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Measurement of inhalation dose due to radon and its progeny in an oil refinery and its dwellings

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ABSTRACT

Background: Radon, an invisible, odorless, heaviest (nine times heavier than air) and radioactive gas is an aberration (the only gas in the long decay chain of heavy metal elements). It is ubiquitously present in dwellings and in the environment. Humans receive the greatest radiation dose in their homes. That's where they spend most time - typically 70%, more for small children. Recent worldwide surveys reveal that an average person receives each year more radiation from radon than from all other natural or man-made sources combined. Over the years, the radiation exposure accumulated at home may exceed the exposure of uranium miners and lead to lung disorders. Therefore it is fundamental and justified to make a quantitative assessment of the radon in dwellings and the environment of work place. In this study, measurement of radon and its progeny levels was carried out in the environment of an oil refinery. Besides, radon and its progeny levels were also measured in the dwellings situated on the refinery premises and the dwellings in the city for comparison.

Materials and Methods: LR-115, Type- II (Kodak Pathe, France), plastic track detectors commonly known as solid state nuclear track detectors (SSNTDs) were used to measure the radon concentration over long integrated times. Alpha particles emitted from radon cause radiation damage tracks, which were subsequently revealed by chemical etching in NaOH. These alpha tracks registered were counted by optical microscope at suitable magnification and converted into radon concentration.

Results: The geometric means (GM) of potential alpha energy concentration (PAEC), Equilibrium Equivalent Concentration of radon (EEC value), annual exposure and annual effective dose in the environment of refinery premises was 10.09 mWL, 93.43 Bq m^{-3}, 0.41 WLM and 1.61 mSv, in refinery dwellings 12.21 mWL, 112.96 Bq m^{-3}, 0.50 WLM and 1.94 mSv and in city dwellings 8.24 mWL, 76.23 Bq m^{-3}, 0.34 WLM and 1.31 mSv respectively.

Conclusion: The dose levels in the refinery premises were found to be marginally below the ICRP recommendations. The radon and its progeny levels were higher in the dwellings of refinery township as compared to the city dwellings. While studying seasonal variation, it was found that the measured values of radon and its progeny levels were higher in winter (November to February) than in summer (May to August). This study showed that the presence of fossil fuels like natural gas, LPG etc. in the environment had resulted into higher levels of radon and its progeny in the refinery dwellings. *Iran. J. Radiat. Res., 2004; 1(4): 181-186*

Keywords: *Radon, refinery, health, dwelling, environment, SSNTDs.*

INTRODUCTION

Radon, which is a topic of public health concern, has been found to be a ubiquitous indoor air pollutant in homes to which all persons are exposed (Cole 1993, Proctor 1995). Risk projections imply that radon is the second leading cause of lung cancer after smoking (Melloni *et al.* 2000). A relationship between lung cancer and inhalation of radon and its progeny has been demonstrated (Lubin and Boice 1997). ^{222}Rn, a progeny of ^{238}U formed from the radioactive decay of ^{226}Ra, is a colorless, odorless, electrically uncharged

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noble but hazardous gas which is radioactive, emits alpha radiation and decays with a half life of 3.824 days. Radon is present in trace amounts almost everywhere (indoor and outdoor) on the earth, being distributed in the soil, the ground water and in the lower atmosphere. The concentration of radon in the atmosphere varies, depending on the place, time, and height above the ground and meteorological conditions.

When radon decays to form its progeny (^{218}Po and ^{214}Po), they can collect electrostatically on tiny dust particles, water vapours, oxygen, trace gases in indoor air and other solid surfaces. These dust particles (aerosols) can easily be inhaled and attach to the bronchial epithelium, produce a high local radiation dose. Alpha radiation being densely ionizing (high LET) can induce DNA double-strand breaks and the development of cancer. It has been estimated that the radon, largely in homes, constitutes more than 50% of the dose equivalent received by general population from all sources of radiation, both naturally occurring and man-made (BEIR V 1990). Radon is well established human carcinogen for which extensive data are available extending into the range of general population exposure. It is well known that exposure of population to high concentrations of radon and its daughters for a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer (BEIR VI 1999). Various researchers have reported that exposure to high levels of environmental smoke at the workplace and in other public sector indoor settings are important risk factors for lung cancer risk in workers (Kreuzer *et al.* 2000). The quantification of individual radon exposure over a long time period is fundamental as it poses grave health hazards not only to uranium miners but also people living in normal houses and buildings and at work place in industry and consideration of changes of building materials and ventilation habits, which influence the radon concentration.

In the present study radon and its progeny levels were measured in an oil refinery in India. In this refinery, crude oil is transported through pipelines. The oil is subsequently refined and a lot of natural gas is produced which is used as fossil fuel in transport vehicles and gas power plants.

MATERIALS AND METHODS

For the measurement of radon and its progeny concentration in the environment of refinery and the dwellings in the refinery premises and outside, track etch technique was used which is simple and inexpensive. LR-115, type II plastic track detectors were fixed at various locations in refinery premises such that the sensitive side of the detector faced the environment. While placing in dwellings, the detectors were kept away from the walls to avoid the exposure from direct alpha emission from building materials. The exposure time of the detectors was three months. Proper arrangements were made to avoid settling of dust on the detectors, which could otherwise affect the radon concentration (Orzechowski *et al.* 1982). At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5 NaOH solution at 60° C for one and half-hour. The tracks produced by the alpha particles, were observed and counted under an optical Olympus microscope at magnification ×600. Large number of graticular fields of the detectors were scanned to reduce statistical errors.

The measured track density (Track/cm^2/day) was converted into potential alpha energy concentration (PAEC) in mWL and then into

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radon concentration (EEC value) in Bq/m^3 (Jojo *et al.* 1994). The annual effective inhalation dose from radon levels measured at various locations in the environment and dwellings was calculated following ICRP Publication (ICRP 1993), discussed elsewhere (Kant *et al.* 2003).

RESULTS AND DISCUSSION

The value of potential alpha energy concentration (PAEC), radon levels (EEC), annual exposure, annual effective dose in the environment of refinery premises varied from 4.98 mWL to 20.54 mWL, 46.1 Bq m^{-3} to 190.3 Bq m^{-3}, 0.20 WLM to 0.85 WLM and 0.79 mSv to 3.27 mSv, in refinery dwellings from 5.97 mWL to 21.17 mWL, 55.3 Bq m^{-3} to 195.8 Bq m^{-3}, 0.25 WLM to 0.87 WLM and 0.95 mSv to 3.37 mSv, and in city dwellings from 3.73 mWL to 14.01 mWL, 34.5 Bq m^{-3} to 129.6 Bq m^{-3}, 0.15 WLM to 0.58 WLM and 0.59 mSv to 2.23 mSv respectively, as shown in table 1, table 2 and table 3 respectively. Table 4 shows the seasonal variation of radon and its progeny levels in the environment and dwellings. The values obtained in the present investigations are in good agreement with the values reported in earlier study (Singh *et al.* 2001).

Table 1. Potential alpha energy concentration, radon concentration, annual exposure and annual effective dose in the environment of refinery premises.

S.No.	Location	PAEC (mWL)	Radon concentration (Bq/m^3)	Annual exposure (WLM)	Annual effective dose (mSv)
1	RF-1	5.6	51.9	0.23	0.89
2	RF-2	7.47	69.2	0.31	1.19
3	RF-3	9.34	86.5	0.38	1.49
4	RF-4	11.2	103.6	0.46	1.78
5	RF-5	13.07	121.1	0.54	2.08
6	RF-6	12.45	115.2	0.51	1.98
7	RF-7	13.69	126.7	0.56	2.18
8	RF-8	20.54	190.3	0.85	3.27
9	RF-9	17.43	161.2	0.71	2.77
10	RF-10	8.71	80.6	0.36	1.39
11	RF-11	9.96	92.1	0.41	1.58
12	RF-12	7.47	69.2	0.31	1.19
13	RF-13	4.98	46.1	0.20	0.79
14	GM ± SE*	10.09±0.35	93.43 ±3.22	0.41± 0.015	1.61 ± 0.05

*SE (standard error) = $\sigma/\sqrt{N}$, Where σ is SD (standard deviation) and N is the no. of observations.

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Table 2. Potential alpha energy concentration, radon concentration, annual exposure and annual effective dose in refinery dwellings.

S.No.	Location	PAEC (mWL)	Radon concentration (Bq/m^3)	Annual exposure (WLM)	Annual effective dose (mSv)
1	RD-1	18.68	172.7	0.77	2.97
2	RD-2	7.47	69.2	0.31	1.19
3	RD-3	8.71	80.6	0.36	1.39
4	RD-4	9.96	92.1	0.41	1.58
5	RD-5	11.2	103.6	0.46	1.78
6	RD-6	12.45	115.2	0.51	1.98
7	RD-7	13.69	126.7	0.56	2.18
8	RD-8	14.94	138.2	0.61	2.38
9	RD-9	16.19	149.7	0.67	2.57
10	RD10	17.43	161.2	0.72	2.77
11	RD11	9.34	86.5	0.38	1.49
12	RD12	19.92	184.3	0.82	3.17
13	RD-13	21.17	195.8	0.87	3.37
14	RD-14	8.71	80.6	0.36	1.39
15	RD-15	5.97	55.3	0.25	0.95
16	GM ± SE*	12.21±0.32	112.96 ±2.96	0.50± 0.013	1.94 ± 0.05

*SE (standard error) = $\sigma/\sqrt{N}$, Where σ is SD (standard deviation) and N is the no. of observations.

Table 3. Potential alpha energy concentration, radon concentration, annual exposure and annual effective dose in city dwellings.

S.No.	Location	PAEC (mWL)	Radon concentration (Bq/m^3)	Annual exposure (WLM)	Annual effective dose (mSv)
1	CD-1	6.22	57.6	0.26	0.99
2	CD-2	11.83	109.4	0.49	1.88
3	CD-3	9.34	86.4	0.38	1.49
4	CD-4	10.58	97.9	0.43	1.68
5	CD-5	13.07	120.9	0.54	2.08
6	CD-6	6.22	57.6	0.26	0.99
7	CD-7	6.85	63.3	0.28	1.09
8	CD-8	9.96	92.1	0.41	1.58
9	CD-9	3.73	34.5	0.15	0.59
10	CD10	8.4	77.7	0.35	1.34
11	CD11	9.34	86.4	0.38	1.49
12	CD12	5.6	51.8	0.23	0.89
13	CD-13	10.58	97.9	0.43	1.68
14	CD-14	14.01	129.6	0.58	2.23
15	CD-15	5.6	51.8	0.23	0.89
16	GM ± SE*	8.24± 0.2	76.23 ±1.85	0.34 ± .008	1.31 ± 0.03

*SE (standard error) = $\sigma/\sqrt{N}$, Where σ is SD (standard deviation) and N is the no. of observations.

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Table 4. Seasonal variation of radon levels in the environment of refinery and in dwellings

Locations	Radon concentration (Bq/m^3) Average± SE			
	(Nov-Feb)	(Feb-May)	(May-Aug)	(Aug-Nov)
Refinery Environment	138.2 ± 2.32	61.1 ± 2.54	86.5 ± 2.84	101 ± 2.79
Refinery Dwellings	155.7 ± 3.19	110.6 ± 2.21	92.1 ± 3.56	120.78 ± 2.96
City Dwellings	97.9 ± 1.47	69.5 ± 2.57	51.9 ± 1.92	81.38 ± 1.86

CONCLUSION

The geometrical mean of overall annual inhalation dose in the refinery dwellings was 1.94 ± 0.05 mSv and in the city dwellings was 1.31 ± 0.03 mSv. This indicates that at certain locations, the inhalation dose is almost 100% more than that the Global average value (UNSCEAR 2000). However the dose levels observed in the environment of the refinery premises were marginally below the ICRP recommendations (ICRP 1993).

The seasonal variations of geometric means of measured radon levels in the refinery and dwellings indicate that the levels were higher in winter (November to February) than in summer (May to August). It is because the ventilation becomes poor in winter due to lower exchange rate of air, as the windows are kept closed. The decrease of radon concentration in monsoon season is due to the fact that the soil is saturated with water (Grasty 1994). In the light of these findings, the refineries may affect doses from external irradiation and the inhalation of radon decay products is significant from health point of view. Necessary steps should be taken to minimise the adverse effects on the environment from refineries.

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