activities in groundwater samples varies from 0.3 $\pm$ 0.2 to 792 $\pm$ 9 Bq l^{-1}. The maximum value of radon concentration is found in groundwater of thermal springs and the minimum value in a water tank. The highest value of radon concentration is recorded in thermal spring (no. III) at Kasol, 792 $\pm$ 9 Bq l^{-1} which is in the Kullu district of Himachal Pradesh. The uranium content of water in the Kasol thermal springs was found to be 37.40 $\pm$ 0.41 ppb.[8] The radon anomalies are related to Shat-Chinnjra and Kasol mineralisation.[22] The radon concentration at Chinnjra also shows a high value of 144 $\pm$ 4 Bq l^{-1} in natural spring (bauli) as compared to other natural springs at Takrer and Bradha in the same area.

Table 1 Radon concentration from different sources of groundwater in the some districts of Himachal Pradesh

Source no.	Place	Source	Average radon concentration/ Bq l^{-1}
Kullu district			
1	Kasol	Thermal spring II	641.8 $\pm$ 8.0
		Thermal spring III	792.0 $\pm$ 9.0
		Thermal spring IV	521.2 $\pm$ 7.2
		Thermal spring V	679.5 $\pm$ 8.2
2	Takrer	Spring	18.7 $\pm$ 1.4
3	Bradha	Spring	6.6 $\pm$ 0.8
4	Chinjira	Spring	144.0 $\pm$ 3.8
Una district			
5	Una	Hand-pump	4.8 $\pm$ 0.7
Hamirpur districts			
6	Nukhel	Water supply	1.0 $\pm$ 0.3
		Well	4.8 $\pm$ 0.7
7	Galot	Water supply	2.3 $\pm$ 0.5
		Spring	2.1 $\pm$ 0.4
		Hand-pump	11.3 $\pm$ 1.1
8	Nailon	Hand-pump	6.7 $\pm$ 0.8
		Hand-pump	10.6 $\pm$ 1.0
9	Changer	Water supply	17.3 $\pm$ 1.3
		Hand-pump	6.7 $\pm$ 0.8
10	Bhota	Water supply	2.4 $\pm$ 0.5
11	Ramera	Well	5.7 $\pm$ 0.7
		Tank	0.3 $\pm$ 0.2
12	Jorre Amb	Hand-pump	9.5 $\pm$ 1.0
13	Neri	Hand-pump	22.2 $\pm$ 1.5
14	Ropa	Hand-pump	10.0 $\pm$ 1.0
15	Hamirpur	Hand-pump	15.4 $\pm$ 1.2
		Hand-pump	13.1 $\pm$ 1.1
Kangra districts			
16	Palampur	Hand-pump	13.4 $\pm$ 1.2
17	Nagrota Bagwan	Water supply	4.6 $\pm$ 0.7
		Hand-pump	12.8 $\pm$ 1.1
18	Ghurkari	Hand-pump	3.5 $\pm$ 0.6
19	Shahpur	Hand-pump	17.4 $\pm$ 1.3
20	Kotla	Hand-pump	2.8 $\pm$ 0.5
21	Nurpur	Hand-pump	7.4 $\pm$ 0.9

In the Una district of Himachal Pradesh only one sample is collected from the hand-pump in Una city only, which shows the value of 4.8 $\pm$ 0.7 Bq l^{-1}. In Hamirpur district the maximum value of radon concentration is found in groundwater drawn by the hand-pump at Neri village, *i.e.* 22.2 $\pm$ 1.5 Bq l^{-1}, where as the minimum value of 0.3 $\pm$ 0.2 Bq l^{-1} is found in the water tank at Ramera. In Kangra district the maximum value of radon concentration is found in groundwater drawn by the hand-pump at Shahpur, *i.e.* 17.4 $\pm$ 1.3 Bq l^{-1} where as the minimum value of 2.8 $\pm$ 0.5 Bq l^{-1} was found at Kotla. Most of water samples collected are from hand-pumps except one sample from Nagrota Bagwan *i.e.* water supply.

Radon concentrations from different sources of potable water used by the residents in different towns and villages of Gurdaspur and Bathinda districts of Punjab state are

Table 2 Radon concentration from different sources of groundwater in the Gurdaspur and Bathinda districts of Punjab

Source no.	Place	Source	Average radon concentration/ Bq l^{-1}
Gurdaspur district			
1	Gurdaspur city	Hand-pump	8.8 ± 0.9
		Electric motor	8.2 ± 0.9
		Water supply	5.6 ± 0.7
		Tube-well	7.3 ± 0.8
2	Batala town	Hand-pump	3.3 ± 0.6
		Electric motor	3.3 ± 0.6
		Water supply	3.0 ± 0.5
		Tube-well	3.5 ± 0.6
		Canal water	2.0 ± 0.5
3	Dhariwal town	Hand-pump	6.4 ± 0.8
		Water supply	5.3 ± 0.7
		Tube-well	4.0 ± 0.6
		Canal water	0.2 ± 0.1
4	Dinanagar town	Hand-pump	8.6 ± 0.9
		Water supply	5.8 ± 0.7
5	Bariar village	Hand-pump	6.0 ± 0.8
		Tube-well	5.2 ±0.7
6	Bathvala village	Hand-pump	6.1 ± 0.8
		Water-supply	4.0 ± 0.6
7	Pathankot	Hand-pump	3.3 ± 0.6
Bathinda district			
8	Jodhpur village	Hand-pump	2.3 ± 1.5
9	Gobindpur village	Hand-pump	4.3 ± 2.1
		Tube-well	5.5 ± 2.3
10	Bibiwala village	Hand-pump	2.7 ± 1.6
11	Bhucho Khurd village	Hand-pump	3.4 ± 1.8
12	Bhucho Kalan village	Hand-pump	4.6 ± 2.1
13	Thermal colony	Tube-well	2.4 ± 1.5
14	NFL colony	Hand-pump	4.2 ± 2.0
		Storage tank	2.0 ± 1.4
15	Thermal colony	Hand-pump	5.0 ± 2.2
	(Lehra Mohabat)	Tube-well	3.0 ± 1.7
16	Pitho Village	Hand-pump	3.3 ± 1.8
		Tube-well	4.1 ± 2.0
17	Rampura Mandi	Hand-pump	4.0 ± 2.0
		Tube-well	2.9 ± 1.7

summarized in Table 2. The commonly used sources are hand-pumps, electric-motor-driven pumps, tube-wells and municipal water supply schemes. The maximum value of radon concentration is found in groundwater drawn by hand-pumps and the minimum value in water supplied through pipes after storage in water tanks.

Radon concentration measurements have also been carried out in groundwaters of some villages and towns of Bathinda district of Punjab. The radon concentrations have been measured in all those areas where high uranium content was reported[19] in groundwater. The average radon concentration in hand-pump drawn water is 3.8 Bq l^{-1} and in tube-well drawn water, its value is 3.6 Bq l^{-1}. Radon values for Bathinda district are lower than the corresponding values for Gurdaspur district. The occurrence of radon in groundwater is reasonably related to the uranium content of the bedrocks and it can easily enter into the interacting groundwater by the effect of lithostatic pressure.[23] Radon is generally in disequilibrium with radium and uranium content and hence shows poor correlation. The radon concentration in hand-pump drawn water samples lies between 3.3 and 8.8 Bq l^{-1}, electric motor drawn water between 3.3 and 8.2 Bq l^{-1}, tube-well water between 3.5 and 7.3 Bq l^{-1} and municipal water supply sources between 3.0 and 5.8 Bq l^{-1}.

In Punjab, the radon concentration is at a maximum in the case of groundwater drawn by hand-pumps, because the least gas is lost in transportation of water from the aquifer while the greatest loss of gas occurs in water supplied after storage in the tank and circulation through the pipes. The electric-motor driven hand-pumps have similar source of groundwater as in case of hand-pumps. As a consequence, there is only a slight variation of radon concentration in these two sources of potable water. Due to agitation and turbulence of tube-well drawn water, the radon gas dissipates at a faster rate into the air, hence lowering the radon concentration substantially. Municipal water supplies also use the deep tube-well drawn water for storage and supply through the pipes. The loss of radon gas is compounded by storage and circulation over long distances. There are no nautral and thermal springs in Punjab.

It is observed that thermal as well as natural springs in Himachal Pradesh record high values, while in Punjab hand-pump shows relative high values to other sources. Radon concentration is usually found to be much higher in ground-water of Himachal Pradesh than in Punjab, but it is mostly within the internationally recommended[24] safe values of 4 to 400 Bq l^{-1} for groundwater used for human consumption except in the Kasol and Chinnjra area which have high uranium content.

Conclusions

1. The thermal springs at Kasol in the Himachal Pradesh show the highest value of radon concentration.

2. The radon concentration from the natural spring of Chinnjra in the Kullu district of Himachal Pradesh shows the highest value in the cold water.

3. The radon values in groundwater of Himachal Pradesh, which is part of Siwalik Himalaya have higher values than in Punjab.

4. The average radon concentration increases as we move from Punjab plains towards Siwalik Himalaya. It is well established that Himalayan rivers and streams, which charge the underground water table in Punjab, contain anomalous values of radon concentration.[8] Similar results are reported by Cosma *et al.*[12] for hydrographic basin in north-west Romania.

5. Radon concentration is usually much higher in ground-water than in surface water. The observed values of radon concentration in groundwaters of different areas of districts of Himachal Pradesh and Punjab states are within the international recommended limit and hence safe for drinking.

6. There is no correlation of radon concentration with high uranium content in groundwater of Bathinda district. The area needs further investigation using sophisticated analytical techniques for estimation of uranium and radium content of groundwater.

References

1 A. B. Tanner, *Nat. Radiat. Environ.*, 1980, **3**, 5.
2 J. Wiegand and S. Feig, *Proceedings of the 5th International Conference on Rare Gas Geochemistry*, ed. I. Hunyadi, I. Ceige and J. Hakl, EP Systema, Debrecen, Hungary, 2001, p. 221.
3 H. C. Zhu, J. M. Charlet and A. Poffin, *Proceedings of the 5th International Conference on Rare Gas Geochemistry*, ed. I. Hunyadil, I. Ceige and J. Hak, EP Systema, Debrecen, Hungary, 2001, p. 239.
4 *ICRP Publication 50, Annals of ICRP*, Pergamon Press, New York, **17**(1), 1987.
5 U. C. Mishra and T. V. Ramachandran, *Proceedings of the 3rd International Conference on Rare Gas Geochemistry*, ed. H. S. Virk, Guru Nanak Dev University Press, Amritsar, 1997, p. 310.
6 W. W. Nazaroff and S. M. Doyle, *Health Phys.*, 1985, **48**, 265.
7 H. S. Virk and B. Singh, *Tectonophysics*, 1993, **227**, 215.
8 H. S. Virk, *Curr. Sci.*, 1997, **73**, 536.
9 H. S. Virk, N. Kumar and A. K. Sharma, *J. Geol. Soc. India*, 1998, **52**, 523.
10 H. S. Virk, N. Kumar, N. Sharma and B. S. Bajwa, *Curr. Sci.*, 1998, **75**, 430.
11 H. S. Virk and Navjeet Sharma, *Curr. Sci.*, 2000, **78**, 1418.
12 C. Cosma, C. Baciu and D. Ristoiu, *Proceedings of the 5th International Conference on Rare Gas Geochemistry*, ed. I. Hunyadi, I. Ceige and J. Hakl, EP Systema, Debrecen, Hungary, 2001, p. 305.
13 M. Singh, R. C. Ramola, S. Singh and H. S. Virk, *J. Assoc. Explor. Geophys.*, 1988, **9**, 85.

14 A. K. Sharma, V. Walia and H. S. Virk, *J. Geophys.*, 2000, **21**, 47.
15 F. T. Cross, N. H. Harley and W. Hofmann, *Health Phys.*, 1985, **48**, 646.
16 C. T. Hess, J. Michel, T. R. Horton, H. M. Prichard and W. A. Coniglio, *Health Phys.*, 1985, **48**, 553.
17 H. S. Virk and M. Singh, *Indian J. Environ. Prot.*, 1999, **19**, 750.
18 V. M. Choubey, S. K. Bartarya, N. K. Saini and R. C. Ramola, *Environ. Geol.*, 2001, **40**, 257.
19 J. Singh, L. Singh and S. Singh, *J. Environ. Radioact.*, 1995, **26**, 217.
20 G.S.I., *Know your district*, Geological Survey of India publication, 1976.
21 G. R. Udas and T. M. Mahadevan, *Proceedings of the International Atomic Energy Agency Symposium*, IAEA, Vienna, 1974, **425**.
22 G. R. Narayan Das, T. N. Parthasarthy, P. C. Taneja and N. V. A. S. Perumal, *J. Geol. Soc. India*, 1979, **20**, 95.
23 L. Toscani, G. Martinelli, C. Dalledonne, L. Gadidolfi, I. Ortalli, R. Sogni, S. Vaccari and G. Venturelli, *Proceedings of the 5th International Conference on Rare Gas Geochemistry* ed. I. Hunyadi, I. Ceige and J. Hakl, EP Systema, Debrecen, Hungary, 2001, p. 321.
24 UNSCEAR, *Report to General Assembly*, United Nations, New York, 1982.