

Radon Exhalation Rates and Radium Estimation Studies in Soil Samples Collected from Various Locations in the Environment of Shahjahanpur District of Uttar Pradesh, India

M. S. A. Khan

Department of Physics, Gandhi Faiz-a-Aam College, Shahjahanpur-242201
Affiliated to M.J.P. Rohilkhand University, Bareilly (U.P.), India

Abstract: *The measurements of radium content and radon exhalation rates in terms of mass and area in soil samples collected from various locations in the shahjahanpur District were carried by using cylindrical can technique(CCT) based on LR-115 type II plastic track detector. From the result it was found that the effective radium content in the study area varies from 0.485Bq/kg to 2.503Bq/kg with an average value of 1.362Bq/kg. The radon exhalation rate in terms of mass varies from $0.389 \times 10^{-1} \text{ BqKg}^{-1}\text{d}^{-1}$ to $2.009 \times 10^{-7} \text{ BqKg}^{-1}\text{d}^{-1}$ with an average of $1.093 \text{ BqKg}^{-1}\text{d}^{-1}$ where as radon exhalation rate in terms of area varies from $1.314 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ to $6.791 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ with an average value of $3.696 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$. Measured values of radium content in soil samples collected from different locations in the study area were found to be less than the permissible value of 370 Bqkg^{-1} and also lower than the average global value of 35 Bqkg^{-1} as recommended by Organization for Economic Cooperation and Development (OECD). Thus the result shows that the study area is safe from health hazard effects point of view.*

Keywords: Radon, cylindrical can technique, soil sample, radium content, LR-115typeII plastic detector

1. Introduction

Radium is a naturally occurring radioactive element and presents in soil, sand, rock, water, plants in parts per million (ppm) [1]. Some types of rocks have higher than average uranium contents. These include light-colored volcanic rocks, granites, dark shales, sedimentary rocks that contain phosphate, and metamorphic rocks derived from these rocks. Radium is a member of uranium radioactive series. The decay of ^{238}U through ^{226}Ra gives Radon. Radon is constantly being generated by the radium in rock, soil, water and materials derived from rocks. The radon generated in rocks usually stays trapped in that material unless the rocks are fractured. ^{222}Rn and its parent ^{226}Ra are part of the long decay chain for ^{238}U . ^{238}U decays to form ^{226}Ra which has a half-life of 1600 years. ^{226}Ra then decays to form ^{222}Rn gas which has a half-life of 3.8 days [2]. Since uranium is essentially everywhere in the earth crust, ^{226}Ra and ^{222}Rn are present in almost all rock and all soil type. Radium is found in soil, water, plants and food at low concentration. Radium mainly enters the body through the food chain. Higher levels of exposure generally occur through food consumption with average levels of 0.6 pCi/d to 1.0 pCi/d or through the drinking water with an average level of 0.6 pCi/d to 1.0 pCi/d [3]. The higher the uranium level is in an area, the greater the chances are that houses in the area have high levels of indoor radon. Radium, being chemically similar to calcium, tends to follow it in metabolic processes and becomes concentrated in bones. The alpha particles given off by radium and radon bombard the bone marrow and destroy tissues that produce red blood cells. It may cause bone cancer. Also the chronic (long-term) exposure to radium in humans, by inhalation has resulted in acute leucopenia while oral exposure has resulted in anemia, necrosis of the jaw, abscess of the brain and terminal bronchopneumonia [3].

Thus the chronic (long-term) exposure to radium in humans is injurious to health. The radium content of a sample also contributes to the level of environmental radon. A higher amount of radium results in a higher concentration of radon, and also a higher level of gamma radiation in the building [4]. Higher values of ^{226}Ra in soil contribute significantly to the enhancement of indoor radon [5].

The major source of radon in the atmosphere at least 80% is from emanations from soil that derived from rocks. Radon gas can enter a home from the soil under the house by process of diffusion through concrete floors and walls, and through cracks in the concrete slab, floors, or walls and through floor drains, sump pumps, construction joints and cracks or pores in hollow-block walls [4]. Normal pressure differences between the house and the soil can create a slight vacuum in the basement, which can draw radon from the soil into the building. Inhalation is the main route of entry, into human body, for radon and its progeny [6]. Most of the radon gas inhaled is also exhaled. However, some of radon's decay products attach to dusts and aerosols in the air and are then readily deposited in the lungs. Some of these are cleared by the lung's natural defense system swallowed or coughed out [6]. The life time of ^{222}Rn is long relative to breathing times. Most of it that is inhaled is exhaled again rather than decaying or becoming lodged in the lungs and later decaying. In contrast, the immediate, promptly decaying daughters of ^{222}Rn (^{218}Po , ^{214}Pb , ^{214}Bi , and ^{214}Po) attach to a surface, typically of aerosols, which can be inhaled. They then deposit on epithelial surfaces within the lung, and shortly decay. The result is that the sensitive surfaces of the bronchi are irradiated by these decays, the most energetic and destructive of which are the heavily ionizing, short range particles from the polonium isotopes ^{214}Po and ^{218}Po [7]. As the chronic (long-term) exposure to radium and indoor radon concentration in humans being is

hazardous to health, the measurement of radium content and radon exhalation rate in soil environment is important to take care of the inhalation indoor radon dose to the general population of the region. The measurement of radon exhalation rates of soil is helpful to study radon health hazard such as lung cancer due to alpha radiation internally and gamma radiation from soil externally ([7], [8], [9], [10]). In the present investigation LR-115 type-II plastic track detector was used to measure the effective radium content of the soil samples from Shahjahanpur District. The main objective of the present study is to estimate the radium content and radon exhalation rate in terms of mass and area.

2. Brief geography of the Study Area

Shahjahanpur District is one of the historical districts of Uttar Pradesh in the republic of India. It is a part of Bareilly division which is situated in south-east of Rohilkhand division. It was established in 1813 by the British Government. Previously it was a part of district Bareilly. The main town is Shahjahanpur city which is its headquarters. Geographically, it is situated at 27.35 N latitude and 79.37 E longitudes. Its geographical area is 4575 sq. kilometers with an elevation of 472 feet above sea level. There exists an army cantonment, and a major clothing factory for defence forces called Ordnance Clothing Factory.



Figure 1: Map showing shahjhanpur District

3. Experimental Technique

For the measurement of radon exhalation rates and radium content from soil samples „Sealed Can Technique“ has been used ([11], [12], [13], [14]). The amount of radon emanated from a given sample per unit mass is known as mass exhalation rate and surface area per unit time is known as surface exhalation rate. In such measurement technique it is expected that the radon exhalation rates (both mass and area exhalation rates) depends upon material, its amount as well as on the geometry and dimension of the can. With sealed can technique [15] both area and mass exhalation rates for radon in the sample can be determined with reasonable accuracy. The experimental Set-up for radium content and radon exhalation rate measurement is shown in the figure 2. In present study LR-115 type-II plastic track

detector was used. Twenty (20) soil samples were collected from different locations (shown in map) from the study area. After collection, soil samples are crushed into fine powder by using Mortar and Pestle. Fine quality of sample is obtained using sieve of 200 micron-mesh size. Before measurement the samples are then dried in an oven at about 110 °C for twenty four hours. After drying, samples were sieved to obtain the fine quality of samples. About 130 gm (130 x10⁻³ kg) of sample was enclosed in a plastic “cylindrical can” ([11], [12], [16]) and sealed for a period of four weeks in order to get equilibrium between radium and radon. After that the LR-115 type-II plastics track detector of size 2cm x 2cm was fixed on the bottom of the lid of each can having dimension 8cm in total height and 7cm in diameter such that the sensitive side of the detector always faced the soil sample as shown in figure 2. The cans were tightly closed and sealed for a period of three months (90 days). The lower sensitive part of the detector was exposed freely to emergent radon from the soil sample in the can so that it could record the alpha particles resulting from the decay of radon in the remaining volume of the cylindrical can and from ²¹⁸Po and ²¹⁴Po deposited on the inner wall of the can.

After the exposure time, the detector was removed and subjected to a chemical etching process in 2.5N NaOH solution at 60 °C for 70 minutes in a constant temperature water bath. The etched detectors are thoroughly washed and dried. The resulting alpha tracks on the exposed face of the track were counted using the spark counter. The effective radium content (or radium concentration) of the soil samples was calculated by using the following formula ([1], [16]).

$$C_{Ra} = (\rho / KT_e) (hA/M) \text{ Bq/kg}$$

where M is the mass of the soil in Kg. (130 x10⁻³ kg), A is the cross sectional area of the can in m² (38.46x10⁻⁴ m²), ρ is the track density in tracks cm⁻², h is the distance between the top of the sample and detector in meters (0.050m), K is the sensitivity factor (0.0245tracks cm⁻²d⁻¹Bqm⁻³) [17] and T_e is the effective exposure time (in hour) given by the following relation:

$$T_e = [T - \{1 - \exp(-\lambda_{Rn})\} / \lambda_{Rn}]$$

The track density ρ (Track.cm⁻²), radon concentration C_{Rn} (Bq.m⁻³), sensitivity factor K (tracks cm⁻²d⁻¹Bqm⁻³) and the exposure time T_e are related in the following way:

$$C_{Rn} = (\rho / KT_e)$$

The radon exhalation rate in terms of mass can be calculated by using the following expression ([12], [18]):

$$E_x (M) (\text{BqKg}^{-1}\text{d}^{-1}) = C_{Ra} [(\lambda_{Ra} / \lambda_{Rn})] (1/T_e)$$

Where λ_{Ra} and λ_{Rn} are the decay constant of ²²⁶Ra and radon ²²²Rn. They are related with half-life period in the following way:

$$\lambda_{Ra} = \log_e 2 / T_{1/2} (T_{1/2} = 1622 \text{ years})$$

$$\text{and } \lambda_{Rn} = \log_e 2 / T_{1/2} (T_{1/2} = 3.8 \text{ days})$$

Similarly the radon exhalation rate in terms of area can be calculated by using the following expression:

$$E_x (S) (\text{Bqm}^{-2}\text{d}^{-1}) = [E_x (M)] (M / A)$$

where E_x (M) is the radon exhalation rate in terms of mass. M is the mass of the soil in Kg. (130×10^{-3} kg) and A is the cross sectional area of the can in m^2 ($38.46 \times 10^{-4} m^2$).

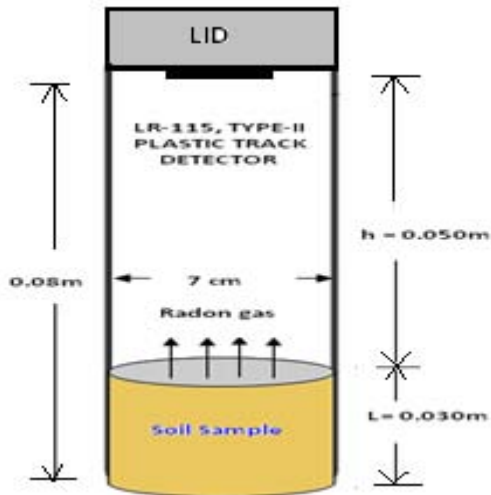


Figure 2: Experimental set-up for the measurement of radium content and radon exhalation rate

4. Result and Discussion

The results of radon exhalation rate (both mass exhalation rate and surface exhalation rate) and radium content of soil samples collected from the different locations are given in the table 1. It is found that the values of radium content and radon exhalation rates in soil samples are different at different location. This is due to the nature of soil and the parameters on which radon exhalation rates are depends. Radon flux density (i.e. ^{222}Rn exhalation rate) depends upon a number of parameters that behave in a stochastic and independent fashion, such as the radioactive disintegration of ^{226}Ra to produce radon, the direction of recoil of radon in the grain, the interstitial soil moisture condition in the vicinity of the ejected radon atom and its diffusion in the pore space [19]. It was found that the values of effective radium content in study area vary from 0.485Bq/kg to 2.503Bq/kg with an average value of 1.362Bq/kg. The values of radium content found to be maximum (2.503Bq/kg) at location sample codes SS-1. This higher value may be due to the different geochemical distribution of this area. The variation of radium concentration at different locations in the study area is shown in the figure 3. The radon exhalation rate in terms of mass varies from $0.389 \times 10^{-7} \text{ BqKg}^{-1}\text{d}^{-1}$ to $2.009 \times 10^{-7} \text{ BqKg}^{-1}\text{d}^{-1}$ with an average of $1.093 \text{ BqKg}^{-1}\text{d}^{-1}$ where as radon exhalation rate in terms of area varies from $1.314 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ to $6.791 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ with an average value of $3.696 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$. The variation of radon exhalation rate in terms of mass and area at different locations in the study area are shown in the figure 4&5 respectively.

Table 1: Radon exhalation rate and radium content studies in some soil samples

S. No.	Sample code	(C_{Ra}) (Bq/Kg)	Radon Exhalation rate	
			$E_x(\text{M})$ ($\text{BqKg}^{-1}\text{d}^{-1}$)	$E_x(\text{S})$ ($\text{Bqm}^{-2}\text{d}^{-1}$)
1	SS-1	2.503	2.009×10^{-7}	6.791×10^{-6}
2	SS-2	0.496	0.397×10^{-7}	1.342×10^{-6}
3	SS-3	1.500	1.204×10^{-7}	4.069×10^{-6}
4	SS-4	1.414	1.135×10^{-7}	3.836×10^{-6}
5	SS-5	0.485	0.389×10^{-7}	1.314×10^{-6}
6	SS-6	0.783	0.628×10^{-7}	2.123×10^{-6}
7	SS-7	1.825	1.465×10^{-7}	4.952×10^{-6}
8	SS-8	2.345	1.883×10^{-7}	6.365×10^{-6}
9	SS-9	0.985	0.791×10^{-7}	2.674×10^{-6}
10	SS-10	1.296	1.041×10^{-7}	3.519×10^{-6}
11	SS-11	1.325	1.063×10^{-7}	3.593×10^{-6}
12	SS-12	1.632	1.310×10^{-7}	4.428×10^{-6}
13	SS-13	0.987	0.793×10^{-7}	2.680×10^{-6}
14	SS-14	1.980	1.589×10^{-7}	5.371×10^{-6}
15	SS-15	0.937	0.752×10^{-7}	2.542×10^{-6}
16	SS-16	0.695	0.558×10^{-7}	1.886×10^{-6}
17	SS-17	0.497	0.399×10^{-7}	1.349×10^{-6}
18	SS-18	1.532	1.230×10^{-7}	4.157×10^{-6}
19	SS-19	1.910	1.533×10^{-7}	5.182×10^{-6}
20	SS-20	2.125	1.706×10^{-7}	5.766×10^{-6}
Maximum		2.503	2.009×10^{-7}	6.791×10^{-6}
Minimum		0.485	0.389×10^{-7}	1.314×10^{-6}
Average value		1.362	1.093×10^{-7}	3.696×10^{-6}

The observed values of radium concentration in soil samples collected from different locations in the study area were found to be less than the permissible value of 370 Bqkg^{-1} as recommended by Organization for Economic Cooperation and Development (OECD) [20] and also lower than the average global value of 35 Bqkg^{-1} . The observed values of radon exhalation rate in the present study were below the world average [21] of $0.016 \text{ Bqm}^{-2}\text{s}^{-1}$ ($57.6 \text{ Bqm}^{-2}\text{h}^{-1}$) [12]. Thus the result shows that the study area is safe as far as the health hazard effects of radium and radon exhalation rate are concerned.

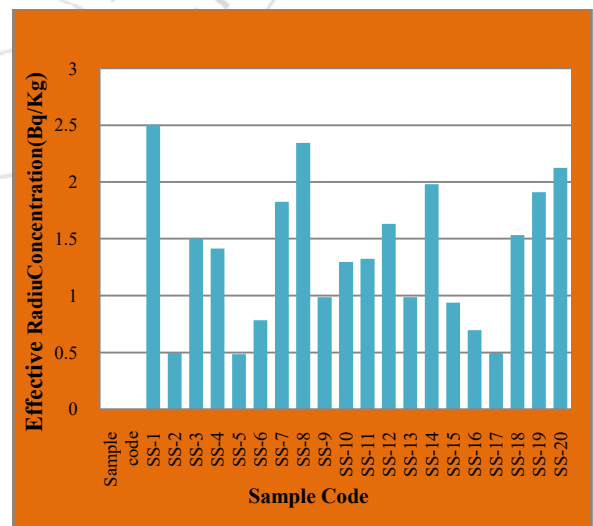


Figure 3: Variation of radium content at different locations

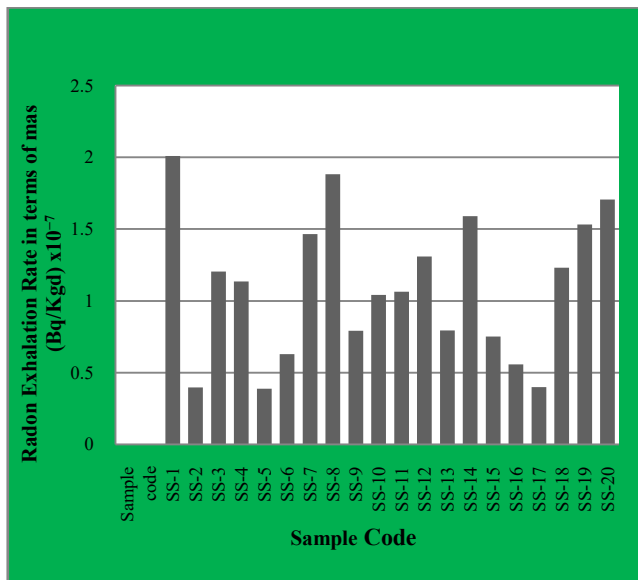


Figure 4: Variation of radon exhalation rate in terms of mass at different locations

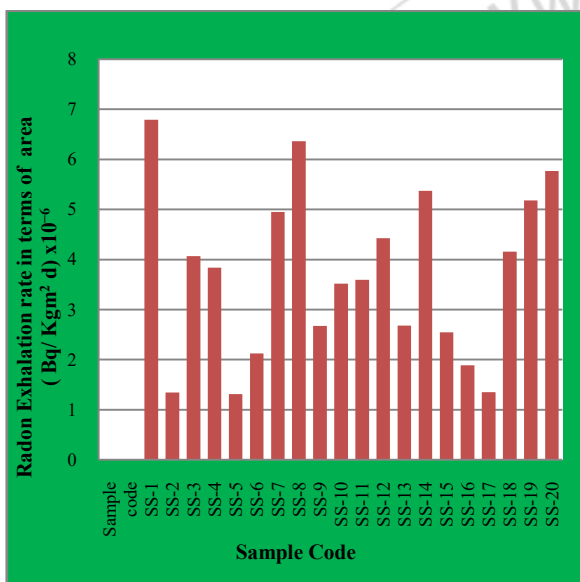


Figure 5: Variation of radon exhalation rate in terms of area at different locations

5. Conclusion

Measured values of radium content and radon exhalation rate in terms of mass and area are given in table 1. From the results it is found that the values of effective radium content in study area vary from 0.485Bq/kg to 2.503Bq/kg with an average value of 1.362Bq/kg. The radon exhalation rate in terms of mass varies from $0.389 \times 10^{-7} \text{ BqKg}^{-1}\text{d}^{-1}$ to $2.009 \times 10^{-7} \text{ BqKg}^{-1}\text{d}^{-1}$ with an average of $1.093 \text{ BqKg}^{-1}\text{d}^{-1}$ where as radon exhalation rate in terms of area varies from $1.314 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ to $6.791 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$ with an average value of $3.696 \times 10^{-6} \text{ Bqm}^{-2}\text{d}^{-1}$. The observed values of radium content in soil samples collected from different locations in the study area were found to be less than the permissible value of 370 Bqkg^{-1} as recommended by Organization for Economic Cooperation and Development (OECD) and also lower than the average global value of 35Bqkg^{-1} . The radon exhalation rates in the present study were also found below the world average value of 0.016

$\text{Bqm}^{-2}\text{s}^{-1}$ ($57.6 \text{ Bqm}^{-2}\text{h}^{-1}$). Thus study area is safe as far as the health hazard effects of radium and radon exhalation rate are concerned.

6. Future Scope

According to the world health organization, radon is first most important cause of lung cancer among nonsmoker. The proportion of lung cancers attributable to radon is estimated to range from 3% to 14%. When radium decays in soil, the resulting atoms of radon isotopes first escape from the mineral to air-filled pores. The measurement of radon exhalation rates in soil is helpful to study radon health hazard [19]. The National Radiological Protection Board (NRPB) has shown that at least 50% of the total dose for an average person in UK is received from combined radon and thoron [20]. In India out of 98% exposure dose from natural radioactive sources, about 75% is due to radon and its progeny. Therefore measurements of radon in the soil samples are important from public health point of view. The motivation of work is to measure radiological health risk level of radon exhalation rates and radium in study area which would be of great help for radiological database of country.

References

- [1] Z. Mohd., M. Shakir Khan and V. Deepak, "International Journal of Applied Science and Engineering" Vol. 9, no.1, pp 43- 47, 2011.
- [2] Agency for toxic Substances and Disease registry (ATSDR). Case studies in environmental medicine. Radon Toxicity, Public (ATSDR). Case studies in environmental medicine. Radon Toxicity. Public Health Service, U.S. Department of Health and Human Services, Atlanta GA. 1992.
- [3] Agency for toxic substances and disease registry (ATSDR). Toxicological Profile for radium. Public Health Service, U.S. Department of Health and Human Services, Atlanta GA. 1990.
- [4] K.M. Stephen Chong, A. Tan Soo Lian, and Ng Ti Lik "Radon review and indoor survey Singapore-Introduction: Natural source of radiation," from <http://home.pacific.net.sg>, 1995.
- [5] M. Shakir Khan, D. S. Srivastava and Azam Ameer, "Study of radium content and radon exhalation rates in soil samples of northern India". Environmental Earth Sciences, ISSN 1866-6280, Environ. Earth Sci. DOI 10.1007/s12665-012-1581-7, 2012.
- [6] EPA., A citizen's guide to radon. Technical report, U. S. Environmental Protection agency, September 2005.
- [7] ATSDR (Agency for Toxic Substances and Disease Registry), U.S Public Health Service, in collaboration with U.S. Environmental Protection Agency, "Toxicological profile for radium", September 1999.
- [8] AB. Tanner, Radon migration in the ground: a review. In: Adams JAS, Lowder WM (eds). The natural radiation environment, University of Chicago Press, Chicago, pp. 61-190, 1964.
- [9] H.I. Asaad, World Academy of Science, Engineering and Technology, Vol.46, pp700-703, 2010.

- [10] B. P. Singh., B. Pandit., V. N. Bhardwaj., P. Singh & R. Kumar., Indian J. of Pure & Appl. Phys. Vol. 48, pp. 493-495, 2010.
- [11] F. Abu-Jarad, J. H. Fremlin and R. Bull, Med. Biol, Vol.25, pp.683, 1988.
- [12] A. J. Khan, R. Prasad and R. K. Tyagi., Nucl. Tracks Radiat. Meas. Vol.20, pp.609-610, 1992.
- [13] K. Kant, R. P. Chauhan and G. S. Sharma., Ind. J. Pure and Appl. Phys. Vol.39, pp.679, 2001.
- [14] R. C. Ramola and V. M. Chaubey, J. Rad. Nuc. Chem. 256, pp. 219-223, 2003.
- [15] G. Somogy., Abdel-Fateh., I. Hunyadi and S. M. Toth., Nucl. Tracks. Vol.12, pp.701-704, 1986.
- [16] M.K. Bhardwaj and H. Gebrehiwet. International Journal of Science and Nature, vol.4 (1). pp.182-184, 2013.
- [17] K. P. Eppan and Y.S. Maya., Radiat. Meas. Vol.38, pp.5-17, 2004.
- [18] R. L. Fleischer and A. Morogo-compero., Geophys. Res. Vol.83, pp.3539-3549, 1978.
- [19] C. E. Lawrence., R.A. Akber and P. Martin., "Radon-222 exhalation from open ground on and around a uranium mine in the wet-dry tropics". J. Environ Radioact., Vol. 100, pp.1-8, 2009.
- [20] OECD. Organization for economic cooperation and development. In: Exposure to radiation from natural radioactivity in building materials. Report by a group of Experts of the OECD Nuclear Energy Agency, OECD, Paris, France. 1979.
- [21] UNSCEAR "Sources and Effects of Ionization Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation Report to the General Assembly with scientific annexes Volume I United Nations New York, 2000.

Author Profile



Dr. Mohd. Salim Ahmad Khan, Assistant Prof.
Department of Physics, Gandhi Faiz-a-Aam College
Shahjahanpur affiliated to M.J.P. Rohilkhand
University, Bareilly (U.P.)-242001, India