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Radon Activity in and Around Coal Mining Areas of Khleihriat (Meghalaya) and its Potential Health Hazards

D. Maibam[1], Y. Sharma[1], K.Shylla[2], A. Saxena[1] and D. Walia*[2]

[1]*Department of Physics, NEHU, Shillong-793022, India.*
[2]*Department of Environmental Studies, NEHU, Shillong-793022, India.*
deves_maibam@yahoo.com, yubarajphysics@gmail.com, atul_nehu@yahoo.co.in, *deveshwa@gmail.com

(**Note**: Please refer all the figures at the end of the article)

Abstract

This paper reports the findings on radon activity in soil-air environment in coal mining areas and neighbouring residential sites in Khleihriat Subdivision of Jaintia Hills district, Meghalaya. Detectors are installed in 10 coal-mining and 10 residential sites for two consecutive cycles of 14 days each. The average radon activity concentration in coal mining areas (41 $kBq.m^{-3}$) is found to be slightly higher than those for residential sites (29 $kBq.m^{-3}$).

Keywords: Soil-air, Radon Activity Concentration, Coal and Mining.

1. Introduction

Determination of properties and characteristics of radon are deeply rooted in the history of the discovery of radioactivity and its experimental studies (Cothern & James Jr., 1987). Underground mines are conducive to the accumulation of radon to high concentrations and miners have been suffering long due to this alpha particle emitting radioactive inert gas. The effects of radon on miners are known since the 16th century even though it has been discovered only three centuries later (Lorenz, 1944). Later in 1920's, radon was suspected of causing lung cancer and other respiratory diseases (Uhlig et al., 1921, Ludewig & Lorenser, 1924, Nazaroff & Nero Jr., 1988). The carcinogenic nature of radon and its progeny, and its associated health risks are now well established through many scientific surveys (BEIR IV, 1988, Jacobi, 1993, Lubin, 1997, Neuberger, 2002, Darby, 2003 Marco, 2004, Daniel, 2005). Radon and its progenies in the atmosphere are reported to account for more than 50% of total natural radiation exposure to humans (UNSCEAR, 2000). Measurements of radon is not confined anymore to mining environments and are significantly extended to dwellings and other built environments, soil-gas, water sources, etc. (Duenas et al., 1996, King et al., 2006, Walia et al., 2009). The present study is an attempt to find the radon activity concentration in subsurface soil-air environment of the coal mining areas and its neighbouring residential areas and to ascertain the potential health risks of the people populating the region.

The study area is a part of the Khleihriat Sub-division of Jaintia Hills District in Meghalaya (Fig 1) and is one of the major coal producing areas in the state. More precisely, the study area consists of sites where coal mining is presently taking place and neighbouring residential sites. The total coal reserve in Meghalaya is estimated to be around 640 million tones. The sub-bituminous type coal found is high in sulphur content and is indicative of the reducing environment of formation, which even promotes uranium to be deposited during the process of formation of coal. Coal is largely composed of organic matter, but inorganic matter such as minerals and trace elements are also present in coal. Some of the trace elements in coal are naturally occurring radioactive elements including Uranium (U), Thorium (Th) and their decay products including Radium (Ra) and Radon (Rn). Uranium is found in both the mineral and organic fractions of coal.

Mining activities are controlled by the indigenous people of the state who own the land and the resource is mostly mined unscientifically. The coal is extracted by primitive surface mining called "rat-hole" mining (Fig 2) that entails clearing ground vegetation and digging pits ranging from 5 to 100 sq. m to reach the coal seams. This form of mining can only be conducted effectively where the deposits occur close to the surface.

2. Materials and Methods

The study is conducted at 10 sites each for coal mining sites as well as neighboring residential areas for two successive cycles. We have used the closed accumulators approach using PVC pipes and plastic disposable cups for our study. This approach involves direct accumulation of radon into a volume (~1105 cubic centimeter) defined by the soil surface at a depth of 70 centimeters and the open end of the PVC pipe (with disposable cups) which is affixed at the depth of the soil (US EPA, 1991). Solid State Nuclear Track Detectors, LR -115 Type II films cut into 2.0 x 2.0 sq. cm sizes are fixed in the disposable cups which are placed on top end of the PVC pipe of ~ 30 cm length and ~ 6.4 cm diameter. We have used this length of the diffusion chamber to put a diffusion barrier a certain length of column of air for thoron to be reduced down to a negligible fraction of its initial amount. This arrangement offers the most rugged way to dispose the thoron problem (Monnin & Seidel, 1997). A detector unit (disposable cup and SSNTD) is placed for 14 days which constitutes one cycle and then replaced with a new one. After retrieving the detectors, they are etched in 2.5 N NaOH at 60°C for 120 min. After drying the films, the etched tracks are manually counted using an Optical Microscope at 150x magnifications. The density of tracks (number of tracks per square centimeter) observed are then converted into Radon Activity Concentration by using the following equation,

$C_R = \frac{\rho}{kT}$ .... (1) where ρ = density of tracks, k = calibration Factor used (0.0312 tracks. cm^{-2} day^{-1} $(Bq.m^{-3})^{-1}$ (Ramola, et al., 1996), T = number of days of exposure.

3. Results and Discussion

As shown in Table 1, it is observed that for the coal mining areas, site M10 has been found to have the highest Radon Activity concentration with 60.34 $kBq.m^{-3}$ and site M3 has the least Radon Activity concentration 25.39 $kBq.m^{-3}$ which gives an average of 41 $kBq.m^{-3}$. In the neighbouring residential areas, R1 records the highest radon activity concentration with 40.46 $kBq.m^{-3}$ and site R4 the least with 13.37 kBq. m^{-3} which gives the average value of 29 $kBq.m^{-3}$.

The result shows that the mean soil-gas radon activity concentration in coal mining areas is higher than the neighbouring residential areas by a factor of 1.4. The high soil-gas radon activity concentration in the coal bearing areas may be due to the high specific activity of Uranium in coal. Coal mining areas have been found to have potential for enhancing ^{222}Rn concentration in surface air as the process has been sometimes associated with high ^{226}Rn activities with acid mine drainage discharges (Chalupnik & Wysocha, 2008).

Radon concentrations in soil within a few meters of the surface of the ground are important in determining radon rates of entry into pore spaces and subsequently into the atmosphere (UNSCEAR, 2000). However, it depends on the distribution and concentrations of the parent radium radionuclides in the bedrock and permeability of the soil. Radon in soil is believed to be the main source of radon in homes, measurements of soil-gas radon concentrations can be used to estimate the variation in radon potential of indoor environments (Akerblom & Millender, 1997). It has been predicted that soil-gas radon activity concentration as low as 10 $kBq.m^{-3}$ can produce an indoor concentration above the UK action level of 200 $Bq.m^{-3}$ (Varley & Flowers, 1998). Using this estimate, we found that with an average radon activity concentration in soil-air to be 35 $kBq.m^{-3}$, the radon activity concentration value of 700 $Bq.m^{-3}$ is estimated for houses built on the surfaces of the sites. The estimated indoor radon concentration for the coal mining and neighboring residential study sites is found to be 820 $Bq.m^{-3}$ and 574 $Bq.m^{-3}$ respectively. The annual effective dose (calculated using the parameters given by UNSCEAR, 1993) for the estimated indoor radon concentration in the coal mining sites is (0.74 $mSv.y^{-1}$) and in neighbouring residential areas is (0.52 $mSv.y^{-1}$) with an overall average value of 0.63 $mSv.y^{-1}$ for both coal mining and neighbouring residential areas (Table 2).

Table 1. *Location and the value of Average Radon Activity concentration in $kBq.m^{-3}$ obtained from coal mining sites and its neighbouring residential areas.*

	Site Name	Latitude	Longitude	Elevation in meters	Average Radon Activity Conc. in $kBq.m^{-3}$
Coal Mining Areas	M1	N 25° 20' 56"	E 92° 21' 26.5"	1115	28.66
	M2	N 25° 20' 48.3"	E 92° 21 '32.8"	1111	39.93
	M3	N25° 20' 43.6"	E 92° 21' 33.1"	1104	25.39
	M4	N 25° 20' 48"	E 92° 21' 39"	1111	47.34
	M5	N 25° 20'46.4"	E 92° 21' 21.4"	1114	35.88
	M6	N 25° 20' 30.1"	E 92° 21' 19.3"	1097	41.07
	M7	N 25° 20' 31.1"	E 92° 21' 13.2"	1108	38.71
	M8	N 25° 20' 45.1"	E 92° 21' 15.8"	1119	43.94

	M9	N 25° 20' 34.1"	E 92° 21' 40"	1094	48.86
	M10	N 25° 20' 26"	E 92° 21' 35.3"	1097	60.34
Neighbouring Areas	R1	N 25° 21' 34.5"	E 92°22' 11.4"	1093	40.46
	R2	N 25° 21' 48.5"	E 92° 21' 59.8"	1114	39.69
	R3	N 25° 21' 50.4"	E 92° 21' 56.6"	1129	39.43
	R4	N 25° 21' 44.8"	E 92° 22' 10.2"	1123	13.37
	R5	N 25° 21' 29.8"	E 92° 22' 14.7"	1110	13.77
	R6	N 25° 21' 42.1"	E 92° 21' 35.5"	1126	29.46
	R7	N 25° 21' 33.7"	E 92° 21' 32.2"	1127	38.32
	R8	N 25° 21' 26.4"	E 92° 21' 34.8"	1146	23.41
	R9	N 25° 21' 22.2"	E 92° 21' 41.7"	1121	19.95
	R10	N 25° 21' 20.5"	E 92° 21' 54.4"	1099	32.36

Table 2. *Location, the measured Radon activity concentration for 1^{st} and 2^{nd} cycle, Estimated Indoor Radon Activity Conc. in the coal bearing sites and its neighbouring residential areas (in Bq.m^{-3}) and the Dose calculated (in mSv.y^{-1}).*

	Site Name	Radon Activity Conc. in Bq.m^{-3}		Average Radon Activity Conc. in Bq.m^{-3}	Estimated Indoor Radon Activity Conc. in Bq.m^{-3}	Dose calculated in mSv.y^{-1}
		1st cycle	2nd cycle			
Coal Mining Areas	M1	28663.45	x	28663.45	573.27	0.52
	M2	40054.86	39814.45	39934.65	798.69	0.72
	M3	28219.63	22560.91	25390.27	507.81	0.46
	M4	47988.16	46693.68	47340.92	946.82	0.85
	M5	37872.74	33878.35	35875.54	717.51	0.65
	M6	42458.89	39685.01	41071.95	821.44	0.74
	M7	39259.68	38168.62	38714.15	774.28	0.7
	M8	42569.84	45306.74	43938.29	878.77	0.79
	M9	55126.28	42588.34	48857.31	977.15	0.88
	M10	61191.84	59490.52	60341.18	1206.82	1.09
Neighbouring Areas	R1	41349.33	39574.05	40461.69	809.23	0.73
	R2	39814.45	39574.05	39694.25	793.89	0.71
	R3	40091.84	38760.38	39426.11	788.52	0.71
	R4	17734.35	8996.62	13365.49	267.31	0.24
	R5	14174.54	13370.11	13772.32	275.45	0.25
	R6	23300.61	35616.65	29458.63	589.17	0.53
	R7	37595.35	39037.77	38316.56	766.33	0.69
	R8	23356.09	23467.04	23411.56	468.23	0.42
	R9	15620.65	24280.71	19950.68	399.01	0.36
	R10	32361.96	x	32361.96	647.24	0.58

4. Conclusion

The estimated annual effective dose measured in 20 sites including mining and its neighbouring residential areas of Khleihriat are less than the average annual effective dose limit for members of general public prescribed by UNSCEAR, 1993 which is 1.2 $mSv.y^{-1}$. However, suggestion is to be made to the people residing in houses near the coal mining and neighbouring residential areas to keep their rooms well ventilated and have them individually checked for Indoor radon activity concentrations for further mitigation measures.

5. Acknowledgements

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Fig.1. *Figure showing locations where the detector are placed in the coal mined areas (M's) and neighbouring residential areas (R's).*

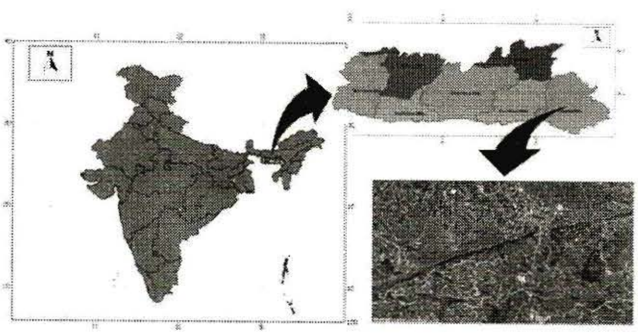


Fig.2. *Photograph showing the method of mining employed*

Fig.3. Bar graph showing average radon activity concentration in $kBq.m^{-3}$ in two cycles for coal mining sites and its neighbouring residential areas.

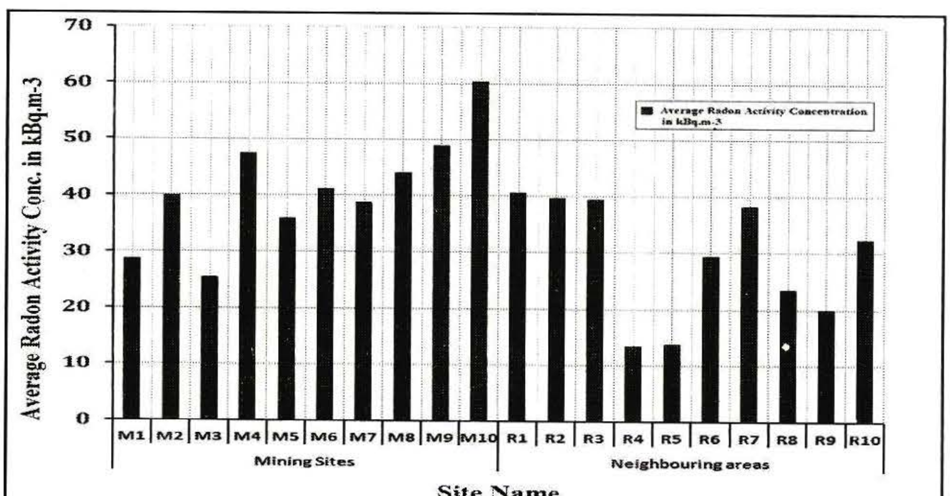
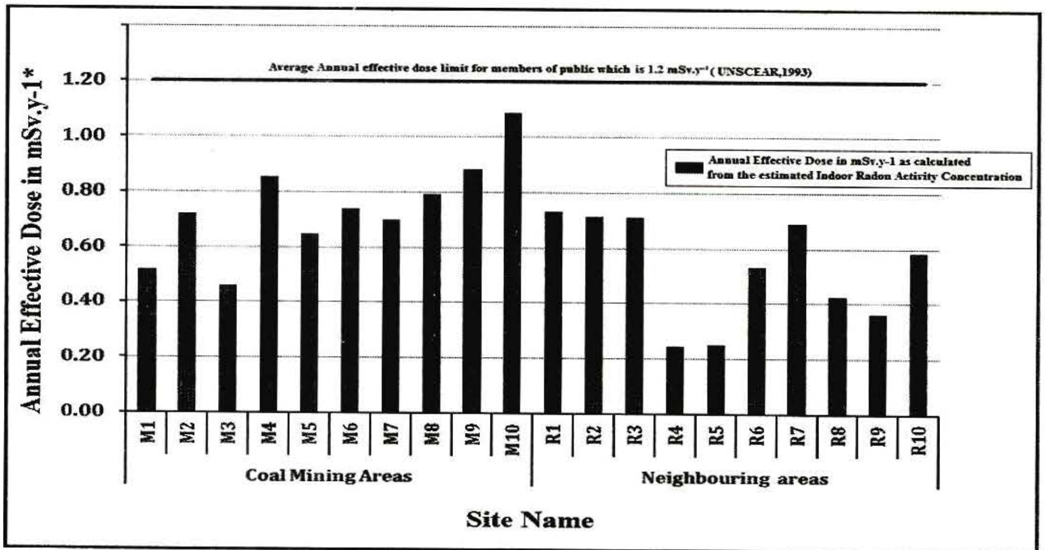


Fig.4. *Bar graph showing annual effective doses in mSv.y^{-1} obtained from estimated indoor radon activity concentration for coal bearing sites and its neighbouring residential areas.*



*from the estimated Indoor Radon Activity Concentration