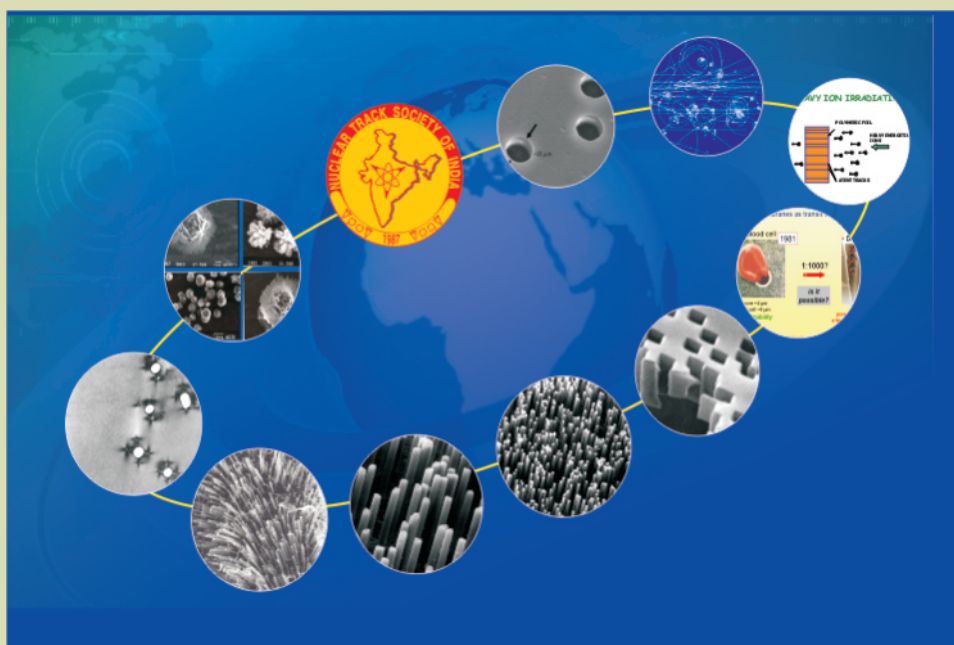


ISST JOURNAL OF APPLIED PHYSICS

Volume 5 No. 2

July – December 2014



Special Issue

On Occasion of : 18th National Symposium on Solid State Nuclear
Track Detectors & Their Applications (**SSNTDs-18**)
October 18-20, 2013

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Guest Editor : **Dr. Krishan Kant Gupta**, Convener, SSNTDs-18 and
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Website: www.aggarwalcollege.org



Intellectuals Society for Socio-Techno Welfare

Ghaziabad – 201 013 (U.P.) India
www.isst.org.in

ISST Journal of Applied Physics

ISSN : 0976-903X

July – December 2014

Volume 5 No. 2

ISST Journal of Applied Physics (IJAP) is a bi-annual peer reviewed journal of Intellectuals Society for Socio-Techno Welfare (ISST), that serves scientists and engineers working in the fields of theoretical, analytical and experimental physics. The scope of Applied Physics has become an identifiable unified discipline of scientific endeavor. The articles published in IJAP span the whole spectrum of applied physics research.

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Published by : Mr. Kewal Sharma, Secretary
INTELLECTUALS SOCIETY FOR SOCIO-TECHNO WELFARE
B-401, Swarnjayantipuram, Govindpuram,
Ghaziabad-201013 (U.P.) INDIA
E-mail : info@isst.org.in URL : www.isst.org.in

Printed by :
Creative Design & Prints
G-21, Ganga Vihar, Delhi - 110094
at NHP Offset, Delhi
E-mail: creativedesignstudio@rediffmail.com

Regd. Office : Intellectuals Society for Socio-Techno Welfare, B-401, Swarnjayantipuram, Govindpuram, Ghaziabad-201003 (U.P.) India
E-mail : info@isst.org.in Web Site : www.isst.org.in

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PREFACE

The 18th National Symposium on Solid State Nuclear Track Detectors and Their Applications (SSNTDs-18) was held on 18-20 October 2013 in Aggarwal College Ballabgarh (Faridabad) Haryana, India in collaboration with the Nuclear Track Society of India (NTSI)

Research on SSNTDs has a long history. Today, it is the one of the core technologies for a modern fully flourishing ion beam application industry. SSNTDs are now specialized in various applications through a long history of research and development. The National Symposium on Solid State Nuclear Track Detectors and Their Applications (SSNTDs-18) has been the most comprehensive academic symposium in the field of SSNTDs research. There is no doubt that the Conference/Symposium has encouraged the further advancement of research through fruitful discussions among specialists and researchers.

The symposium featured invited talks, contributed papers and poster presentations by eminent scientists, academicians and research students. This symposium provided a chance for academic and industry professionals as well to discuss recent progress in the area of SSNTDs and related applications in diverse fields of science and technology. About 117 abstracts, besides 24 invited talks, proposals were received from all over the country and abroad and most of them were accepted by the technical committee.

In this symposium, about 200 delegates from 19 states of India and very few foreign delegates from various research institutes of national and international repute, universities and colleges participated. In the three day seminar, there were actually 01 Keynote Address; 18 Invited Talks; 25 Oral Presentations and 47 Poster Presentations in the following categories:

- ❖ Basic Studies and Methodologies
- ❖ Latent Tracks in Materials and Ion Track Technology
- ❖ Heavy Ion Nuclear Physics and Cosmic Rays
- ❖ Radon, Thoron Studies, Applications in Environmental and Earthquake Studies
- ❖ Radiation Measurements and Dosimetry
- ❖ Trace Analysis
- ❖ Nuclear Track Filters and Their Applications
- ❖ Fission Track Dating & Geochronology
- ❖ Instrumentation, Devices and Software
- ❖ SSNTDs in Teaching
- ❖ Radiation Induced Modification of Materials

The programme started with the inaugural function. Er. H.S. Chahal, Vice Chancellor, MD University Rohtak was the chief guest of the function and he delivered the inaugural address. Sh. Rattan Singh Ji Gupta, Chairman, Aggarwal Vidya Pracharni Sabha and President, GB, Aggarwal College, Ballabgarh presided over the function and Prof. Vimlendu Tayal ji, Former Vice Chancellor, MGS University Bikaner and Principal, Nehru Memorial Law PG College Hanumangarh was the guest of Honour. The NTSI Organizing Committee discussed and laid a course of the conference. The Committee allocated time slots for each category and nominated invited speakers. The Scientific Programming Committee consisted of experts in the various source subfields. The Technical Committee judged all abstracts and selected oral speakers and poster presentations. I would like to thank all members for their huge efforts within the too short time.

I would like to express my deep appreciation to all those members who participated and advised the organizers to launch Life Time Achievement Awards to few renowned scientists in the field of SSNTDs. The list included Prof. S.K. Chakravarti, Associated Dean Research & Development, Manav Rachna International University, Faridabad; Dr. M.R. Iyer (Retd.) Head, Radiation Safety Systems Division Bhabha Atomic Research Centre, Mumbai; Prof. R.H. Iyer, Former Head, Radiochemistry Division Bhabha Atomic Research Centre Mumbai & Ex- Emeritus Scientist (CSIR); Prof. T.V. Ramachandran, Ex-BARC and Prof. Rajendera Prasad, Ex-AMU and Director General, VCTM Aligarh. There were also best poster awards for the Best Posters which were won by L.A. Sathish, Bangalore, Jaskiran Kaur, Jyoti Sharma Aligarh, Nitin Gupta, Ballabgarh, Paramjit Singh Delhi and Rashi Gupta, Delhi University.

The Local Organizing Committee managed everything following the policy of NTSI and the respective chairpersons smoothly managed the oral and poster sessions. An excursion to the holy cities Vrindavan and Mathura had brought visible pleasure and eternal relief to the participants.

I would like to express my special thanks to all my colleagues and staff at Aggarwal College Ballabgarh for putting in hard work and tireless efforts in making the SSNTDs-18 a grand success with a special mention of the NSS Volunteers. Special thanks are due to Prof. S.K. Chakarvarti for his valuable suggestions and advices from time to time.

The three day symposium ended with the valedictory function. Prof. Dr. P.B. Sharma, Vice Chancellor, Delhi Technological University, Delhi, was the chief guest of the function and delivered the valedictory address. Sh. Tarun Gupta, CA presided over the function and Sh. Devender Gupta, Director, Pivotal Infrastructure was the guest of Honour. Dr. Krishan Kant, Newly elected president of NTSI, Convener of the Symposium and Principal, Aggarwal P.G. College Ballabgarh was felicitated by the NTSI for his exemplary work done in organizing the symposium.

The conference proceedings are being published as a special issue of ISST Journal of Applied Physics. I would like to express my special thanks to the publisher for their tremendous efforts.

I would like to announce that the Prof. J. Sannappa had been selected by the NTSI as the next 19th National Conference on Solid State Nuclear Track Detectors and Their Applications (SSNTDs-19) host and the venue will be Department of Studies and Research in Physics, Kuvempu University, Shankaraghatta – 577451. The chair of SSNTDs-19 is Dr. Krishan Kant, President NTSI. I hope old participants and new comers join with him in 2015 and fill the history with their cooperation.

At the end of this preface, I would like to express my deep appreciation and thanks to all the Government sponsors namely UGC New Delhi, DST New Delhi, DGHE Haryana, DST Haryana, CSIR, AERB, BRNS, IOCL, INSA, OBC Bank and Private sponsors in Faridabad for their financial support. Their support turned out to be a prime reason for the grand success of the SSNTDs-18. The website, <http://www.ntsindia.org> is in operation and will be maintained by NTSI. Again, I would like to thank all members of Local Organizing Committee, Secretaries, and student Volunteers.

Dr. Krishan Kant

Convener SSNTDs-18, Principal Aggarwal College Ballabgarh & President NTSI
(A Post Graduate Co-educational College accredited 'A' Grade by NAAC)

“TRACKS” IN TECHNOLOGY AND TEACHING

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ABSTRACT

It is now more than four decades since Young and Silk and Barnes published their first observation on nuclear tracks in solids. Young showed how to obtain the shallow pits of fission fragments in lithium fluoride and Silk and Barnes described their results on TEM of fission tracks from uranium in mica. These opened up new vistas for further initiation and research and development of new track detectors, their applications in various areas. From their very inception, Solid State Nuclear Track detectors (SSNTDs) have found various applications in a myriad of fields of science and technology - from high energy particle physics to generation of nano/micro structures and nano-particles encompassing nanotechnology into their folds. Being adorned with simplicity, ease in handling, versatility, low cost and independence from complicated electronic processing and circuitry intricacies, they have been primarily used as particle detectors, and in understanding and investigating some basic nuclear laboratory experiments. The beginners may find several reviews and published work encompassing information and stimulation

However, these have not been able to attract much attention of the students and teachers as well for their exploitation and possible inclusion in the undergraduate laboratory curriculum. The curiosity on the experimental observations may lead to such questions as "Why do we get nuclear tracks?"; "How do we get them?"; and "What are they good for?". By the use of SSNTDs one may carry out several useful and impressive educational experiments and demonstrations to illustrate different phenomena when teaching of nuclear physics.

This talk describes some of the technological applications of the tracks besides possible undergraduate low cost and simple experiments like range and half-life measurements; nuclear statistics; alpha, fission fragments, and auto-radiography techniques; filtration characteristics and electrical conduction measurements etc.- all involving the use of SSNTDs. The apparatus involved is simple and inexpensive, avoiding costly electronics, and the very high efficiency of plastic detectors in particular makes them ideally suited for work with very weak radioactive sources.

Some interesting experiments for the students of Botany and Zoology have also been suggested.

STUDY OF URANIUM CONCENTRATION IN GROUNDWATER SAMPLES OF SW-PUNJAB

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ABSTRACT

In the present investigation, an extensive study of uranium in groundwater samples of the four SW districts of Punjab – mainly the Bathinda, Mansa, Faridkot and Ferozpur, has been carried out using the Laser Fluorimetric technique. The maximum concentration of uranium in groundwater has been observed to be 684 ppb in the Bathinda district, with variation from 0.4 to 684.3 ppb, with mean value around 82 ppb. In Mansa district the variation has been observed to be from 0.3- 579 ppb, with mean value of 77 ppb. In the other two districts the maximum uranium concentration has been observed to be around 476 ppb. From the frequency distribution of all the samples analyzed in these districts, it has been observed that about 41% of the samples have uranium concentration more than the national prescribed limit of 60 ppb, which is the radiological limit set by the Atomic Energy regulatory board (AERB) of India for drinking waters. Overall, the observed mean values of uranium concentration in all these four districts of SW- Punjab, were found above the permissible limits recommended by the AERB & particularly the limit of 30 ppb set by the World Health Organization (WHO) has been crossed by majority of the samples. No depth wise distribution relation with uranium gets established, except the Bathinda district. A good correlation between uranium content in groundwater with the total dissolved solids (TDS) and the salinity was also observed. The results of the variation of uranium content in soil samples collected from of the study region will also be discussed, along with the possible source for high concentration groundwater.

RADIATION AND HEALTH: LOW-LEVEL-IONIZING RADIATION EXPOSURE AND EFFECTS

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ABSTRACT

We are living in a milieu of radiations and continuously exposed to radiations (natural and manmade) from conception to death. We are exposed to radiation from Sun and outer space, radioactive materials present in the earth, house we live in, buildings and workplace, food we eat & air we breath. Each flake of snow, grain of soil, drop of rain, a flower, and even each man in the street is a source of this radiation Even our own bodies contain naturally occurring radioactive elements. With the increasing use of radiation in health facilities, scientific research, industry and agriculture, the study of impact of low-level ionizing radiation on environment and possible health effects on future generations has been a cause of concern in recent years. Some of the exposures are fairly constant and uniform for all individuals everywhere, whereas the other exposures vary depending on the place, time, height above the ground and meteorological conditions. Exposures can also vary as a result of human activities and practices. The general belief is that the radiations are harmful and everybody is scared of the same and the cancer is the most important concern on account of exposure to Ionizing Radiation which is initiated by the damage to DNA. As regards the effects, it is established fact that high doses of ionizing radiation are harmful to health, there exists, however, a low-dose (exposure to low-level-ionizing radiation) controversy.

The LNT theory which is considered to be the radiation paradigm considers all radiation at all levels to be harmful and the severity of the deleterious effect increases with the increase in dose. The purpose of the talk is to address the question, whether the radiation is harmful at all levels or it is simply media hype and the truth is different, and to promote harmony with nature and to improve our quality of life with the knowledge that cancer mortality rates decrease following exposure to LLIR. In the present paper, brief review of the available literature, data and reports of various radiation exposure and protection studies is presented. An in-depth analysis of the reports available suggests that the possible beneficial outcomes of exposure to LLIR are: Increased Growth rate, Development, Neurogenesis, Memory, Fecundity (Fertility), Immunity (Resistance to diseases due to large doses of radiation) and Lifespan (Longevity) and Decreased Cancer deaths, Cardiovascular deaths, Respiratory deaths, Neonatal deaths, Sterility, Infection, Premature deaths. The findings also suggest that the LNT theory is overly stated for assessing carcinogenic risks at low doses. It is not scientifically justified and should be banned as it creates radio phobia thereby blocking the efforts to supply reliable, environmentally friendly nuclear energy and important medical therapies. There is no need for anyone to live in fear of serious health consequences from the radioactivity that comes out from nuclear installations and exposures in the range of background radiation.

A linear quadratic model has been given illustrating the validity of radiation hormesis, besides the comparison of the dose rates arising from natural and manmade sources to the Indian population.

MODIFICATION OF OPTICAL, STRUCTURAL AND DIELECTRIC PROPERTIES OF MeV ION IRRADIATED PS/Ag AND PMMA/Ag NANOCOMPOSITES

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ABSTRACT

In order to study structural, thermal, optical and dielectric behaviors, samples of PS/Ag and PMMA/Ag nanocomposites were irradiated with carbon (85 MeV) ions. The changes in properties were analyzed using different techniques viz: X-ray diffraction, UV-visible spectroscopy, differential scanning calorimetry, and impedance gain phase analyzer. A noticeable increase and decrease in the intensity of X-ray diffraction peaks were observed after irradiation with 85 MeV C-ions, which may be attributed to radiation-induced cross-linking and chain scissioning in PS and PMMA nanocomposites respectively. Optical properties like band gap was estimated for pure polymer and nanocomposite films from their optical absorption spectra in the wavelength region 200-800 nm. It was found that the band gap value shifted to lower energy on doping with silver nanoparticles and also upon irradiation. Differential scanning calorimetry analysis revealed an increase in the glass transition temperature upon irradiation, which may be attributed to cross linking of polymer chain due to ion beam irradiation which is also corroborated with XRD analysis in PS nanocomposites and scissioning of polymer chain due to irradiation in PMMA nanocomposites. Dependence of dielectric properties on frequency, fluence and filler concentration was studied. The results revealed the enhancement in dielectric properties after doping nanoparticles and also upon irradiation. The results of same ion induced on different polymer matrices will be discussed.

NATURAL RADIOACTIVITY IN SOME PARTS OF ANDHRA PRADESH: A REVIEW

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ABSTRACT

The environmental nuclear radiation is invisible, odorless and poorly understood by the public. Its exposure to human beings from natural sources is continuing and inescapable feature and it has been a cause of extreme public concern. The Andhra Pradesh state capital, Hyderabad, is located in the granitic areas of Deccan plateau forming a part of the peninsular gneissic complex designated as unclassified crystalline consisting of varieties of granites, granite gneisses and pegmatites. In addition, rich mineralization of different metals found in various parts of the state is due to the diversified geology of Andhra Pradesh. Uranium mineralization is present in crescent shaped Cuddapah basin. The extraction of uranium has been initiated in Thummalapally of Kadapa district and the same is proposed in Lambapur and Peddagattu areas of Nalgonda district. Heavy metal mineralization is found in Northeast coast and huge coal mineralization along Godavari river basin is being extracted by Singareni Coal Mines Company Limited. It is expected that such mining and extraction activities can enhance the radiation levels in the environment leading to exposure of higher dose to the living population. Hence, there is a need to estimate the environmental radiation levels in the habitats of these areas and to this end, our group has initiated a systematic study on dose received by the population in the different environs of Andhra Pradesh state. The present work reviews the data on nuclear radiation levels in these mineralized areas along with some districts of the state including the capital city, Hyderabad.

ENVIRONMENTAL THORON (^{220}Rn) : A REVIEW

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ABSTRACT

Ever since studies on uranium miners established the presence of a positive risk coefficient for the occurrence of lung cancer in miners exposed to elevated levels of ^{222}Rn and its progeny, there was a great upsurge of interest in the measurement of ^{222}Rn in the environment and considerable data is generated on the levels of ^{222}Rn in the environment across the worlds and is periodically reported by UNSCEAR. In contrast to this, data pertaining to ^{220}Rn in indoors and workplace environment is scare due to the general perception that its levels are negligible due to its shorter half life, and subsequently its contribution to the total inhalation dose is ignored, in the presence of other significant sources of natural radiation. Many locations have higher levels of natural background radiation due to elevated levels of primordial radio nuclides in the soil and their decay products like radon (^{222}Rn), and thoron (^{220}Rn) in the environment. It is estimated inhalation of ^{222}Rn , ^{220}Rn and their short lived progenies contribute more than 54 % of the total natural background radiation dose received by the general population. This component is not adequately estimated for any country so far on a national level. ^{220}Rn problem will also be a problem in industries which uses thorium nitrate. Including India, lamps using thoriated gas mantles are being still used for indoor and outdoor lighting and hawkers in rural as well as urban areas. Considering the fact that large amount of thorium nitrate is being handled by these industries, contribution to the inhalation dose of workers from ^{220}Rn gas emanated and build up of the progeny in ambient air may also be quite significant. In this article current status of ^{220}Rn levels in the indoor environment and workplaces as well as in other industries where large amount of ^{232}Th is being handled are being summarized.

LOW ENERGY ACCELERATORS FOR RESEARCH AND APPLICATIONS

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ABSTRACT

Charged particle accelerators are instruments for producing a variety of radiations under controlled conditions for basic and applied research as well as applications. They have helped enormously to study the matter, atoms, nuclei, sub-nuclear particles and their constituents, forces involved in the related phenomena etc. No other man-made instrument has been so effective in such studies as the accelerator. The largest accelerator constructed so far is the Large Hadron Collider (LHC) housed in a tunnel of 27 km circumference, while a small accelerator can fit inside a room. Small accelerators accelerate charged particles such as electrons, protons, deuterons, alphas and, in general, ions to low energy, generally, below several MeV. These particle beams are used for studies in nuclear astrophysics, atomic physics, material science, surface physics, bio-sciences etc. They are used for ion beam analysis such as RBS, PIXE, NRA, AMS, CPAA etc. More importantly, the ion beams have important industrial applications like ion implantation, surface modification, isotope production etc. while electron beams are used for material processing, material modification, sterilization, food preservation, non destructive testing etc. In this talk, role of low energy accelerators in research and industry as well as medicine will be discussed.

MEASUREMENT OF EQUILIBRIUM EQUIVALENT RADON AND THORON CONCENTRATION USING DRPS/DTPS TECHNIQUE

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ABSTRACT

Radon measurements are relatively simple to perform however, to assess radon concentrations in homes, the measurements need to be based on standardized protocols to ensure accuracy and consistency. Radon and thoron progeny concentrations contribute to the natural radiation dose to general public. Due to the fact that the inhalation doses due to radon and thoron are contributed predominantly by their decay products, development of passive techniques for monitoring the decay products directly assumes considerable significance. The concentrations of progenies are determined through Equivalent Equilibrium Concentrations of radon as well as thoron (EERC & EETC) respectively. EERC and EETC are measured by deposition based Direct Progeny Sensors (DPS) in bare modes. This DPS system uses absorber-mounted nuclear track detectors (LR-115 type II) which selectively register the tracks due to alpha emissions from ^{212}Po (α energy 8.78 MeV) and ^{214}Po (α energy 7.69 MeV) from the deposited atoms of thoron and radon progeny species, respectively. These are termed as DTPS (Direct thoron progeny sensor) and DRPS (Direct radon progeny sensor). Direct thoron progeny sensors (DTPS) and Direct radon progeny sensors (DRPS) are developed which are depositions based systems and hence ensure that they respond only to the decay products and not to gas concentrations. The recently developed DRPS (Direct Radon Progeny Sensors) technique for radon measurements for the present study will be better than previous available techniques viz. use of SSNTDs in bare and cup mode as both these provide information of radon gas concentrations and one has to apply equilibrium factor considerations for assessing the decay product exposures.

RADON REMEDIATION METHODS IN DWELLINGS

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ABSTRACT

Radon in soil air can enter the houses through any openings in the building that is in contact with the underlying ground. The major contributors to radioactive air pollutants in dwellings are radon and its progeny. As per the ICRP recommendations, it becomes necessary to take remedial steps for the reduction of radon daughters in a dwelling place if the level is found to be more than 200 Bq m^{-3} . There are different methods of indoor radon remediation viz.; pressurisation of air in the building, sealing the floor, enkavent mat method, Suction pit method, Subfloor depressurisation, subfloor ventilation and ventilation. Ventilation process can simulate the conditions generated through advection or diffusion; therefore it may be the major factors that control the indoor radon concentration in a room. The selection of building materials with low diffusion coefficient is also important for radon mitigation in new dwellings. In the present investigations, the effects of ventilation and type of building materials used were studied for indoor radon mitigation. The radon diffusion study through some building materials was also carried out. For radon concentration measurements the LR-115 type II solid-state nuclear track detectors (SSNTDs) were used. The results were also verified with active measurements using scintillation radon monitor (SRM). The effect of mixing of some materials in cement in order to reduce radon diffusion was also studied. The results indicate that optimized ventilation conditions and selection of proper building materials can be simple means of radon remediation in dwellings.

FREE VOLUME STUDY IN SHI IRRADIATED POLYMERS AND NANOCOMPOSITS BY POSITRON ANNIHILATION SPECTROSCOPY

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ABSTRACT

Polymers have potential applications in all fields of science and technology, especially in optics, electronics, biotechnology, photonics and space research. Interest in ion beam modification of the polymers has increased in recent years, prompted by the ion induced improvements in the mechanical, chemical, optical and electrical properties of various polymeric substrates and thus modification of polymer properties under ionizing radiation is a subject of great importance due to the enhanced utility of the polymers in a hard radiation environment such as high-energy particle accelerators, sterilization irradiators, nuclear power plants and space-crafts etc. Macroscopic properties of a polymer mainly depends on the atomic scale free volume holes and the determination of these free volume holes plays an important role in characterizing the microstructural properties of the polymer. Among various techniques which yield free volume information in polymeric materials, Positron Annihilation Lifetime Spectroscopy (PALS) is considered to be a most versatile and direct method. PALS have two prominent advantages in polymer research namely, the ability to detect the atomic scale free volume and the high sensitivity to the free volume related microstructural changes. Not only does the technique probe the free volume size and fractions of free volume but it also gives detailed information on the distribution of free volume hole size in the range from 1 to 10 Å. The atomic scale free volume holes are detected on the basis that positronium (Ps) atoms are formed and localized in the free volume holes. In Positron Annihilation Lifetime Spectroscopy (PALS) o-Ps pick off annihilation represents long lived component δ_3 which is directly correlated to the free volume hole size. The intensity of this component contains information about the free volume concentration. Swift Heavy Ion (SHI) irradiations of the samples were carried out at IUAC, New Delhi, VECC, Kolkata and GSI (Gesellschaft für Schwerionenforschung), Darmstadt, Germany. o-Ps lifetimes were measured through Positron Annihilation Lifetime Spectroscopy (PALS). Results for the polymers and nano composites in the present study indicate that o-Ps lifetime and, therefore, the free volume hole radius increases with the fluences in the lower region (10^5 to 10^8 ions / cm²). Its value decreases at higher fluences (10^{10} to 10^{13} ions /cm²). Physical and chemical properties were also studied by XRD, UV- Visible Spectroscopy and FTIR. The results will be discussed.

INDOOR RADON LEVELS IN BANGALORE METROPOLITAN: A REVIEW

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ABSTRACT

Indoor ^{222}Rn and ^{220}Rn levels for the environment of Bangalore city are surveyed for 7 years. The area of present study is Bangalore city lies over a hard and moderately dense gneissic basement dated back to the Archean era (2500–3500mya). A large granitic intrusion in the south central part of the city extends from the Golf Course in the north central to Vasantpur (VV Nagar) in the south of the city (almost 13 km in length) and on an average 4 km from East to West along the way. A magmatite intrusion formed within the granitic one extends for approximately 7.3 km running parallel with Krishna Rajendra road/Kanakapura road from Puttanna Chetty road in Chamrajpet till Bikaspura road in the south. These basic intrusions which mark the close of Archean era (Lower Proterozoic; 1600–2500 mya) mainly constitute hard massive rocks such as Gabbro, Dolerite, Norite and Pyroxenite. Solid State Nuclear Track Detectors were used for the long term measurements. Indoor ^{222}Rn and ^{220}Rn levels were measured for the environment of Bangalore city on room wise, flooring wise, wall wise, season wise, volume wise, ventilation wise and location wise. The measured range and mean value of ^{222}Rn levels in the ground water of different locations were found to be $14.3 - 480.2 \text{ BqL}^{-1}$ and 166.2 BqL^{-1} respectively. In all the study locations the concentration is higher than the permissible limit of 11.1 BqL^{-1} for drinking water. The maximum values of dose rates for the analyzed granite samples used for construction of buildings were in the range of 1.72 to 2.71 and the minimum values were varied from 1.05 to 1.66 mSvy^{-1} , whereas the AM and GM were in the range of 1.34 to 2.08 and 1.33 to 2.02 mSvy^{-1} respectively. Indoor ^{222}Rn and ^{220}Rn concentrations were ranged from 16.6 ± 0.9 to 81.0 ± 3.5 and 10.6 ± 1.7 to $38.6 \pm 6.1 \text{ Bqm}^{-3}$ for good and poor ventilation conditions respectively, for winter and summer seasons they were 42.42 ± 2.1 and $26.78 \pm 1.34 \text{ Bqm}^{-3}$ and 17.13 ± 0.69 and $15.2 \pm 0.76 \text{ Bqm}^{-3}$ respectively, 12.56 ± 0.62 and 10.78 ± 0.54 and 42.36 ± 2.1 and $21.34 \pm 1.0 \text{ Bqm}^{-3}$ for concrete and mud wall respectively for mosaic and granite flooring houses they were 20.13 ± 1.0 and 18.34 ± 0.9 and 47.80 ± 2.3 and $29.67 \pm 1.4 \text{ Bqm}^{-3}$ respectively, for living room and bed room they were 15.61 ± 0.7 and 13.46 ± 0.6 and 54.68 ± 2.7 and $30.91 \pm 1.5 \text{ Bqm}^{-3}$ respectively. The concentrations in a dwelling of volume ranged from 30-300 were 93 ± 4.6 and $14 \pm 0.7 \text{ Bqm}^{-3}$ respectively. The location wise arithmetic mean of ^{222}Rn concentration varies from 17.2 ± 1.2 to $85.9 \pm 2.3 \text{ Bqm}^{-3}$ with a mean of $33.4 \pm 6.1 \text{ Bqm}^{-3}$, whereas for ^{220}Rn it vary from 8.3 ± 1.2 to $38.3 \pm 5.4 \text{ Bqm}^{-3}$ with a mean of $21.6 \pm 2.5 \text{ Bqm}^{-3}$. Results in detail are presented.

INFLUENCE OF 100 MeV O¹⁶ ION IRRADIATION ON FET AND CHEMIREISTIVE PROPERTIES OF CONDUCTING POLYMER/SWNT COMPOSITE NANOFIBRILLAR MATRIX

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ABSTRACT

The foundation of present generation of sensors has been laid by the advent of 1-D nanomaterials together with state of the art nanofabrication technology. Among the highest explored sensing backbones, conducting polymers (CPs) and SWNTs have shown potential outcomes [1-4] in room temperature sensing applications. Bulk polymeric materials, mostly in form of thin films, have been reported to exhibit morphological deformation [5] due to high amount of energy transfer when subjected to SHI irradiation. Till date, investigations on SHI irradiation effects on SWNTs have been carried out, by and large, with low energy ions [6-7]. The behavior of the irradiation induced effects is governed in part by annealing and diffusion of parent defects i.e. vacancies and interstitials [6]. However, influence of SHI on FET and chemiresistive properties of Conducting Polymer / SWNTs composite has not been explored much.

The present communication deals with a report on electrochemical synthesis of P(NMP)/SWNTs composite nanofibrillar composite to bridge a 3 μ m gap between microstructured Au fingerpatterns on Si/SiO₂ substrate and influence of SHI irradiation of 100 MeV O¹⁶ ion at a vacuum level of 5 $\times$ 10⁻⁶ mbar (15UD Pelletron; Inter University Accelerator Center, New Delhi, India) under fluences of 1 $\times$ 10¹⁰ ions/cm², 5 $\times$ 10¹⁰ ions/cm² and 5 $\times$ 10¹¹ ions/cm² on composite nanostructure.

Formation of the composite nanofibrillar matrix was confirmed by comparative morphological and electrochemical study. Influence of SHI (100 MeV O¹⁶ ion) on the morphological, FET and chemiresistive properties of Conducting Polymer/SWNT Composite Nanofibrillar Matrix has been systematically studied.

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CHEMICAL, STRUCTURAL AND MORPHOLOGICAL MODIFICATIONS INDUCED BY SWIFT HEAVY ION BEAMS ON ELECTROCHEMICALLY SYNTHESIZED METAL POLYMER NANO COMPOSITES

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ABSTRACT

Metal conducting polymer composites Au-Polyaniline (Au-PANI) and Ag-Polypyrrole (Ag-PPy) are synthesised using two step electrochemical techniques. The first comprised of Galvanostatic technique for fabrication of Polypyrrole (PPy) film using various optimised process parameters and second step followed by the surface decoration of synthesized PPy film by Ag and Au metal particles using Cyclic Voltammetry under definite potential window and scan segment.

Study of the effect of 120 MeV Nickel (Ni^{9+}) ion beams on the (Au-PANI) composites films, and 120 MeV Nickel (Ni^{9+}) on Ag-PPy composite films is reported. Correlation between structural, chemical, microscopic properties and the role of Linear Transfer of Energy (LET) is discussed in detail. The effects of irradiation parameters such as energy, mass of ion, linear energy transfer (LET) and ion fluence on the structural, chemical and morphological properties of these composites are investigated. The composite films Au-PANI and Ag-PPy are characterized by using Raman spectroscopy, X-ray diffraction (XRD), I-V measurement and Scanning electron microscope (SEM) techniques before and after irradiation. Other parameters like interplanar and interchain distance, micro strain, dislocation density and distraction parameters are also calculated. The magnitude of the effect of ion beam energy and the influence of target material during the SHI irradiation are presented. An attempt is made to study the effect of SHI irradiation on Au-PANI and Ag-PANI on the basis of different Linear Energy Transfer (LET) of the ion beams. It is observed that the SHI irradiation of these materials enhances the physicochemical properties of the target material due to material modification.

COMPARATIVE STUDY OF SWIFT HEAVY IONS AND GAMMA RADIATION INDUCED MODIFICATION IN POLYMERIC MATERIALS AND THEIR CHARACTERIZATIONS

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ABSTRACT

Ion beam and radiation induced modifications of polymeric materials have shown great potential for improving their structural, optical as well as chemical and free volume properties. As a result, the past few years have seen many advances in the field of ion beam modification of polymeric materials in terms of applying conventional ion beam techniques to various types of polymers for industrial and scientific applications. The industrial and biomedical polymers were purchased from Goodfellow, U.K. and Bayer, Germany. Some of the doped polymer nanocomposites were synthesized Micro- emulsion method and solution cast method [1-3]. The different samples of these polymeric materials were irradiated by different ions and exposed to gamma rays at different fluences and doses at Inter University Accelerator Centre, New Delhi, India. A comparative study of these gamma rays and ion irradiated polymeric materials was carried out using X ray diffraction, UV- visible spectroscopy, Fourier transform infrared spectroscopy, Positron annihilation lifetime spectroscopy, Doppler broadening spectroscopy and Gas permeability [4,5]. The results will be discussed during the presentation.

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ELECTRON IRRADIATED MODIFIED PROPERTIES OF CONDUCTING POLYMER FOR SUPER CAPACITOR

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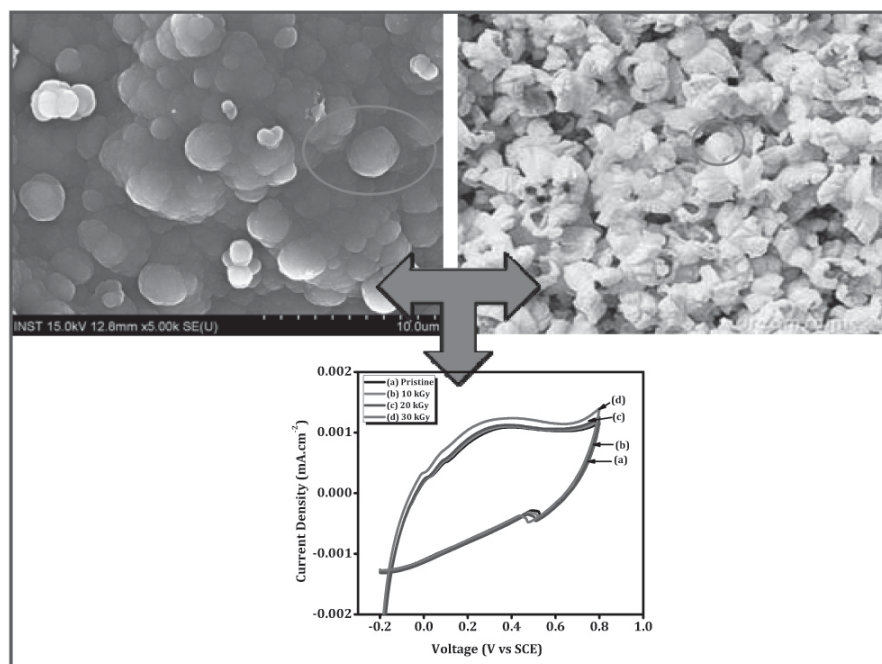
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ABSTRACT

Conducting polymers have wide applications in many types of device fabrication, apart from this; it has excellent ability for supercapacitor behavior. After optimization for the Polypyrrole films by electrodeposition, it shows the uniform in nature with compact adherent film on stainless steel substrate. As deposited and irradiated polypyrrole films show the different properties for different deposition times. The exercise has been made by different electron doses 10 – 50 kGy. In actual practice, it was cleared that, as - deposited polypyrrole films shows that capacitor as well as stability cycles are less than the irradiated one. The XRD shown that, after irradiation crystallite size increases. SEM clarified the same behavior i.e rise in grain size with decrease in band gap. Also, polypyrrole films was confirmed by FT-Raman and FT-IR techniques.

All the results show that, irradiated polypyrrole films are a promising member from polymer family for supercapacitor application with maximum capacitor and good stability.



RADIATION RELIABILITY STUDY OF HfO_2 HIGH-K GATE DIELECTRIC THIN FILMS FOR ADVANCED CMOS TECHNOLOGY

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Space systems require advanced CMOS technology to perform functions including communication, control, power conversion, and imaging. In space, the electronic devices are exposed to various forms of radiation, including electrons, protons, neutrons, and heavy ions. The radiation may produce effects in the electronic devices ranging from temporary loss of data to catastrophic failure. Electronic device failure can occur because of long-term degradation caused by continuous exposure to the space-radiation environment (total dose effects) or as a result of transient, high energy particle radiation (single event effects).

Most space systems are designed conservatively using electronic parts that are at least several generations behind the current state of the art. However, the demand for higher performance and reduced time from design to flight has increased the pressure to use advanced technologies in space. The effects of radiation in some advanced technologies are poorly understood, or in some cases, completely unknown. At present, it is not clear that it will be possible to use some advanced technologies in space, no matter how impressive the performance they promise. In addition, highly scaled devices may be sensitive to the naturally occurring radiation at the earth's surface, even though the atmosphere provides significant protection.

High-k dielectric materials have been considered as alternative gate oxides to overcome the scaling limit of SiO_2 due to high tunneling and reliability concerns. Among the various high-k dielectrics materials HfO_2 is considered as one of the most promising materials. HfO_2 exhibits desirable properties including a high dielectrics constant, high density, large bandgap, and a good thermal stability in contact with silicon relative to the other high-k materials. However it has several drawbacks too. Low crystallization temperature (600– 700 °C), large increase in EOT at high temperature due to interfacial layer growth, uncontrolled oxide formation at the Si/high-k interface, large hysteresis, fixed charge, charge trapping at the bulk, significant boron penetration, low channel mobility, and other reliability issues are the sources of serious concern. For ultrathin regime of equivalent oxide thickness (EOT) <1 nm, penetration of oxygen and impurities should be suppressed to maintain

low EOT and reduce flatband voltage fluctuation. Many issues such as electrical performance and thermal stability are directly affected by that interface. Other studies on the thermal behavior of HfO_2 reported relatively poor stability and formation of metallic silicide. Those studies report crystallization and morphological changes in the HfO_2 films. Some annealing studies reported changes in the interfacial chemical structure that suggest silicide formation. However, the physical and electrical properties of HfO_2 may suffer from its crystallization at high temperature during post deposition annealing, which in turn induces higher leakage current and severe boron penetration issues. High temperature annealing will lead to fast diffusion of oxygen through the HfO_2 , resulting in the growth of uncontrolled low-k interfacial layers. The uncontrolled low-k layers pose a serious limitation to further scaling of the equivalent oxide thickness (EOT) for HfO_2 gate dielectrics. Nevertheless, several integration challenges remain for these films in terms of their chemical stability, crystallinity, and stoichiometry, etc. Variables affecting overall gate stack quality include surface cleaning, specific deposition process (layer thickness, material composition and microstructure, structural defects) and post deposition annealing methodologies. All of these could have an impact on the gate stack quality and electrical properties such as equivalent oxide thickness (EOT), gate leakage current, and transistor characteristics such as the threshold voltage shift.

Despite large amount of ongoing research into alternative gate dielectric materials, very little work is done to understand the radiation responses of these materials. Therefore, the high-k system could become particularly important in radiation hard system utilized in space applications. For devices used in space systems, radiation exposure is another reliability problem. Over the last few decades, semiconductors have become the most important material for the fabrication of electronic and opto-electronic devices. The electronic systems embarked on board of spacecrafts are subjected to energetic radiations either of cosmic or solar origin and may cause change in behavior of the semiconductor devices. Considerable attention must therefore be given to the possible effects of such an environment on electronic components, and particularly on

semiconductor devices. The subject of radiation effects on semiconductor devices is very complex because of the numerous possible combinations of different types of radiation, radiation damage, and semiconductor devices affected by radiation. Hence, it is essential to know the behavior of these devices when exposed to various species of radiation at different energy levels, so that specific design margins can be kept in devices to make them survive in radiation harsh environments. For more than two decades a number of research groups tried exploring the behavioral changes of radiation exposed semiconductor devices and still a consensus could not be achieved about the exact mechanism that leads to degradation. One of the recent examples is the GAIA space mission which is due to launch in year 2012 by European Space Agency (ESA). It has been reported that the radiation issue is a top-level risk for GAIA mission which cannot be cured by any shielding as the solar activity with high energy particles is expected to be maximum in 2012. Under these circumstances, understanding the exact degradation mechanism and providing the necessary shielding with radhard designs calls for a higher priority along with other technological advances. The amount of radiation that semiconductor devices and materials encounter during their life cycle strongly depends on radiation environment and their operating conditions. Some of the environments where radiations can be encountered are space, nuclear reactors; high energy physics experiments using Bosons and Muons, ion implantation and e-beam/X-ray lithography during semiconductor device processing etc. The radiations can be broadly classified into charged particles and neutral particles. Charged particles consist of Protons, Electrons and heavy ions while the Neutrons and Photons are the neutral particles. Each type of radiation interacts with the matter in a different way which depends on the type, energy and mass of the incident particle and the mass, atomic number and the density of the target material. Semiconductor devices, when exposed to energetic radiations degrade, which is basically due to two phenomena (i) Ionization and (ii) Atomic displacement. Ionization effect creates electron-hole pairs while the displacement gives origin to interstitial atom and vacancy, which are together called a Frankel pair. Ionization effects can be divided into two types – Transient damage effects (in bulk) and Surface damage effects (in insulator). The transient effect refers to the transient changes in the electrical properties of devices caused due to ionization in the bulk silicon. Surface effects are the semi-permanent changes in the electrical behavior of the semiconductor devices caused due to the ionization near the surface of the silicon or the insulator layer. The charge collection and migration in the silicon dioxide layer on the surface of a transistor persists for years after the radiation exposure.

A lot of work has been done by the radiation effects community to investigate changes in Si-SiO₂ MOS-structures. With regard to the high-k systems, hardly any information is available on interaction of ion irradiation with HfO₂-Si MOS structures. With present day technology, HfO₂ as gate oxide finds its importance and is considered to be a suitable replacement for conventional SiO₂ and hence technologically it becomes very necessary to study the radiation interaction on these devices for reliability in radiation harsh environments and space applications. The radiation effects community may be entering a situation somewhat analogous to that of 30 years ago, early in silicon dioxide technology. An enormous amount of effort was required to develop conventional silicon dioxide based radiation hard technologies. A similar effort may be required to adapt the new high-k systems for radiation hard applications. Although the radiation hardness of thin EOT HfO₂ gate oxides appears to be relatively good, recent results have shown that the combined effects of irradiation and bias temperature stress (BTS) can lead to enhanced degradation. It has been of long standing concern that ionizing radiation will degrade the metal oxide semiconductor field effect transistor (MOSFET) performance and eventually make the device malfunction. This degradation is related to the radiation induced oxide charge buildup in the oxide layer and interface state generation at the Si/SiO₂ interface.

In this study, ultra thin film of HfO₂ gate dielectric was prepared on Si (100) substrate at room temperature by rf-sputtering and thermal treatment was given in Nitrogen and Oxygen ambient to study the structural and electrical properties of HfO₂ thin films. Positive Bias Temperature Instability (PBTI) on high-k HfO₂ sputtered thin films is compared and the effect of thermal annealing in oxygen and nitrogen ambient is studied. The systematic investigation of the fluencies effect of ions irradiations on series resistance and interface state density of HfO₂ based MOS-capacitor from C-V and G-V characteristics has been reported. The electrical properties of MOS devices were investigated at room temperature before and after ions irradiations. The results are analyzed and data are compared with the estimated interface trap densities obtained experimentally using Hill-Coleman's single-frequency technique before and after irradiation. We studied the effects of high-energy Li ions on electrical properties of high-k based MOS devices. The reason for choosing Li ion as a radiation source has been discussed. First sections give the fabrication details of HfO₂ MOS capacitors. In second section, the effect of Li-ion irradiation on the electrical properties of HfO₂ based MOS capacitors has been discussed. The first investigation on the effects of 50 MeV Li³⁺ ions on the interface trap density (D_{it}) and series

resistance (R_s) reveals the improvement in the dielectric properties of rf-sputtered HfO_2 -MOS capacitor. The samples were irradiated and characterized at room temperature. The D_{it} and R_s were determined from the capacitance–voltage (C–V) and conduction–voltage (G–V) characteristics at 1MHz. The measured capacitance and conductance were corrected for series resistance. It is found that the series resistance of Al/ HfO_2 /p-Si MOS capacitors increases with ion fluence, calculated at strong accumulation region before and after irradiation. The interface state density of MOS devices before and after irradiation is found to decrease with increasing ion fluence. In last section, the frequency dependent effect of 50 MeV Li^{3+} ion irradiation on the series resistance and interface state density determined from capacitance–voltage (C–V)

and conductance–voltage (G–V) characteristics in HfO_2 based MOS capacitors prepared by rf-sputtering are studied. The series resistance was estimated at various frequencies from 1 KHz to 1 MHz before and after irradiation. The results have been discussed. It was observed that the series resistance decreases from 6344.5 to 322 Ω as a function of frequency before irradiation and 8954 to 134 Ω after irradiation. HfO_2 based MOS capacitors were irradiated with high energy ion beam of 80 MeV O^{6+} ions. The samples were irradiated and characterized at room temperature. Devices were characterized via 1MHz capacitance–voltage (C–V) measurements using the midgap method. The irradiation dispersion induced in accumulation and depletion regions with increasing fluence is observed.

SOME INNOVATIVE USES OF SSNTDs IN BASIC AND APPLIED SCIENCES

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ABSTRACT

Solid State Nuclear Track Detectors (SSNTDs) which are dielectric materials, stand by a class by themselves in terms of their versatility, very high sensitivity for detection of energetic charged particles, incredibly low cost, unmatched simplicity to use and vast potential for basic and applied research in diverse fields of science and technology - all of which have attracted many Indian Universities and scientists all over the world working in diverse disciplines of science and technology to use it as a powerful tool in their own work.

These Unique features of SSNTDs particularly, their unmatched simplicity and incredibly low cost eminently qualify them for the title **“Aam Aadmi’s Research Tool”** (common man’s research tool). Any laboratory with basic facilities and having access to common chemicals such as NaOH, HF etc and a good optical microscope coupled with some ingenuity and innovative approach on the part of the researcher, can take up front-line R&D work in basic and applied sciences as we have demonstrated through our work in BARC over the last few decades. With a view to motivating young scholars, some specific cases from work done in BARC are cited in this paper, where the innovative use of SSNTD has led to results of profound significance both in basic and applied areas of physics and chemistry of nuclear fission process.

Key words; Fission tracks, cross sections, excitation functions, fission barriers, level density parameters, low-Z elements, trans-actinides, fission yields.

1. INTRODUCTION

The science of Solid State Nuclear Track Detectors (SSNTDs)- “Trackology” developed by R.L.Fleischer, P.B.Price and R.M.Walker in the early 1960’s of the last century is an interesting and potentially useful concept with something to offer to almost all branches of science and technology [1]. They are dielectric materials such as : Minerals → Mica, Quartz, Olivine, Zircon etc ; Glasses → Soda lime glass, Phosphate glass etc; Plastics → Polycarbonates : Lexan, Makrafol, CR-39, Milar, etc; → Cellulose nitrate : Daicel, LR115, CA-80-15, etc → Poly imides : Kapton, Upilex etc. which record and store the tracks of fast moving charged particles. The stored information can be conveniently retrieved by the experimenter by selective chemical etching and observation under an optical microscope.

Precision measurements in scientific research have generally come through the use of expensive instruments. The extreme simplicity of the SSNTD technique, coupled with the lack of dependence on costly electronics has made precision measurements, particularly investigations of rare and low cross-section events involving neutron and charged particle-induced nuclear reactions so inexpensive that even small laboratories with some basic facilities can

take up R&D work using this technique. A brief discussion of one or two areas of R&D work done in BARC, exploiting some of the special features of SSNTDs to demonstrate some innovative uses of SSNTDs and sensitize young scholars about the vast potential of SSNTDs in basic and applied sciences is presented in this paper. The topics discussed are in the area of physics and chemistry of nuclear fission involving measurement of extremely low fission cross sections (of the order of 10^{-33} cm^2) viz, fission properties of Low-Z ($Z \leq 80$) rare earth elements and an application of nuclear track registration from solution media for absolute fission yield measurements in the fast neutron-induced fission of trans-actinide elements (^{238}U , ^{237}Np , ^{238}Pu , ^{240}Pu , ^{243}Am , ^{244}Cm). The results have contributed both to our basic understanding of the systematics of fission process and generated data relevant to nuclear reactor technology.

2. SPECIAL FEATURES OF SSNTDs

Let us briefly examine some of the special features of SSNTDs, apart from their simplicity and inexpensive nature which make them extremely valuable for studies related to the fission process:

(a) they are insensitive to high background radiations making investigations on specific, rare and extremely low

cross-section nuclear reactions ($\leq 10^{-33} \text{ cm}^2$) possible.
 (b) they are amenable to different geometrical arrangements e.g. 2, 4, forward or backward recoil geometry etc.
 (c) they can be used in any size ranging from a few square millimeters (as in nuclear track registration from solution media) to several hundreds of square meters (as in cosmic ray and space science studies)
 (d) it is a non-electronic technique ,so no electronics breakdown to worry about.
 Taking advantage of these special features of SSNTDS an example each of some significant contributions in basic and applied the areas fission are outlined below:

3. SSNTDs FOR FISSION PROPERTIES OF LOW-Z ($Z \leq 80$) ELEMENTS IN THE RARE EARTH REGION ($Z \leq 65-70$)

While voluminous data are available in the literature on the fission properties of heavy elements ($Z \leq 90$) [1], those on lighter elements. ($Z \leq 80$) are very limited. This is because, the fission cross-sections of lighter elements even at excitation energies well above the fission threshold (fission barrier) are extremely small ,of the order of nano barns (10^{-33} cm^2) as compared to large fission cross sections of the order of barns (10^{-24} cm^2) for heavy elements even at moderate excitation energies. This puts extremely stringent conditions on the purity of the lighter elements targets with respect to heavy element contaminations to be less than a few parts per billion (ppb) . Additionally, the measurement methods should ,not only be extremely sensitive but also be highly discriminating against non-fission nuclear reactions. The fragile nature of the rare earth targets in the form of thin layers of oxides deposited on high purity silver foils and requirement of intense doses of helium ions ruled out the use of 2 geometry set-up

In spite of all these stringent experimental constraints, fission studies on a range of low-Z elements induced by moderate energy ($<100 \text{ MeV}$) charged particles also provide excellent opportunities for determining important nuclear parameters, such as fission barriers, (E_f), level density parameters for neutron emission (a_n) and fission (a_f), influence of shell effects etc by analysing the fission excitation functions (i.e. ; fission cross-sections as a function of excitation energy) and for comparing these parameters with predictions of theoretical models [2]

Reliable and accurate measurements of fission barriers particularly for lighter elements below Pb, ($Z = 82$) which are equivalent to measurement of nuclear masses at a “distorted saddle-point configuration” not only help in the understanding of the systematics of fission process in general , but also would enhance our understanding of the systematics of nuclear masses in general.

The importance of the present studies on the fission properties of elements in the rare earth region ($Z=65-70$) is that these elements have large ellipticity (Q/ZR^2 ; Q = quadrupole moment, Z =nuclear charge, R = nuclear radius) or large ground state deformation [3] which should , in principle, lead to a lowering of fission barrier by a few MeV i.e. larger than expected fission cross-sections as predicted by Hill and Wheeler [4]. Since the expected fission cross-sections are extremely low i.e.; of the order of nano- barns ($\sim 10^{-33} \text{ cm}^2$) , it would appear that even small effects of ground state distortion on the fission barrier might be seen around $Z=70$ from studies of neighbouring elements, all of which have large ground state deformation.

3.1 EXPERIMENTAL PROCEDURES.

As part of a long range program of work on fission properties of low -Z elements, the results of fission excitation functions of Terbium ($Z=65$), Holmium ($Z=67$), natural Erbium ($Z=68$) , and natural Ytterbium ($Z=70$) induced by He-ions in the energy 40-70 MeV from the variable energy cyclotron at Calcutta are reported here. The list of targets, irradiation conditions, compound nucleus formed etc. are briefly listed below:

3.1.1 Systems Studied:

Sr.#	Target	Projectile	Compound Nucleus
1	$^{159}_{65} \text{Tb}$	$^4_2 \text{He}$	$\rightarrow ^{163}_{67} \text{Ho}$
2	$^{165}_{67} \text{Ho}$	$^4_2 \text{He}$	$\rightarrow ^{169}_{69} \text{Tm}$
3	$^{167.3}_{68} \text{Er}^*$	$^4_2 \text{He}$	$\rightarrow ^{171.3}_{70} \text{Yb}$
4	$^{173.1}_{70} \text{Yb}^*$	$^4_2 \text{He}$	$\rightarrow ^{177.1}_{72} \text{Hf}$

* Natural abundance

3.1.2 Irradiation conditions:

- Cylindrical lexan detector system of 2.5cm height, 1.6cm diameter
- Projectile: 30-70 MeV Helium ions, 3 mm size, and a total integrated current $\approx 1-2 \mu\text{Ah}$
- Targets ultra high purity rare earth oxides of 1-2 mg/cm² thickness deposited on: 99.9999 % Silver foils of 10-12 mg /cm²

Details of experimental procedures, for the purification of the targets and backing foils, irradiation, data processing etc are available elsewhere [5,6,7] and are given here very briefly. A novel experimental set-up, almost identical to the one used by Raisbeck and Cobble [5] , in which fission fragments recoiling out of the thin targets in the backward direction with respect to the incident beam of alpha particles

were collected in a cylindrical lexan plastic detector .This arrangement provided both the sensitivity and the necessary discrimination against non-fission nuclear reactions. It also allowed fission fragments recoiling uni-directionally in the backward hemisphere over the laboratory angles 90° -- 165° to be detected. (in most cases, measurements were made over laboratory angles from 122° — 148°). A schematic sketch of the irradiation assembly is shown in Fig.1.

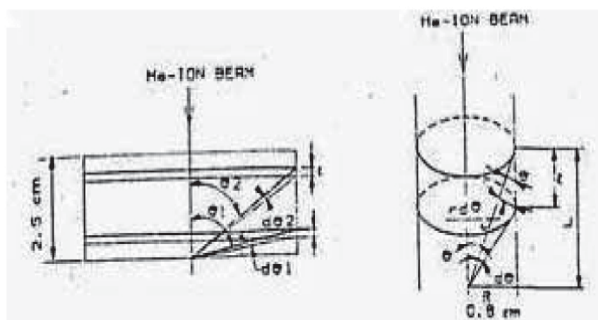


Fig.1: Schematic diagram showing track registration geometry .

The right hand diagram shows the position of the cylindrical lexan detector inside the target holder during irradiation. The left hand diagram shows the unfolded lexan foil fixed on the microscope slide. Each horizontal strip l scanned corresponds to a definite angle which the fission fragments make with the He-ion beam.

After irradiation, the lexan detector were etched in 6N NaOH at 60° for one h. Horizontal strips of the detector were scanned under an optical microscope. A photomicrograph of the uni-directionally oriented fission tracks is shown in Fig. 2.

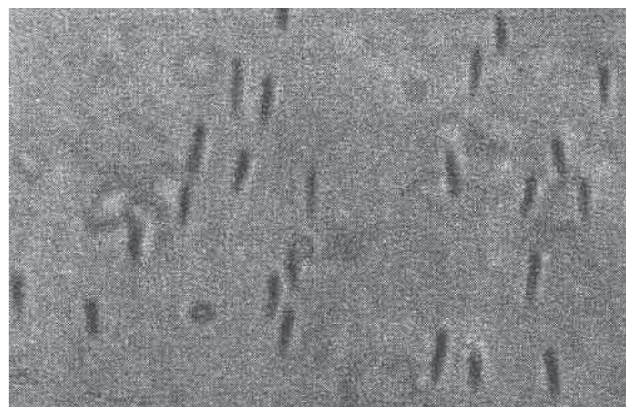


Fig. 2: Photomicrograph of the uni-directionally oriented fission tracks

The absolute cross-sections were calculated by comparing the number of tracks in a specified area (observation solid angle) of the sample with the number of tracks in the same area of a standard irradiated under the same conditions. In these experiments, we used both lutetium ($_{71}\text{Lu}^{175}$ and gold ($_{79}\text{Au}^{197}$) as standards whose absolute cross-sections as a function of Helium ion energy are known [5,8].

3.1.3 DATA ANALYSIS

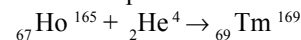
In the case of low Z elements fission, neutron emission predominates over fission and the ratio of fission cross-section to total reaction cross-section is nearly equal to the ratio of fission width to neutron emission width :

$$\sigma_f / \sigma_R \approx \Gamma_f / \Gamma_n .$$

The total reaction cross-sections were calculated using the optical model parameters of Huizenga and Igo [9]

As a representative result, the measured fission cross-sections, excitation function and the plot of fission to neutron emission width ratio of $_{67}\text{Ho}^{165} + _2\text{He}^4 \rightarrow _{69}\text{Tm}^{169}$ are given in Table 1 and Fig.3 (a,b) respectively. The excitation energies were calculated by assuming full momentum transfer and using Q -values derived from the mass tables of Myers and Swiatecki [10]

Table-1 Experimental fission cross-sections for holmium:



^4He ion energy (MeV)	Excitation energy (MeV)	Measured fission cross section σ_f (cm^2)	Calculated reaction cross section σ_R (cm^2)	$\Gamma_f/\Gamma_n \approx (\sigma_f/\sigma_R)$
70.0	67.2	$(2.75 \pm 0.09) \times 10^{-30}$	2.185×10^{-24}	1.259×10^{-6}
65.0	62.3	$(1.50 \pm 0.16) \times 10^{-30}$	2.146×10^{-24}	6.990×10^{-7}
60.0	57.4	$(8.42 \pm 0.44) \times 10^{-31}$	2.098×10^{-24}	4.013×10^{-7}
55.0	52.6	$(2.29 \pm 0.39) \times 10^{-31}$	2.038×10^{-24}	1.124×10^{-7}
50.0	47.7	$(8.90 \pm 0.78) \times 10^{-32}$	1.962×10^{-24}	4.536×10^{-8}
45.3	43.1	$(5.80 \pm 0.80) \times 10^{-33}$	1.864×10^{-24}	3.112×10^{-9}
45.0	42.8	$(2.50 \pm 0.90) \times 10^{-33}$ *	1.864×10^{-24}	1.341×10^{-9}
40.0	37.9	$(0.71 \pm 0.30) \times 10^{-33}$	1.735×10^{-24}	4.092×10^{-10}

* This value was not included in barrier calculations because the blank corrections were large.

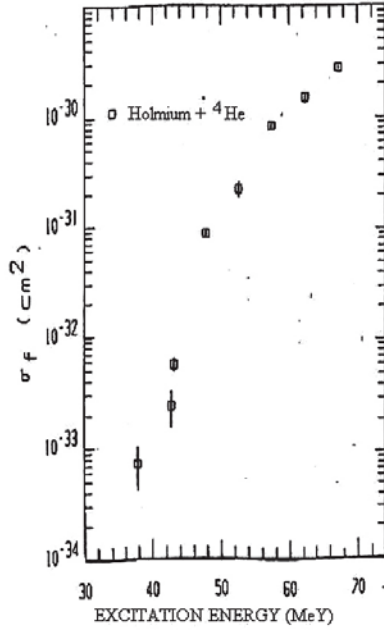


Fig. 3a : Measured fission cross-sections in the He-ion induced fission of holmium

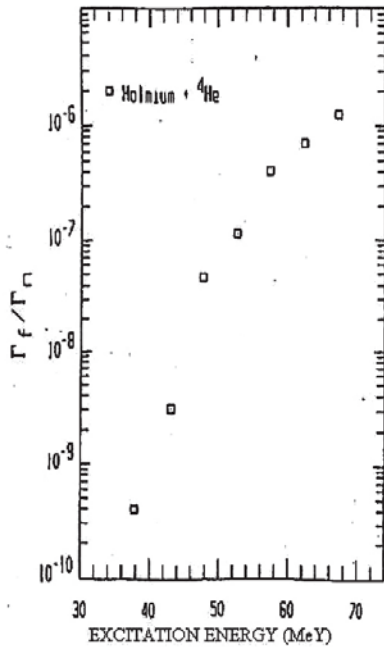


Fig. 3b: Plot of the fission to neutron emission width ratios v/s excitation energy for the He-ion induced fission of holmium

The experimental data were analysed by using the statistical model expression suggested by Vandenbosch and Huizenga [2]

$$\sigma_f / \sigma_n = \Gamma_f / \Gamma_n = K_0 \frac{a_n [2a_f^{1/2} \{E - E_f\}^{1/2} - 1]}{4A^{2/3} a_f \{E - B_n\}} \times \exp[2a_f^{1/2} \{E - E_f\}^{1/2} - 2a_f^{1/2} \{E - B_n\}^{1/2}]$$

In the above expression, E_f is the fission barrier, a_n and a_f are the level density parameters for neutron emission and fission respectively, E is excitation energy, B_n is the neutron binding energy, A is the mass number of the compound nucleus, and K_0 is a constant taken as :10.7 MeV. A least-square fitting procedure was used to fit the experimental Γ_f / Γ_n values to obtain the “best fit values” of E_f , a_f and a_n as shown in Fig.4

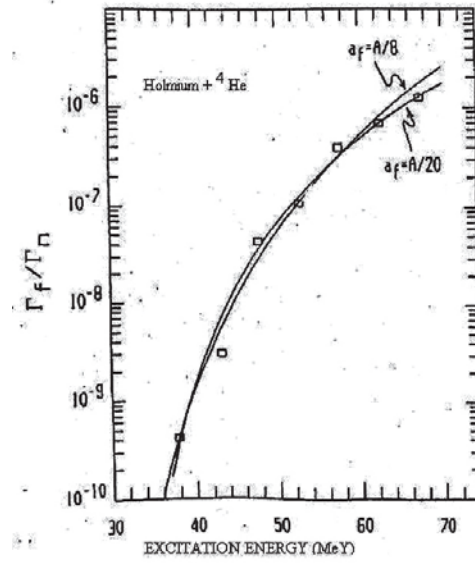


Fig. 4: Theoretical fits to the Γ_f / Γ_n data for the He-ion induced fission of Ho165 using a_f values $A/8$ and $A/20$

3.1.4 RESULTS AND CONCLUSIONS

The calculated fission barriers E_f , a_f and a_n for the systems studied are given below :

Sr.#	Compound nucleus	Fission barrier, E_f	Ratio σ_f / σ_n
1	$^{163}_{67}\text{Ho}$	31.5 ± 3.5 MeV	1.03 -- 1.00
2	$^{169}_{69}\text{Tm}$	29.8 ± 3.0 MeV	1.06 — 1.00
3	$^{171}_{70}\text{Yb}$	27.8 ± 3.0 MeV	1.03 — 1.00
4	$^{177}_{72}\text{Hf}$	26.7 ± 3.0 MeV	1.11 — 1.10

It is abundantly clear that these low cross-section measurements ($\sigma f \approx 10^{-33} - 10^{-30} \text{ cm}^2$) were difficult but made possible **exclusively by the innovative use of SSNTD**. The effort paid off in the sense that we are able to bring out some systematics concerning fission barriers, level density parameters, shell effects, ground state deformation, two-mode fission etc. Some of the significant findings of this work are:

- (i) The present measurements extend the range of low-Z elements in the deformed region for which fission barriers are determined experimentally.
- (ii) ${}^{67}\text{Ho}^{163}$ represents the lightest compound nucleus for which fission barrier has been determined experimentally
- (iii) Ground state deformation has very little, if any, influence on lowering the fission barriers in the deformed region.
- (iv) A systematic trend is observed in the ratios of level density parameters at saddle point to those at ground state (a_f/a_n) as a function of Z^2/A of the compound nucleus; The ratios tend to decrease as we move away from closed shell region and tend to approach unity in the region of deformed nuclei i.e. Ho^{163} , Tm^{169} , $\text{Yb}^{171..3}$, and Lu^{173} . This means that for nuclei in the deformed region, ground state and the “saddle point” have similar level structures and a_f and a_n tend to become equal

(The work described above formed part of the PhD thesis of one of my students, A.K. Pandey)

4. APPLICATIONS OF NUCLEAR TRACK REGISTRATION FROM SOLUTION MEDIA FOR ABSOLUTE FISSION YIELD MEASUREMENTS

We have had a glimpse of one aspect of fission studies where the direct or indirect use of SSNTDs have contributed to the growth of fundamental knowledge. We now cite another area of fission studies where the innovative use of these detectors has yielded results of applied interest to nuclear technology, namely absolute fission yield measurements. This is particularly relevant in the present context when the relevance of basic research is often debated upon.

The main constraints in the extensive use of SSNTDs in analytical applications is the time and effort involved in the manual counting of tracks under an optical microscope. Although some attractive instrumental methods of track counting are available, they are not simple enough for routine and general applications. In most analytical applications, tracks are usually registered from thin sources of the sample in contact with the detector in 2 geometry

(known as “dry method”). Though the registration efficiency is high, the distribution of tracks in different areas over the surface of the detector will not be uniform. Hence for any quantitative determination with reasonable accuracy, it is essential to scan the entire area of the detector to get the total number of tracks.

In this context nuclear track registration on detectors immersed in solution media known as “the wet method” or “solution detector method” is an important development. In spite of its lower sensitivity, “solution detector method” has greatly simplified the use of SSNTDs for analytical applications and substantially increased the accuracy and ease of quantitative measurements, both stemming from the uniform registration and distribution of track density in the detector. The flexibility and ease of sample preparation as also ease of scanning the detector and data evaluation has lead to many important applications in nuclear science and technology [11-15]. It has been extensively used for neutron flux monitoring, microanalysis of boron, lithium, actinides etc in various matrices at ultra trace levels as well as for measurement of absolute fission yields in the neutron-induced fission of actinides. [12 -14]. The unique feature of this technique is that for any given experiment, not more than about 200 μl of the target solution in a polypropylene tube and a detector size of 2 mm x 3 cm are needed. Details of the experimental procedure are available in some earlier publications. [11-15]. A photograph of the solution-detector arrangement is shown in Fig.5. A brief report on the use of this technique in combination with high resolution gamma spectrometry for the measurement of absolute fission yields in the neutron-induced fission of actinides is given below.

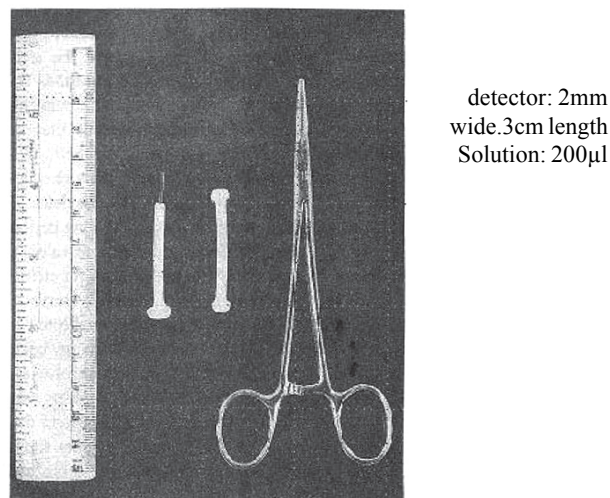


Fig. 5: Photograph showing poly propylene tube with lexan / mica detector partially inserted and the solution detector assembly and the haemostat used for pressure sealing.

4.1 “TRACK-ETCH-CUM-GAMMARAY SPECTROMETRY” FOR ABSOLUTE FISSION YIELD MEASUREMENTS

Accurate fission product nuclear data such as fission yields, cross-sections, decay schemes etc are required to resolve a number of problems associated with the design and operation of thermal and fast reactors as well as for other related applications such as calculation of burn-up, fission product inventory, shielding requirements, fuel handling procedures, evaluation of heat production, safeguards etc. The yields of short-lived fission products are required for decay heat calculations following a potential loss of coolant situation and also for testing the adequacy of models used for mass and charge distribution studies and for prediction of unmeasured yields.

While fission yield data are available in sufficient detail to meet the requirements for the thermal neutron-induced fissioning systems, the data for the fast neutron (reactor neutron) induced fission are scarce and are available only in a limited way for some of the actinide isotopes.

The advent and development of fast reactors have highlighted the need for accurate determination of fission yields in the fission of actinides induced by neutrons in the energy range 10 keV to 2 MeV. In the absence of sufficient experimental data, the yield data are calculations and models based on fission systematics.

Taking advantage of the recent availability of heavy element isotopes in a highly pure form through International Atomic Energy Agency (IAEA), and combining the unique features of nuclear track registration from solution media with high resolution gamma ray spectrometry, a simple and elegant methodology known as “Track-etch-cum-gamma spectrometry” was developed by us and used for the determination of an exhaustive and comprehensive set of absolute fission product yields in the fast neutron-induced fission of pure ^{238}U (99.9997 at %), pure ^{237}Np , ^{238}Pu (99.21 at %), ^{240}Pu (99.48 at %), ^{243}Am (99.998 at %) and ^{244}Cm (99.43 at %).

Many of the data obtained in this work are from first-time measurements. All these trans-actinide isotopes figure prominently in the present and future fast reactor programs [15]

The novelty and merit of the technique lie in the fact that it eliminates the need for the measurement of neutron flux, fission cross-section and the exact number of target atoms, thereby eliminating the errors associated with those measurements. The two crucial quantities: (i) the total number of fissions occurring in the target is determined

directly with a high degree of accuracy by recording in a mica/lexan strip, the number of fissions occurring in a dilute solution of the same target material. The solutions containing the mica/lexan strip and the target are irradiated simultaneously in the same irradiation environment. (ii) The number of atoms of fission products formed are determined by direct counting of their characteristic gamma radiations using a pre-calibrated Ge(Li) detector coupled to a PC-based 4k analyzer system.

The other major advantages of the technique are: the technique is simple, applicable to volatile and gaseous fission products such as Kr, Xe, Br, I and short-lived fission products. **It is also applicable to highly alpha active and sparingly available actinide isotopes requiring only a few micrograms of the isotopes for exhaustive and comprehensive measurements as we have demonstrated in this work.**

5. CONCLUDING REMARKS

We have had a glimpse of an example of the innovative use of SSNTDs in probing one of the many facets of the complex phenomena, namely nuclear fission. These results, arising out of front-line basic research have indeed contributed to the growth of fundamental knowledge.

Basic research is an adventure into uncharted territories with no guarantee of what may be found. There is of course, the possibility of finding something new and potentially useful. The development of “nuclear track registration from solution media” which has opened up many applications in nuclear science and technology is a classic example. It has simplified the use of SSNTDs in analytical applications and increased the accuracy and ease of quantitative measurements, both stemming from uniform registration and distribution of track density in the detector.

The message is clear: “Please maintain the tempo of front-line basic research in the country as a whole; The role of basic research as an essential ingredient of any R&D program cannot be reasonably questioned.”

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RADON DIFFUSION THROUGH SANDY CONSTRUCTION MATERIALS: EFFECT OF TEMPERATURE AND GRAIN SIZE

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ABSTRACT

Radon appears mainly by diffusion process from the point of origin, say, under ground soil and building materials used in construction of house following alpha decay of radium. The radon diffusion through different building construction materials can be compared by calculating radon diffusion coefficient for them. In the present work, we studied the effect of temperature and grain size on radon diffusion of coarse sand as construction material. The coarse sand was collected from Yamuna river bed, originated from Himalayas. For this study, a steel pipe of diameter 10 cm and length 30 cm., divided into four sectors of equal size, was filled in different sectors with different grain sized (800, 600 and 425 μm) sand as building construction material. A number of LR-115 type-II particle track detectors were placed with inter-detector distance of 10 cm in the sectorial compartments. The bottom end of steel pipe assembly was fixed with a radon chamber containing radon source with upper end sealed with a cap. The whole arrangement was then placed into a sand-clay pipe wrapped around by a controlled heating filament, resulting into temperature variations from 25°C to 60°C. After 100 days interval, the detectors were retrieved, processed, and the α -tracks counted for the calculation of radon concentration. It is observed that the radon diffusion coefficient increases with the increase in temperature and decreases with decrease in grain size of the coarse sand.

Keywords: Radon diffusion; Coarse sand; Temperature and grain size effects; LR-115.

1. INTRODUCTION

Radon, which is a topic of public health concern, has been found to be a ubiquitous indoor radioactive air pollutant to which all living organisms are exposed. It is well known that exposure of population to high concentrations of radon and its progeny for a long period leads to pathological effects like the respiratory functional changes and the occurrence of lung cancer [1]. Its transport mechanism, therefore, calls for innovative investigations. There are three main factors dictating radon entrance in to a building environment: a) Emission of radon from building materials used in construction, b) Convection through cracks and openings in the building and c) Diffusion from soil through voids and pore space within construction materials [2]. The diffusion of radon in dwellings is a process mainly determined by the radon concentration gradient across the building material structure between the radon source and the surrounding air. Radon diffusion and transport through different media is a complex process and is affected by

several factors [3,4]. The diffusion from soil via pore space of building materials is reduced when thickness of the basement slab is about three times the radon diffusion length [5]. The transport phenomenon of radon through diffusion, therefore, is a significant contributor to indoor radon entry [6,7].

For any material medium, the porosity, permeability and the diffusion coefficient are the parameters, which can quantify their capability to hinder the flow of radon soil gas. An increase in porosity will provide more air space within the material for radon to travel, thus reducing resistance to radon transport. The permeability of material describes ability to act as a barrier to gas movement when a pressure gradient exists across it and is closely related to the porosity of material. The radon diffusion coefficient of a material quantifies the ability of radon gas to move through it when a concentration gradient is the driving force. This parameter is proportional to the porosity and permeability of the

medium. Radon diffusion through material media obeys the equation:

$$N = N_0 \exp. (-\sqrt{\lambda/D}) X \quad (1)$$

where N is the concentration of radon at any time t at a distance X from source, N_0 is the concentration of radon at source, λ is the decay constant of radon, and D is the diffusion coefficient of radon. If N_1 and N_2 are the radon concentrations at distances X_1 and X_2 from source respectively,

then using eqⁿ (1), the diffusion coefficient D is given by:

$$D = \lambda [(X_2 - X_1) / \ln (N_1 / N_2)]^2 \quad (2)$$

Eqⁿ (2) can be used to calculate radon diffusion coefficient through material medium.

The diffusion length can be calculated using the eqⁿ:

$$L = \sqrt{D/\lambda}, \quad (3)$$

where D is radon diffusion coefficient and λ is decay constant of radon.

In the present study, radon diffusion coefficients and diffusion lengths have been calculated using eqⁿ (2) & (3).

2. EXPERIMENTAL DETAILS

The experimental set up designed for the study of radon diffusion through coarse sand of different grain size at different temperatures (25°C to 60°C), consists of a hollow steel cylinder of inner diameter 10 cm and length 30 cm deployed vertically in a sand-clay pipe equipped with controlled heating arrangement with temperature control system (Fig.1).

The radon source covered with latex membrane was fixed at the bottom of the cylinder in the cavity. Plastic cylindrical capsules, each 3 cm in length and 2.5 cm in diameter and closed at upper end, were used to fix LR-115 type-II plastic track detectors with sensitive side of the detector facing the source. The coarse sand under study in the pulverized form was filled in the four sectors created within the cylinder. The system was closed and left undisturbed for a period of 100 days for each medium under study.

At the end of the exposure time, the detectors were removed and subjected to a standardized chemical etching process for 90 min. in 2.5N NaOH solution at 60°C in etching bath with a constant speed magnetic stirrer so as to provide

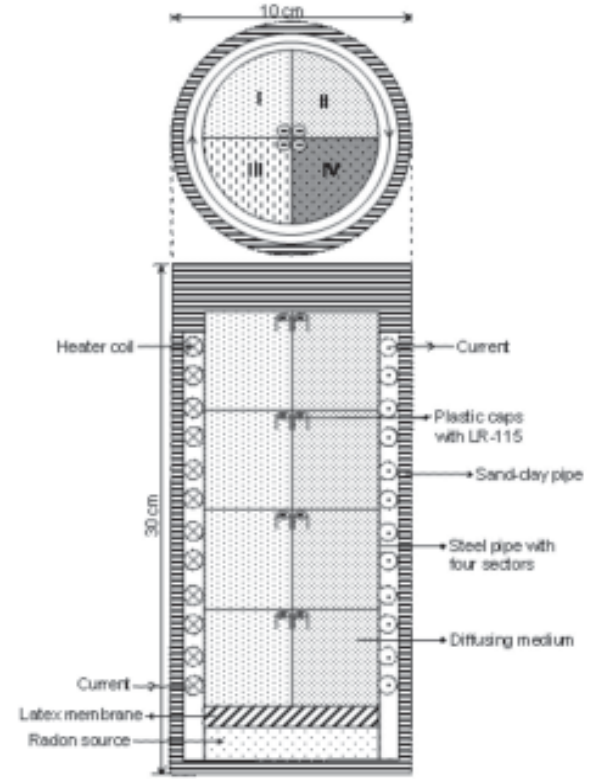


Fig. 1: The experimental set up used for the study of radon diffusion

homogeneous concentration of the etchant. After etching, the detectors were thoroughly washed, dried and the alpha tracks were counted using an optical Olympus microscope with CCTV camera and a monitor, at 600 X. Large number of graticular fields of the detectors were scanned to reduce statistical errors. The radon concentration was calculated for each sample in different cases using a calibration factor for LR-115 [8,9]. The correction due to material's own contribution towards background radon was also applied in each case under study. The values of diffusion coefficients for different media were calculated using eqⁿ (2) and the diffusion lengths using eqⁿ (3)

3. RESULTS AND DISCUSSION

The average values of diffusion coefficients are found to vary from $1.85 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ to $5.66 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ for coarse sand of grain size $425 \mu\text{m}$ when temperature was varied from 25°C to 60°C. In case of $600 \mu\text{m}$ size, the variation in diffusion coefficient varied from $3.57 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ to $8.40 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ while in case of $800 \mu\text{m}$ the values varied from $4.46 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ to $13.44 \times 10^{-6} \text{ m}^2 \text{ s}^{-1}$ for the same variation in temperature (Tables 1-4).

Table 1 Variation of diffusion coefficient and diffusion length of radon for coarse sand with different grain sizes at temperature 25°C.

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

Grain size (μm)	Diffusion coefficient $\times 10^{-6} (\text{m}^2 \text{s}^{-1})$	Diffusion length (m)
800	D1=4.34 D2=3.89 D3=5.16	L1=1.43 L2=1.35 L3=1.56
AM $\pm$ SE*	D=4.46 $\pm$ 0.36	L=1.44 $\pm$ 0.06
600	D1=3.64 D2=4.13 D3=2.94	L1=1.31 L2=1.39 L3=1.18
AM $\pm$ SE*	D=3.57 $\pm$ 0.34	L=1.29 $\pm$ 0.06
425	D1=1.97 D2=2.05 D3=1.54	L1=0.96 L2=0.98 L3=0.85
AM $\pm$ SE*	D=1.85 $\pm$ 0.15	L=0.93 $\pm$ 0.07

Table 2

Variation of diffusion coefficient and diffusion length of radon for coarse sand with different grain sizes at temperature 40°C.

Grain size(μm)	Diffusion coefficient $\times 10^{-6} (\text{m}^2 \text{s}^{-1})$	Diffusion length (m)
800	D1=7.22 D2=7.60 D3=6.86	L1=1.84 L2=1.89 L3=1.80
AM $\pm$ SE*	D=7.22 $\pm$ 0.21	L=1.84 $\pm$ 0.02
600	D1=5.07 D2=4.44 D3=3.84	L1=1.55 L2=1.45 L3=1.34
AM $\pm$ SE*	D=4.45 $\pm$ 0.35	L=1.44 $\pm$ 0.06
425	D1=2.81 D2=2.34 D3=2.54	L1=1.15 L2=1.05 L3=1.09
AM $\pm$ SE*	D=2.56 $\pm$ 0.13	L=1.09 $\pm$ 0.03

Table 3

Variation of diffusion coefficient and diffusion length of radon for coarse sand with different grain sizes at temperature 50°C.

Grain size(μm)	Diffusion coefficient $\times 10^{-6} (\text{m}^2 \text{s}^{-1})$	Diffusion length(m)
800	D1=10.43 D2=9.21 D3=8.97	L1=2.22 L2=2.08 L3=2.06
AM $\pm$ SE*	D=9.53 $\pm$ 0.45	L=2.12 $\pm$ 0.05
600	D1=6.23 D2=7.05 D3=5.49	L1=1.71 L2=1.82 L3=1.61
AM $\pm$ SE*	D=6.25 $\pm$ 0.45	L=1.71 $\pm$ 0.06
425	D1=3.73 D2=2.98 D3=3.94	D1=1.33 D2=1.18 D3=1.36
AM $\pm$ SE*	D=3.55 $\pm$ 0.05	D=1.29 $\pm$ 0.05

Table 4

Variation of diffusion coefficient and diffusion length of radon for coarse sand with different grain sizes at temperature 60°C.

Grain size (μm)	Diffusion coefficient $\times 10^{-6} (\text{m}^2 \text{s}^{-1})$	Diffusion length(m)
800	D1=13.43 D2=15.56 D3=11.34	L1=2.52 L2=2.71 L3=2.31
AM $\pm$ SE*	D=13.44 $\pm$ 1.21	L=2.51 $\pm$ 0.11
600	D1=8.86 D2=8.90 D3=7.46	L1=2.04 L2=2.05 L3=1.88
AM $\pm$ SE*	D=8.40 $\pm$ 0.04	L=1.99 $\pm$ 0.05
425	D1=5.84 D2=4.92 D3=6.23	L1=1.66 L2=1.52 L3=1.71
AM $\pm$ SE*	D=5.66 $\pm$ 0.38	L=1.63 $\pm$ 0.05

Table 5

Comparison of diffusion coefficient and diffusion length of radon for sand with other studies

S.No.	Diffusion coefficient $\times 10^{-6} (\text{m}^2 \text{s}^{-1})$	Diffusion length (m)	Reference
1	3.69	1.32	[10]
2	3.75	1.34	[4]
3	3.2	1.92	[11]
4	3.44	1.28	[12]
5	1.85-13.44	0.93-2.51	Present study*

* variation with temperature and grain size

The variation in D ($\text{m}^2 \text{s}^{-1}$) with temperature (K) is shown in the Fig.2 for different grain size of coarse sand.

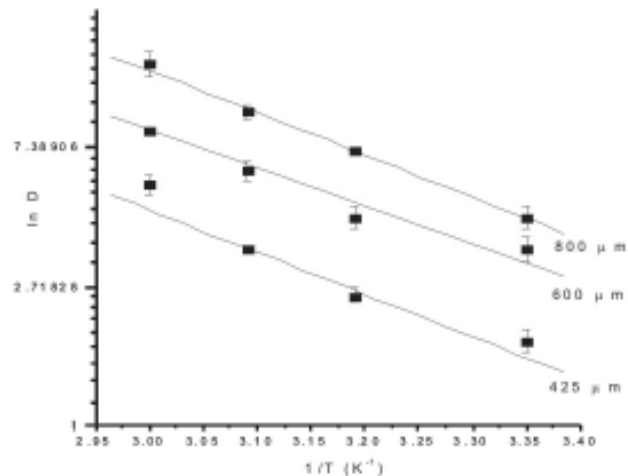


Fig. 2: The variation of radon diffusion coefficient with temperature for different grain sized coarse sand

The present study for radon diffusion through sandy materials and variation of diffusion coefficient with temperature of the medium is in accordance with Arrhenius equation,

$$D = D_0 \exp(-E/RT) \quad (4)$$

where R is a gas constant, T is the temperature (K) and D_0 is frequency factor. E is called the activation energy of diffusion, which is the energy required to produce the diffusive motion of one mole of atoms.

Taking logarithm, Eq. (4) gives:

$$\ln D = \ln D_0 - (E/RT) \quad (5)$$

The graph between $\ln D$ and $1/T$ for the present study is linear with a slope $(-E/R)$ and obeys the above eqn

At a particular temperature, the radon diffusion coefficient was found to decrease with decrease in grain size which may be due to decrease in porosity of the medium (Tables 1-4). Similar results for sandy materials have been reported by several researchers (Table-5) without taking into consideration the effect of temperature. The minor differences may be due to the difference in the nature, grain size and porosity of the materials. The results of our investigations also provide better insight into the selection of building construction materials capable of controlling the indoor radon levels.

4. ACKNOWLEDGEMENTS

The financial-aid and fellowship granted to A.K. Narula under FIP Scheme of University Grants Commission, New Delhi, India is thankfully acknowledged.

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STUDY OF INDOOR RADON AND THORON IN SOME DWELLINGS OF TUMKUR, KARNATAKA, INDIA

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ABSTRACT

Radon, a radioactive noble gas, daughter of ^{226}Ra , is present in the atmosphere in large concentration compared to other radioactive elements and contributes to a major portion of the average dose received by a human from all other radiation sources. Radon, thoron and their progenies are also present in indoor and outdoor atmosphere. Their concentration in indoor atmosphere is higher than that of outdoor due to accumulation. In the present study, twin cup dosimeters with alpha sensitive films, LR- 115 type-II, were used for the measurement of activities of radionuclides. The concentrations of radon, thoron and their progenies in dwellings with four different type of floorings viz. Marble, Mosaic, Cement and Granites with good and poor ventilation conditions in Tumkur district were measured. The mean inhalation doses in good and poor ventilated dwellings in all five taluks were 0.98 and 1.17mSv y^{-1} respectively. The inhalation dose was found to be highest in Madhugiri with 1.10 and 1.32mSv y^{-1} for good and poorly ventilated houses respectively. Also the study showed that, the concentrations of radon and thoron was more in dwellings with granite floorings. The dwelling situated near the granite rocks showed higher concentrations.

Keywords: Radon, Thoron, Floorings, Inhalation Dose, Solid State Nuclear Track Detector (SSNTD).

1. INTRODUCTION

Worldwide average annual effective dose from ionizing radiation from natural sources is estimated to be 2.4 mSv , of which about 1.0 mSv is due to radon exposure [1]. There are three isotopes of the element radon present in nature, viz. ^{219}Rn , ^{220}Rn and ^{222}Rn called Actinon, thoron and radon, which are the intermediate products of the decay of ^{238}U , ^{232}Th and ^{235}U series, respectively. The half lives of Actinon, thoron and radon are 3.96 s , 55.6 s and 3.823 days respectively. Among the three, Radon and thoron play a major role in the radiation effects produced due to considerably high half life period than actinon. The isotopes ^{226}Ra and ^{224}Ra if present in the earth crust, soil, building materials, rocks, ground water etc., decay to produce radon and thoron respectively. Since the building materials are made out of rock, soil, bricks, clay, sand, cement etc, which contain ^{226}Ra and ^{238}U , radon gas produced from them can easily escape into the indoor and outdoor atmosphere [2,3].

The building materials such as sand, clay bricks, mosaic, clay, tiles, fly ash, gypsum, concrete blocks, granite marble

stone etc. contain high radium, which is a source of radon. Usually houses are built with a concrete foundation and flooring. The flooring is again covered with tiles, marble or granite. Granite is the chief source of radium hence radon concentration may increase in such buildings. The ventilation conditions also change the concentrations of radon, thoron and their progenies in the dwellings.

2. MATERIALS AND METHODS

In the present study, poorly and good ventilated houses of area $30^1 \times 40^1$ made up of floors with cement, mosaic, marble and granites in five taluks of Tumkur district were studied. The indoor ambient gamma radiation levels around the study area have been measured using Scintillometer (Type SM 141D). State Nuclear Track Detector (SSNTD), LR 115 type II, detectors were used in the twin cup dosimeters to measure the concentrations of radon, thoron and their progenies in different dwellings in the study area. The schematic diagram of twin cup dosimeter is shown in Fig. 1. The dosimeters were suspended at a height of 2 m from the floor of the dwellings and exposed for 90 days , developed; tracks

Table 1
Indoor gamma dose rates in some taluks of Tumkur district.

Sl no.	Location	Gamma exposure rate ($\mu\text{R} \cdot \text{hr}^{-1}$)	Absorbed dose ($\text{nGy} \cdot \text{hr}^{-1}$)	Effective gamma dose ($\text{mSv} \cdot \text{yr}^{-1}$)
1	Tiptur	18.2	158.3	0.77
2	C.N. halli	16.2	140.9	0.69
3	Pavagada	29.4	255.7	1.25
4	Madhugiri	26.2	227.9	1.11
5	Koratagere	24.2	210.5	1.03
Mean	0.97			

Table 2
Radon, thoron and their progeny concentrations and dose rates in good ventilated houses (STDEV = Standard Deviation).

Sl no.	Location	Type of flooring	Concentrations ($\text{Bq} \cdot \text{m}^{-3}$)		Progeny conc.(mWL)		Annual inhalation dose (mSv)
			Radon	Thoron	Radon	Thoron	
1	Tiptur	Marble	25.54	2.32	2.76	0.84	0.72
		Mosaic	31.24	2.53	3.37	0.92	0.88
		Cement	39.00	2.99	4.22	1.09	1.10
		Granite	38.00	3.37	4.10	1.22	1.08
		STDEV	6.30	0.47	0.68	0.17	0.18
2	C.N. halli	Marble	21.53	1.94	2.32	0.70	0.61
		Mosaic	26.60	2.36	2.87	0.86	0.75
		Cement	31.24	2.87	3.37	1.04	0.89
		Granite	35.25	3.16	3.81	1.15	1.00
		STDEV	5.92	0.54	0.64	0.20	0.17
3	Pavagada	Marble	27.65	2.06	2.98	0.75	0.77
		Mosaic	32.08	2.78	3.46	1.01	0.91
		Cement	37.78	3.29	4.08	1.19	1.07
		Granite	41.80	3.58	4.51	1.30	1.18
		STDEV	6.23	0.67	0.67	0.24	0.18
4	Madhugiri	Marble	32.72	2.74	3.53	0.99	0.92
		Mosaic	34.20	3.29	3.69	1.19	0.97
		Cement	41.80	3.80	4.51	1.38	1.19
		Granite	46.86	4.64	5.06	1.68	1.34
		STDEV	6.63	0.81	0.72	0.29	0.20
5	Koratagere	Marble	31.03	1.94	3.35	0.70	0.86
		Mosaic	37.78	2.78	4.08	1.01	1.06
		Cement	42.64	3.29	4.61	1.19	1.20
		Granite	44.96	4.01	4.86	1.45	1.27
		STDEV	6.16	0.87	0.67	0.32	0.18

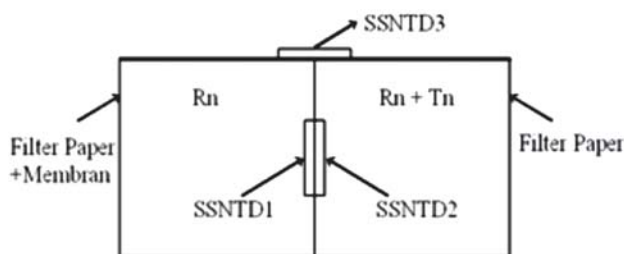


Fig. 1: Schematic diagram of twincup dosimeter.

produced were counted using a spark counter and converted into concentrations of radioactive gases and different dose parameters such as annual effective dose,

Life time fatality risk factor etc. were determined using suitable formulae [4,5].

3. RESULTS AND DISCUSSION

Table 1 shows the variation of indoor ambient gamma level in different dwellings. The indoor effective doses were found to be highest in Pavagada with $1.25 \text{ mSv} \cdot \text{yr}^{-1}$ and lowest was found in C.N.Halli with $0.69 \text{ mSv} \cdot \text{yr}^{-1}$. The elevated gamma radiation dose in Pavagada is mainly due to the underground morphology which is made up of granite. The lowest in C.N.Halli is due to the presence of red soil and lack of granitic geology.

Table 3
Annual exposure and life time fatality risk due to Radon and thoron in good ventilated houses.

Sl no.	Location	Type of flooring	Annual exposure (WLM)		Annual exposure (WLM)($^{222}\text{Rn} + ^{220}\text{Rn}$)	Life time fatality risk (10^{-4})	Annual effective dose (mSv)
			^{222}Rn	^{220}Rn			
1	Tiptur	Marble	0.11	0.03	0.15	0.44	0.58
		Mosaic	0.14	0.04	0.18	0.53	0.69
		Cement	0.17	0.04	0.22	0.66	0.85
		Granite	0.17	0.05	0.22	0.66	0.85
		STDEV	0.03	0.01	0.03	0.10	0.13
2	C.N. halli	Marble	0.10	0.03	0.12	0.37	0.48
		Mosaic	0.12	0.04	0.15	0.46	0.60
		Cement	0.14	0.04	0.18	0.55	0.70
		Granite	0.16	0.05	0.20	0.61	0.79
		STDEV	0.03	0.01	0.03	0.10	0.13
3	Pavagada	Marble	0.12	0.03	0.15	0.46	0.60
		Mosaic	0.14	0.04	0.18	0.55	0.71
		Cement	0.17	0.05	0.22	0.65	0.84
		Granite	0.19	0.05	0.24	0.72	0.93
		STDEV	0.03	0.01	0.04	0.11	0.15
4	Madhugiri	Marble	0.15	0.04	0.19	0.56	0.72
		Mosaic	0.15	0.05	0.20	0.60	0.78
		Cement	0.19	0.06	0.24	0.73	0.94
		Granite	0.21	0.07	0.28	0.83	1.08
		STDEV	0.03	0.01	0.04	0.12	0.16
5	Koratagere	Marble	0.14	0.03	0.17	0.50	0.65
		Mosaic	0.17	0.04	0.21	0.63	0.81
		Cement	0.19	0.05	0.24	0.72	0.93
		Granite	0.20	0.06	0.26	0.78	1.01
		STDEV	0.03	0.01	0.04	0.12	0.16

Table 4
Radon, thoron and their progeny concentrations and dose rates in poorly ventilated houses.

Sl no.	Location	Type of flooring	Concentrations (Bqm ⁻³)		Progeny conc.(mWL)		Annual inhalation dose (mSv)
			Radon	Thoron	Radon	Thoron	
1	Tiptur	Marble	33.67	2.66	3.64	0.96	0.95
		Mosaic	37.68	2.99	4.07	1.09	1.06
		Cement	41.37	3.33	4.47	1.21	1.16
		Granite	45.17	3.75	4.88	1.36	1.27
		STDEV	4.93	0.47	0.53	0.17	0.14
2	C.N. halli	Marble	36.52	2.38	3.94	0.86	1.01
		Mosaic	39.26	2.76	4.24	1.00	1.10
		Cement	41.58	3.25	4.49	1.18	1.17
		Granite	43.70	3.99	4.72	1.45	1.24
		STDEV	3.09	0.69	0.34	0.25	0.10
3	Pavagada	Marble	32.72	2.68	3.53	0.97	0.92
		Mosaic	36.31	3.20	3.92	1.16	1.03
		Cement	41.16	3.71	4.45	1.35	1.17
		Granite	44.75	4.05	4.83	1.47	1.27
		STDEV	5.30	0.60	0.57	0.22	0.15
4	Madhugiri	Marble	41.80	3.46	4.51	1.25	1.18
		Mosaic	44.54	4.01	4.81	1.45	1.26
		Cement	48.97	4.43	5.29	1.61	1.39
		Granite	51.72	5.06	5.59	1.84	1.48
		STDEV	4.44	0.68	0.48	0.25	0.13

5	Koratagere	Marble	36.31	2.40	3.92	0.87	1.01
		Mosaic	41.80	3.27	4.51	1.18	1.17
		Cement	45.81	3.71	4.95	1.35	1.29
		Granite	48.55	4.53	5.24	1.65	1.38
		STDEV	5.32	0.89	0.57	0.33	0.16

Table 5
Annual exposure and life time fatality risk due to Radon and thoron in poorly ventilated houses.

Sl no.	Location	Type of flooring	Annual exposure (WLM)		Annual exposure (WLM)(²²² Rn+ ²²⁰ Rn)	Life time fatality risk (10 ⁻⁴)	Annual effective dose (mSv)
			²²² Rn	²²⁰ Rn			
1	Tiptur	Marble	0.15	0.04	0.19	0.57	0.74
		Mosaic	0.17	0.04	0.21	0.64	0.82
		Cement	0.18	0.05	0.23	0.70	0.91
		Granite	0.20	0.06	0.26	0.77	1.00
		STDEV	0.02	0.01	0.03	0.09	0.11
2	C.N. halli	Marble	0.16	0.04	0.20	0.59	0.77
		Mosaic	0.17	0.04	0.22	0.65	0.84
		Cement	0.18	0.05	0.23	0.70	0.91
		Granite	0.19	0.06	0.25	0.76	0.99
		STDEV	0.01	0.01	0.02	0.07	0.09
3	Pavagada	Marble	0.15	0.04	0.19	0.56	0.72
		Mosaic	0.16	0.05	0.21	0.63	0.81
		Cement	0.18	0.06	0.24	0.72	0.93
		Granite	0.20	0.06	0.26	0.78	1.01
		STDEV	0.02	0.01	0.03	0.10	0.13
4	Madhugiri	Marble	0.19	0.05	0.24	0.71	0.92
		Mosaic	0.20	0.06	0.26	0.77	1.00
		Cement	0.22	0.07	0.28	0.85	1.10
		Granite	0.23	0.08	0.31	0.92	1.19
		STDEV	0.02	0.01	0.03	0.09	0.12
5	Koratagere	Marble	0.16	0.04	0.20	0.59	0.77
		Mosaic	0.19	0.05	0.23	0.70	0.91
		Cement	0.20	0.06	0.26	0.78	1.01
		Granite	0.22	0.07	0.28	0.85	1.10
		STDEV	0.02	0.01	0.04	0.11	0.14

From table 2, in good ventilated dwellings, it is observed that the concentration of radon, thoron and their progeny were found to be highest in dwellings made up of granitic floorings (35.25 to 46.86 Bqm⁻³) in all the five taluks under study and the lowest were observed in marble floorings (21.53 to 32.72 Bqm⁻³) in five regions.

Also from table 4, in poorly ventilated dwellings, it is observed that, the concentration of radon, thoron and their progeny were found to be again highest in dwellings made up of granitic floorings (43.7 to 51.72 Bqm⁻³) in all the five taluks under study and the lowest were observed in marble floorings.

The radon concentration in dwellings with cement floorings were higher than that with marble flooring. This is because

cement is made up of mixture of lime stone and gypsum and cement flooring make use of gravel cement mixture which increases the radium content of the floor hence radon exhalations were higher. Marble mainly contains silica and lower activity of radio nuclides compared to granites hence radon concentrations were found to be less than that of dwellings with cement, mosaic and granitic floorings. Granites contains high amount of Uranium and radium, hence produces higher radon exhalation resulting in elevated indoor radon concentrations [6, 7]. L.A. Sathish et al found that, houses with mosaic floorings showed slightly less radon exhalation rates than with cement flooring in Mysore city [8]. Jing Chen et al. [9] studied radon exhalation from building materials. They found that, when the entire doors were covered with granite slabs, the radon exhalation rates were to be 300 Bqm⁻²h⁻¹, which adds 18 Bqm⁻³ to indoor

radon when an air exchange system was operating properly. Without ventilation there would be elevated radon levels [9]. The ventilation of the dwellings is also responsible for the increased indoor radon and thoron concentration which intern enhances the inhalation dose. Poor ventilation hinders the air exchange from the surroundings thereby accumulating and increasing the radioactive gas concentration inside the dwelling. The risk factor called life time fatality risk factor was highest in Madhugiri and lowest in C.N.Halli with a mean of 0.60 and 0.71×10^{-4} in good and poorly ventilated dwellings among the five taluks under study.

5. CONCLUSION

The average annual effective dose radon and thoron in the Five taluks of Tumkur district was 0.78 and 0.92 mSvy 1 for good and poorly ventilated dwellings. The regions with granite geology showed elevated amount of radon concentrations. The dwellings made with marble flooring showed low concentration of radon and that of granite higher radon concentration.

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RADON, THORON AND THEIR PROGENY LEVELS IN SOME DWELLINGS OF UNION TERRITORY CHANDIGARH, INDIA, USING SSNTDs

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ABSTRACT

Indoor air quality is an important issue for protection against adverse health effects caused by the inhalation of pollutants because most individuals spend 90% of their time indoors and that indoor air quality is deteriorated by a large variety of sources. Out of these sources radon is a major pollutant and is an important global problem of radiation hygiene. Radon and its progeny are the major contributors in the radiation dose received by general population of the world. Next to cigarette smoking, the inhalation of radon gas and the products of its radioactive disintegration are considered the most significant cause of lung cancer. Due to the potentially serious public health implications of exposure to high levels of radon, the environmental monitoring of radon, thoron and their progeny in some dwellings of Chandigarh, India has been carried out. The radon-thoron twin dosimeter cups were used for the study. The aim of the study is the possible health risk assessment in the dwellings under consideration.

Keywords: Radon, thoron, Solid State Nuclear Track Detectors (SSNTDs), Dwellings.

1. INTRODUCTION

Radon comes from its parent radium which is common in earth's crust. Radon contributes about half of the background radiation to which we are all exposed [1]. The main sources of indoor radon are soils and rocks source emanations and emanation from building materials. The radon emanation from the soil depends upon various factors of the soil viz. its radium content, porosity, grain size, moisture content and permeability through host rock and soil [2]. The entry of the radon in the buildings can be through cracks and other openings in it, which may be due to the aging of the structure or due to any other problem. Penetrations through basement walls, joints between the basement walls and floor are the examples of openings that facilitate the entry of radon. The entry of radon indoor is also facilitated by less value of pressure inside the home than the surroundings. Being soluble in water radon gets indoors as water is drawn indoors by the capillary action of the pores in concrete or pushed by hydrostatic pressure [3].

After entering indoor it mixes up with indoor air and gets inhaled by the residents of the dwellings. Inhaled with air

radon and its progeny can irradiate the lung tissues leading to the damage of these cells and may cause lung cancer [4]. Due to this International Commission on Radiological Protection (ICRP) has made recommendations for the control of this exposure in dwellings and work place [5]. Keeping this in mind the levels of radon and thoron in some dwellings of Chandigarh has been measured using solid state nuclear track detectors and twin cup dosimeters.

These types of studies are useful for the assessment of radiation dose received by the inhabitants and also for producing the data for producing the radon map of the country. The values measured were looked into as per the recommendations given by the International Commission on Radiological Protection (ICRP).

Fig. 1 shows the area Chandigarh where the study has been conducted. It is located between 30° 40' N and 30° 46' N latitude and between 76° 42' E and 76° 51' E longitude. It is located at the foothills of the Siwaliks and shares its borders with the states of Haryana and Punjab. Three different types of dwellings were selected according to their ventilation

conditions viz. poor, average and good ventilated. The building material of dwellings was similar and was having cemented walls and floorings. The dwellings monitored were from the different localities of the Chandigarh for a uniform distribution. The annual effective dose received by the inhabitants was looked into in the light of guidelines given by International Commission on Radiological Protection, 2009 [6].



Fig. 1: Geo location map of Chandigarh

2. MATERIALS AND METHODS

Indoor radon and thoron concentration was measured using passive technique of exposing solid state nuclear track detectors in radon-thoron twin dosimeter cups [7]. The radon-thoron dosimeter cup has three different modes namely bare mode, filter mode and membrane mode. The membrane mode detector registers tracks only due to radon; the filter mode detector registers tracks due to radon and thoron while bare mode detector registers tracks due to radon, thoron and their progeny. Three pieces each of size (2 cm x 2 cm) of LR-115 type 2 strippable Solid-State Nuclear Track Detectors were fixed in the dosimeters and were suspended in the room for three months at a height more than 2 m above the ground level and about 1 meter below the ceiling of the room. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5 N NaOH solutions at 60°C for 90 minutes. The tracks produced by the alpha particles were counted using a spark counter. The measured track density (tracks/cm²/day) was converted into radon and thoron

concentration using calibration factors [18]. For calculating the radon and thoron progeny levels in mWL the indoor equilibrium factor of 0.4 for radon and 0.1 for thoron are used [9]. Annual dose received by the inhabitants in the dwellings under study in mSv was estimated using the relation given elsewhere [10].

3. RESULT AND DISCUSSION

The indoor radon and thoron concentrations in some dwellings of Chandigarh are listed in table 1.

Table 1
Radon and thoron levels in dwellings of Chandigarh

Dwelling	Radon Conc. C_R (Bq m ⁻³)	Thoron Conc. C_T (Bq m ⁻³)	Annual Dose (mSv)
1	27.1	24.1	1.25
2	27.9	7.8	0.91
3	18.5	2.7	0.53
4	25.9	3.8	0.78
5	21.2	6.3	0.70
6	18.5	19.1	0.93
7	29.3	16.0	1.13
8	14.9	15.7	0.73
9	34.2	17.1	1.34
10	28.2	2.8	0.79

The indoor radon concentration in Chandigarh varied from 14.9 Bq m⁻³ to 34.2 Bq m⁻³ with an average of 24.6 Bq m⁻³ while the thoron concentration in the same dwellings varied from 2.7 Bq m⁻³ to 24.1 Bq m⁻³ with an average of 11.5 Bq m⁻³. Annual dose received by the inhabitants in the dwellings under study varied from 0.53 to 1.34 mSv with an average of 0.91 mSv. The value of annual dose received by the inhabitants of dwelling no. 1, 7 and 9 are found to be on higher side because of the poor ventilation conditions of these dwellings. The dwellings 3, 5 and 8 are good ventilated and the dwellings 2, 4, 6 and 10 are average ventilated and so the annual dose received by the inhabitants shows small values. However, the values of indoor radon levels found were below the lower limits of reference level as recommended by the ICRP, 2009 [6]. These values are also matching with the world average of 40 Bq m⁻³ [11]. The variation found in the radon concentration of different dwellings may be explained due to different ventilation rates, the nature and type of building material used during construction and the variation in the radioactive levels in the soil beneath the dwellings.

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ESTIMATION OF ANNUAL RADIATION DOSE RECEIVED BY SOME INDUSTRIAL WORKERS

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ABSTRACT

Radon in its progeny in the atmosphere, soil, ground water, oil and gas deposits contribute the largest fraction of the natural radiation dose to populations, enhanced interest exhibits in tracking its concentration is thus fundamental for radiation protection. The combustion of coal in various industrial units like thermal power plants, National fertilizer plants, paper mill etc. results in the release of some natural radioactivity to the atmosphere through formation of fly ash and bottom ash or slag. This consequently increases the radioactivity in soil, water and atmosphere around the thermal power plant. Keeping this in mind the measurement of radon, thoron and their progeny concentration in the environment of some industrial unit has been carried out using solid state nuclear track detectors (SSNTD). The specially designed twin cup dosimeter used here consists of two chamber of cylindrical geometry separated by a wall in the middle of each having a length of 4.5 cm and 3.1 cm. The annual effective dose received by the workers in some industrial units been calculated. The results indicate some higher levels in coal handling and fly ash area of plants.

Keywords: Radon; thoron; Decay products; SSNTD; Industrial unit; Annual effective dose.

1 INTRODUCTION

The measurement of radon and thoron in human's environment is of interest because of its alpha emitting nature. A certain fraction of the radon escapes into the air where, in the outdoors, it is quickly diluted and is of less concern. However, in confined spaces such as homes and office buildings, radon can accumulate to harmful levels. Radon is a naturally occurring odourless, colourless, tasteless inert gas which is imperceptible to our senses. The half life 3.824 days of radon makes it important to study as far as radiation dose is concerned. Radon is able to escape from the soil and building materials cement sand etc. and enter the atmosphere. Many environmental pollutants are classified as cancer-causing solely on the basis of laboratory studies using either animals or cell cultures. In the case of radon and thoron there is direct evidence from human studies of a link between exposure to radon and lung cancer. For this reason radon has been classified by the International Agency for Research on Cancer, World Health Organization [1] as a Group 1 carcinogen. This places radon in the same group of carcinogens as asbestos and tobacco

smoke. General public living in dwellings are exposed to radon and its short-lived progeny, because uranium is widely distributed in the Earth's crust [2]. Hence, radon can become a health hazard to the general public living in such environment. Considerable data is generated on the levels of ^{222}Rn in the environment [3,4]. In contrast, data on ^{220}Rn is scarce due to the general perception that its level is negligible due to its shorter half life (55 sec), and its contribution to inhalation dose is ignored, in the presence of other more significant natural radiation. This may not be true from the recent studies resulted in the observation of high ^{220}Rn in the living environments in various countries and it is now increasingly felt that it may be necessary to have information on ^{220}Rn levels in the environment for obtaining a complete picture of inhalation dose [5]. This makes the necessity of measurement of indoor radioactive pollutants like radon, thoron and absorbed dose to lung including their impact on health.

Electrical energy is the most fundamental requirement and coal, a fossil fuel, is the most abundant resource for

electricity generation. Thermal power generation is associated with the dispersal of radionuclides in the environment and the activities of radionuclides discharged in the atmosphere from a thermal power plant depend on a number of factors such as activity concentration in coal, ash content in coal, temperature of combustion and efficiency of the filtering systems etc. In the production of electric power, coal is burnt in furnaces operating at temperature up to 1700°C and by this process most of the mineral matter in the coal is fused into vitrified ash. A portion of ash and incompletely burnt organic matter drop to the bottom of the furnace as bottom ash or slag. The fly ash, however, is carried through the boiler along with the hot flue gases to the stack where some fractions are collected while the rest escape in to the atmosphere. The exposure of population to high concentrations of radon and its daughters for a long period leads to pathological effects like the respiratory functional changes and the occurrence of lung cancer [6]. Similarly the raw products used in other industries also cause emission of radioactive gas. The goal of the present investigations is the radon, thoron monitoring of various industrial unit and estimate the annual effective dose received by the workers.

2. MATERIALS AND METHODS

For the measurement of concentration of radon, radon and thoron both, and total sum of radon, thoron and their progeny in the dwellings, the radon-thoron mixed field dosimeter popularly known as, 'Twin Chamber Radon-Thoron Dosimeter, developed by Bhabha Atomic Research Centre (BARC) has been employed. The specially designed twin cup dosimeter used in present study consists of two chambers of cylindrical geometry separated by a wall in the middle with each having a length of 4.5 cm and radius of 3.1 cm. This dosimeter employs three SSNTDs out of which two detectors were placed in each chamber and a third one was placed on the outer surface of the dosimeter. One chamber is fitted with glass fiber filter so that radon and thoron both can diffuse into the chamber while in other chamber, a semi permeable membrane made of latex or cellulose nitrate, having a thickness of 25 µm is used. The membrane mode measures the radon concentration alone as it can diffuse through the membrane but suppresses the thoron. The twin cup dosimeter also has a provision for bare mode enabling it to register tracks due to radon, thoron and their progeny in total. Therefore, using this dosimeter we can measure the individual concentration of radon, thoron, and their progeny at the same time (Fig.1).

The dosimeters were suspended at a height a height of about 1.5 m in order to evaluate the annual average indoor radon levels. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process

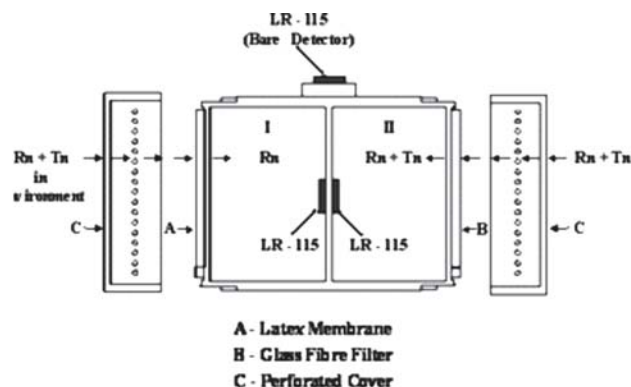


Fig. 1: Twin Chamber Radon-thoron Dosimeter

in 2.5N NaOH solution at 60°C for 90 minutes. The detectors were washed and dried and the tracks produced by the alpha particles were observed and counted under an optical Olympus microscope at 600X. A large number of graticular fields of the detectors were scanned to reduce statistical errors. The measured track density (Track/cm²/day) was converted into radon and thoron concentration using calibration factors [7]. Radon and thoron progeny levels in mWL has also been calculated using indoor equilibrium factor as 0.4 for radon and 0.1 for thoron from UNSCEAR [8]. Annual dose received by the inhabitants in the dwellings under study in mSv was estimated using the relation [9-10]:

$$D = [(0.17 + 9F_R)C_R + (0.11 + 32F_T)C_T] \times 7000 \times 10^{-6},$$

where, F_R = equilibrium factor for radon; C_R = radon concentration; F_T = equilibrium factor for thoron and C_T = thoron concentration

3. RESULTS AND DISCUSSION

The results of the measurement of radon, thoron and their progeny from various industrials unit an location are listed in table 1-3. The radon and thoron concentration from Indian Oil refinery, Panipat varied from 30 to 91 and 3 to 48 Bq/m³ with an average of 52 ± 7 and 22 ± 6 Bq/m³ respectively. The radon and thoron progeny levels varied from 3.3 to 7.4 mWL and 0.1 to 1.3 mWL with an average of 5.3 ± 0.5 and 0.6 ± 0.1 respectively. The annual effective dose received by the worker of Indian Oil refinery, Panipat due to radon and thoron varied from 1.5 to 2.6 mSv with an average of 1.9 ± 0.2 . The radon and thoron concentration from of L.P.G Bottling Plant, Panipat, Haryana varied from 61 to 91 and 10 to 24 Bq/m³ with an average of 76 ± 5 and 16 ± 2 Bq/m³ respectively. The radon and thoron progeny levels varied from 4.9 to 9.1 mWL and 0.3 to 0.7 mWL with an average of 7.0 ± 0.5 and 0.4 ± 0.05 respectively. The annual effective dose received by the worker of of L.P.G Bottling Plant, Panipat, Haryana due to radon and thoron varied from 1.9

Table 1
Radioactivity Levels and Annual Effective Dose Received by the Workers of Indian Oil Refinery Panipat, Haryana

Location	Radon Conc. Bq/m ³	Thoron Conc. Bq/m ³	Radon Progeny (mWL)	Thoron Progeny (mWL)	Annual Effective Dose (mSv)
Utility Control Room	53	36	5.8	0.9	2.2
Air Monitoring Station	91	9	7.4	0.3	2.6
Boiling Area	46	12	4.9	0.4	1.5
Sulphur Treat Unit	46	20	4.9	0.6	1.7
Cooling Tower	46	29	4.9	0.8	1.7
Laboratory	53	3	5.8	0.1	1.5
TPS Control Room	30	48	3.3	1.3	1.8
AM $\pm$ SE*	52 $\pm$ 7	22 $\pm$ 6	5.3 $\pm$ 0.5	0.6 $\pm$ 0.1	1.9 $\pm$ 0.2

Table 2
Radioactivity Levels and Annual Effective Dose Received by the Workers of L.P.G Bottling Plant, Panipat, Haryana

Location	Radon Conc. Bq/m ³	Thoron Conc. Bq/m ³	Radon Progeny (mWL)	Thoron Progeny (mWL)	Annual Effective Dose (mSv)
Comp. House	91	24	6.3	0.7	3
Pump House	91	10	4.9	0.3	2.7
Canteen	84	16	9.1	0.4	2.6
Air Comp. House	76	17	8.2	0.5	2.4
Fire Pump Area	69	18	7.4	0.4	2.3
Generator Room	61	19	6.6	0.5	2
Store	61	10	6.6	0.3	1.9
AM $\pm$ SE*	76 $\pm$ 5	16 $\pm$ 2	7.0 $\pm$ 0.5	0.4 $\pm$ 0.05	2.4 $\pm$ 0.2

Table 3
Radioactivity Levels and Annual Effective Dose Received by the workers at Thermal Power Station, Yamuna Nagar, Haryana

Location	Radon Conc. Bq/m ³	Thoron Conc. Bq/m ³	Radon Progeny (mWL)	Thoron Progeny (mWL)	Annual Effective Dose (mSv)
Coal Area	206	105	22	2.8	7.9
Boiler Area	114	89	12	2.4	5.1
Office	122	71	13	1.9	4.9
Generation Area	168	134	18	3.6	7.5
Near ENT. Gate	168	117	18	3.1	7.2
Store	146	61	16	1.6	5.2
Fly Ash Area	229	94	25	2.5	8.1
AM $\pm$ SE*	165 $\pm$ 16	96 $\pm$ 10	18 $\pm$ 2	2.6 $\pm$ 0.3	6.6 $\pm$ 0.5

AM (arithmetic mean);*SE (statistical error)

to 3.0 mSv with an average of 2.4 ± 0.2 mSv. The radon and thoron concentration from of Thermal Power Station, Yamuna Nagar, Haryana varied from 114 to 229 and 61 to 134 Bq/m³ with an average of 165 ± 16 and 96 ± 10 Bq/m³ respectively. The radon and thoron progeny levels varied from 12 to 25 mWL and 1.6 to 3.6 mWL with an average of 18 ± 2 and 2.6 ± 0.3 respectively. The annual effective dose received by the worker of Thermal Power Station, Yamuna Nagar, Haryana due to radon and thoron varied from 5.1 to 8.1 mSv with an average of 6.6 ± 0.5 mSv. In the present

investigations the measurements indicate moderate to some higher levels of radon, thoron and progeny concentration in the environment of plants.

It may be seen from the data obtained that the levels are higher in fly ash and coal handling area of the plant due to higher contents of uranium and radium in them. The levels are enhanced in the dwellings adjacent to thermal as compare to the dwellings at distance. In the present case study however, the annual effective dose is less than 20

mSv the recommended occupational dose [11]. The use of fly ash as building material should not be encouraged as it may enhance indoor doses from external irradiation besides inhalation of radon decay products may increase significantly. In a similar study on radiation hazard of coal-slugs as building material in Tatabanya Town (Hungary), it has been reported that the radon concentration in the houses where coal-slugs were used as building material exceeded the world average [12]. The information calls for necessary steps to be taken to minimize the emission of fly ash and coal dust produced in thermal power plants. The workers in thermal power plants are exposed to higher doses compared with other workers due to use of coal and production of fly ash in the plants.

4. CONCLUSIONS

Following conclusions are drawn from the present study

1. The radon thoron levels are within ICRP recommended limits in industrial units.
2. The radon thoron levels are higher in coal fired thermal power plants compared with other industrial units. It may be due to higher radium contents in the coal.
3. In thermal power plant, the radon levels are higher in coal handling and fly ash area. It may be due to the higher radium contents in coal which are further concentrated in fly ash during its combustion at high temperature.
4. The radioactivity levels in neighbouring soil and water of the area may be enhanced due to their exposure to coal and fly ash dust.

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INDOOR RADON CONCENTRATION AND RADON FLUX MEASUREMENT IN NORTH EAST INDIA

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ABSTRACT

Indoor radon concentration had been measured in Mizoram which is located in the North Eastern part of India. A total of 316 houses were selected from all the eight districts of Mizoram for indoor radon measurement. These houses were selected according to types of materials used for construction and their geological place of location viz. fault region or regions where fossil materials were found and geologically undefined locations. A Solid State Nuclear Track Detector (SSNTD) based pin-hole dosimeters have been used to obtain indoor radon concentrations. Simultaneously, Radon flux measurement had been done from nearby soil of some of these dwellings by using RAD7 in accumulator technique. The maximum annual average value of indoor radon was found to be 93.5 Bq/m³, while GM is 46.4 Bq/m³ with a GSD of 1.2. Maximum value of radon flux observed was 98 Bq/m²/s. The overall GM of measured radon flux was 28.4 mBq/m²/s.

Keywords: Accumulator technique, passive time integrated method, exhalation, progeny, radon flux, SSNTD.

1. INTRODUCTION

Radon and its progeny contribute about 54% of the total the annual population exposure. These gases are available in the environment produced from the radioactive decay of radium isotopes, produced as a result of decay of ²³⁸U, ²³²Th and ²³⁵U. As a result, the amount of radon concentration in the soil is determined by the amount of uranium and thorium presence in the bedrock and soil materials. Monitoring of radon exhalation from soil and its concentration in indoor as well as outdoor air is found to be helpful in many investigations such as uranium exploration, earthquake prediction, ground water transport, assessment of geothermal resources and health risk assessment [1-3]. Radon is continually formed in soil from its parent nucleus ²²⁶Ra and being gaseous it is exhaled to air through pores and fractured portion of the earth and subsequent decay products are formed in the air.

The existence of radon within dwellings is the significant risk of lung cancer [4] and the amount of indoor radon concentration is influenced by ventilation pattern,

architectural style of building, building materials [5], water, burning gas, etc. It is also partly influenced by the geological characteristics and also the meteorological conditions [6].

Mizoram is a mountainous state nestling in the southern tip of the north-east region of India. It is a vibrant land of rolling hills, verdant valleys, rivers and lakes. It is located within Latitude 21° 58' & 24° 35' N, Longitude 92° 15' & 93° 29' E having an area of 21,081 square Km.. The climate of the state remains pleasant through out the year and the temperature also remains moderate throughout the year. Winter starts from November to February with the minimum temperature as low as 6°C. Winter is followed by summer which starts from March to June. During April, summer reaches a maximum temperature of about 35°C. Although the summers are not very hot, Mizoram witnesses heavy rainfall in the monsoon months that starts in June and lasts till the end of September with the average rainfall of about 3000mm. During the months of March and April heavy storms occur in most parts of the state which is a unique feature about the state. The state consists of eight districts

namely; Aizawl, Champhai, Kolasib, Lunglei, Serchhip, Mamit, Lawngtlai and Saiha districts and our observations had been done in all the districts of the state.

The importance of study of indoor radon concentration in Mizoram situated in the North Eastern part of India, lies with the fact that Mizoram has the highest lung cancer rates among males and females in Age Adjusted Rate (AAR) in India as indicated by Population Based Cancer Registry Report 2008[7].

2. METHOD OF MEASUREMENT

An extensive survey of indoor radon in a total of 316 dwellings had been carried out in Mizoram, covering 23 towns and villages for three years during 2009-2011 noting the variations in seasonal concentrations.

2.1 Materials and method

A time integrated method of measurement was employed by using a solid state nuclear track detector (SSNTD) type (LR-115films) kept inside a twin cup dosimeter [8] for measurement of concentration of radon. The dosimeters were suspended over bed rooms or living rooms in selected dwellings. They were deployed for a period of about 120 days at a time for a season. After the desired period of exposure, the detectors were retrieved and chemically etched which were then counted by using a spark counter. The recorded nuclear track densities are then converted into air concentrations of radon. Simultaneously, radon flux from soil surface in 35 places nearby dwellings were also measured with RAD7 by using accumulator technique[9] which is of active method.

2.2 Characteristics of Dwellings

The types of houses in the region of study are mainly Reinforced Cement Concrete (R.C.C.) and Assam Type. In Assam type of construction the roofs consists of G.I. Sheets/ tin sheets and walls are mostly made up of asbestos (tile), wooden or bamboo; and floors are made of concrete, wooden planks or earth. Assam type of houses are either elevated or grounded depending on their location. The elevation and size of the room are also noted during the survey. It is interesting to note that Mizoram being a hilly terrain landscape, some RCC buildings are constructed on a steep slope in such a way that the fifth floor may have a wall adjacent to the earth on its sides and hence radon/thoron emanation from these walls is supposed to increase in addition to the contribution due to materials of the wall.

2.3 Geological characteristics of the region

The geological characteristics available are also marked. Prominent fault regions are observed in some part of the region which could be clearly identified from the satellite

photograph as shown in Fig.1 produced by the Mizoram Remote Sensing Application Centre, Aizawl, Mizoram.

Mizoram is in seismic zone V like other north- eastern states of India, because of its location being at the meeting point of Indian plate with Burma plate. As a result, it is expected to have higher concentration of radon on the basis of its geological and seismic characteristics [10]. Active landslide prone areas are observed in these fault regions which cause natural calamities from time to time to the dwellers residing in these regions.

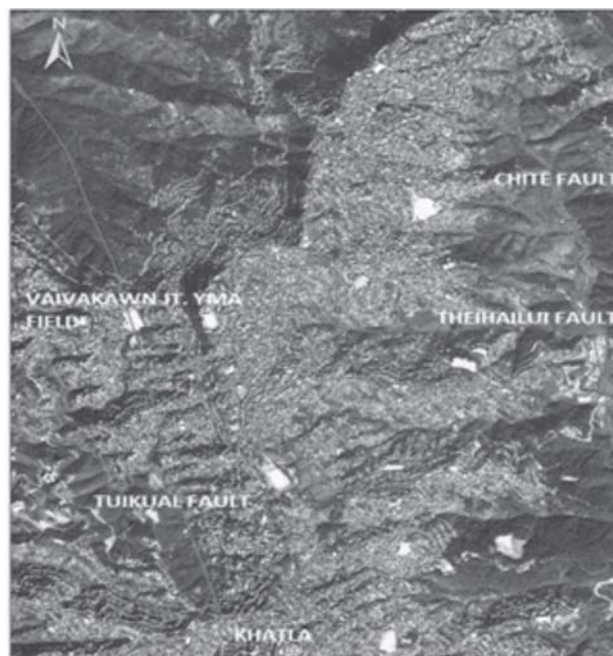


Fig. 1: Satellite picture of part of Aizawl City showing fault regions.

3. RESULTS AND DISCUSSIONS

Investigation has been carried out by monitoring seasonal variation in concentration of radon in Mizoram for the year 2009-2011 in various type of houses, viz. RCC., houses with bamboo or asbestos wall, etc. A total of 316 houses were selected for deployment of dosimeters according to the type of construction and their place of locations viz. fault region, places where fossil remains of marine deposits were found and geologically unidentified region. The radon flux from soil surface in 35 places of nearby dwellings was also measured with RAD7 by accumulator technique which is of active method. Out of 35 radon flux measured, 10 are from fault regions.

Fig.2. shows the annual average indoor concentration of radon in different districts of Mizoram in which 316

dosimeters were deployed. Some of the dosimeters were in fault regions and some in geologically unknown locations and some of them in fossil areas. The place where fossil remains of marine deposits were found consists of stone quarry and dwellings nearby are few and types of construction were almost similar.

Out of 316 houses studied, the overall annual average concentration of radon for a particular house is highest in fault region. Seasonal variation in concentrations of radon were measured in which radon concentration is highest during winter season in a concrete house. The main reason for this observation is due to poor ventilation system in that house during winter. During other seasons viz. rainy and summer season, low concentrations were measured in this very house which gives a low average annual concentration. The maximum annual average value for radon is 93.5 Bq/m³, while GM is 46.4 Bq/m³ with a GSD of 1.2. However, it was observed that even the highest concentration of radon (93.5 Bq/m³) is below the action limit of WHO and hence did not pose much of a health hazard.

Of the 35 observations taken for radon flux near the dwellings, the maximum value observed is 98 Bq/m²/s. The overall GM of measured radon flux is 28.4 mBq/m²/s which is comparable to the world average value of 22 mBq/m²/s.

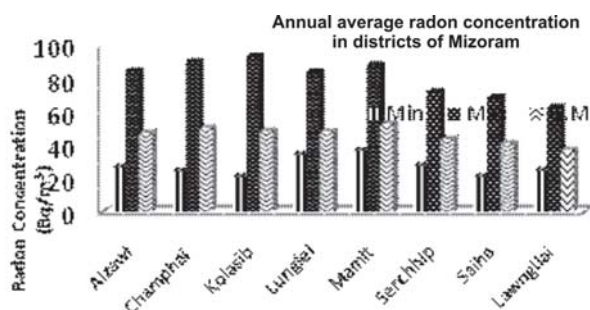


Fig. 2: Annual average radon concentration in different districts of Mizoram.

We have tried to correlate the indoor concentration of radon with the radon flux that has been observed in 35 locations near these dwellings; a graph plotted in Fig.3. shows that the gradient of the line is low. This may be attributed due to the fact that the method of indoor radon concentration measurement is a time integrated type which took at least 120 days while radon flux measurement is an active method for a duration of about an hour having a cycle of 5 minutes. Owing to the different method of measurements, radon flux and indoor radon concentration, in this case may not be well related. However, correlation of indoor concentration with radon flux observed from fault areas showed better correlation[11]

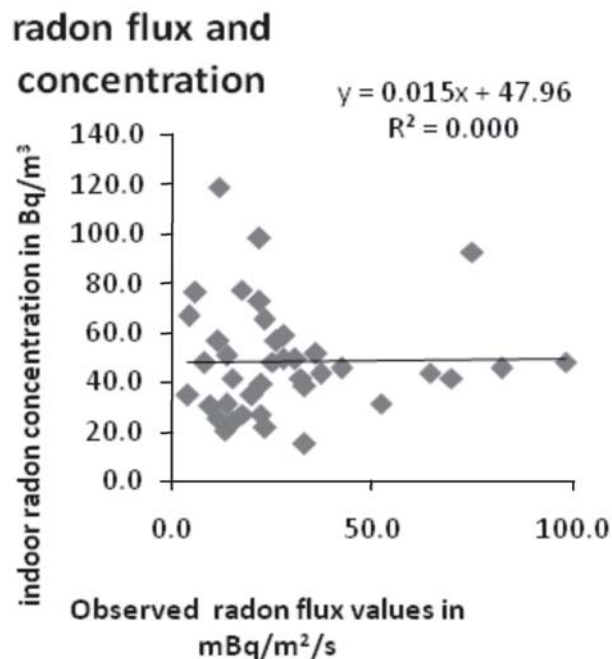


Fig. 3: Correlation between radon flux and indoor radon concentration.

4. CONCLUSION

We have observed indoor radon concentrations in all the eight districts of Mizoram and radon flux from the soil nearby some dwellings had been measured too. From our observations we may conclude that:

- Maximum value of indoor radon concentration is observed in dwellings located in fault areas.
- Comparing seasonal variations, we observed maximum indoor radon concentrations during winter season.
- The overall GM of radon flux is 22.6 mBq/m²/s which is in agreement with the world average value of 22 mBq/m²/s [12].
- The correlation between radon flux and the radon concentration inside nearby dwellings do not come up to expectation.
- The annual concentration of the gases in the region of study is below the action limit of WHO (100-400 Bq/m³) [13]. Therefore, the actual contribution of the radon/thoron gas and their progenies in causing lung cancer at the region of interest might be understood only if a case-control study is conducted. However, the derived data of measurement may be useful to provide baseline data for further studies.

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ENVIRONMENTAL RADIATION HAZARDS AROUND IRON MINES AND STEEL PLANTS OF KARNATAKA STATE

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ABSTRACT

The naturally occurring radioactive materials (NORMs) contain primordial radionuclides and are the potential sources of terrestrial radiation. The NORMs contain primordial radionuclides such as ^{226}Ra , ^{232}Th and ^{40}K are distributed throughout the earth crust, in water, rocks, minerals and soil. Many of the ores and mineral contains primordial radionuclides. The Iron ore (Hematite, Magnetite) is widely distributed in Bellary, Tumkur, Chitradurga and Chickmagalore districts of Karnataka state. The ambient gamma radiation and activity of radionuclides at some iron mines and steel plants of Bellary district, VISL of Bhadravathi and manganese and limestone mines of Tumkur district were measured by using environmental Scintillometer and HPGe detector. The higher equivalent effective doses were observed at very near to the steel plants, mining activity areas and where the large quantity of iron ore and fines were dumped at the mining sites. The lower activity was observed at lime stone and manganese mines of Kondly and Janehar of Tumkur district. The average absorbed gamma dose to the workers of study area is slightly higher than the global average. The present work highlights the influence of mining activity on environmental radioactivity and also radiation exposure to the workers and public. The mining creates a number of environmental problems, that is destructions of important fauna and flora in this affected areas and also this leads to various diseases like asthma, leukemia intestine, kidney and liver damage and lung cancer. This produces various environmental impacts on land, air and water.

Keywords: NORMs, Gamma Radiation, HPGe, Environmental impact.

1. INTRODUCTION

Mining is an ancient occupation, long recognized as hazardous and liable to injury and diseases [1-2]. Naturally Occurring Radioactive Materials (NORMs) is the term used to describe the materials that contains primordial radionuclides that exist in natural environments. Many of the ores, minerals (coal, iron ore, bauxite etc.) and commodities (water, building materials, and fertilizers etc.) contain NORMs. The NORMs contain primordial radionuclides such as ^{235}U , ^{238}U , ^{226}Ra , ^{232}Th and ^{40}K . Iron plays an important and versatile role in the service of man. Karnataka is endowed with rich deposits of iron ores, with approximately 9.03 billion tones or about 41% of India's estimated total hematitic and magnetitic iron resources. In Karnataka important iron ore deposits are located in the districts of Bellary, Chickmagalore, Chitradurga, and Tumkur. The iron and lime stone mining has grown rapidly in the last few years due to an increased indigenous demand and upsurge in overseas. Mining operations in iron, Manganese and lime stone mines change the levels of natural radioactivity in the environment. These changes in

the environmental radioactivity contribute collective radiation dose to the workers and public. Human activities in mines are generally well known to be hazardous but it is unclear if those involving the mining work of iron and lime stone are aware of the potential risk of exposure to NORMs [1-4]. For metalliferous mining, many of the occupational health hazardous relate to the metallurgical processes. Late in the 19th century, crystalline silica has long been a serious hazard in mining with the risk of the silicosis at its worst during dry drilling [7]. Prolong exposure to crystalline silica can also cause chronic obstructive pulmonary disease and increases the risk of lung cancer [8-11]. Exposure to some metal ores including lead, cadmium, iron, platinum and cobalt can cause health hazard [12-16]. The risks are usually greatest during metallurgical processing, when air concentrations exceed those experienced during mining of the ore. The mining activities have disturbed the ecology and environmental balance of the region [17-18]. The objective of the survey is to assess the risk and identify the required remedial work to reduce the radiation exposure to public and workers.

2. STUDY AREA

The present study area is the Iron mines and steel plants of Bellary district, Lime stone and manganese mines of Tumkur district.

The Bellary, a district of north east Karnataka lies at latitude 15° 09' N and longitude 76° 55' E. The iron ore deposits of Bellary- Hospete sector are confined to two main bands forming the spindle shaped Sandur schist belt.

1. The east and copper mountain belt
2. The western Sandur belt

The Sandur schist belt is characterized by a thick pile of volcanic rocks with minor amounts of sedimentary. Iron ore and banded quartzite are intimately associated with meta basalt and both have been traversed by gabbro of free tectonic and post tectonic origin.

Tumkur district is situated at the southern part of Karnataka. Graphically this district lies in the eastern part of the state, between 12° 45' and 14° 20' N latitude and 76° 20' to 77° 31' E longitude. The iron ore deposits of Tumkur are Kondly, Janehar, Chikkanayakanahall and Karekurchi area. The common types of rocks are peninsular gneiss, schistose rocks and closepet granite. The common minerals are available in the district are chlorite, quartzite, limestone, hematite bearing quartzite, dolomite and pegmatite. The beds of manganese ore, lime stone and dolomite are closely associated.

3. MATERIALS AND METHODS

3.1. Sample collection and preparation

The ore samples were collected at several locations of the mining area. The places, which were free from surface run off during heavy rain, were carefully selected. An area of about 0.5 m² was marked and was cleared of vegetation and roots. The marked spots were dug up to a depth of 15cm and about 2kg of ore was collected at each spot. Finally they were mixed thoroughly and extraneous materials like plants, debris, big piece of stones and pebbles were removed [19]. Composites samples of about 2kg was taken and sealed in a polythene bag. The samples were transferred to a porcelain dish and dried overnight at 110° C. the samples were powdered and sieved through 150µm sieve, weighed and sealed in a 300ml plastic container, and kept for a month before counting by gamma spectrometry, in order to ensure that radioactive equilibrium was reached between ²²⁶Ra, ²²²Rn and its progeny.

3.2. Experimental methods

The gamma ray spectrometry method was employed to estimate the activity of ²²⁶Ra, ²³²Th and ⁴⁰K in the ore samples.

The spectrometer consisted of n-type HPGe coaxial detector of 17% efficiency having a resolution of 1.75 keV at 1.33 MeV and 641eV at 5.9 keV and coupled to a 4096 channel MCA. The detector was surrounded with lead shielding to reduce the background radiation entering it. The gamma spectrometric procedure is followed to estimate the activity of ²²⁶Ra, ²³²Th, and ⁴⁰K. The gamma peak of energy 609.51 keV (which is emitted by ²¹⁴Bi, a decay product of ²²⁶Ra) with intensity of 46.1% was used as proxy for the quantitative determination of ²²⁶Ra by gamma spectrometry. Activity of ²³²Th was estimated using photo peak of 583.19KeV with intensity 85.97% and 911.05 keV with intensity 27.7%. The characteristic photo peak of ⁴⁰K is at 1460.8 keV with intensity of 10.7%. The activity of radionuclides was calculated using the relation [20],

$$\text{Activity (Bqkg}^{-1}\text{)} = \frac{(s \pm \sigma)100 \times 1000 \times 100}{EWA} \quad (1)$$

where S is the net counts per second under the photo peak of intensity, σ is the standard deviation of s, E is the counting efficiency (%), W is the mass of the sample (kg) and A is the gamma abundance (%) of the radionuclides.

The outdoor ambient gamma radiation levels were measured by using Scintillometer. All measurements were made 1m above the ground level. The arithmetic mean of the readings was taken as representative figure for each location. The exposure rate in μRh^{-1} was converted into absorbed dose rate nGyh^{-1} using the conversion factor of $1 \mu\text{Rh}^{-1} = 8.7 \text{ nGyh}^{-1}$ which stems from the definition of Roentgen [21].

4. RESULTS AND DISCUSSION

The average outdoor ambient gamma absorbed and equivalent effective dose were summarized in the Table 1 and Table 2. The equivalent effective dose was calculated from the measured gamma exposure rate. The conversion coefficient 0.7 Gy^{-1} and occupation factor for outdoor is 0.2 was used to convert the absorbed dose in air to effective equivalent dose for an adults [5]. The outdoor ambient gamma absorbed dose rate at iron of Bellary district varies from 113.1 to 228.81 nGyh^{-1} with an average value of 163.68 nGyh^{-1} , and manganese and lime stone mines of Tumkur district ranges from 69.6 to 165.3 nGyh^{-1} with an average value of 108.75 nGyh^{-1} . Similarly the outdoor absorbed dose rate at Steel and Thermal power plant of Bhadravathi Taluk and Bellary district varies from 95.7 to 308.41 nGyh^{-1} with an average value of 189.71 nGyh^{-1} .

The data from the above Table 1 shows that the higher gamma equivalent effective doses were observed at Donimallai and Taranagara of Sandur mines of Bellary

Table 1
Average outdoor ambient gamma radiation exposure and Equivalent effective dose in iron, manganese and lime stone mines of Bellary and Tumkur districts.

S. No.	Place	Exposure rate (μ R/h)	Absorbed dose rate (n Gy/h)	Equivalent effective dose (m Sv/y)
1	Bellary iron mines			
2	Sandur near bus stand	17.5	152.25	0.186
3	Sandur old fort	18.5	160.95	0.197
4	Thara nagara	21.6	187.92	0.23
5	Dhrma pura	15	130.5	0.161
6	Thara nagara Project	13	113.1	0.138
7	Donimallai school	19.8	172.26	0.211
8	Donimallai near dumpining area	26.3	228.81	0.28
9	Tumkur district			
10	Kondly Iron and Manganese deposited area	8	69.6	0.085
	Kondly lime stone mines			
	a) At the mining activity	19	165.3	0.202
	b) Lime stone deposit region	8	69.6	0.085
	c) Laborers stop quarters	14	121.8	0.143
	d) Kondly cross away from the mining areas	11	95.7	0.117
	Janehar iron mines	10.5	91.35	0.112
	Average	15.65	136.21	0.166

Table 2
Average outdoor ambient gamma radiation exposure and Equivalent effective dose around Steel and Thermal power plant of Bhadravathi Taluk and Bellary district.

S. No.	Place	Exposure rate (μ R/h)	Absorbed Dose Rate (n Gy/h)	Equivalent effective dose (m Sv/y)
1	Steel Plant Bhadravathi			
2	V.I.S.L plant (Near the plant)	25	208.8	0.255
3	New town	18.5	160.95	0.197
4	VISL quarters	22.3	194.01	0.237
5	Loyar hutta	15.4	133.98	0.164
6	V.I.S.L inside the plant	35.45	308.41	0.377
7	Jindal plant Bellary			
8	Thoragallu station	13.5	117.45	0.144
9	Thoragallu town	11	95.7	0.117
10	Near the steel plant	17.5	152.25	0.186
	Thermal power plant			
	Kudithini	21	182.7	0.224
	Thimmlapura	23.5	204.45	0.25
	Average	21.81	189.79	0.232

district. This is due to the various reasons, during mining activity (drilling, crushing, plant operations) large quantity of fines were generated and it is dumped at some mining places of Donimallai. The size of fines are very small, the radio emission increases with decreasing the size of the particle [16, 22]. Another reason is the formation of cracks and fissures which are formed due to the mining activity in the ore bed. The more radon gas is entering into the atmosphere through these cracks and it enhances the gamma radiation levels. The slightly lower radiation levels were observed at Taranagara this is because this region is

surrounded by hills and there is no mining activity around this place. The iron ore was transported from Donimalai to Jindal steel plant by using more than two thousand trucks and dumpers every day through the Taranagara. Due to this heavy transportation a large amount of dust and fines are generated and deposited at this place and it slightly varies the radiation level. The ambient gamma radiation level at a particular area mainly depends on geology, the activity of primordial radionuclides present in soil, rocks and ores. The higher equivalent effective doses were observed at VISL of Bhadravathi and Jindhal plant of Hosadaruji of Bellary

Table 3
The average activity concentration of ^{226}Ra , ^{232}Th and ^{40}K in iron and lime stone mines of Bellary and Tumkur districts.

S. No.	Place	^{226}Ra (Bq kg ⁻¹)	^{232}Th (Bq kg ⁻¹)	^{40}K (Bq kg ⁻¹)	Outdoor external dose (n Gyh ⁻¹)	Total equivalent effective dose (mSvy ⁻¹)
1	Bellary iron mines					
1	Kuditini	15.6±1.2	22 ± 1.6	45± 5	22.38	0.027
2	Thimalapura	25±2.3	18.16±1.5	60± 6.5	25.03	0.031
3	Hosadaruji	32±1.8	24.5± 2.4	45± 4.8	31.71	0.038
4	Jumbunathanhalli	28± 3.2	29.66± 5.2	254±5	41.51	0.051
	Tumkur district					
1	Sondekoppa	37.5± 2.6	56± 3.2	170± 6.8	58.28	0.071
2	Karekuchi	34.8± 3.7	45±2.8	165± 5.6	50.18	0.061
3	Kondli	30.5± 3.5	36.8± 3.8	187±6.8	44.17	0.054
	Average	29.05±2.6	33.21±2.91	132.28±5.7	39.04	0.048

district. Due to the human activity and industrial operations, the grain size of the ore decreases this leads increases the surface area. Because of this the activity of radionuclides and exposure rate increases [16, 22]. The radionuclides present in these raw materials are released to the atmosphere by large thermal process such as those are used to the production of iron and steel. For other mineral processing industries during handling and shipment of ores, is the main reason for release of radionuclides into the air. In those circumstances, the rather coarse particles are generally released mainly to the immediate surroundings of the plants, hence the reason for observing the higher gamma dose at the iron and steel plants. The lower gamma radiations were observed in some villages away from the plants. About more than 1000 laborers are working shift wise basis in both the plants. The higher gamma dose is also due to the mining activity and handling of the ore. The lower activities were observed at manganese mines and limestone mines of Janehar and Kondly region of Tumkur district. This is because of the fact that the ore minerals contain lower activity of radionuclides and the lime stone pieces were transported from Kondly mines to Hamsandra cement factory by Trdlies hence we observe the lower activity of gamma radiation levels.

The average activity concentration of ^{226}Ra , ^{232}Th and ^{40}K present in the iron, manganese and lime stone ore samples are summarized in the Table 3. The iron ore contains slightly higher activity of radionuclides compared to lime stone and manganese ore as shown in Table 3. The average values of ^{226}Ra , ^{232}Th and ^{40}K are 29.05 Bq kg⁻¹, 33.21 Bq kg⁻¹ and 132.28 Bq kg⁻¹ respectively. The activity of radionuclides mainly depends on composition of the minerals. The concentration of radionuclides of ore samples are within the global average values. The outdoor absorbed gamma dose rates in air from the concentration of ^{226}Ra , ^{232}Th and ^{40}K of ore samples of the study area were calculated using

the UNSCEAR relation $D = (0.604C_{\text{Th}} + 0.462C_{\text{Ra}} + 0.0417C_{\text{K}})$ nGyh⁻¹. Where C_{Ra} , C_{Th} and C_{K} are the average activity concentration of ^{226}Ra , ^{232}Th and ^{40}K respectively. The calculated equivalent effective gamma doses from the activity of the radionuclides in air are compared with measured gamma equivalent effective dose, which is very well correlated and with the correlation coefficient of 0.86. The mining activity has disturbed the ecology and environmental balance of the region and also produces the various environmental problems. The fines generated during the mining has to be taken care of, otherwise it would damage the environment and ecology considerably. The fine dust also produces various types of diseases to the workers. In iron ore mines several million tons of fines are produced. In addition to these points there are large deposits of blue dust which is unused because of its fine sized. During the rainy season, the dumped ore washed down along the hill slopes results in the destruction of agricultural lands. The impact of each results in the progressive degradation of soil cover, deterioration of vegetation, pollution of surface and groundwater. Crystalline silica has long been a serious hazard in mining with the risk of silicosis at its worst during dry drilling. Prolonged exposure to crystalline silica can also cause chronic abstractive pulmonary diseases. Prolonged exposure to the silica increases the risk of lung cancer this produced during mining activity.

5. CONCLUSIONS

The activity of radionuclides in the ore samples of iron mines were found within the range of worldwide values [5]. The higher radiation levels were observed at the mining activity and where the large quantities of fine were dumped. The survey shows that the work involving the mining activity as a risk of occupational exposure to the NORMs due to the mining and industrial activity. The most significant pathway of radiation exposure is crushing, drilling, blasting and operation of the plants of iron and ore with fine grains. The

iron ore mining is currently unregulated. To reduce the radiation exposure the workers should wearing appropriate protective clothing including glows and dust masks.

6. ACKNOWLEDGEMENTS

The authors are grateful to University Grant Commission (UGC) for providing the financial support to carry out this research work.

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ALPHA DOSIMETRIC STUDIES IN RADIOBIOLOGY EXPERIMENTS USING SSNTD TECHNIQUE

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ABSTRACT

In the present work alpha dosimetric studies were carried out using an automated alpha particle irradiator (named as 'BARC BioAlpha') developed at BARC for in vitro radiobiological studies. The dosimetry and uniformity of the source was evaluated by CR-39 detector using ²⁴¹Am source (0.13 μ Ci; 5 mm diameter). The dose rates were evaluated at various concentric circles from the centre of the detector. The circularity of alpha track diameter which indicates its normal incidence was also measured at different collimator speed of 50, 100, 150 and 200 rpm. Around 2500 alpha tracks were counted for each collimator speed. SRIM code was also used in determination of alpha energy.

Keywords: Alpha Dosimetry, SSNTD, Radiobiology, Alpha Irradiator.

1. INTRODUCTION

Alpha emitters represent an important component of the exposure to the natural background radiation, which is largely by inhalation of radon and its daughters. The biological effects of inhalation of these radio-nuclides have been studied extensively both in vitro and in vivo experiments. Solid State Nuclear Track Detectors (SSNTDs) play a vital role in analyzing radiation risk associated with inhalation of these radio-nuclides on biological systems particularly in in-vitro experiments [1]. The alpha-particle radiobiological experiments involve irradiating cells with alpha particles and require accurate positions where the alpha particles hit the cells.

Durante [2] in 1994 proposed a method based on application of the LR 115 film, the active layer of which was cellulose nitrate. Irradiation was performed with 3.2 MeV alpha particles from below the substrate. Dorschel [3] in 2003 then investigated the performance of the LR 115 SSNTD for radiobiological experiments. The basic experimental setup was similar to that of Durante [2]. They noticed that the red dye from the LR 115 SSNTD could diffuse into the medium that was conditioning the cells. Because of this, they proposed to use the colorless LR 115 SSNTDs, which could be obtained from the manufacturer of LR 115

(DOSIRAD) upon special request. Chan [4] in 2006 further studied the feasibility of colorless LR 115 SSNTDs for alpha-particle radiobiological experiments. They found that the track revelation time on the bottom side (the side attached to the polyester base) was much longer than that on the top side (the side not attached to the polyester base) of the active layer so track formation on the top side was more desirable. The feasibility of using this SSNTD for alpha-particle radiobiological experiments was demonstrated by culturing cells on the bottom side while performing alpha-particle irradiation and chemical etching on the top side, and by taking photographs of the cells and alpha-particle tracks together under the optical microscope. Gaillard [5] in 2005 fabricated ultra-thin CR-39 films as support substrates for cell cultures. They developed special procedures based on UV-curing to produce CR-39 films with a thickness of 10 μ m. Human primary cells were successfully grown in these PADC-PET dishes. K. N. Yu and D. Nikezic co workers [1] also fabricated thin PADC films (<20 μ m) for radiobiological experiments from commercially available μ m CR-39 SSNTDs with a thickness of 100 μ m.

In the present preliminary work, CR-39 film of thickness 500 microns, kept at the exit window of the alpha particle Irradiator was exposed to alpha particle flux. The alpha dose

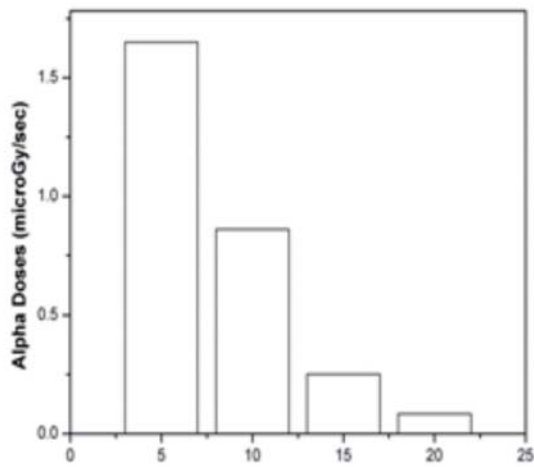


Fig.1: Alpha doses at different concentric radii on CR-39 detector at 50 rpm

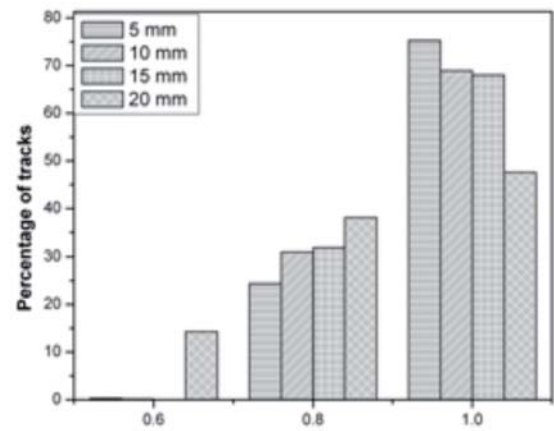


Fig.4: Circularity of tracks for different concentric radii (mm) at 100 rpm

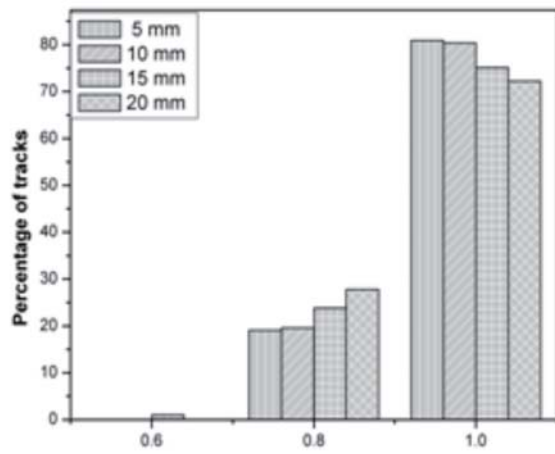


Fig.2: Circularity of tracks for different concentric radii (mm) at 50 rpm

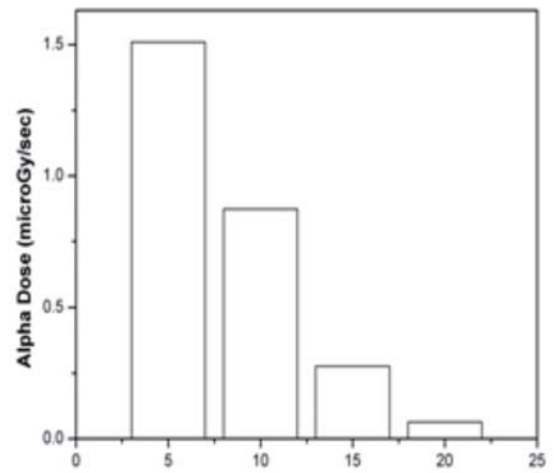


Fig.5: Alpha Doses at different concentric radii on CR-39 detector at 150 rpm

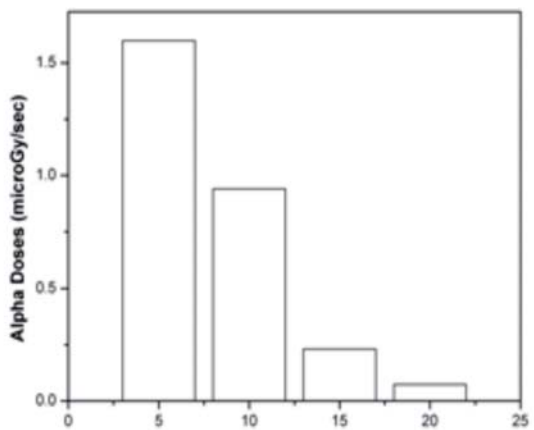


Fig.3: Alpha Doses at different concentric radii on CR-39 detector at 100 rpm

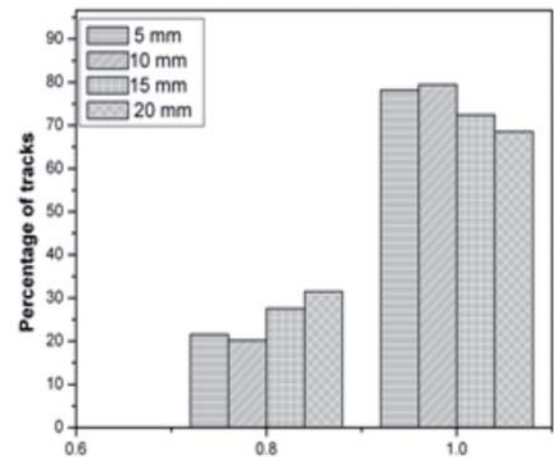


Fig.6: Circularity of tracks for different concentric radii (mm) at 150 rpm

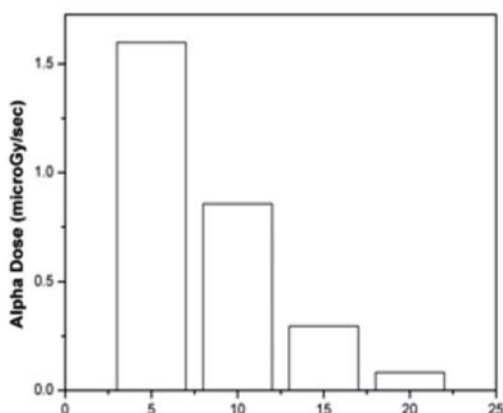


Fig.7: Alpha Dose at different concentric radii (mm) on CR-39 detector at 200 rpm

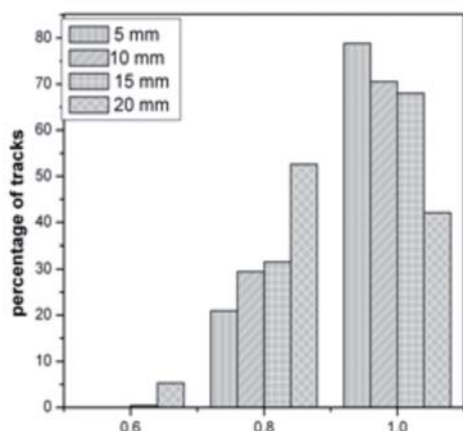


Fig.8: Circularity of tracks for different concentric radii (mm) at 200 rpm

profile from the centre of the film was obtained. Further the circularity of alpha tracks was used as a parameter for estimating the normal incidence. Alpha particle energy was calculated using the Stopping and Range of Ions in Matter (SRIM) code.

2. MATERIALS AND METHODS

CR-39 films (also called as PADC films) were procured from M/S Page mouldings, U.K. The films were 500 microns thick and were cut in circular shape (45 mm diameter) to fit into the exit window of the alpha particle Irradiator. For the uniformity of the fluence, the alpha source needs to be rotated at a pre-defined angular velocity and the collimator needs to slide above the source at different collimator speeds of 50, 100, 150 and 200 rpm.

3. RESULTS AND DISCUSSIONS

The alpha particle dose at the exit window can be determined if the alpha particle flux and its energy is known.

3.1 Alpha particle flux measurements: The alpha particle flux at the exit window was measured by counting the alpha particle tracks on the surface of CR-39 detector. All the alphas were incident almost normally with the detector surface so the efficiency is 100%.

3.2 Determination of alpha energy: SRIM code was used to determine the alpha energy incident on the CR-39 surface. The dose rates were evaluated at various concentric circles (5, 10, 15 and 20 mm diameter) from the centre of the detector for collimator speed of 50, 100, 150 and 200 rpm. The circularity of alpha track diameter which indicates its normal incidence was also measured at different collimator speeds. Around 2500 alpha tracks were counted for each collimator speed. The figures 1-8 shows the dose profile and circularity of tracks for various concentric circles of 5, 10, 15 and 20 mm diameter from the centre of the detector. This information helps us to get the profile of alpha track dose from the centre of the film. The circularity of tracks helps us to understand the angular incidence of alpha tracks.

4. CONCLUSION

CR-39 detector can be used to carry radiobiological experiments in alpha particle Irradiator. Further alpha dose at a particular point can be co related to the number of damaged cells at that location. The dose profile is independent of collimator speed. The circularity of alpha tracks helps us to find the fraction of normal incidence at different collimator speed.

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TEMPLATE FACILITATED ELECTRODEPOSITION OF NANOSTRUCTURES

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ABSTRACT

Nanostructures occupy the centre of scientific interest because of their unique novel properties and potential applications in the future nanodevices. This paper presents template based method for the fabrication of nanostructures. The template approach has been extensively used in the synthesis of various nanostructures (nanowires, nanorods, nanofibers etc.). This approach necessitates the synthesis of the desired nanostructure within the pores of the membrane which results in the production of true replica of the pore geometry. The most commonly used and commercially available templates are anodized alumina membrane (AAM) and track-etched polycarbonate (PC) membranes. PC membranes may be preferred over anodized alumina membranes since they exhibit greater flexibility. The production of PC membranes is a two step process consisting of an irradiation of a polymer layer or a film by energetic heavy ions creating linear damage tracks, followed by a chemical etching of these tracks to pores. Control over the irradiation and etching condition enables the production of membranes with channels of predefined geometries, sizes and aspect ratios. The etched pores of membrane are filled with a chosen material via electrodeposition to form one-dimensional nanostructures.

Keywords: *Template Synthesis, Nanostructures, Anodized Alumina Membrane, Track Etched Polycarbonate Membrane.*

1. INTRODUCTION

Nanostructures show superior physical properties including superconductivity, enhanced magnetic coercivity, enhanced optical and electrical properties than their bulk counterpart because electrons are strongly confined in one, two or three dimensions. Hence, development of low dimensional materials has become the focus of research and development over the past few decades. Various nanodevices, such as field-effect transistors [1], sensors [2], and lasers [3] have been fabricated using nanostructures as building blocks. To use the potential of nanostructures up to full extent, convenient methods must be used for their synthesis at large scale.

The two main approaches used for nanostructure fabrication are bottom up and top down approaches [4]. Top down approach includes lithography techniques (X-ray, electron beam, soft lithography etc.), mechanical methods (ball milling) and high energy methods (i.e. laser ablation and arc discharge). Bottom up techniques include chemical vapor deposition (CVD), physical vapor deposition (PVD), pulsed laser deposition (PLD), sol-gel method and

electro-deposition etc. Electron beam lithography was the first method used for nanostructure fabrication to define the structures on a molecular beam epitaxy (MBE) grown film which were then etched using reactive ion etching [5]. However, there were some drawbacks associated with this technique such as process related damage which can significantly degrade the device performance and the serial nature of process due to which it is not suitable for fabrication of large array of nanostructures. These drawbacks lead to the need of a fabrication technique to economically fabricate a large periodic array of nanostructures. Among the previously mentioned methods template synthesis via electro-deposition is a suitable method for nanostructure formation. Template based growth is a solution or colloidal dispersion based process. The advantages associated with template synthesis are low cost, easy to perform, accurate control of the shape and size of nanostructures, control of composition of nanostructure through the electrolyte and electro-deposition parameters and batch fabrication ability. It also offers the advantages of less contamination and is environmentally benign. However, template-based synthesis suffers from some

drawbacks such as the polycrystalline nature of the resultant nanostructures, the difficulties to find appropriate templates with pore channels of desired diameter and to remove the template completely without compromising the integrity of grown nanostructures [6].

This review presents different types of templates available commercially and their fabrication method. The methodology for template facilitated electro-deposition and future perspective of this technique are also discussed.

2. TEMPLATES AND TEMPLATE FABRICATION

A template is a pre-designed structure within which a network exists which can be utilized for nanostructure formation. The principle of template assisted synthesis is similar to that of the process of moulding in which goods are manufactured by shaping liquid or pliable raw material using a rigid frame called a mold or matrix. In template assisted electro-deposition, growth of nanostructures is realized by using templates to confine the growth space for electro-deposits. The template- assisted electro-deposition is one of the most effective methods for synthesis of nanostructures of numerous materials, including metals, semiconductors and conductive polymers etc.

Templates can be classified as ‘hard’ and ‘soft’. Hard templates are usually solid-state materials with particular structure and morphology, whereas soft templates are generally in a fluid-like state. Hard templating is a conceptually straightforward and highly effective method to prepare nanostructures that mimic and/or complement the original shape of the templates. Hard templates include AAO (anodic aluminium oxide) and polycarbonate membranes, nanochannel array glass and Zeolite. Soft templates include proteins derived from a bacterium and having nanoscopic pores, mesoscale structures which are self assembled from block copolymers, liquid crystal materials and surfactants [7]. The advantage of hard template is to have a better control of the product, but it's difficult to remove the template and usually the remover is environmental-unfriendly. The soft template is relative easier to eliminate, however, the morphology control of target products is hard to obtain. The most commonly used and commercially available hard templates are anodized alumina membrane (AAM) and radiation track-etched membranes (TEMs).

The commonly used alumina membranes with uniform pores are made by anodic oxidation of aluminum sheet in solutions of sulfuric, oxalic, or phosphoric acids. Alumina (Al_2O_3) provides good electrical insulation ($10^{18} \Omega\text{-cm}$ resistivity), optical transparency over a wide energy band, chemical inertness which makes it an ideal embedding material for

optical and electrical devices. Alumina membranes can be produced by a two step anodization process. First, a cleaned aluminium sheet is electropolished and then anodized in an oxalic acid solution for several hours. Then, the barrier oxide layer is removed in chromic acid and phosphorous acid, a second anodization is done for a short period of time in the same oxalic acid solution used in the first anodization process[8]. The pores obtained after the process are arranged in a regular hexagonal array, and densities as high as 10^{11} pores/ cm^2 can be achieved. Pore size ranging from 10 nm to 100 nm can be made, which can be accurately controlled by controlling the process parameters [9].

Track-etch templates with pore diameter from 10 nm to several nm with a length to diameter ratio in the range 10–1000 are available. In track etched membranes (TEMs) nano or micro pores can be produced by a two step method. This consists of irradiation of a polymer layer by energetic heavy ions such as Ar^{+9} , Au of energy on the order of several MeV or with fragments from the fission of heavy nuclei such as californium or uranium creating linear damage tracks. This is followed by chemical etching of membrane in temperature regulated bath to widen the tracks produced by ions or radiations. Sometimes patterning of track etch membranes which is combination of thermal treatment (for track fading) and light track sensitization, can be introduced to create the known number of pores in designated area[10]. According to sensitization and etching conditions uniform cylindrical, conical, tunnel-like, or cigar-like pores can be obtained. Pore sizes or dimensions depend upon the nature and energy of incident particles, the target material, etch conditions, e.g. temperature, nature of etchant, pre-etch storage conditions etc. and are controllable. Mainly polyethylene terephthalate (PET) and polycarbonate are used as polymers for ion track membranes, but work has also been done on other polymers such as polyvinylidene fluoride and polyimide, which have better chemical and heat resistance.

Both anodized alumina membrane (AAM) and track etched membranes (TEMs) are most commonly used for the synthesis of nanostructure arrays. Both templates are very convenient to use during the growth of nanostructures by various growth mechanisms i.e. using the capillary action of the pores, electro-deposition, chemical polymerization or electroless plating [11] but each type of template have some advantages and limitations. The advantage of using TEM as the template is its easy handling and flexibility, but because of their low thermal resistance TEM is more prone to distortion during the high temperature processes, also they do not offer many pore sizes in the range 10-100nm where the most interesting nanomaterial properties are expected. The advantage of using AAM as the template is

its rigidity, controllable pore size and resistance to high temperatures, allowing for the nanostructures to densify completely before removal. This would result in a larger surface area of fairly free-standing and well aligned nanostructure arrays. Also, alumina is amphoteric in nature and can be easily dissolved in an acidic or basic solution. The AAO template is extremely fragile and cannot sustain stress. This disadvantage precludes AAO from many applications.

3. METHODOLOGY FOR TEMPLATE FACILITATED ELECTRODEPOSITION

In this technique, the nanostructures are synthesized by selective electro-deposition of the desired material inside the template pores from an appropriate chemical solution. Other methods are also available for pores filling but electro-deposition method provides best selectivity and control over material growth. Irrespective of the material to be deposited, the template assisted electro-deposition follows the same procedure described in fig 1 for track etched membranes. Firstly, a thin layer of metal (gold, silver etc.) is deposited on one side of template, which will act like the cathode in two electrode electrochemical cell. The electro-deposition takes place inside the pores of template over the pre deposited metal layer. The shape and surface roughness of the nanostructures are determined by size,

shape and texture of pores in template. Finally the template can be removed by dissolving it in an acidic or alkaline solution in which the desired nanostructure does not dissolve and then the final desired nanostructure is obtained. Besides nanostructure of single composition, nanostructures with multilayer structures and hetero junctions of different compositions can also be produced by varying the electrolyte composition and concentration. Metallic nanowires [12,13] and semiconducting nanowires[14] synthesized by two electrode electro-deposition technique were reported in literature. Metal-semiconductor- metal hetero-structures were also fabricated for Ni, Au as metal and CdSe as semiconductor [15].

We fabricated CdSe nanowires by two electrode electro-deposition cell using copper electrodes and CdSO_4 and SeO_2 in aqueous solution as electrolyte. The SEM image of as synthesized nanowires is shown in fig.2.

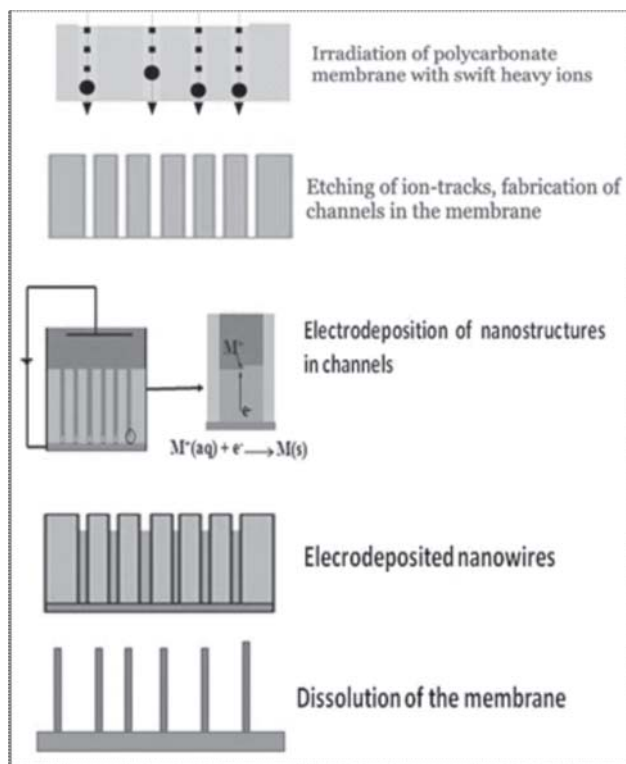


Fig. 1: Electrodeposition of nanowires via track etched membrane (TEM) as template.

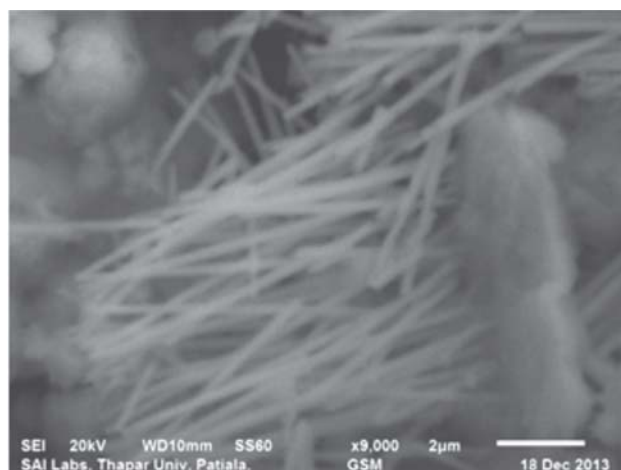


Fig. 2: SEM image of CdSe nanowires.

4. APPLICATIONS AND FUTURE SCOPE

A novel technology for the fabrication of nanostructures by template assisted electro-deposition has been presented in this paper. This technology is inexpensive, reliable and suitable for the fabrication of a variety of nanostructures. Nano-structures of many materials, including metals, semiconductors and conductive polymers etc. have been successfully synthesized by the template-assisted electro-deposition. Currently this fabrication technique is used to develop a variety of different optoelectronic and nanoelectronic devices. The multijunction solar cells currently under development are expected to show high energy conversion efficiency due to enhanced absorption and carrier collection efficiency of the nanostructures. The template-based nanostructure fabrication method is used to develop advanced gas sensors which will be inexpensive

and sensitive to multiple gas species. The nanostructure-based radiation detectors currently under development will use the ultrafast response time and high recombination efficiency of semiconductor nanostructures to increase detector efficiency and speed. The template-based nanostructures are also investigated to implement low-cost flat panel displays. The displays will use the large electro-optic effect observed in semiconductor nanostructures. To obtain nanodevices with excellent performances and practicability, the morphologies, dimensions and properties of the nanostructures should be optimized. Every parameter in the electrodeposition process must be controllable in order to produce nanostructures to meet the requirements.

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MEASUREMENT OF RADON EXHALATION RATES IN SOIL SAMPLES FROM WESTERN HARYANA

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ABSTRACT

Indoor radon has been recognized as one of the health hazards for the general people. Soil and building materials used for construction of houses are considered as major sources of radon gas in indoor environment. The radon exhaled from the soil accumulate in indoor environment and contributes to 55% of inhalation dose. In the present work, the radon exhalation rates in some soil sample from western Haryana were measured using 'Canister' technique. The alpha sensitive solid state nuclear track detectors (LR-115 type-II) were used in the canisters for recording tracks produced by alpha particles from radon. From the measurement, it can be concluded that the exhalation rate varies from 11.44 mBq/kg/h to 42.66 mBq/kg/h (for mass exhalation rate) and 210.48 mBq/m²/h to 785.03 mBq/m²/h (for surface exhalation rate). The annual effective dose varies from 0.019 to 0.073 mSv for Ellanabad and Mallekan respectively. The annual effective dose calculated for a model room from area under study is below the limit recommended by ICRP.

Keywords: Radon; Exhalation rates, Soil; SSNTD; canister technique.

1. INTRODUCTION

Knowledge of radioactivity present in soil enables one to assess any possible radiological hazard to general population. Indoor radon and its decay product contribute 55 % of the total radiation dose from the natural source to the population. This contribution can be much higher in radon prone areas, the natural dose exposure being 5-10 times higher. Many studies have demonstrated the evidence of occurrence of lung cancer with radon even at low levels of radon in residential buildings [1-14]. But the efforts of the various agencies working to reduce the number of lung cancers related to radon exposures are stymied in some countries due to very high radon exposure.

The approach of indoor radon studies in connection with radon gas from soil and building material due to many factors linked to the underlying geological formations and building structure results in increased levels of radon inside houses. This study has been carried out in many countries [15-16]. The worldwide average indoor effective dose due to gamma rays from building materials is estimated to be about 0.4 mSv per year [17]. As individual spend more than

80% of their time indoors, the internal and external radiation exposure from building materials (made from effected soil) creates prolonged exposure situations [18]. Generally, natural building materials reflect the geology of their site of origin. The elevated levels of natural radio nuclides causing annual doses above the recommended limits were identified in some regions around the world, e.g. in Brazil, France, India, Nigeria, Iran etc. The 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 occurrences of lung cancer. Radon now has been identified as occupational respiratory carcinogen by International Agency for Research and Classified Cancer. Radon is the second major cause of lung cancer after smoking. According to BEIR reports [19], the exposure of population to high concentrations of radon and its daughter a long period lead to pathological effects like the respiratory functional changes and the occurrence of lung cancer. Thus, it is important to study the radon emission from the soil samples. In present work, the radon exhalation was measured from some soil sample from Sirsa Districts, Haryana, India as shown in Fig 1. In the light of the above-

mentioned facts, it is, therefore, important to assess the radioactivity in building construction materials, cement and fly-ash samples. The following is the location map of area under the study of district Sirsa, India. The samples were selected uniformly from the districts that make this useful for radon exhalation mapping of soil for this districts.



Fig. 1: Map of the study area

2. MATERIALS AND METHODS

Solid State Nuclear Track Detectors (SSNTDs) is an important technique that can be used for measurement of radon soil exhalation rate. The passive canister technique can be used in the present study. This technique is one of the most widely used for radon measurement. The detection principle consists of the damage caused in the detector by alpha particles from radon. As the track produced per unit area in a detector is proportional to exposure time and rate, so the tracks density per time could be used to calculate radon concentration and hence exhalation rate. For the measurement of exhalation rates from soil samples, the “Can Technique” given by Abu-Jarad [20] was used. A known quantity of soil sample were sealed in a plastic can having same dimension as used in the calibration exercise [20]. LR-115 Type-II nuclear track detector was fixed on the inner side of lid of each can with tape such that sensitive side of the detector facing the material sample. The can was tightly closed and sealed for 100 days. After 100 days, the detectors were removed, etched and tracks were counted using an optical microscope at a magnification of 400X. These tracks were converted into radon concentrations using calibration factor.

The mass and surface exhalation rates, radon concentration and annual effective dose for 18 villages of Sirsa district can be calculated using following relation

$$E_M = \frac{CV\lambda}{M(T + \frac{1}{\lambda}(e^{-\lambda T} - 1))} \quad (1)$$

$$E_A = \frac{CV\lambda}{A(T + \frac{1}{\lambda}(e^{-\lambda T} - 1))} \quad (2)$$

where E_M and E_A are mass and surface exhalation rates, C is the Integrated radon exposure ($\text{Bq m}^{-3} \text{h}$), M is the mass of sample (kg), V is the volume of air in the canister (m^3), T is the exposure time (h), λ is the decay constant for radon (h^{-1}), and A is the area covered by the canister or surface area of the sample (m^2).

The risk of lung cancer due to radon and its daughters is estimated from the radon exhalation rates in terms of effective dose equivalent. The contribution to indoor radon concentration from building materials can be obtained from the expression.

$$C = \frac{E_s \times S}{V \times \lambda_v} \quad (3)$$

where, C , E_s , V and λ_v are radon concentration (Bq m^{-3}), radon exhalation rate ($\text{Bq m}^{-2} \text{h}^{-1}$), room volume (m^3) and air exchange rate (h^{-1}) respectively. The radon concentration from the building material is assessed by assuming the room as a cavity with $S/V = 2.0 \text{ m}^{-1}$ and air exchange rate of 0.63 h^{-1} . Annual exposure to potential alpha energy E_p (effective dose equivalent) is then related to the average radon concentration C by the following expression

$$E_p (\text{mSv/y}) = \frac{8760 \times n \times F \times C}{170 \times 3700} \times (6.3) \quad (4)$$

where C is in Bq m^{-3} , n the fraction of time spent indoors; 8760, the number of hours per year and 170, the number of hours per working month. The values of $n = 0.8$ and $F = 0.42$ were used to calculate E_p . From radon exposure, the effective dose equivalents were estimated by using a conversion factor of 6.3 mSv/(WLM)

3. RESULTS AND DISCUSSIONS

The radon mass and surface exhalation rate from the soil sample collected from the Sirsa districts of western Haryana is listed in table 1.

The radon mass exhalation rates from the soil sample varied from 11.44 mBq/kg/h to 42.66 mBq/kg/h while radon surface exhalation rate varied from $210.48 \text{ mBq/m}^2/\text{h}$ to 785.03 for Ellanabad and Mallken village respectively. From the measured exhalation rate of the soil sample, the annual

Table 1
Radon concentration and radon exhalation rates
from soil samples

Code	Sample location	Surface exhalation rate (mBqm ⁻² h ⁻¹)	Mass exhalation rate (mBqkg ⁻¹ h ⁻¹)	Annual effective dose (mSv)
S-1	Sahuwala	409.58	22.26	0.038
S-2	Chaupata	455.09	24.73	0.042
S-3	Dabbwali	529.04	28.75	0.049
S-4	Gauriwala	420.96	22.88	0.039
S-5	Kalanwali	233.23	12.68	0.021
S-6	Patli Dabar	216.17	11.75	0.020
S-7	Pana	472.15	25.66	0.044
S-8	Sirsa city	540.42	29.37	0.050
S-9	Ellanabad	210.48	11.44	0.019
S-10	Maihnapur	602.99	32.77	0.056
S-11	Jamaal	449.39	24.42	0.042
S-12	Gudiyan khera	614.37	33.39	0.057
S-13	Odhan	750.89	40.81	0.070
S-14	Modiyan khera	511.97	27.83	0.047
S-15	Mallekan	785.03	42.67	0.073
S-16	Gajjuwala	489.22	26.59	0.045
S-17	Dudiawala	540.42	29.37	0.050
S-18	Dhookra	648.50	35.25	0.060

effective dose were calculated for a model room with surface to volume ratio $S/V=2 \text{ m}^{-1}$ and annual average ventilation rate 0.63 h^{-1} . The comparison of the annual effective dose from various location described in Fig.1 is shown in Fig.2. The radon exhalation rate from the soil sample are less than the world wide average $56 \text{ mBq/m}^2/\text{h}$. The annual effective doses from all location of the area under study are less than the world average (0.4 mSv).

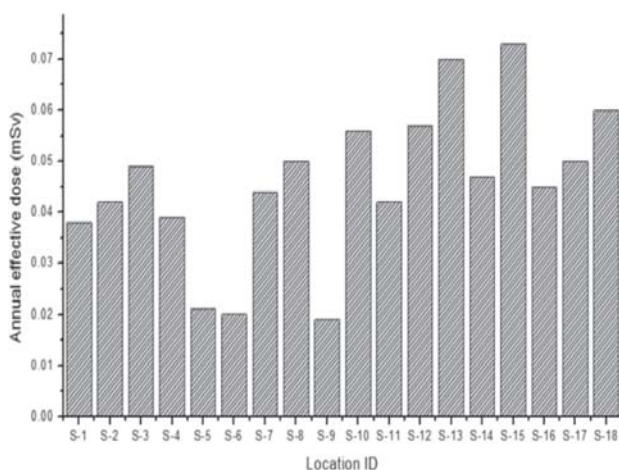


Fig. 2: Annual effective dose from different villages under study.

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RADON-THORON AND THEIR PROGENY MEASUREMENTS IN HIGH RISE BUILDINGS IN DISTRICT FARIDABAD, HARYANA

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ABSTRACT

The District Faridabad situated in Southern Haryana is an industrial hub and has seen a radical upsurge in the construction of high rise buildings (residential and official both) in the recent past. The city is densely populated and a large number of people spent a lot of time, both working and living, in high rise buildings made up of concrete blocks and fired bricks. The building materials and the ventilation conditions are the major contributing and controlling factors for the levels of radioactivity in general and concentration of Radon-Thoron and their progeny in particular in dwellings and workplaces. It is well established that indoor radon/thoron and daughters are the largest contributor to total radiation dose received by populations and they account for more than 50% of the total dose. More so, radiation exposure beyond permissible levels can lead to many deleterious effects. As per the data available in the literature, such studies have not yet been carried out in such buildings and therefore call for an initiative for the captioned measurements. In the present paper we have reported on the measurements of Radon-Thoron and their progeny levels in high rise buildings in Faridabad carried out using solid state nuclear track detectors, LR-115 type II exposed in the environment at different levels of high rise buildings for 90 days using twin chamber dosimetry cups. The incorporated data shows that as the level increases, the concentration of radon and thoron decreases. The annual inhalation dose and effective dose to the inhabitants have also been calculated.

Keywords: Radon, ventilation, high-rise, measurements, radon, thorn, LR-115 type II.

1. INTRODUCTION

Radon (^{222}Rn) is a colourless, odourless, tasteless radioactive gas with half life of 3.824 days that comes from the disintegration of radium, which is a decay product of uranium. Radon emits alpha radiations and produces several solid radioactive products called radon daughters such as polonium, bismuth and lead [1]. Radon and its short-lived daughters are the most important source of ionizing radiations prevalent in our environment, which are probably responsible for causing adverse effects on human health. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports that nearly half of dose received by man from natural sources is due to breathing radon and its progenies in the indoor environments [2].

During breathing, radon is exhaled, but the progenies, being material particles, may deposit on to the lungs [3] which is one of the main cancers cause. This gas is well established

as causative agent of death after lung cancer. Radon was identified as a human lung carcinogen in 1986 by the WHO. The major sources of indoor radon include: building materials, water, energy sources and geological structures underneath the built-up area. The other factors like surrounding climate, design of a building, the ventilation system, the heating and cooling system, the sanitary fittings, etc. play an important role in radon accumulation inside the buildings.

In the present study radon, thoron and its progeny levels were measured in high rise buildings of Faridabad situated in Southern Haryana. In modern lifestyle people spend most of the time (70-80%), both working and living, in high rise buildings. Recently used design of building structure reduces the intake of outside air (ventilation) and worsens the situation. Low ventilation rates may result in increased concentration of indoor-generated pollutants, which are associated with sick building syndrome symptoms and other comfort and health effects [4].

2. EXPERIMENTAL TECHNIQUE

The twin chamber dosimeter cup was used for monitoring radon, thoron and their progeny. The length of the chamber is 11 cm and the radius is 7 cm. There is a wall in between the cup, which divides the chamber in to two equal compartments of 5.5 cm each with two open ends as shown in the fig.1 [5-6].

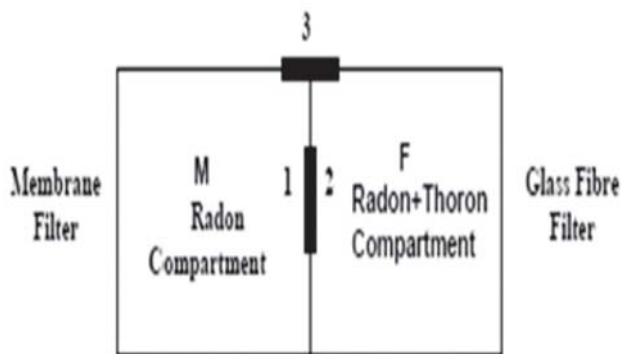


Fig. 1: Radon-Thoron Mixed Field Dosimeter System

The detector employed is LR-115 (Type-II) which is strippable cellulose nitrate film. These films used in the

dosimeter are of approximately 12 μm thickness. The LR-115 (type II) films are cut into 2.5cm x 2.5cm pieces and placed in the dosimeter cup in the three compartments: Compartment-1 measures only radon, in which air diffuses into the compartment through a semi-permeable membrane. The permeability constants range of these membranes is $10^{-12} - 10^{-11} \text{ m}^2 \text{ s}^{-1}$ which allow more than 95% of the radon gas to diffuse into the compartment [7-8].

On the opposite side, the compartment-2 allows both radon and thoron gas to diffuse into the chamber through the glass fibre filter paper and measure the concentration of both radon and thoron gases. In the compartment - 3, detector exposed in the bare mode records all the tracks due to radon, thoron and their progeny. These dosimeters are then installed at the different floors of the building chosen for 90 days after which they are retrieved.

The detectors were then etched with 2.5 N NaOH solution for 90 min. at temperature of 60°C in a constant temperature bath. After that, the films were washed in cold running water then dried and kept for observation. The counting of the visible tracks was then performed using Spark Counter. This technique was developed by Cross and Tommasino and is discussed by Garkani [9-10].

Table 1
Radon and thoron concentration, progeny level in high rise building

Location	Radon Conc. C_R (Bq/m ³)	Thoron Conc. C_T (Bq/m ³)	PAEC (Rn) (mWL)	PAEC (Th) (mWL)
Basement-3	86.97±2.37	38.66±1.78	9.4	1.04
Basement-2	65.37±1.16	22.79±0.73	7.07	0.62
Basement-1	49.03±1.25	16.47±0.48	5.3	0.45
Ground Floor	35.12±0.66	14.64±0.19	3.8	0.4
Floor-1	29.93±0.69	12.68±0.31	3.24	0.34
Floor-2	26.27±0.52	11.10±0.18	2.84	0.3
Floor-3	22.22±0.32	10.70±0.38	2.4	0.29
Av.±SE*			4.86±0.97	0.49±0.10

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

Table 2
Radon and thoron annual exposure, inhalation dose and annual effective dose in high rise building

Location	Annual exposure (Rn) (WLM)	Annual exposure (Th) (WLMx10 ⁻³)	Annual exposure (Rn+Th) (WLM)	Inhalation dose (mSv/y)	Annual effective dose (mSv)
Basement-3	0.387	4.30	0.43	3.21	1.62
Basement-2	0.291	2.54	0.32	2.26	1.19
Basement-1	0.218	1.83	0.24	1.68	0.89
Ground Floor	0.156	1.63	0.17	1.27	0.65
Floor-1	0.133	1.41	0.15	1.09	0.55
Floor-2	0.117	1.24	0.12	0.95	0.49
Floor-3	0.099	1.19	0.11	0.84	0.42
Av±SE*				1.61±0.32	0.83±0.17

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

3. RESULTS AND DISCUSSION

The concentrations of radon (C_R) and Thoron (C_T) were calculated by using the following relations [11].

$$C_R (\text{Bq m}^{-3}) = T_m / d \times S_m$$

$$C_T (\text{Bq m}^{-3}) = T_f - d C_R \times S_{ff} / d \times S_{tf}$$

Where,

C_R = Radon concentration

C_T = Thoron concentration

T_m = Track density in membrane compartment

T_f = Track density in filter compartment

d = Exposure time (90days)

S_{ff} = Sensitivity factor for radon in filter compartment

S_{tf} = Sensitivity factor for thoron in filter compartment

The inhalation dose in mSv/y was estimated using the formula.

$$D_{in} = \{(0.17 + 9F_R) C_R + (0.11 + 32F_T) C_T\} \times 7000 \times 10^{-6}$$

where F_R and F_T is equilibrium factor for radon and thoron respectively.

Annual exposure due to radon and its progeny have been calculated by using the generic relations [12]. The PAEC was converted into annual effective dose by using dose conversion factors; the radon daughter dose conversion factor for members of the public is 3.88 mSv per WLM [13], where as the effective dose equivalent for thoron is 3.4 mSv per WLM [14].

The values of radon and thoron concentration and progeny level (PAEC) varied from $22.22 \pm 0.32 \text{ Bqm}^{-3}$ to $86.97 \pm 2.37 \text{ Bqm}^{-3}$, $10.70 \pm 0.38 \text{ Bqm}^{-3}$ to $38.66 \pm 1.78 \text{ Bqm}^{-3}$, 2.24 mWL to 9.40 mWL with an average value of $4.86 \pm 0.97 \text{ mWL}$, and 0.29 mWL to 1.04 mWL with an average value of $0.49 \pm 0.10 \text{ mWL}$ respectively as shown in table 1.

The value of radon and thoron annual exposure, inhalation dose and annual effective dose varied from 0.099 WLM to 0.387 WLM, $1.19 \times 10^{-3} \text{ WLM}$ to $4.30 \times 10^{-3} \text{ WLM}$, 0.84 mSv/y to 3.21 mSv/y with an average value of $1.61 \pm 0.32 \text{ mSv/y}$ and 0.42 mSv to 1.62 mSv with an average value of $0.83 \pm 0.17 \text{ mSv}$ respectively as shown in table 2.

4. CONCLUSION

Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. Radon levels are generally highest in cellars and basements because these areas are poorly ventilated and affect the human health. Latest construction patterns of buildings reduce the ventilation of air and worsen the situation. Thus, it is important to estimate the radon,

thoron levels in these building where people spent their time either working or living there. From the table 1 and table 2 it is clear that as the level of building increases (basement to higher floor), radon and thoron concentration decrease. The radon concentration level is higher in basements as compared to higher levels of the buildings because of poor ventilation. The radon concentration. At certain locations, the maximum value of annual effective dose is slightly higher than the recommended safety limit of 1.0 mSv/y averaged over five consecutive years [13]. This calls for the remedial measures to be adopted to reduce/ remediate the levels by way of proper ventilation, selection of proper building material and proper sealing of the floors and other remedial measures.

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STUDY OF EFFECT OF ADDITION OF FLY ASH ON RADON EXHALATION RATE IN CEMENT SAMPLES

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ABSTRACT

Most of the building materials like cement and fly ash contain naturally occurring radioactive materials (NORMs). Increased interest in measuring radon exhalation rate in building products is due to the concern about health hazards of NORMs. This paper focuses on studying the effect of addition of fly ash on radon exhalation rate in cement samples. Ordinary Portland Cement (OPC) and coal fly ash were used for finding the exhalation rate of cement in this paper. To study the effect on exhalation rate of cement, fly ash is added in different proportions to cement samples. The measurement was conducted by CAN Technique using SSNTDs. A gradual increase has been observed in radon exhalation rate up to certain proportion and then starts to decrease.

Keywords: Radon, Exhalation rate, SSNTDs, NORMs, CAN Technique.

1. INTRODUCTION

India depends largely on coal reserves for energy needs, which alone contribute 72% of the total power generated in India [1]. Coal like other materials found in nature, contains radionuclide like uranium, thorium and potassium. Combustion of coal enhances the natural radiation in the vicinity of the thermal power plant through the release of the radionuclide and their daughters in the surrounding ecosystem. These radioactive materials may be concentrated in the fly ash by thermal power plant combustion [2]. The environmental problems of fly ash such as wide area requirements for disposal, pollution of air, soil and water associated with ponds of ashes stored near the power plants have become preventing items for coal-fired power plants. As environmental consciousness increases throughout the world, utilization of fly ash like other waste materials have become important and provide economic advantages such as providing cheap mineral resource for construction. Uses of fly ash in building materials, as underground cavity filling material and in the production of cement etc., fly ash has become a subject of worldwide interest in recent years. Radon exhalation rate from fly ash is of prime importance for the estimation of radiation risk. Fly ash could also affect human health through direct inhalation or ingestion of airborne or settled ash.

In the present study, radon exhalation rates from the cement and fly ash samples collected from the National Council for Cement and Building Materials (NCB), Faridabad situated in Haryana, India have been measured to estimation of radiation risk by mixture of cement and fly ash in different proportion, to the habitants.

2. EXPERIMENTAL METHOD

Can technique was used for the radon exhalation measurements. This is supposed to be the most efficient method for the measurement of time integrated radon exhalation rate. The sample is placed in the lower part of a sealed cylindrical can and sensitive solid state nuclear track detector is fixed on the inner upper surface of the can [3]. In such measurements, it is expected that the exhalation rate depends upon the material and its amount as well as on the geometry and dimension of the Can. Samples collected from the NCB were dried and sieved through a 100-mesh sieve. Equal amount of each sample (100 gm) was placed in the Cans (diameter 8.1 cm and height 11.1 cm). In each Can a LR-115 type-II plastic track detector (2 cm × 2 cm) was fixed at the top inside of the Can. The sensitive lower surface of the detector is thus freely exposed to the emergent radon from the material in the Can so that it is capable of recording the alpha particles resulting from the decay of radon in the Can.

Radon and its daughters reach an equilibrium concentration after a week or more and thus the equilibrium activity of emergent radon could be obtained from the time of exposure and the geometry of the Can. After the exposure for 100 days, the detectors from all the Cans were retrieved and were etched in 2.5N NaOH at $60 \pm 1^\circ\text{C}$ for a period of 90 min in a constant temperature water bath for revelation of tracks. Resulting alpha tracks on the exposed face of the detector foils were scanned under an optical microscope at a magnification of 400X. The calibration factor of 0.056 Tr/cm²/d obtained from an earlier calibration experiment for LR-115 type-II detector⁴ was used to compute the radon activity from the track density [4].

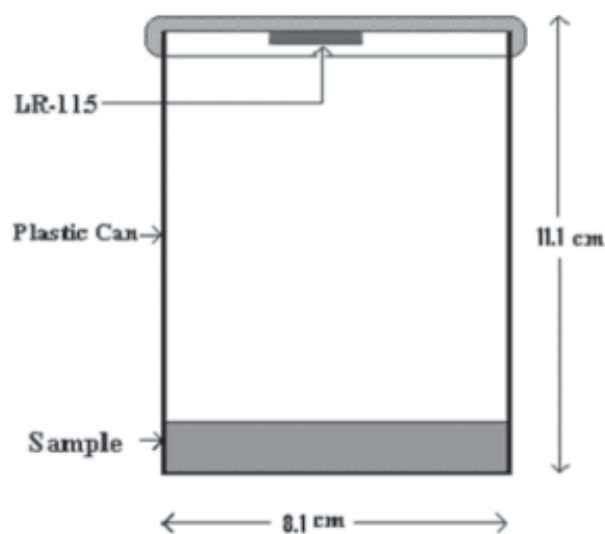


Fig. 1: Can used for experiment

3. EXPERIMENTAL RESULT

Following expression gives the exhalation rate [5-6]

$$Ex = CV\lambda A [T + 1/\lambda \{e^{-\lambda T} - 1\}]$$

where Ex is the radon exhalation rate in Bqm⁻² h⁻¹, C is the integrated radon exposure as measured by LR-115 type II

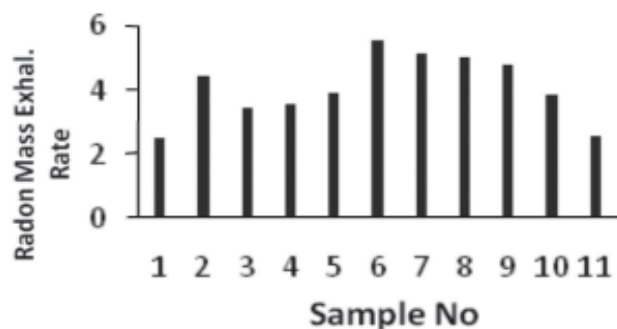


Fig. 2: Radon mass exhalation rate

Table 1
Content of Cement sample and their respective exhalation rate
(C here represents Cement and FA Fly ash)

Sample no.	Sample Content	Radon Mass Exhal. Rate (mBq/kg ⁻¹ h ⁻¹)	Radon Surface Exhal. Rate (mBq/m ² h ⁻¹)
1	100% C	2.51354	48.803
2	100%FA	4.44247	86.2552
3	10% FA	3.48298	67.6256
4	20%FA	3.61114	70.114
5	30% FA	3.93942	76.4879
6	40% FA	5.58085	108.358
7	50% FA	5.19774	100.919
8	60% FA	5.03531	97.7656
9	70% FA	4.82148	93.6139
10	80% FA	3.85718	74.8911
11	90% FA	2.57145	49.9274

plastic track detector in Bqm⁻³h, V is the effective volume of Can in m³, λ is the decay constant for radon in h⁻¹, T is the exposure time in h and A is the area covered by the Can in m².

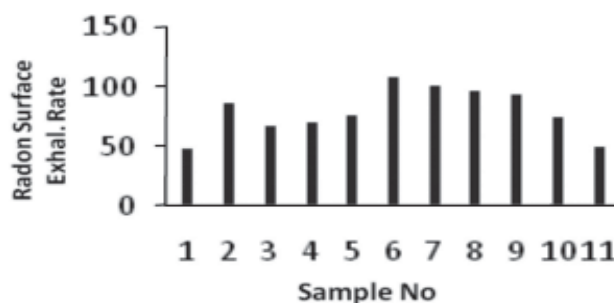


Fig. 3: Radon Surface Exhalation Rate

4. CONCLUSION

The cement is the basic ingredient used in construction materials in India. The mixture of fly ash and cement is commonly used binding material for the construction and preparation of concrete. Thus, it is quite important to find its radon exhalation rate to have an estimation of radiation risk to the habitants as reported in various research [7-13]. From the figure 2 and figure 3 it can be observed that radon mass exhalation rate and radon surface exhalation rate increases up to sample no 6 (40% fly ash+60% cement) and then start to decrease gradually. As fly ash itself is a radio active material, adding it in cement will result in increase in radon exhalation rate but after certain limit, exhalation rate start to decrease. The grain size of fly ash is small and mixing it in higher concentration will decrease the porosity, which eventually result in decrease radon exhalation rate as evident from the figure 2 and 3 above.

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ESTIMATION OF RADON EXHALATION RATE FROM SOIL SAMPLES USING SSNTD

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ABSTRACT

Radon is the gaseous progeny of ²³⁸U, which is present in the earth crust in trace quantities. Radon reaches the indoor atmospheres from the matrix of soil by two processes. The first stage is emanation from the material and the second is exhalation from the matrix. Transport of radon from pore space to the environment takes place mainly by diffusion and this contributes to the environmental radon level. In the present study, 10 samples were collected from different elevations of Yelagiri hills in Tamil Nadu. The activity concentration of ²³⁸U, ²³²Th and ⁴⁰K were measured by gamma spectrometry. The activity concentration of ²³⁸U ranges from 10.1Bq/kg to 53.23 Bq/kg; ²³²Th ranges from 35.95 Bq/kg to 100.42 Bq/kg and ⁴⁰K ranges from 2105.4 Bq/kg to 261.11 Bq/kg. Based on high ²³⁸U content, four samples were considered for radon exhalation measurements. The radon exhalation rates were measured by the sealed can technique using LR 115 film. The radon exhalation rate ranges from $0.08 \pm 0.003 \text{ Bqkg}^{-1} \text{ h}^{-1}$ to $0.402 \pm 0.006 \text{ Bqkg}^{-1} \text{ h}^{-1}$ with an average value of $0.228 \text{ Bq kg}^{-1} \text{ h}^{-1}$. Radium equivalent activity obtained from activity concentrations is found to vary from 119.4 BqKg^{-1} to 243.8 Bqkg^{-1} with an average value of 186.4 Bqkg^{-1} , which are within the prescribed limits.

Keywords: Radon, Exhalation, LR-115, Gamma Spectrometry.

1. INTRODUCTION

During the recent past, there has been growing attention towards the estimation of dose due to exposure to natural radiation. The primordial radionuclides ²³⁸U, ²³²Th and ⁴⁰K present in the earth's crust, termed as terrestrial radiation; contribute a significant part to the natural background radiation. Radon and thoron are gaseous progenies of ²³⁸U and ²³²Th respectively which further decay to form radioisotopes which are solids. Freshly formed decay products soon attach to existing aerosol particles and are suspended in air. The inhalation of radon, thoron and their decay products contribute about 50% of the natural background radiation dose to humans. Hence, monitoring of environmental radon levels has gained considerable interest among scientists and general public.

Measurement of natural radioactivity in soil is very important to determine the amount of change of the environmental radon level with time as a result of any radon release from soil. The infiltration of radon gas from soil has been identified as one of the main mechanisms influencing

indoor radon levels in many buildings. A significant fraction of indoor radon comes from the ground and surrounding soil of buildings. Radon reaches the atmosphere from the matrix of soil and building material by two processes. The first stage is emanation from the material and the second is exhalation from the matrix. Emanation is the process by which radon atom is released from the solid mineral grains to the air filled pores. Exhalation is the process of transport of radon gas from air filled pores to the atmosphere. Transport of radon from pore space to the environment takes place mainly by diffusion as a result of concentration gradient.

Solid state nuclear track detectors (SSNTDs) are usually used for indoor radon monitoring as well as for radon measurements in soil and water. This technique is based on the fact that latent tracks are produced in certain dielectrics due to interaction of alpha particles emitted by radon and its progeny. After exposure, the irradiated material is etched in aqueous solutions of chemically active substances, for plastics usually NaOH.

This leaves tracks in the material. The track density is a measure of the time integrated radon concentration to which the SSNTD is exposed.

In the present study 10 samples were collected from different locations of Yelagiri in Tamil Nadu. The activity concentration of ^{238}U , ^{232}Th and ^{40}K were measured by gamma spectrometry. Based on high ^{238}U content, four samples were considered for radon exhalation measurements. The radon exhalation rates were measured by the sealed can technique using LR115 SSNTD.

2. MEASUREMENT METHODOLOGY

2.1 Estimation of ^{238}U , ^{232}Th and ^{40}K

Soil samples (10 Nos.) were collected from different elevations of Yelagiri hills in Tamil Nadu. The samples were dried and sieved. They were packed in plastic airtight containers, of 250 ml volume, and sealed. This sealing is to ensure that all the daughter products of Uranium and Thorium, especially the gaseous Radon and Thoron that would be formed would not escape. They were stored for 30 days to enable ^{226}Ra / ^{232}Th and their progenies to attain equilibrium. The samples were then counted for 10,000 seconds in a NaI (Tl) detector based system equipped with PC based MCA. The efficiency of the system was determined using IAEA reference standards. The activity of ^{40}K was identified by 1460 keV gamma ray line, that of ^{238}U by 1764 keV (^{214}Bi) and that of ^{232}Th , by 2614 keV (^{208}Tl). From these values, the activity concentrations of ^{238}U , ^{232}Th and ^{40}K were estimated in Bq/kg.

2.2 Radon exhalation rate

Based on the radioactivity content obtained from gamma spectrometry, four samples with relatively higher ^{238}U content were chosen for radon exhalation studies. The mass exhalation rate of the soil samples was measured by the Sealed can technique. [1, 2, 3]. LR115 type II plastic track detector was fixed on the top inside the cylindrical container. Each sample was weighed (50 g) and placed in the container. The container was sealed and left for two months. The concentration of radon varies initially due to exhalation from the sample and radioactive decay. After about a month, it saturates reaching the steady state concentration. After the exposure, the detectors were etched in 2.5 N, NaOH at 60 °C for a period of 90 minutes in constant temperature water bath for revelations of tracks. The detector was washed in running water and dried. The film was peeled off and counted using spark counter. From the track density obtained, the exhalation rate was calculated using the expression [4, 5]:

$$E = \frac{CV\lambda}{M \left[T + \frac{1}{\lambda} (e^{-\lambda T} - 1) \right]} \quad (1)$$

E radon exhalation rate ($\text{Bqm}^{-2} \text{h}^{-1}$)

C time integrated radon concentration measured by LR115 (Bqm^{-3}h)

V Effective volume of container (m^3)

λ Decay constant for radon (h^{-1})

T exposure time (h) and

M Mass of the sample. (kg)

3. RESULTS AND DISCUSSION

The activity concentrations of the three primordial radionuclide ^{238}U , ^{232}Th and ^{40}K in the soil samples reveal a non-uniform profile (Table1). Uniformity with respect to exposure to radiation can be defined in terms of Radium Equivalent activity of materials containing different amounts of ^{238}U , ^{232}Th and ^{40}K . It has been estimated that 370 Bq kg^{-1} of ^{226}Ra or 259 Bq kg^{-1} of ^{232}Th or 4810 Bq kg^{-1} of ^{40}K produce the same gamma dose rate. Thus radium equivalent activities (Ra_{eq}) are estimated using the following equation [6, 7]

$$\text{Ra}_{\text{eq}} = C_{\text{U}} + 1.43 C_{\text{Th}} + 0.07 C_{\text{K}}$$

where C_{U} , C_{Th} , C_{K} are activity concentrations of ^{238}U , ^{232}Th and ^{40}K .

The activity concentration of ^{238}U ranges from 10.1 Bq/kg to 53.23 Bq/kg; ^{232}Th ranges from 35.95 Bq/kg to 100.42 Bq/kg and ^{40}K ranges from 261.11 Bq/kg to 2105.4 Bq/kg

Radium equivalent activity (Ra_{eq}) obtained from activity concentrations is found to vary from 119.4 Bq kg^{-1} to 243.8 Bq kg^{-1} with an average value of 186.4 Bq kg^{-1}

The calculated radon mass exhalation rates for the four samples are given in Table2. The radon exhalation rate ranges from 0.08 ± 0.003 Bq $\text{kg}^{-1} \text{h}^{-1}$ to 0.402 ± 0.006 Bq $\text{kg}^{-1} \text{h}^{-1}$ with an average value of 0.228 Bq $\text{kg}^{-1} \text{h}^{-1}$

4. CONCLUSION

The Radium equivalent activity (Ra_{eq}) in the soil samples are below 370 Bq kg^{-1} , which are acceptable for safe use. (OECD, 1979)[8]. The lack of correlation between Uranium content and radon exhalation can be attributed to the fact that radon exhalation rate also depends on the emanation factor of the soil which varies with the soil grain parameters.

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SYNTHESIS OF COPPER MICROWIRES AND THEIR ANTIMICROBIAL CHARACTERIZATION

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ABSTRACT

This paper describes synthesis of copper microwires via template assisted electrodeposition method using polycarbonate track etch membrane as template. Template assisted synthesis by electrodeposition method is easy and low cost. Copper microwires were fabricated by using the commercially available polycarbonate track etch membranes as template. The morphological characterization of fabricated microwires was carried out by scanning electron microscopy and material confirmation is accomplished by X-Ray diffractometry. SEM micrographs illustrate the uniform directional growth of microwires and morphology of synthesized microwires are consistent with the morphology of voids in the host template. Length of wires is same as of thickness of the template. Synthesized samples were analyzed for the antimicrobial activity against bacterial strains *Escherichia coli* and *Bacillus subtilis* via disc diffusion method and found the zone of inhibition with diameter 2.3 cm and 2.0 cm against bacteria *Bacillus subtilis* and *Escherichia coli* respectively.

Keywords: *Microwires, Electrodeposition, Template, Polycarbonate, Track Etch Membrane.*

1. INTRODUCTION

Low dimensional structures have attracted considerable attention owing to their novel physical and chemical properties leading to the potential applications in new generation of nanodevices [1]. Nano/microwires compared to other low dimensional systems have two quantum confined directions, while still leaving one unconfined direction for electrical conduction [2, 3]. This allows nano/microwires to be used in applications where electrical conduction, rather than tunneling transport, is required. Microwire designs, in conjunction with microsensors, are expanding the capability of devices to the healthcare market [4, 5]. Researchers have developed various techniques for synthesizing nano/microwires that includes lithographic patterning, vapor transport techniques and template-based-synthesis [6]. Among these techniques, the template-assisted electrodeposition technique is comparatively easy and cost effective. The growth of nano/microstructures via electrodeposition method can be controlled by changing

the conditions of electrolyte like pH, temperature, concentration, and external applied voltage. This method works under mild conditions rather than requiring high temperatures, high vacuum or expensive instrumentation [7-9]. The desired morphology of deposited materials depends on the morphology of voids in template that act as molds. The track etch membrane (TEM) acts as excellent template for synthesis of low dimension structures because of its unique characteristics of well defined uniform ordered array of pores with narrow pore size distribution [6-8]. The desired morphology of pores can be obtained by controlling the irradiation of ions and etching conditions during the fabrication of TEMs [9,10]. Various materials such as mica, ceramics and polymers have been used to fabricate TEMs. Polycarbonate material is preferred because of its higher mechanical strength, environmental stability, chemical inertness and biocompatibility [11-13]. Polycarbonate TEM membrane has another advantage of its smooth and flexible surface making it potential candidate for wide applications

in microdevices and microelectrodes. Polycarbonate TEM provides an excellent alternative to be used as template since they can be easily handled because of their ruggedness and durability [14, 15]. Copper has rapid, broad spectrum antimicrobial efficacy against most of the toxic species of bacteria, fungi and viruses [16, 17]. Copper's rate of microbial inactivation is affected by temperature, concentration, surface to volume ratio and the type of microorganism with which it is in contact [17-19]. Copper is superior to other antimicrobial materials because antimicrobial copper is the most effective touch surface material in the fight against bacteria, killing greater than 99.9% of bacteria within 2 hours of exposure than other material, such as silver containing coatings, or stainless steel. Antimicrobial copper is the only solid surface material registered by the US Environment Protection Agency (EPA) to continuously kill bacteria [19, 20]. Comparative to the antimicrobial efficacy of copper, aluminum, stainless steel, PVC, polyethylene have very low antimicrobial property. Earlier studies have revealed that *Acinetobacter baumannii*, *Klebsiella pneumonia*, Adeno virus, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* cannot survive on the copper surface and the efficacy of copper alloys as hygienic antimicrobial materials for pathogenic microbes in diverse environments [21-23].

This work describes the application of Polycarbonate TEMs as templates to synthesize copper microwires. Morphological, material confirmation and antimicrobial characterization have been accomplished by scanning electron microscopy, X-Ray diffractometry and disc diffusion method.

2. EXPERIMENTAL DETAILS

Materials

Polycarbonate TEMs were used as template to synthesize the copper microwires that are procured from Sartorius Stedium Biotech. These membranes possess uniform cylindrical pores of diameter $0.4\ \mu\text{m}$ and aligned vertically to surface with narrow pore size distribution. Thickness of the membrane was about $15\ \mu\text{m}$ and the porosity of the membrane is 15%. Copper sulphate (CuSO_4) solution was used to make the electrolyte solution with concentration of 1M for electrodeposition. The copper tape with conductive adhesive on one side of template was used as substrate surface for the deposition. Double distilled water was used to prepare the solution of copper sulphate. Dichloromethane was used for post treatment of synthesis to dissolve the polycarbonate membrane and ethanol is used to wash the microwires. All the chemicals and reagents used were of AR grade procured from Molychem, Mumbai, India.

Antimicrobial activity of copper microwires was studied against two model bacteria *Escherichia coli* and *Bacillus*

subtilis using disc diffusion method. Media used to check the antimicrobial activity is nutrient agar. The experiment was carried out in aseptic conditions.

Method and Experimental Set-Up

Electrochemical cell with two electrodes was used for the synthesis of copper microwires via electrodeposition method [1-5]. Copper tape on one side of the TEM perform as working electrode (cathode) and copper rod dipped in electrolyte solution performs as reference electrode (anode) on the other side of template. The O ring was used to avoid the leakage of electrolyte from the reservoir. Copper tape was adhered on tapered glass surface to avoid the gap or air bubbles between copper and template surface. The schematic of experimental set up for the electrodeposition of copper microwires is shown in Figure 1. Polycarbonate TEM was used as template. By electrodeposition method, copper ions were deposited within confined space of the pores in template placed on copper tape without air gap to provide a stable substrate for the homogeneous growth of the wires and serves as cathode in the electrochemical cell. Utilizing the process of electrodeposition, free standing copper microwires of $0.4\ \mu\text{m}$ diameter were synthesized on copper substrate.

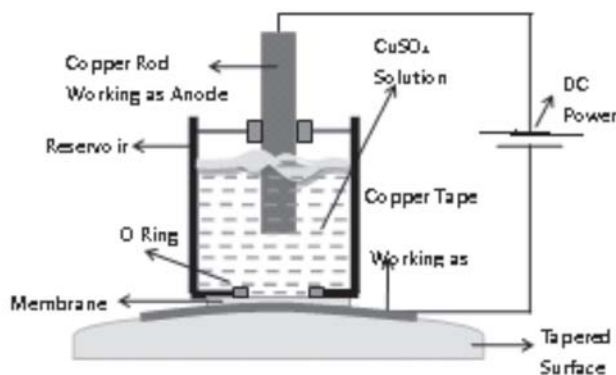


Fig. 1: Experimental Set-Up for Electro-deposition

Characterization

Morphological characterization of the synthesized copper microwires was carried out by scanning electron microscope (SEM) SEMTRAC mini, SM-3000. The cleaned and dried samples were mounted on the specially designed aluminum stubs with the help of double side adhesive tape. The polycarbonate material of the sample was dissolved by dropping the dichloromethane on the sample with the help of micropipette for about 15 minutes followed by washing with the ethanol. Sample on stub is again dried and coated with a layer of gold using JEOL, fine sputter MCM-100 sputter coater. Images were recorded at different magnifications.

Material characterization of synthesized microwires was carried out by performing X-Ray diffractometry. XRD

spectra of prepared sample was recorded on a Riga KuC/max-2500 diffractometer using graphite filtered CuK α radiation ($\lambda = 1.54 \text{ \AA}$) at 30 kV and 15mA with a scanning rate of 3° min^{-1} from 2θ angle varying from 20° to 80° .

The antimicrobial activity of the synthesized microwires was examined and tested by disc diffusion method. Nutrient agar medium was autoclaved at 120° C for 21 min. About thirty ml of media was poured into each petridish and then left it to cool at 45 to 50° C , so that media get solidified. Now the bacterial strains were spread over the sterile plates using a spreading loop. Circular discs (4.5 mm) of the synthesized samples of Polycarbonate TEM impregnated with copper microwires were placed in the petridish and control discs of copper tape of the same size, representing bulk copper, were also placed in the same petridish to make the comparison of antimicrobial effect easy. Petridish were incubated at temperature of 28° C for 48 hours. After incubation, the zone of inhibition was observed.

3. RESULTS AND DISCUSSION

The SEM images in Figure 2 and 3 illustrate the directional growth of ordered array of free standing copper microwires. Morphology, alignment and orientation of synthesized copper microwires are quite uniform as they grow homogeneously via electrodeposition within the confined, ordered & symmetric pores of the host TEM template. The morphology of microwires is consistent with morphology of voids in host TEM template. The average diameter of the synthesized wires is about $0.4 \text{ }\mu\text{m}$ which is equal to the average pore size of TEM templates. The standard deviation of the pore morphology in TEMs is significantly small due to its unique feature of narrow pore size distribution. Segment to segment and wire to wire variation is assumed to be within the limits of the variation in morphology and alignment of pores that can be minimized by controlling

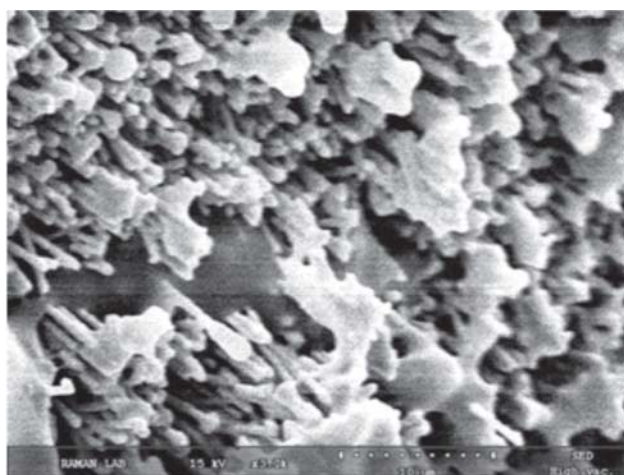


Fig. 2: SEM image of copper microwires from top view

homogeneity of the incident ion beam, target material and etching conditions during the fabrication process of TEMs. The various shapes of electrodeposited material can be achieved by changing the pore shape in host TEM template.

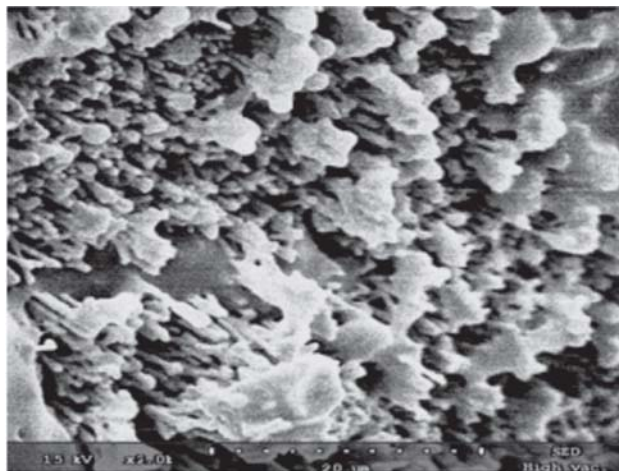


Fig. 3: SEM image of copper microwires from side view

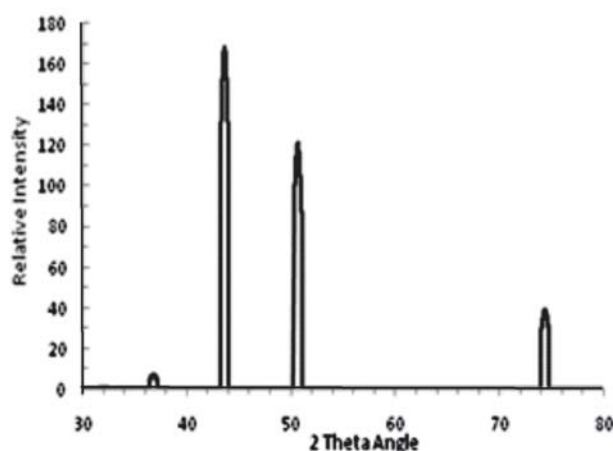


Fig. 4: XRD spectrum of copper microwires

The Figure 4 shows the XRD spectra recorded for the synthesized samples with a scanning rate 3° min^{-1} for 2θ angle varying from 20° to 80° . The position of peaks in XRD spectra matches with the peaks for copper and confirms that the material deposited within pores of polycarbonate TEMs is copper [1, 5, 24].

These microwires were characterized for their antimicrobial activity via disc diffusion method, with the motive to establish their viability as antimicrobial material for micro/nano devices for various biomedical applications. The samples of synthesized copper microwires were tested for antimicrobial resistance against two bacterial strains *Escherichia coli* and *Bacillus subtilis*. Also discs of

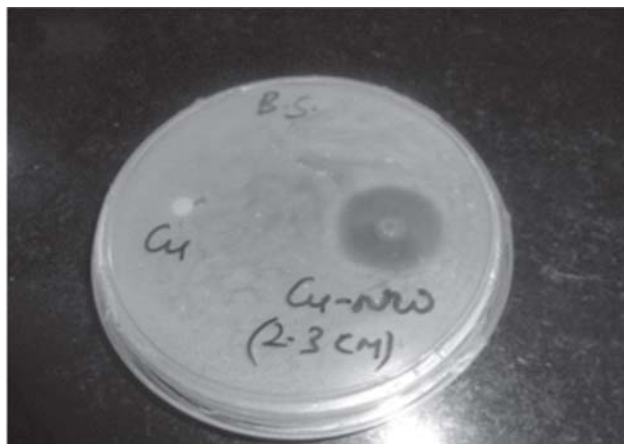


Fig. 5: Antimicrobial activity against bacterial strain *Bacillus subtilis*



Fig. 6: Antimicrobial activity against bacterial strain *Escherichia coli*

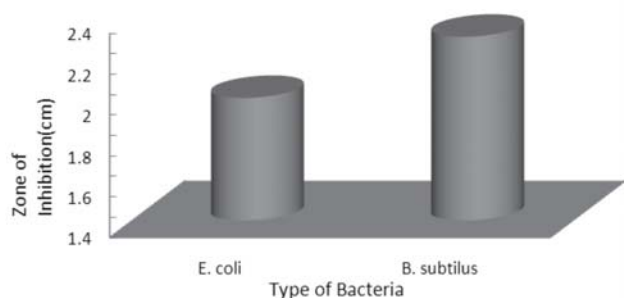


Fig. 7: Relative antimicrobial activity of copper microwires

copper tape of same size were used as controls in the same petridish representing bulk copper as shown in Figures 5 and 6, discs in the left represent bulk copper and on the right synthesized samples of copper microwires were placed.

It is observed from Figure 5 and 6, discs of TEM impregnated with copper microwires have zone of inhibition of 2.3 cm in diameter against bacteria- *Bacillus subtilis* and 2.0 cm

in diameter against *Escherichia coli*. Control discs did not illustrate any antimicrobial resistance against these bacteria. Figure 7 shows the relative antimicrobial activity of copper microwires between two bacteria *Escherichia coli* and *Bacillus subtilis* which infers that copper microwires have higher antimicrobial activity against *Bacillus subtilis* than *Escherichia coli*.

4. CONCLUSION

Copper microwires of diameter 0.4 μm were synthesized at room temperature via template assisted electrodeposition method. The morphology of these microwires is consistent with the morphology of pores in host TEM template. Copper microwires are vertically aligned, uniform and ordered having cylindrical shape. By changing the morphology of pores in host TEM template, the micro structures of different shapes and sizes can be fabricated. These microwires have good antimicrobial activity against bacteria, hence possess avenues for potential applications in nano/micro biomedical devices and systems.

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STUDY OF RADON IN GROUNDWATER AND PHYSICOCHEMICAL PARAMETERS AROUND TUMKUR DISTRICT OF KARNATAKA STATE

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ABSTRACT

Water, a natural resource, basic amenity and universal solvent, is utilized by plants, animals including human beings. The study of radon in groundwater and groundwater quality around Tumkur district has been taken up to evaluate its suitability for potable purposes. The groundwater samples were collected from different bore wells of the study area. The radon concentration in ground water was determined by Emanometry method. Its concentration in groundwater has been found to vary varies from 9.95 Bq l⁻¹ to 284.75 Bq l⁻¹ with an average value of 62.31 Bq l⁻¹. The higher concentration of radon is due to higher activity of radium bearing bedrock present in the study area. The estimated inhalation and ingestion dose is varies from 0.024 mSv.y⁻¹ to 0.717 mSv.y⁻¹ with an average value of 0.156 mSv.y⁻¹ and 0.002 mSv.y⁻¹ to 0.059 mSv.y⁻¹ with an average value of 0.012 mSv.y⁻¹ respectively. The total annual effective dose from the six locations (about 55%) of the studied area is found to be greater than the safe limit. The quality of ground water has been made through the analysis of pH, total dissolved solids, chlorides, fluoride, nitrite and sulphate. This highlights the quality problems encountered in groundwater in the study area. The chemical parameters which are present in groundwater in excess of the prescribed norms and which are considered harmful beyond the permissible limits are discussed in detail. There is no correlation was observed between the radon concentration in groundwater and physiochemical parameters.

Keywords: *Groundwater, Emanometry, Inhalation, Ingestion, Annual effective dose.*

1. INTRODUCTION

Ground water is a weak electrolyte containing various elements and their associated radicals in ionic equilibrium. The major cations determined are calcium, magnesium, sodium and potassium. The major anions are carbonates, nitrate, bicarbonates, chloride and sulphate. The other parameters determined are total dissolved solids, total hardness, pH, iron and natural gas. The natural gas contains radioactive gas like ²²²Rn is a naturally occurring radioactive noble gas in the environment formed by radioactive decay of ²²⁶Ra. It undergoes radioactive decay by emission of alpha particles with a characteristic half-life of 3.82 days. It decays by emission of alpha particle to form radon decay products, which could be divided into short-lived and long-lived progeny species. When radon decays to ²¹⁸Po and ²¹⁴Po, which are charged, they can attach themselves to tiny dust particles, water vapours, oxygen, trace gases in indoor air and other solid surfaces form aerosols. The changes in quality of groundwater response to variation in physical, chemical and biological environments through

which it passes [1]. Groundwater resource in the study area is widely exploited for irrigation and other domestic purposes in addition to drinking purpose. The residents of the study area mainly depend on ground water for their drinking purposes. Concentration of radon and physiochemical parameters more than their permissible limits in drinking water leads to health problems such as water borne diseases like fluorosis, typhoid jaundice, cholera, premature baby and other problems, especially infants [2].

2. STUDY AREA

The area of study is the Tumkur district and is located between north latitudes 12°45' to 14°20' and east longitudes 76°20' to 77°31'. The district is divided into two zones, the eastern and western hilly zone with a plateau in between. The landscape is undulating except in the two hilly regions. A major part of Tumkur district is covered by peninsular gneisses, closepet granite and Dharwar Schist and intrusive like dyke, pegmatite, and quartz veins [3]. The closepet granites are chiefly composed of medium to coarse grained

phosphoritic granite. The main rock types in the Dharwar group are hornblende schist, with quartz-seritite, limestone with chart bands and quartzite and quartzite-chlorite schist. The major industries are that of chemicals, oil, cotton, soap, tools, food processing, rice mills, stone crushing and mining. Occurrence, movement and storage of groundwater are influenced by lithology, thickness and structure of rock formations.

3. MATERIALS AND METHODS

3.1. Estimation of radon level in water samples

The activity concentration of ^{222}Rn in ground water was estimated by the Emanometry [4 -5]. Schematic diagram of Radon bubbler is as shown in Fig. 1. The bore well and hand pump water samples were collected from different selected locations in and around Tumkur districts during February and March 2013. In order to obtain fresh water from bore well, the water was allowed run fully at least five or ten minutes before the sample was taken. About 100 ml of water samples were collected in air tight plastic bottle with minimum disturbance. The plastic bottles were filled completely in a gentle manner, so that zero head space was present. Care was taken to see that no air bubbles were seeing inside the container and also to avoid aeration during the sampling processes, which might lead to out gassing [6]. After collecting the water samples by using the standard procedure, the samples were brought to the laboratory with minimal loss of time and were analysed immediately. In this method, about 40 to 60 ml of the water samples was transferred into the bubbler by the vacuum transfer technique. The dissolved radon in the water was transferred into pre-evacuated and background counted scintillation cell. The scintillation cell was stored for 180 minutes to allow radon to attain equilibrium with its daughters and then it was coupled to a photomultiplier and alpha counting assembly and finally, concentration of radon samples have been measured using the relation [5].

$$^{222}\text{Rn} (\text{BqL}^{-1}) = \frac{6.97 \times 10^{-6} \times D}{V \times E \times (1 - e^{-\lambda t}) \times e^{-\lambda T} \times e^{-\lambda \theta}} \quad (1)$$

where, D = Counts above background, V = Volume of water, E = Efficiency of the scintillation cell (74%), λ = Decay constant for radon ($2.098 \times 10^{-6} \text{ s}^{-1}$), T = Counting delay after sampling, t = counting duration (s) and θ = build up time in the bubbler (s).

3.2. Measurement of water physicochemical parameters

After pumping out the sufficient quantity of water from the source about 1 litre of water samples were collected in polythene containers for physicochemical analysis. 0.5 litre

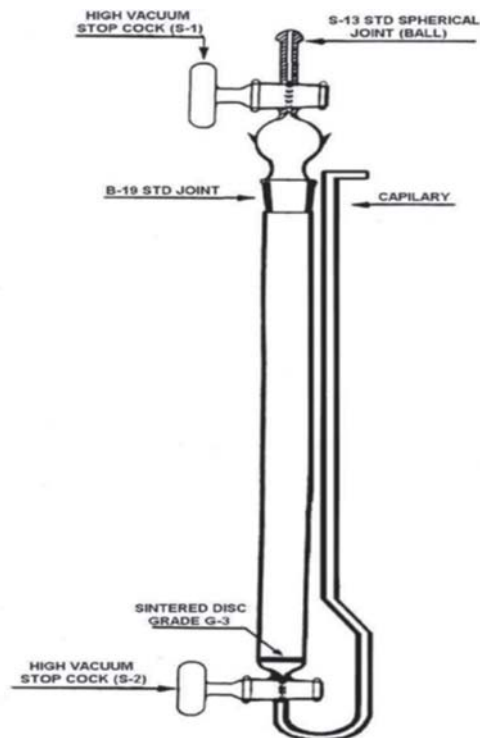


Fig. 1: Schematic diagram of Radon bubbler

of water samples used for the determination of physicochemical parameters such as pH, colour, electrical conductivity, total dissolved solids, chlorides, total hardness, calcium hardness, nitrates, sulphates, iron, fluorides and lead. Using standard methods like ion selective electrode method is used to find fluoride. UV spectrophotometric method is used to find Nitrate. EDTA trimetric method is used for total hardness, Phenanthroline spectrophotometric method is used for the detection of total iron and water quality kit is used for monitoring pH, conductivity and TDS in groundwater.

4. RESULTS AND DISCUSSION

4.1. Analysis of ^{222}Rn concentration in ground water

The recorded average values of ^{222}Rn concentrations, inhalation, ingestion and equivalent effective doses due to the ^{222}Rn to the public were summarized in Table 1. The activity concentration of ^{222}Rn in groundwater of Tumkur district varies from varies from 9.95 Bq l^{-1} to 284.75 Bq l^{-1} with an average value of 62.31 Bq l^{-1} . The higher activity concentrations of radon in ground water were observed in Tumbadi and Dodderi. Radon in water depends on the local geology, radium and uranium dissolved in water and hydro geological conditions and rock of the aquifer and the presence of thrusts, faults and shears which facilitate upward migration of radon gas [7-8]. High radon concentration appears due to the fact that these areas are

attributed by gray pink granite rocks; these rocks contain higher activity of radionuclides. They are younger than altered and gray granite rocks [9–11]. The minimum ^{222}Rn concentrations were observed at Korategere city, this is due to the fact that all the locations are attributed by gray granites and dolerites, these rocks contains lower activity of radionuclides when compared to gray pink granites. US Environment Protection Agency has proposed that the allowed maximum contamination level (MCL) for radon concentration in water is 11Bq l^{-1} . It was observed that except two remaining all the samples from the study area the recorded values were found to be higher than the recommended value [12]. The estimated inhalation and ingestion dose is varies from 0.024 mSv.y^{-1} to 0.717 mSv.y^{-1} with an average value of 0.156 mSv.y^{-1} and 0.002 mSv.y^{-1} to 0.059 mSv.y^{-1} with an average value of 0.012 mSv.y^{-1} respectively. The estimated annual effective dose due to radon inhalation and ingestion is ranges from 0.026 mSv.y^{-1} to 0.776 mSv.y^{-1} with an average value of 0.169 mSv.y^{-1} . The World Health Organization [13] and EU Council [14] recommended the safe limit of the annual effective dose received from drinking water consumption to be 0.1 mSv.y^{-1}

from these three radioisotopes: ^{222}Rn , ^3H ^{40}K . So the total annual effective dose from the six locations (about 55%) of the studied area is found to be greater than the safe limit.

4.2. Analysis of Physicochemical parameters of ground water

The radon concentration and physicochemical parameters of water such as chloride, Fluoride, nitrite, sulfate, pH, TDS also measured in order to know about the impact of these parameters on radon concentration and their health risks to the publics are discussed. The radon concentration and physicochemical parameters of water are summarized in Table 2. The physicochemical results have been subjected to statistical analysis. The observed ranges of the samples were compared with Bureau of Indian Standards (BIS- 10500: 1991) [15]. The samples collected showed considerable variations in the quality of groundwater [16-17]. This might be due to irregular distribution of rocks or due to variation in the depth of sample points.

From the Tables 2, it is observed that, the pH value of the samples in the study area varied from 7.04 to 7.57 with a

Table 1
The average activity concentration of Radon and their Inhalation and ingestion dose rate of Tumkur district water samples.

Places	^{222}Rn (Bq l ⁻¹)	Inhalation (m Svy ⁻¹)	Ingestion (m Svy ⁻¹)	Total dose (m Svy ⁻¹)
Makenahalli	47.19	0.118	0.009	0.127
Hanumanthapura	42.29	0.106	0.008	0.114
Siddaganag hills	9.95	0.025	0.002	0.027
Tumbadi	78.5498	0.197	0.016	0.213
Nagenahalli	35.2314	0.088	0.007	0.095
Jumpenahalli	37.2225	0.093	0.007	0.1
Dodderi	284.75	0.717	0.059	0.776
Korategere near the hills	59.5064	0.149	0.012	0.161
Korategere city	9.6949	0.024	0.002	0.026
Antharasanahalli	18.7318	0.047	0.004	0.051
Average	62.31	0.156	0.012	0.169

Table 2
The concentration of radon in ground water and physicochemical parameters around Tumkur district.

Places	Radon Bq/l	Chloride mg/l	Fluoride mg/l	Nitrate mg/l	Sulphate mg/l	pH Value	TDS
Makenahalli	47.19	36	4.81	1.06	62.5	7.34	420
Hanumanthapura	42.29	95	0.57	10.2	89.2	7.53	570
Siddaganag hills	9.95	67	2.21	0.21	76.1	7.57	435
Tumbadi	78.54	82	3.05	1.09	144	7.46	680
Nagenahalli	35.23	59	1.42	25.6	63.4	7.05	410
Jumpenahalli	37.22	199	3.48	64.6	201	7.04	1040
Dodderi	284.75	286	1.52	486	263	7.24	1685
Korategere near the hills	59.5	174	1.42	31.7	175	7.28	1100
Korategere city	9.69	246	2.46	28.6	166	7.35	1090
Antharasanahalli	18.73	36	0.72	0.24	3.4	7.12	220
Average	62.31	128	2.16	64.93	124.36	7.29	765

mean of 7.29. The safe limit for pH as recommended by [18] WHO is 7.0 - 8.5 and similarly the safe limit for pH as recommended by BIS is 6.5 - 8.5. All the water samples have a pH value within the safe limit recommended by WHO and BIS.

The total dissolved solids (TDS) in the study area varied from 220 to 1685 mg/l with a mean value of 765 mg/l. The TDS value for all the water samples are well within the maximum permissible limit recommended by BIS of 2000 mg/l.

The chlorides varied widely from 36 to 286 mg/l with a mean value of 128 mg/l. All the recorded chloride values were found to be well within the maximum permissible limit of BIS. Naturally, chloride occurs in all types of waters. The contribution of chloride in the groundwater is due to minerals like apatite, mica, and hornblende and also from the liquid inclusions of igneous rocks [19].

Fluoride content in the study area varied from 0.57 to 4.81 mg/l with a mean value of 2.16 mg/l. This study shows that about 50% of the water samples have a fluoride values found to higher than the maximum permissible limits of 1.5 mg/l recommended by BIS Standards Fluorides samples which exceeded the acceptable limit are not recommended for consumption without treatment. Fluoride is considered as an essential element though health problems may arise from either deficiency or excess amount [20]. Much of the fluoride entering the human body is obtained from drinking water [21]. Fluoride concentration of 0.4ppm in drinking water causes mild type of dental fluorosis.

Nitrate concentration in the study area ranged from 0.21 to 486 mg/l with a mean concentration of 64.93 mg/l which indicates that the groundwater has affected by nitrate. Human and animal wastes, industrial effluents, application of fertilizers and chemicals, seepage and silage through drainage system are the main sources of nitrate contamination of groundwater [22]. The high concentration of nitrates in drinking water causes methenoglobinemia in infants, a disease characterized by blood changes.

Sulphate in the study area varied between 3.4 to 263 mg/l with a mean value of 124.36 mg/l. In this present study all the recorded sulfate values are well within the maximum acceptable limit of 400 mg/l recommended by BIS. A sulphate ion is one of the major anions occurring in natural waters. Many sulphate compounds are readily soluble in water.

From this study it is evident that none of the major ion concentrations showed a significant statistical correlation

with radon concentrations. This is mainly due to the fact that radon is an inert gas.

5. CONCLUSION

From the above study it is conclude that the higher radon concentrations values are found to be present in samples collected from Tumbadi and Dodderi. This is due to the fact that these areas are attributed by gray pink granite rocks; these rocks contain higher activity of radionuclides. About 82% of the samples have radon concentration values are higher than the maximum contamination limit recommended by the EPA of 11 Bql⁻¹. The total annual effective dose from the six locations (about 55%) of the studied area is found to be greater than the safe limit of 0.1 mSv.y⁻¹ recommended by WHO. The study shows that about 50% of the water samples have a fluoride values found to higher than the acceptable limits of BIS Standards. There is no correlation was observed between radon and water physicochemical parameters.

ACKNOWLEDGEMENT

Authors would like to express their sincere thanks to the University Grant Commission (UGC) for granting fund to carry out this research work.

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ASSESSMENT OF INDOOR RADON CONCENTRATION IN AIR USING RAD7 AND RADON EXHALATION RATE MEASUREMENT IN SOIL SAMPLES

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ABSTRACT

For the assessment of indoor radon concentration in the dwellings in the Fatehabad district of Haryana, an active technique using RAD7 (an electronic radon detector) has been employed, also the radon gas exhalation rates in the soil samples from the studied area has also been carried out by sealed Can Technique using LR-115 solid state nuclear track detectors (SSNTDs). The measured surface exhalation rates in the soil samples vary from 195.33 to 305.12 mBq m⁻²h⁻¹ and mass exhalation rates vary from 8.85 to 13.84 mBq kg⁻¹h⁻¹. The measured indoor radon values in the study area varies from 52.79 to 309.97 Bq m⁻³ with an average value of 153.16 Bq m⁻³ which is well within the recommended action level 200-300 Bq m⁻³ (ICRP, 2009). The indoor radon values obtained in the present investigation are more than the world average of 40 Bq m⁻³. The annual average dose received by the residents of the study area varies from 1.33 mSv to 7.81 mSv with an average value of 3.81 mSv which was calculated using parameters introduced in report by UNSCEAR (2000). These values suggest that there is no significance threat to the human beings due to the presence of natural radon in the dwellings.

Keywords: RAD7, LR-115, Dwellings, Radon, Dose, Exhalation.

1. INTRODUCTION

Human beings have always been exposed to natural radiations arising from within and outside the earth. Presence of radioactive aerosols in the atmospheric air constitutes a potential health hazard globally. Radon (²²²Rn) and thoron (²²⁰Rn) are two main sources of natural radioactivity in the atmosphere, out of which radon (²²²Rn) pollution is an important global problem of radiation hygiene as it contributes more than half of the natural background radiation dose received by general population [1] due to its short half life ($T_{1/2}=3.82$ sec). Radon isotopes can isolate themselves and migrate away from the parent mineral due to diffusion process through the soil and enter the atmosphere. The radon and its progeny attached to aerosols present in the ambient air constitute significant radioactive hazards to human lungs. Radon has been shown to be a cause of lung cancers in miners [2-3]. The results from combined analysis of 7 North American Case-Control studies on residential radon and risk of lung cancer provide direct evidence of an association between residential radon

and lung cancer risk, a finding predicted using miner data and consistent with results from animal and in vitro studies [4]. On the basis of collaborative analysis of individual data from 13 European case-control studies, Darby et al. [5] have concluded that collectively, though not separately, these studies show appreciable hazards from residential radon, particularly for smokers and recent ex-smokers, and indicate that it is responsible for about 2% of all deaths from cancer in Europe. Lubin and Boice [6] have reviewed eight epidemiological studies and concluded that levels in buildings can be high enough to be a risk to occupants, and this has been confirmed in some case control studies [7-8].

The growing worldwide interest in natural radiation exposure has led to extensive surveys in many countries. Many studies have been carried out worldwide and a large amount of data is available for the radon and its progeny concentrations and their health effects [9-12] and also in India in order to determine the risks and effects of long

term, low level and natural radiation exposure. From literature review it is observed that though some studies have been done in the adjoining states of Punjab [13,14] and Himachal Pradesh [15], Rajasthan [16] and also for the Indian soils [17] and the data on the contents of radioactive elements is available for some states of India, but the data available for western districts of Haryana is quite meager. The detailed investigation for analysis and assessment of indoor radon gas using RAD7 and soil exhalation rates has been carried out for the first time in the Fatehabad district of Haryana.

2. GEOLOGY OF THE AREA

Fig. 1 shows the geographic location of the states of the Haryana, as well as the location of the sampling sites in Fatehabad district. Haryana is one of the Northern states of India lies between 27.47°-30.30° North Latitude and 74.29°-77.22° East longitudes. Soil of this part of Haryana occurs in the form of alluvium.

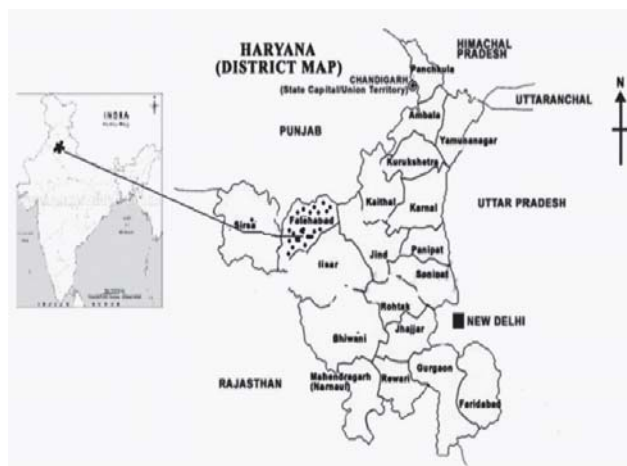


Fig. 1: Map of Haryana showing the studied area (dotted) of Fatehabad district

3. EXPERIMENTAL TECHNIQUES AND METHODS

I. Assessment of Indoor radon concentration in air using RAD7:

For the active measurement of radon and thoron concentrations in the indoor air, RAD7 an electronic detector has been used. Fig. 2 shows the detailed diagram for the measurement of radon/thoron gas concentration in indoor air in the dwellings. For the accurate measurements, at first purging is done to reduce the background radon concentration and moisture from inside the detector. For the removal of the moisture from the detector chamber of the instrument, hose is connected from the RAD7 to the drying unit, as a loop. After purging, the instrument was run in thoron protocol for the measurement of radon and thoron concentrations in air. The RAD7 an electronic radon detector was connected to a Drystick accessory (Durrig

co., USA) in a closed loop configuration for measurement purpose.

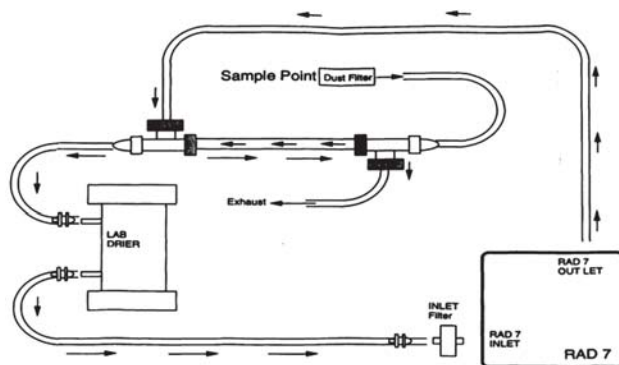


Fig. 2: Diagram for the measurement of radon gas concentration in indoor air

4. RESULTS AND DISCUSSION

Table 1 shows the measured values of indoor radon and thoron concentrations in the dwellings of the study area and the average annual effective dose due to radon. The measured indoor radon values in the study area varies from 52.79 to 309.97 Bq m⁻³ with an average value of 153.16 Bq m⁻³ which is well within the recommended action level 200-300 Bq m⁻³ [23]. The indoor radon values obtained in the present investigation are more than the world average of 40 Bq m⁻³. The annual average dose received by the residents of the study area varies from 1.33 mSv to 7.81 mSv with an average value of 3.81 mSv which was calculated using parameters introduced in report by UNSCEAR [10]. These values suggest that there is no significance threat to the human beings due to the presence of natural radon in the dwellings.

II. Radon exhalation rate measurements in soil:

Closed Can Technique (Fig. 3) has been used for the measurement of radon exhalation rate in the soil samples,. The soil samples were collected in clean, dry polyethylene bags from 60 different locations in the Fatehabad district of western Haryana, India. The soil was collected from an auger hole at a depth of about 0.75 m from the ground so as to get the natural soil. After collection, samples were crushed into fine powder using a mortar and pestle. A fine quality of the sample was obtained using a scientific sieve with a 150 micron mesh size. Before measurement samples were dried in an oven at about 383 K for 24 hours. Each sample was packed and sealed in an airtight PVC container and kept for about a four-week period to allow radioactive equilibrium between radon (²²²Rn), thoron (²²⁰Rn), and their short-lived progenies. On an average 0.25 kg of soil was taken for each sample.

A glass bottle of about 1 litre capacity was used as an emanation chamber. The samples (0.25 kg) were placed at

Table 1
Indoor Radon, Thoron concentrations and Average Annual Effective Dose calculations for dwellings
of some parts of Fatehabad districts of Western Haryana, India.

Sr. No.	Village/Town	Radon conc. (Bqm ⁻³)	Relative Humidity (%)	Temperature (°C)	Thoron Conc. (Bqm ⁻³)	Average Annual Effective Dose due to radon (mSv)
1	<i>Fatehabad district</i>					
1	Ratia	203.04	6	21.4	82.64	5.12
2	Bahmanwala	309.97	6	22	24.07	7.81
3	Fatehabad	257.68	7	22.4	13.23	6.49
4	Jakhal	185.69	7	23.7	43.66	4.68
5	Tohana	115.37	8	22.5	52.09	2.91
6	Bhattu Kallan	52.79	7	22.7	21.47	1.33
7	Sampla	76.31	7	23.8	BDL	1.92
8	Bhodiya Khera	210.16	8	24	BDL	5.3
9	Jandli Khurd	65.86	6	23.7	23.31	1.66
10	Dhanger	54.76	5	21.6	27.31	1.38

Table 2
Radon Exhalation rates in soil samples collected from some parts of Fatehabad districts of Western Haryana, India.

Sr. No.	Sample location (Village)	Radon Exhalation Rates	
		Surface Exhalation Rate (mBqm ⁻² h ⁻¹)	Mass Exhalation Rate (mBkg ⁻¹ h ⁻¹)
1	<i>Fatehabad District</i>		
1	Ratia	257.81	11.68
2	Bahmanwala	246.78	11.12
3	Fatehabad	229.8	10.28
4	Jakhal	282.34	12.94
5	Tohana	295.32	13.11
6	Bhattu Kallan	195.33	8.85
7	Sampla	245.21	11.11
8	Bhodiya Khera	265.23	12.02
9	Jandli Khurd	247	11.19
10	Dhanger	305.12	13.84

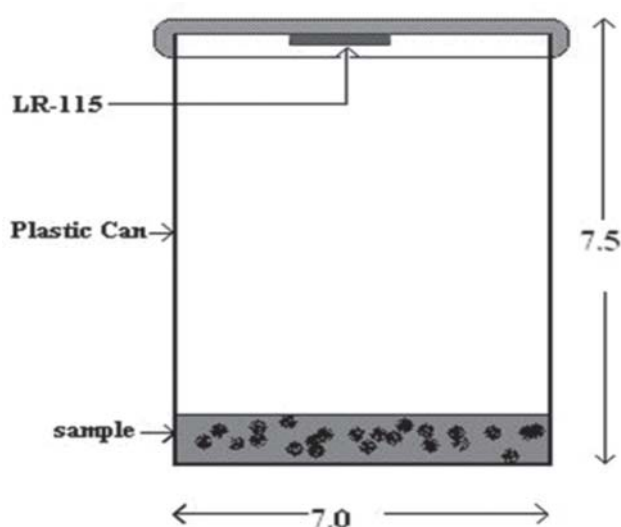


Fig. 3: 'Closed Can Technique' set up for measurement of exhalation rate.

the bottom of the bottles, which were then closed for about 1 month in order to establish equilibrium between radium-radon members of the decay series. After one month the bottles were opened and LR-115 type-II plastic track detectors were suspended inside the bottles in a bare mode. The height of the detector was selected such that direct alpha particles do not reach the detectors. The bottles were then closed for about three months to record alpha activity under secular equilibrium conditions [18].

After exposure the detectors were removed and etched in 2.5N NaOH solution at 60°C for 90 minutes, using a constant temperature bath to develop the clear tracks of alpha particles on the detector films. The tracks were counted using an Olympus microscope at a magnification of 400. The resulting track density was then converted into Bq.m⁻³ by appropriate calibration factor [19]. The 'radon exhalation rate' in terms of area was obtained from the expression [20].

$$E_A = \frac{CV\lambda}{A[T+1/\lambda(e^{-\lambda T}-1)]},$$

where E_A = radon exhalation rate in terms of area ($\text{mBq m}^{-2} \text{hr}^{-1}$); C = the integrated radon exposure as measured by a LR-115 plastic track detector ($\text{Bq m}^{-3} \text{hr}$); V = the effective volume of the bottle (m^3); λ = the decay constant for radon (hr^{-1}); T = the exposure time (hr); A = the area of the bottle (m^2).

Now to calculate the radon exhalation rate in terms of mass ($\text{mBq kg}^{-1} \text{hr}^{-1}$):

$$E_M = \frac{CV\lambda}{M[T+1/\lambda(e^{-\lambda T}-1)]},$$

where E_M is the radon exhalation rate in terms of mass ($\text{mBq.kg}^{-1} \text{hr}^{-1}$) and M is the mass of the sample (0.25 kg).

5. RESULTS AND DISCUSSION

The calculated values of radon exhalation rate for soil samples are presented in Table 2. The measured surface exhalation rates in the soil samples vary from 195.33 to 305.12 $\text{mBq m}^{-2} \text{h}^{-1}$ and mass exhalation rates vary from 8.85 to 13.84 $\text{mBq kg}^{-1} \text{h}^{-1}$. These values are lower than those reported by Mehra et al. [14] for the soils adjoining the Malwa region of Punjab. The variation in values of radon exhalation rate may be due to the difference in radium content [21] and porosity of the soil [22].

6. CONCLUSION

1. The annual average dose received by the residents of the study area varies from 1.33 mSv to 7.81 mSv with an average value of 3.81 mSv which was calculated using parameters introduced in report by UNSCEAR [10].
2. The measured surface exhalation rates in the soil samples vary from 195.33 to 305.12 $\text{mBq m}^{-2} \text{h}^{-1}$ and mass exhalation rates vary from 8.85 to 13.84 $\text{mBq kg}^{-1} \text{h}^{-1}$. The high exhalation rates may be due the high emanation rate of radon gas from the underneath soil as it permeates from the soil through cracks, fissures, porosity of the soil etc and enters our environment.

7. ACKNOWLEDGMENTS

The authors are thankful to the residents of the study area for their cooperation during the fieldwork, and my research colleagues for their support in providing the necessary help during the research work.

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MEASUREMENT OF INHALATION DOSE FOR RADON IN DWELLINGS USING DIRECT PROGENY SENSORS IN SOUTHERN PART OF MIZORAM, INDIA

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ABSTRACT

Inhalation dose for radon had been measured in southern part of Mizoram, namely, Lawgtlai and Saiha Districts. The inhalation dose calculation had been derived from measured values of indoor radon concentrations and their progenies. In this report, radon and their progenies concentrations have been measured in 34 number of dwellings in the southern part of Mizoram during 2010-2011. The indoor radon concentrations were measured by using a time integrated Solid State Nuclear Track Detector (SSNTD) based dosimeters developed by BARC. The deposition based passive detector system named as DTPS (Direct Thoron Progeny Sensor) and DRPS (Direct Radon Progeny Sensor) are used to measure the progenies of radon and thoron. The measurement was taken place in the selected dwellings for a period of about 120 days where one has maximum occupancy. The inhalation dose rate in 34 dwellings of the selected towns of Mizoram varies between 304.33 $\mu\text{Sv/y}$ to 1425.94 $\mu\text{Sv/y}$ with geometric mean of 547.15 $\mu\text{Sv/y}$ during rainy season. In winter, it ranges from 132.49 $\mu\text{Sv/y}$ to 2222.07 $\mu\text{Sv/y}$ with geometric mean of 381.87 $\mu\text{Sv/y}$ and ranges from 163.02 $\mu\text{Sv/y}$ to 885.75 $\mu\text{Sv/y}$ with geometric mean of 370.65 $\mu\text{Sv/y}$ in summer season. The annual average inhalation dose rate varies from 257.11 $\mu\text{Sv/y}$ to 1191.10 $\mu\text{Sv/y}$ with geometric mean of 451.69 $\mu\text{Sv/y}$.

Keywords: SSNTD, DTPS, DRPS, Radon, Progeny, Inhalation dose.

1. INTRODUCTION

Short-lived radon and its decay products are the most important sources of radiation from natural sources which affect human beings [1]. Radon and their progenies contribute more than 50% to the natural background radiation dose to general population. The effect of radon and their progenies on human population has been well-established and the health hazard is mainly due to the inhalation of its short-lived daughters, especially ^{218}Po and ^{214}Po . Radon is the product of ^{238}U decay series and continuously formed in the soil and being gaseous it is released to the air. The exhalation from the surface of soil is influenced by many factors like porosity of the soil, humidity, etc. The outdoor radon concentration is not a threat to health as it is easily diluted in the ambient air. The radon concentration may vary with geological, geographical and the meteorological conditions while particularly the

indoor radon concentration is also influenced by ventilation pattern, house construction type, heating system and even the life style of the people [2].

Absorbed dose rates to the critical cells of the respiratory tract due to radon, thoron and their progeny can be estimated on the basis of aerosol characteristics, its size distribution, unattached fraction, breathing fraction, fractional deposition in the airways, mucous clearance rate and location of the target cells in the airways. Several models have been developed to assess the inhalation dose rates to the population due to radon, thoron and their progeny. Lung dose distribution assessment carried out by different agencies right from 1956 to 2000 given in details in UNSCEAR reports [3-4] shows a large variation in dose conversion factors. Calculations of alpha particle doses delivered to the sensitive bronchial target cells after

inhalation of radon and its progenies are based on the following assumptions: (a) The bronchial region of the human lung is represented by a sequence of symmetrically bifurcating straight cylindrical tubes, i.e., all airways in a given generation have identical dimensions. As a result of this, particle deposition fractions, particle clearance fractions, and, finally, alpha emitting ^{218}Po and ^{214}Po surface activities are the same in all airways of a given bronchial generation., (b) furthermore, sensitive target cells in bronchial epithelium are assumed to be uniformly distributed throughout given depth intervals. Hence, such deterministic models produce single dose values for basal and secretory cells in a given airway generation. However, the tracheobronchial tree consists of an asymmetrically dividing stochastic branching system and sensitive target cells are non-uniformly distributed in relation to the depth in bronchial epithelium. Due to this symmetries and variabilities, target cell populations may experience significant variations in the absorbed dose.

2. METHOD OF MEASUREMENT

The indoor radon concentrations were measured by using a time integrated Solid State Nuclear Track Detector (SSNTD) based dosimeters developed by BARC [5]. The deposition based passive detector system named as DTSP (Direct Thoron Progeny Sensor) and DRPS (Direct Radon Progeny Sensor) are used to measure the progenies of radon and thoron. This system uses absorber-mounted nuclear track detectors (LR-115) which selectively register the tracks due to alpha emissions from ^{212}Po (α energy 8.78 MeV) and ^{214}Po (energy 7.69MeV) from the deposited atoms of radon and thoron progeny species, respectively [6]. The dosimeters along with DTSP and DRPS were hanged over bed rooms or living rooms in the selected dwellings for a period of about 120 days where one has maximum occupancy. After the desired period of exposure, the detectors were retrieved and chemically etched which were then counted by using a spark counter. The recorded nuclear tract densities are then converted into air concentrations of radon and their progenies. The inhalation dose rate, D ($\mu\text{Sv/hr}$) is compiled as per UNSCEAR, 2000 is shown below:

$$D = 10^{-3} [(0.17 + 9 F_R) C_R + (0.11 + 40 F_T) C_T]$$

Numerical numbers given in the above equation are the dose conversion factors for gas and progeny concentrations. F_R and F_T represent the equilibrium factor of radon and thoron progenies respectively. C_R and C_T represent the radon and thoron concentration respectively. In estimating the inhalation dose rate the annual effective dose is calculated taking occupancy factor of 0.8 for indoor.

3. RESULTS

In this report, radon and their progenies concentrations have been measured in 34 number of dwellings of Lawngtlai and Saiha Towns (Fig. 1), which are in the southern part of Mizoram during 2010-2011 for three seasons of the year, namely, rainy, winter and summer seasons. The inhalation dose rate in 34 dwellings of the selected towns of Mizoram

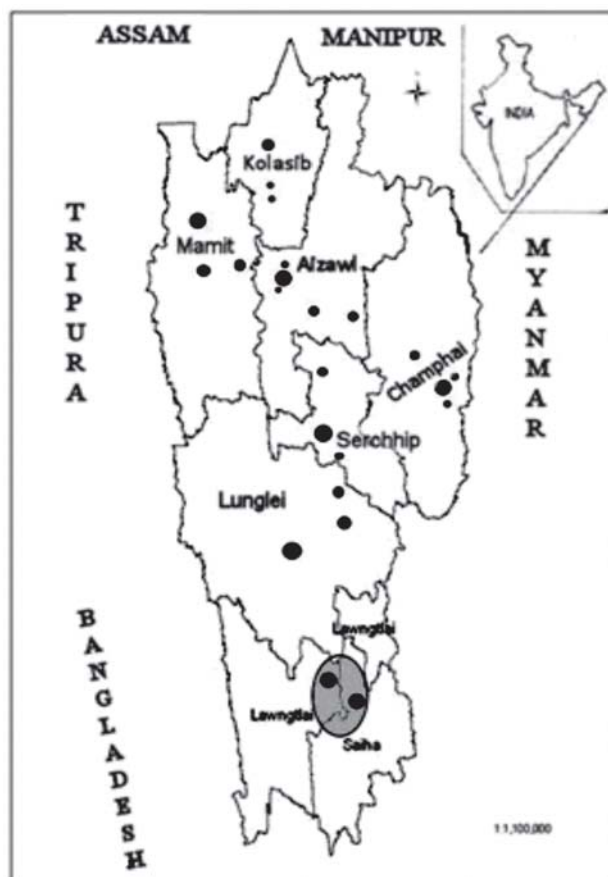


Fig. 1: Map of Mizoram showing the sampling sites

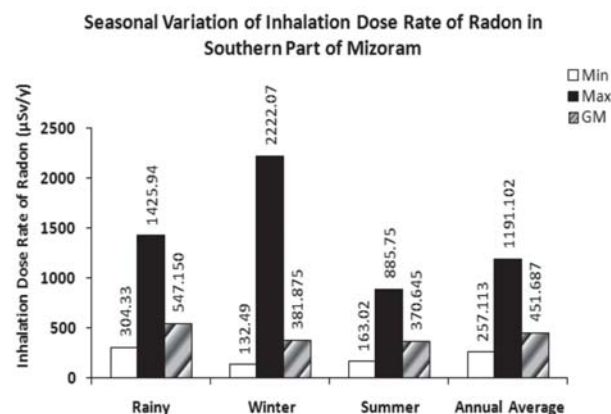


Fig. 2: Seasonal variation of Inhalation Dose rate of Radon in Southern part of Mizoram

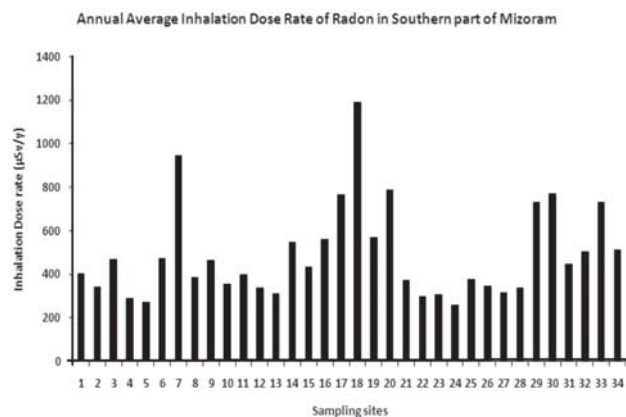


Fig. 3: Annual average Inhalation Dose rate of Radon in Southern part of Mizoram.

varies between 304.33 $\mu\text{Sv/y}$ to 1425.94 $\mu\text{Sv/y}$ with geometric mean of 547.15 $\mu\text{Sv/y}$ during rainy season. In winter, it ranges from 132.49 $\mu\text{Sv/y}$ to 2222.07 $\mu\text{Sv/y}$ with geometric mean of 381.87 $\mu\text{Sv/y}$ and ranges from 163.02 $\mu\text{Sv/y}$ to 885.75 $\mu\text{Sv/y}$ with geometric mean of 370.65 $\mu\text{Sv/y}$ in summer season.

The annual average inhalation dose rate varies from 257.11 $\mu\text{Sv/y}$ to 1191.10 $\mu\text{Sv/y}$ with geometric mean of 451.69 $\mu\text{Sv/y}$.

4. DISCUSSION

From the observation results, the inhalation dose rate of radon is maximum in rainy season and minimum in summer season. In winter season, it is higher than in summer. Low temperature in winter may be responsible for reduction in the equivalent mixing height, which might be limiting the vertical diffusibility of radon and its progeny, resulting in high concentrations at the ground level. During winter, the doors and windows of most of the houses are kept closed for most of the times of a day to protect from low temperature. This reduces the exchange of air inside the house which perhaps may be the reason for high level of radon daughter inside the house during this season.

The low values of inhalation dose rate during summer may be attributed to relatively high prevailing temperatures, which perhaps elevate the equivalent mixing height and hence resulting in increase in dilution.

The annual average inhalation dose rate varies is different in different houses. However they are comparable to the average values as calculated by UNSCEAR 2000 [5] which is 1009 $\mu\text{Sv/y}$.

5. ACKNOWLEDGEMENTS

PC, MP & BZ are grateful for the research grant from Board of Research in Nuclear Science (BRNS), Department of Atomic Energy, Govt. of India. They also thank to the people who have helped in carrying out this survey.

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EFFECT OF FERTILIZERS ON SOIL TO PLANT TRANSFER OF ALPHA RADIOACTIVITY IN POTATO PLANTS USING SSNTD TECHNIQUE

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ABSTRACT

Radionuclides in the phosphate fertilizers belonging to ^{232}Th and ^{238}U and ^{40}K are the major contributors of the outdoor terrestrial natural radiation. These radionuclides transferred from fertilizer to food through the soil. Present work deals with the alpha radioactivity in the different parts of the potato plant grown under control pots experiment using different amount of phosphate fertilizers and urea. Alpha radioactivity have been measured by sandwich track etch technique using the solid-state nuclear track detectors (LR-115). The results showed that the alpha activity in the potato plants found to be high in case of plants grown with use of phosphate fertilizers as compared to others. The translocation factors increased with increase in amount of fertilizers and time of plantation. The study showed that the alpha radioactivity in the different parts of plants grown with fertilizers was higher than that of plant grown without fertilizers.

Keywords: Potato plant; SSNTD; Alpha radioactivity; Fertilizers; Radionuclides.

1. INTRODUCTION

The human and other living organisms are continuously exposed to ionizing radiation from natural and anthropogenic sources which are present everywhere in the environment [1]. Weathering of the earth's crust is the ultimate mechanism for the release of primordial radionuclides into the soil, which constitutes the principal source of natural background radiation [2]. Primordial radionuclides have very long half-lives nearly of billions years. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soils, rocks, plants, water and air [3-8]. Higher values of ^{226}Ra in soil contribute significantly in the enhancement of environmental radon [9]. Fertilizers are chemical compounds that provide necessary chemical elements and nutrients to the plants. The radiological impact assessment in an integrated manner assessing doses to members of the public via the atmospheric aquatic and secondary pathways was made. Occupational exposures mainly occur during mining process and transportation of phosphate rock, as well as during transportation and utilization of phosphate fertilizers. Radionuclides in phosphate fertilizer belonging to ^{232}Th and

^{238}U series as well as radioisotopes of potassium (^{40}K) are major contributor of outdoor terrestrial natural radiation [10]. The concentrations of natural radionuclides in phosphate fertilizers were reviewed in the UNSCEAR reports [11-12]. The radiological impact of the use of fertilizers in soil is due to the internal irradiation of the lung by the alpha particles, short lived radon-thoron progeny and the external irradiation of the body by gamma rays emitted from the radionuclides. Radionuclides present in fertilizers affect the common people and farmers immensely. One of the essential elements phosphorus (P) does not occur free in nature but its compounds are widely distributed, mainly as phosphates, and are found in many rocks and minerals. For uranium a range from 3 to 400ppm, corresponding to 37-4900 Bq ^{238}U /kg (1 ppm U = 12.23 Bq ^{238}U /kg) and for ^{226}Ra a range from 100 to 10,000 Bq/Kg are reported [13-14]. The degree of accumulation of natural radioactive elements is reported to be affected by the metal selective function of plants during uptake of elements so as to maintain the mechanism of homeostasis in normal environment [15]. The availability of essential nutrients like calcium and potassium for uptake by plants regulates the uptake of non-essential elements.

Due to the presence of naturally occurring radionuclides in soil and phosphate fertilizers, primordial radionuclide and their progeny are transferred via the food chain to human body.

The study of natural radioactivity in plants and associated radiation exposure through the specific food materials is an important study. Soil to plant is major pathway for accumulation of radionuclide to human being. The specific metabolic character of the plant species may lead to accumulation of radio-nuclides in their organs which may further depend upon the physico-chemical characteristics of the soil. Soil-plant-man is recognized as one of the major pathway for transfer of radionuclide to human being [16]. The uptake of uranium in plants is also found to depend upon the nature and age of the plants [17]. Migration and accumulation of contaminants in the soil-plant system is complex, and assessment models commonly utilize a soil-plant concentration ratio, referred to as a transfer factor (TF). Plants acquire these radionuclides via their roots or leaves, and animals acquire them through consumption of plants, phosphate-based mineral food supplements and soils. There are different kinds of vegetables which may be edible roots, stems, leaves, fruits or seeds. Each group contributes to diet in its own way [18]. Contamination of vegetables and other food crops occurs mainly by direct contact with contaminated air or by uptake of radionuclides from the soil by root system. There are two main routes by which vegetation may be contaminated. One is the direct contact with contaminated air or dust and another is the absorption of radionuclides from the contaminated soil through root system of the vegetation. The radionuclides present in the environment transfer to plants through (i) uptake from soil through roots, and (ii) direct absorption through aerial parts of the plants. Thus it is necessary to measure the radionuclide content of food and water samples to assess potential radiation doses. In present investigation the potato plants were chosen for study as it is used as vegetables and other fast food throughout the world. The consumption of potato is highest among all vegetables. In order to increase the crop yield various kinds of fertilizers were used. The use of fertilizers provides the requirement of essential element and also increases the radionuclides content. These radionuclides transfer from soil to plant through root which can be quantified in term of alpha activity from different part of plants.

2. MATERIALS AND METHODS

The potato plants were grown by planting the small potato seeds in earthen pots. 20 and 50 gm of different fertilizers [Diammonium Phosphate (DAP), Nitrogen, phosphorus and potassium (NPK), single super phosphate (SSP), potash (PF), zinc sulphate (ZnSO_4), urea (URA), and organic fertilizer

(OF)] were added to the soil during the plantation of the seeds of plants in the pots. All the plant were kept in open and identical environment and subjected to equal watering (Fig.1). The healthy leaves from different plants samples after 30, 70 and 105 days were plucked, dried in an oven at 40°C . The dried sample then sandwiched between two plastic track detectors each of same size ($2\text{ cm} \times 2\text{ cm}$) by wrapping a cello tape tightly to record the tracks for alpha particles emitted from both upper and bottom faces of the leaves. The detector attached leaves were kept enclosed in a plastic container for 60 days. At the end of 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 detectors were washed, dried and after that, the tracks caused by alpha radiations emitted from the leaves were counted using spark counter. The background track density were also measured due to environment and subtracted from track density due to samples.



Fig. 1: Potato plants after 30 days of plantation

3. RESULTS AND DISCUSSIONS

The alpha track density from the leaves of the potato plant after 30, 70 and 105 days of plantation are listed in table.1. The alpha- activity from sample grown with different fertilizers vary with their type and amount added in the fertilizers. The alpha track density from upper part of leaf varied from 6.5 ± 0.7 to $25.5 \pm 4.4\text{ Tr. cm}^{-2}$, 11.5 ± 1.8 to $31.0 \pm 2.0\text{ Tr. cm}^{-2}$ and 18.7 ± 8.4 to $62.4 \pm 17.3\text{ Tr. cm}^{-2}$ for 30, 60 and 105 days of plantation while for lower part of leaf it varied from 10.8 ± 2.1 to $48.5 \pm 10.0\text{ Tr. cm}^{-2}$, 3.2 ± 8.4 to $52.5 \pm 0.7\text{ Tr. cm}^{-2}$, and 14.0 ± 5.2 to $80.5 \pm 0.5\text{ Tr. cm}^{-2}$ for 30, 60 and 105 days respectively.

The alpha track density from lower face of the leaf are higher than that of upper face which may be due to the presence of large number of trichomes at the lower face to which dust particle in the environment with the radon daughters attached, and get stuck. The higher trichrome densities provide the large surface area from which the alpha particle can eject out and form track on detector. Also the alpha track densities from different potato plant sample increased

Table 1
Alpha track densities after different age of plantation.

Fertilizer used*	Alpha track density (Tr. cm ⁻²) from leaves of the potato plant after					
	30 days (AM±SE)		60 days (AM±SE)		105 days (AM±SE)	
	Upper face	Lower face	Upper face	Lower face	Upper face	Lower face
UA-1	6.5±0.7	10.8±2.1	11.5±1.8	17.6±1.1	33.0±1.0	44.5±21.9
UA-2	8.3±4.0	14.3±3.9	13.8±3.4	22.0±1.8	30.8±7.9	70.0±2.0
SSP-1	13.7±0.5	19.0±2.0	23.2±3.94	25.6±6.7	20.4±1.5	28.8±7.6
SSP-2	18.0±1.0	26.8±3.6	20.5±1.29	28.0±5.3	57.5±19.6	46.4±15.5
NPK-1	12.0±1.0	31.0±4.2	20.5±5.3	20.8±7.2	29.0±2.0	26.5±0.5
NPK-2	8.0±0.0	33.0±0.0	27.5±9.2	28.8±2.5	57.6±2.1	61.0±1.0
ZNS-1	25.5±4.4	48.5±10.0	22.0±5.0	39.0±1.7	30.8±7.9	37.4±2.1
ZNS-2	18.0±2.2	20.6±0.6	23.2±3.56	3.2±8.4	62.4±17.3	70.6±18.8
PF-1	16.0±3.1	22.5±3.4	22.75±1.5	24.2±6.7	29.5±0.5	24.5±0.5
PF-2	17.0±1.7	28.6±2.6	22.8±4.9	52.5±0.7	41.5±2.1	80.5±0.5
DAP-1	24.3±15.8	27.2±13.6	31.0±2.0	17.6±4.2	24.2±0.8	30.2±2.2
DAP-2	14.0±1.7	28.0±7.0	18.7±1.7	26.0±3.16	31.2±2.6	50.5±7.6
WO	SNR	SNR	SNR	SNR	18.7±8.4	14.0±5.2

Table 2
Alpha track density in different part of Potato plant at the age of 105 days.

Fertilizers used	Alpha track density (Tr. cm ⁻²) from different parts leaves of the potato plant				
	Root	Stem	Fruit	Leaf	
				Lower	Upper
Ua-1	SNR	SNR	SNR	44.5±21.9	33.0±1.0
Ua-2	39.5±11.6	60.2±14.7	8.7±4.4	70.0±2.0	30.8±7.9
SSP-1	46.0±12.1	82.4±11.3	26.3±11.8	28.8±7.6	20.4±1.5
SSP-2	90.0±7.1	110.7±10.1	85.5±2.1	46.4±15.5	57.5±9.6
NPK-1	56.3±14.1	76.0±5.6	6.8±1.6	26.5±0.5	29.0±2.0
NPK-2	98.6±3.5	30.6±7.1	20.8±4.4	61.0±1.0	57.6±2.1
ZNS-1	5.5±27.7	65.4±15.2	23.3±2.1	37.4±2.1	30.8±7.9
ZNS-2	73.2±0.3	88.2±4.1	32.7±4.4	70.6±18.8	62.4±17.3
PF-1	37.3±9.8	53.7±18.2	27.7±3.9	24.5±0.5	29.5±0.5
PF-2	61.6±39.2	63.0±5.2	43.2±2.2	80.5±0.5	41.5±2.1
DAP-1	91.4±2.1	77.5±20.2	12.0±2.9	30.2±2.2	24.2±0.8
DAP-2	SNR	89.9±9.2	30.0±5.8	50.5±7.6	31.2±2.6
WO	SNR	57.0±1.0	4.0±0.9	18.7±8.4	14±5.2

* Diammonium Phosphate (DAP), Nitrogen, phosphorus and potassium (NPK), Single Super Phosphate (SSP), Potash (PF), Zinc Sulphate (ZnSO₄), Urea (Ua), Without fertilizers (WF) and Organic fertilizer (OR). 1 and 2 is used for 20 and 50 g of fertilizers used. AM: Arithmetic mean, SE= Standard error= $\sigma/\sqrt{N}$, where σ is standard deviation and N is number of measurements; SNR: Sample not retrieved

with increase of fertilizers added to soil. The fertilizers are manufactured from the phosphate rocks which contain higher radionuclide contents from their origination. The uranium and radium from these phosphate rock transfer into fertilizers and increase the radionuclide content in agriculture field when added to increase the crop yields. These radionuclide transfer from soil to plant through roots and increase the alpha activity in plants. Fertilizers were added to soil to increase the composition of essential nutrient in soil. It also affects the pH value of soil and alters the metabolism of plant which in turn changes the intake of

different materials. Different fertilizers have different composition of chemicals and thus behave differently, due to which the alpha activity of different fertilizers differ from one another when equal amount of fertilizers were added. The alpha-activity from the plant grown with phosphate fertilizers are higher than that of urea and organic fertilizers, while the alpha-activity was found minimum for plants grown without any use of fertilizers. The accumulation of radionuclides in different part of plant is not equal. The variation of alpha-activity from various part of plant on the age of 105 days of plantation is listed in table 2 for potato plants.

The potato plant is divided into four parts namely leaf, root (hair portion below ground), edible root (fruit) and stem. The alpha activity from various parts of plant was measured by SSNTD technique. The alpha activity from the stem and root of the plant was found higher than that of leaf and fruit part. The stem of the potato plant contain higher glandular density from where the water and other mineral transfer from root to other parts of the plants due to capillary action. The radionuclide during translocation from root to other parts of the plant deposited in the stem and thus cause higher alpha radioactivity. While the root of the plant contain hair which provide a large surface area through which alpha particle from radionuclide can emit out. Also the uranium enter through roots cannot translocate in other part of the plant due to *casparian strip*, the most effective in roots of plants. The fruit of the potato plant start growing after 40 days of plantation while the roots and stem in 10 days. Thus the time of accumulation of radionuclides in fruit part are smaller causing low alpha activity compare to other parts. That is why the higher alpha activity from root and stem was observed as compared to leaf and fruit.

4. ACKNOWLEDGEMENTS

The financial assistance granted to R P Chauhan from University Grants Commission, New Delhi, India is thankfully acknowledged.

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RADON EXHALATION RATES OF CONCRETE MODIFIED WITH FLY ASH AND SILICA FUME

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ABSTRACT

Since many decades, the radiological impact of the environmental gas radon on the health of general public has been of concern. Cement used for the construction blended with fly ash and silica fumes is recommended by Government in order to avoid the soil and environmental pollution. But these additions step-up the indoor radon levels in the dwellings due to radioactivity contents. The exhalation of radon from concrete blended with silica fumes and fly ash depends upon addition level, porosity, moisture and radioactivity content. In order to optimize the level of substitution of silica fumes and fly ash, measurements of radon exhalation rates from the concrete blended with different proportions of fly ash and silica fumes was carried out using active scintillation radon monitor. The effect of porosity, and radioactivity content of the concrete on exhalation rates is studied.

Keywords: Radon exhalation rate, Silica fume, Fly ash, Porosity, Moisture.

1. INTRODUCTION

Soil and building materials are the important source of indoor radon and thoron. The indoor radon and thoron levels depends upon the type of dwellings i.e. the selection of building materials used for the construction purpose are important [1]. The radium (^{226}Ra) and thorium (^{232}Th) present in every geological samples (soil and building materials) used for construction. The decay series of these radionuclides continuously produce the radioactive gas radon and thoron which can be quantified in term of radon and thoron exhalation rates. The radon and thoron exhalation rate of materials is defined as the emission of radon and thoron gas per unit mass or surface area of the sample per unit time. The emitted radon and thoron from the surface of structural building materials also termed as radon flux. Radon and flux from wall and floor of the building materials contributes to indoor radon and thoron levels. Due to long half life of radon (3.824 days), it was assumed that the contribution of radon for inhalation dose is higher than that of thoron. Beside building materials various kinds of additive like silica fume and fly ash are now added to cement to modified the mechanical property and durability of concrete. Fly ash, also known as flue ash, comprising the fine particles that rise with the flue gases ash is one of

the residues generated during the combustion of coal in thermal power plant. The fly ash generated in thermal power plant, when disposed on the open land, affects the fertility of the soil. The Government of India forced the use of fly ash for making bricks and promoting the utilization of fly ash in the manufacturing building materials [2]. Coal contains low levels of uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K). The careful consideration should be given to relevant dosimetric calculations for this application [3], as the natural radionuclide concentrations in fly ash produced from coal-fired power plants are significantly higher than the corresponding concentrations in coal and soil [4]. The main problem concerned with the use of fly ash is higher radioactivity content which enhances indoor radon level as compared to brick, cemented and mud houses of same tropical region [5]. Thus it is necessary to optimize the use of fly ash for building construction with reduced health hazards. Silica fume is the byproduct of ferrosilicon glass industries. The higher silica content of silica fume attracts its application in concrete industries. The addition of these materials in cement causes the modification in different property of concretes. The radon exhalation from the concrete depends upon many factors like porosity, moisture, radium content and amount of additives. The aim

of the present work is to study the effect of these factors on the radon surface exhalation rate of the concrete using active techniques.

2. MATERIALS AND METHODS

Preparation of Concrete for exhalation study

The concrete tiles of dimension 21.5 cm×21.5 cm×2.3 cm were prepared by cement: sand mix proportion 1:3 for different replacement of fly ash and silica fume. Eleven test specimens for each set were prepared as per ASTM (American Society for Testing and Materials) standard with 0 % to 50% replacement of cement with fly ash and silica fume [6-8]. The concrete specimen were cured in fresh water for 40 days before performing exhalation study.

Porosity and moisture content of concrete

The moisture content of the samples was determined by the difference in their masses from dried and wet stage. The porosity of the structural building materials were measured by the water absorption method described elsewhere [9-10]. Knowing the difference in the weight after drying, density of water at laboratory temperature and volume of the tiles the porosity of the specimen can be find out by following relation.

$$\text{Porosity} = \frac{B - A}{V \times \rho} \quad (1)$$

where B and A are the weight of the concrete tile before and after drying, V the volume of tiles and ρ the density of water at laboratory temperature.

Measurement of Radon exhalation rate

The radon exhalation rate was measured by hermetically closing the sample in a container and following the radon

activity growth as a function of time as shown in Fig.1. Emanated radon from the grains of the sample following an effective diffusion model, migrated through the pore system of the sample and finally exhaled from the surface. The growth of radon in chamber was determined by scintillation radon monitor.

The rate of growth of radon concentration in a chamber of volume V is given by [11]

$$C = \frac{E A}{V \lambda_e} (1 - e^{-\lambda_e t}) + C_i e^{-\lambda_e t} \quad (2)$$

where E represent the radon surface exhalation rates in (Bq/m²/h), A and V represent the surface area of sample and effective volume of the chamber including the volume of the scintillation cell. λ_e represent the effective decay constant which is sum of radon decay constant and chamber leakage rates if any, C_i is initial radon concentration in chamber.

3. RESULTS AND DISCUSSION

The measurement of radon exhalation rate from concrete samples was carried out after completely drying the specimen. The moisture content of the sample is negligible so that it does not affect the radon exhalation rates. The radon exhalation rates of concrete first decreased with increase in the fly ash addition up to 25 % then remained constant up to 35 % fly ash substitution after that it decreased as shown in Fig.2. The radium content of the fly ash is higher than the cement. Thus, the surface exhalation rate of concrete substituted with fly ash is expected to be higher than that of control concrete. On the other hand the radon exhalation is strongly dependent on the porosity of the concrete. The porosity is the measure of pore space through which the radon atoms diffusing out. With decrease in the porosity, the micro-channel or the capillary decreased, thus, reducing the number of radon atoms to exhaled out causing decrease in radon exhalation. The porosity of the concrete depends upon the quantum of CSH linkage, higher the CSH linkage, smaller the porosity. Thus, the resultant effect of two opposing phenomenon i.e. radium content and porosity determines the net radon surface exhalation rate. With increase in the fly ash in cement causes decrease in the porosity by formation of additional CSH linkage, thus reduced the radon surface exhalation rate [12]. This means that the porosity dominates for radon surface exhalation up to 25 % of fly ash addition. In between the 25 % to 35 %, the two effects may be exactly canceling out so that we have nearly constant radon exhalation rates. Beyond 35 % fly ash substitution the increase in radium content

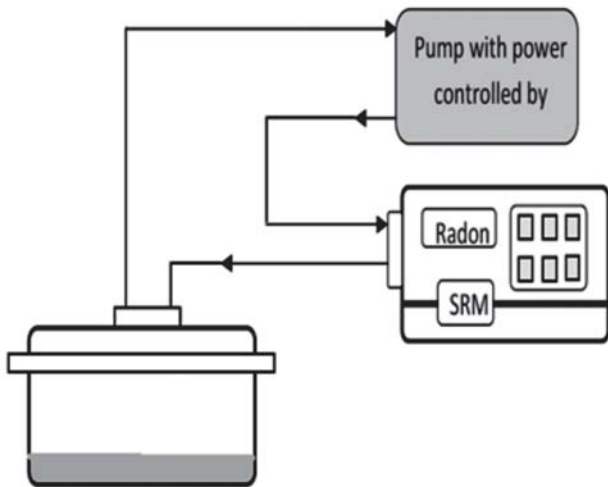


Fig. 1: Experimental set up used for radon exhalation rate

dominates over the decrease in porosity and hence causes the increase in the radon surface exhalation rates. The radon exhalation rates of the concretes treated with different amounts of silica fume decreased as the silica fume content increased and were reduced to approximately one-third the rates of the control concrete. The increase in the silica content caused by the addition of silica fume to the cement resulting in increase in silica of the mixed material leading to formation of additional CSH linkage and hence reduction in the porosity (Fig.3). Yu et al. [13] reported a reduction in radon exhalation rates between 40 and 45 % of the rate of the control concrete.

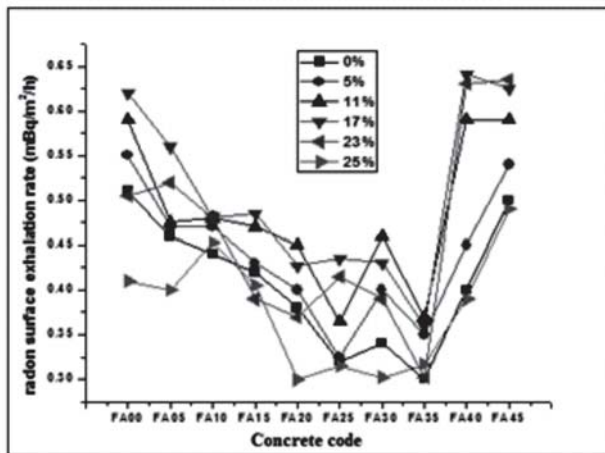


Fig. 2: Variation of radon exhalation rates with moisture content for fly ash concrete

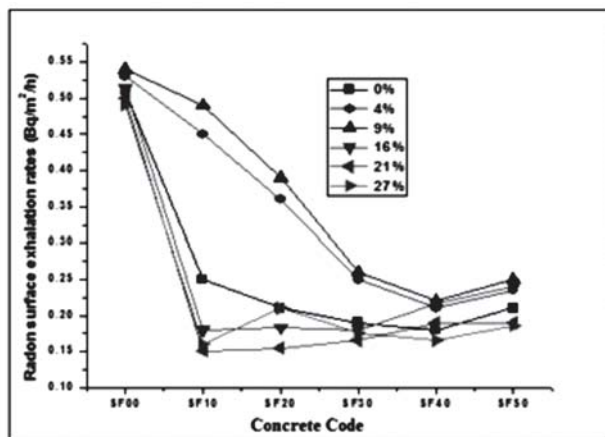


Fig. 3: Variation of radon exhalation rates with moisture content for silica fume concrete

The effect of moisture on radon exhalation rates of concrete was measured by drying the wet concrete for different time period so that the concrete had different moisture contents. The percentage moisture contents of concrete were determined by the difference in the mass of wet and dry

concrete. The results of the measurement are shown in Fig.2 and 3 for fly ash and silica fume concrete. The radon exhalation rates of fly ash concrete first increased with increase of water content up to 17 % after that it decreases. On the other hand, for silica fume concrete, the increase is restricted up to 9 % before increase. This shows the dependence of radon emanation and exhalation from a grain and concrete blocks and tiles upon the moisture content. The radon emanates from its parent nuclides through alpha decay of radium-226. The recoils of alpha particle push the radon in opposite direction with a recoil length 30-50 nm in solid grain [14-16]. For the recoiled radon atom there are following possibilities (i) the recoiled radon atom may be retained inside the same grain due to small recoil length (ii) it may enter into the neighbouring grain (iii) it may emanate out from grain and enter in pore space. If radon stays in the pore space then it can be transferred to air by diffusion or advection. The recoil length of radon in water is smaller than that of air, thus due to presence of water in pore space more number of atoms trap in water present in pores rather than to enter in another grain. This may cause increase in the radon exhalation rate of materials. But with increase in moisture contents, the water in pore space of material increases, causing more radon atoms to decay in water rather than escaping out of the material and hence shows a decrease in exhalation rates.

4. CONCLUSIONS

The exhalation of radon from concrete blended with silica fumes and fly ash depends upon addition level, porosity, moisture and radioactivity content. The radon exhalation rate of concrete decreased with decrease of porosity. The decrease of porosity can be attributed to the formation of CSH linkage by addition of different additives. The addition of fly ash above optimum level increase the radon exhalation rates while that of silica fume it continuously decreases. The moisture content of the specimen affects the measurements. The exhalation rate first increase with moisture contents up to 9 and 17 % for silica fume and fly ash and then decreases. Thus care should be taken about the moisture content when measuring radon exhalation rates.

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STUDY OF RADON EXHALATION AND EMANATION RATES FROM FLY ASH SAMPLES

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ABSTRACT

Radon exhalation and emanation rates from fly ash samples have been measured due to its health hazards and environmental pollution and to assess the radiological impact of radon emanated from fly ash samples. Samples of fly ash from different thermal power stations, other fly ash handling facilities and National Council for Cement and Building Materials (NCB) were collected and analyzed for the exhalation rate measurements using alpha sensitive LR-115 type II plastic track detectors in can technique. Gamma spectrometry was used for radioactivity measurements, i.e. activity concentration of ²²⁶Ra, ²³²Th and ⁴⁰K. The values of exhalation rates varied from 5.8±1.1 to 19.4±0.8 mBqkg⁻¹h⁻¹ for mass exhalation rate and from 106±11.1 to 354±23.4 mBqm⁻²h⁻¹ for surface exhalation rate. The emanation factor varied from 0.4 to 3.3 (%). The experimental data shows that fly ash samples emanate radon in significant amount and this consequently may result in significant radiation exposure to workers and may result in increased radon levels in dwellings built by using fly ash bricks.

Keywords: Radon, Radium, Thorium, Radium, Health, Environment, Coal, Fly ash, Exhalation rate, Emanation rate.

1. INTRODUCTION

Man is continuously exposed to ionizing radiation from radioactive materials, the materials include Naturally Occurring Radioactive Materials (NORMs) and manmade i.e. Technologically Enhanced Natural Occurring Radioactive Materials (TENORMs). The origin of these materials is considered to be Earth's crust, but at present these materials are omnipresent. The building materials containing radioactive material have been used for years. As human spend more than 75% of their time indoors, so the exposure of radiation to human is inevitable. The prolonged exposure of radiation is potentially hazardous to mankind.

Most building materials contain small amounts of NORMs, mainly radionuclides from the ²²⁶Ra and ²³²Th decay chains and the radioactive isotope of potassium, ⁴⁰K. Industrial by products containing TENORMs are extensively used in the construction industry. In general, NORMs are materials containing radionuclides which are naturally present in rocks, soils, water and minerals. These radionuclides have

become concentrated in direct contact due to human activities such as manufacturing, water treatment and mining operations, so the measurements of radioactivity in TENORMs are important as a protection solution from radiation. As more than 50% of the total dose of radiation to human is contributed by these materials. The main contribution is due to inhalation of ²²²Rn (radon), ²²⁰Rn (thoron) and their progeny.

Generally, the varying concentration of radon in natural building materials depends upon the geographical condition. The average activity concentrations of ²²⁶Ra, ²³²Th and ⁴⁰K in the Earth's crust are 35, 30 and 400 Bq/kg respectively [1]. However, in some places like Brazil, France, Nigeria, Iran, India, the higher levels of radionuclide were reported.

Coal ash or fly ash, is a kind of TENORM, produced as waste in the combustion of coal, is used as an additive to cement, in concrete and in bricks. Natural radioactivity in fly ash comes from ²²⁶Ra and ²³²Th series and natural ⁴⁰K. It has been reported that the combustion of coal in various

thermal power plants results in the release of only some natural radioactivity to the environment and the largest part of the coal radioactivity remains with the ashes [1]. When used in building construction materials it becomes potentially hazardous to human. Measurement of radioactivity in fly ash samples in terms of activity concentration of ^{226}Ra , ^{232}Th and ^{40}K , radon concentration and radon exhalation rate in fly ash is due to its health hazards posed to human and environmental pollution. Radon concentration has been reported higher in a house with fly ash than in a house built without it [2-4]. The internal (inhalation) radiation exposure is due to ^{222}Rn , and somewhat due to ^{220}Rn , and their short lived decay products, radiated from building materials made from radionuclide, into the room air.

Emanation rate of radon from building materials has also been the subject of many studies [5-8] as the building materials are a significant source of radon in a house, corrective actions have to be taken in addition to ventilation to reduce the concentration of radon.

In the present paper, samples of fly ash from different thermal power stations in northern India were collected and analyzed for the activity concentration of the natural radionuclide namely ^{226}Ra , ^{232}Th and ^{40}K using gamma spectrometry and radon activity and exhalation rates using alpha sensitive LR-115 type II plastic track detectors in Can Technique. Doses from the gamma radiation and the radon indoor concentration are assessed by means of direct exposure measurements and by mathematical calculations.

2. EXPERIMENTAL DETAILS OF MEASUREMENT

(i) Measuring Activity Concentration of Radium, Thorium and Potassium

The fly ash samples were collected from different thermal power stations in northern India and National Council for Cement and Building Materials (NCB). After collection, 300 gm of each sample was crushed into fine powder. Samples were passed through scientific sieve of 150 micron-mesh size to get fine quality of powder. After it, first samples were dried in an oven at about 110°C for 24 hr then samples were packed and sealed in an airtight PVC container and kept for about 4 week period to allow radioactive equilibrium between ^{226}Ra and the radon (^{222}Rn) and their short lived decay products. About 250-300gms of sample in powder form was taken for each sample material. Calibration of the low background counting system were carried out as suggested by International Atomic Energy Agency Gamma transitions like 186 keV for ^{226}Ra , 295 and 352 keV for ^{214}Pb , 609, 1120 and 1764 keV for ^{214}Bi , 338, 463, 911 and 968 keV for ^{228}Ac , 727 keV for ^{212}Bi , 238 keV for ^{212}Pb were used for the laboratory measurement of activity concentration.

Activity in the samples was measured using HPGe detector of high-resolution gamma spectrometry system. The detector is a co-axial *n*-type high purity germanium detector (Make EG&G, ORTEC, Oak Ridge, USA). The detector has a resolution of 20 keV at 1332 keV and relative efficiency of 20%. The output of the detector is analyzed using a 4K ADC system connected to PC, the spectrum is analyzed using the locally developed software "CANDLE (Collection and Analysis of Nuclear Data using Linux nEtwor)". The detector is shielded using 4" lead on all sides to reduce the background level of the system. The efficiency calibration for the system is carried out using secondary standard source of Radium ore in geometry available for the sample counting. Efficiency values are plotted against energy for particular geometry and fitted by least squares method to an empirical relation that takes care of the nature of efficiency curve for the HPGe detector. The samples were counted for a period of 72000 seconds and the spectra are analyzed for the photo peak of Radium, thorium and radium. The net count rate under the most prominent photo peaks of radium and thorium daughter peaks is calculated by subtracting the respective count rate from the background spectrum obtained for the same counting time. Then, the activity of the radionuclide is calculated from the background subtracted area of prominent gamma ray peaks.

(ii) Measuring Radon Equivalent and Radon Exhalation Rates from Fly-Ash Samples

For radon concentration and exhalation rate measurements from the samples, 'Can Technique' is an efficient technique as reported by various studies [9-11]. Samples of grain size $150\text{ }\mu\text{m}$, having each of mass 0.10 kg was kept in plastic cylindrical cans of 10 cm height and 7 cm diameter. An alpha sensitive LR-115 plastic track detector was fixed on the bottom of the lid of each can with the help of cello tape. Such that the sensitive side of the detector always faced the specimen and is exposed freely to the emergent radon from the sample in the can so that it could record alpha particles resulting from the decay of radon. Following the exposure for a stipulated period (about 90 days), the LR-115 films (SSNTDs) were chemically etched in 2.5 N NaOH (sodium hydroxide) solution in an etching bath tub at a temperature of 60°C for a period of 90 min for developing the tracks recorded and registered in the films [12]. The detectors are then washed in triple distilled water and de-ionized water in succession during washing. The detectors having a residual thickness of around $8\text{ }\mu\text{m}$ after etching are peeled off from their plastic bases and the registered tracks of alpha particles can be counted by using spark counter. The spark counter is pre-sparked at a voltage of 900V and is operated at 450V [13].

3. RESULTS AND DISCUSSION

(i) Estimation of Radium, Thorium and Potassium in Various Samples

The concentrations of Radium, thorium and potassium were calculated using the following equation [14-16].

Activity (Bq) =

$$\frac{CPS \times 100 \times 100}{B.I. \times Eff} \pm \frac{CPS_{error} \times 100 \times 100}{B.I. \times Eff} \quad (1)$$

where, CPS is net count rate per second; B I the Branching Intensity, and Eff is efficiency of the detector.

Table 1
Activity Concentrations of Radium, Thorium and Potassium

Sr. No	Sample Code	Activity concentration(Bq/kg)		
		²²⁶ Ra	²³² Th	⁴⁰ K
1	FA-1	89±3	103±6	344±1
2	FA-2	76±3	123±2	154±2
3	FA-3	23±6	197±3	342±5
4	FA-4	89±4	212±1	786±6
5	FA-5	221±2	154±4	698±4
6	FA-6	89±1	123±5	BDL
7	FA-7	230±2	67±3	455±4
8	FA-8	98±5	103±2	654±4
9	FA-9	56±3	99±5	412±5
10	FA-10	112±4	45±1	BDL
11	FA-11	56±3	109±2	543±6
12	FA-12	69±1	125±2	876±5
13	FA-13	114±5	167±1	345±3
14	FA-14	109±6	67±4	453±2
15	FA-15	234±6	54±6	BDL
16	FA-16	169±3	BDL	BDL
17	FA-17	154±2	76±5	BDL
18	FA-18	64±4	123±3	659±5
19	FA-19	89±4	107±4	352±3
20	FA-20	106±5	BDL	230±2

BDL: Below Detectable Limit

Table 1 presents the average concentration of the radionuclides, ²²⁶Ra, ²³²Th and ⁴⁰K, as well as the corresponding standard deviation in the materials under investigation. The activity concentration for ²²⁶Ra, ²³²Th and ⁴⁰K varies from 56±3 to 234±6 Bq/kg, 45±1 to 212±1 Bq/kg, and 154±2 to 786±6 Bq/kg, respectively in various samples studied in the present work. This activity concentration is matching the standards reported in various reports [15-17].

4. RADON EXHALATION RATE MEASUREMENTS, RADON EQUIVALENT CONCENTRATION AND RADON EMANATION RATE

The radon activity or integrated radon exposure inside the can was obtained by using the calibration factor 0.056 tracks cm⁻² day⁻¹ = 1 Bqm⁻³

Exhalation rates (E_x) were calculated using the Eqs (2) and (3) used by various researchers [12-15].

For mass exhalation rate:

$$E_x = \frac{CV\lambda/M}{T + 1/\lambda(e^{-\lambda T} - 1)} \quad (\text{Bqkg}^{-1}\text{h}^{-1}) \quad (2)$$

And for surface exhalation rate:

$$E_x = \frac{CV\lambda/M}{T + 1/\lambda(e^{-\lambda T} - 1)} \quad (\text{Bqm}^{-2}\text{h}^{-1}) \quad (3)$$

where C is the integrated radon exposure (Bqm⁻³ h); V the volume of air in can (m³); T the time of exposure (hrs); λ the decay constant for radon (h⁻¹); A is the area covered by the can or surface area of the sample (m²).

The radium equivalent activity was calculated using Eq. (4).

$$Ra_{eq} (\text{Bqkg}^{-1}) = (C_{Ra} + 1.43 C_{Th} + 0.077 C_K) \quad (4)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq/kg) of Radium, thorium and potassium in the samples¹⁷.

Radon emanation factor¹⁸⁻¹⁹ was calculated using Eq. (5)

$$\epsilon = E/C_{Ra} \times \lambda_d \quad (5)$$

Where E is Mass exhalation rate (Bqkg⁻¹h⁻¹), C_{Ra} is radium content (Bqkg⁻¹) and λ_d is decay constant of ²²²Rn (h⁻¹).

The calculated values are presented in Table 2.

The radium equivalent activity was varied from 229 to 495 Bq/kg, radon exhalation rate from 5.8 to 19.4 mBqkg⁻¹h⁻¹ for mass exhalation rate and from 106 to 354 mBqm⁻²h⁻¹ for surface exhalation rate in the fly ash samples used. The emanation factor varied from 0.4 to 3.3 (%). The observed values are matching with the others researcher reports [18-19].

The findings clearly indicate that the addition of fly ash in other building materials augments the activity and may

Table 2
Radium Equivalent Concentration, Radon Exhalation
Rate and Emanation factor.

Sr. No.	Sample Code	Radium Equivalent (Bqkg ⁻¹)	Mass exhalation rate (mBqkg ⁻¹ h ⁻¹)	Surface exhalation rate (mBqm ⁻² h ⁻¹)	Emanation factor (%)
1	FA-1	263	14.6±1.2	268±21.2	2.2
2	FA-2	264	11.7±1.3	214±19.3	2
3	FA-3	331	5.8±1.1	106±11.1	3.3
4	FA-4	453	6.7±1.4	123±9.3	1
5	FA-5	495	14.4±1.8	257±23.9	0.8
6	FA-6	453	10.9±0.9	197±12.5	1.6
7	FA-7	361	7.2±1.4	132±08.9	0.4
8	FA-8	296	6.7±0.7	123±12.1	0.9
9	FA-9	229	13.0±0.5	239±16.2	3.1
10	FA-10	243	9.9±0.4	181±11.3	1.2
11	FA-11	254	8.1±0.9	149±8.3	1.9
12	FA-12	315	6.7±1.2	124±14.5	1.3
13	FA-13	379	13.0±1.6	239±14.3	1.5
14	FA-14	240	9.9±1.8	181±12.3	1.2
15	FA-15	365	8.1±1.4	149±21.3	0.5
16	FA-16	432	7.2±1.6	132±17.9	0.6
17	FA-17	342	19.4±0.8	354±23.4	1.7
18	FA-18	291	12.8±0.4	235±17.1	2.7
19	FA-19	269	9.7±1.4	178±26.3	1.5
20	FA-20	321	6.9±1.7	127±9.6	0.9

present a radiation hazard to people and the environment as reported in various studies [9-11]. The radon activity and exhalation rates are found to vary appreciably in various samples. It is due to the fact that the samples collected from different thermal power stations were supplied from different collieries. The variation observed in exhalation rate of the samples may be due to the differences in the radium content.

5. CONCLUSIONS

The present study shows that the building construction materials which have been technologically enhanced as fly ash to be used for construction purpose, do have inborn radioactivity in them due to presence of primordial radionuclide and the radioactivity is modified in these materials during technological enhancement. The presence of natural radioactivity levels in the fly ash samples analyzed in the present study is well below the acceptable limits.

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ELECTRICAL CONDUCTION STUDIES THROUGH MICRO POROUS TRACK ETCH MEMBRANES OF EQUAL PORE DENSITY AND POROSITY

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ABSTRACT

Transport studies across track etch membranes are of considerable importance for various applications like separations, flow control, molecular detection and analysis where these membranes act as a barrier between two phases. Since porosity is embodied variability of pore size and pore density, a better understanding of the influence of porosity and pore density on transport mechanism of molecules across track etch membrane is required for new applications in various thrust areas. In the present work, electrical conduction studies of electrolyte through cylindrical micro pores of track etch membranes with same pore density, but different porosity, are accomplished using an electrochemical cell at room temperature. A similar study is also carried out for the membranes having same porosity with different pore density. The electrical potential difference has been used as the driving force for the transport of electrolytic ions across the membrane. Experimental observations corroborate the theoretical results that electrolytic transport through pores increases with increase in pore size for membranes having same pore density, but different porosity and is independent of the pore size for the membranes having same porosity with different pore density. Forward and backward conduction are found significantly same for the cylindrical pores of track etch membranes.

Keywords: *Track Etch Membrane (TEM), Porosity, Pore Size, Pore Density, Ion Transport.*

1. INTRODUCTION

Recently, special attention has been drawn to study the transport mechanism of molecules through pores of track etch membranes (TEMs), where these membranes act as a barrier between two phases. There exist diverse potential applications where transport mechanism plays a decisive role. These applications of porous membranes include separations, flow control, cell capture, counting of bacteria and virus, biosensing, and molecular detection, analysis and simulation [1-11]. The ion track-etching has become well established technique for creating uniform ordered pores in insulators. Basically, it is a two-step technique involving formation of latent tracks by irradiating the target sample, subsequently followed by etching of the damaged area along the trajectory of latent track [12-15]. Desired size, shape and alignment of these pores can be achieved via controlling irradiation and etching conditions during fabrication of TEMs [16-19]. Under suitable conditions,

pores size can be produced from a few nanometers to micrometers in diameter. TEMs offer distinct advantages over conventional membranes due to their precisely determined structure and number of unique properties, which are controllable such as optical transparency, smooth surface, narrow pore size distribution, thinness and low diffusion rate [17, 20, 21]. Recent advances in membrane applications demand for the precise control over pore morphology as well as physical and chemical properties of membranes that TEMs can cater due to capability of technique and materials involved in the production of these membranes, making them increasingly attractive for regulating transport mechanism and their use in various sensing applications.

The porosity is an important factor of a porous membrane that affects the transport phenomena across it [22]. To compute accurate porosity of a membrane is difficult,

because it comprises cumulative variability of pore size and pore density [20, 23]. Therefore, an easy, simple and low cost technique is required for better understanding of the influence of porosity, with variability of embodied factors-pore size and pore density, on the transport mechanism through TEMs for new exciting applications in the field of nano/micro technology.

In an earlier study [20], the transport of electrolytes across TEMs having the same porosity with different pore size and pore density was carried out under the influence of electric potential as driving force. In the present work, electrical conduction is investigated for electrolytes through cylindrical micro pores of track etch membranes with same pore density but having different porosity. A similar study is carried out for the membranes having same porosity but with different pore density. Experimental observations corroborate the theoretical model that electrolytic transport through pores increases with increase in pore size for membranes having same pore density with different porosity and is independent of the pore size for the membranes having same porosity but with different pore size and pore density. Forward and backward conduction are found significantly same for the cylindrical pores of track etch membranes.

2. EXPERIMENTAL DETAILS

2.1. Materials and methods

Samples of polycarbonate (monomer composition $C_{16}H_{14}O_3$, trade name Makrofol, Bayer, film of thickness 20 μm) were irradiated with 13.02 MeV/n Xe particles (fluence 10^6 ions/ cm^2) utilizing the heavy ion accelerator UNILAC facility at GSI, Darmstadt, Germany. The irradiation with charged-particles of polycarbonate film resulted in the formation of damage trails known as latent tracks. After that, two similar samples were chemically etched to form the pores using 6N NaOH solution at 50°C [24-28]. One sample was etched for 8 minutes and the other sample was etched for 10 minutes resulting in the formation of discrete cylindrical pores with average pore size of 0.16 μm and 0.2 μm in diameter, respectively. It is observed that their pore diameter increases almost linearly with time of chemical etching. These samples have different pore size with a same pore density, which is equal to the irradiation density of heavy ions (10^6 pores/ cm^2).

Other samples of polycarbonate TEMs (manufactured by Sartorius Stedium Biotech) having same porosity of 15 % but different pore size 0.2 μm and 0.4 μm with different pore density of 4.77×10^8 and 1.19×10^8 pores/ cm^2 respectively were used for similar transport studies. These TEMs possess uniform cylindrical pores. Electrolytes were procured from Molychem, Mumbai, India of GR grade and

distilled water was used to prepare the electrolyte solution for transport studies.

2.2. Transport studies

Transport studies of electrolyte solutions through pores of TEMs were carried out in electrochemical cell using conductometric technique [24-27 & 29]. The TEM was sandwiched between the two chambers in such a way that it acted as a barrier between the two chambers of cell. Two chambers were filled with desired electrolyte solution whose transport was to be studied through pores of TEMs. The experimental set up for transport studies is explained elsewhere [20]. The electrolytic solution of 0.5 molar concentration of KCl made in pure distilled water was utilized for conduction measurements through TEMs. The I-V characteristics were measured and drawn at room temperature by varying the voltage between “-10 to +10 V as driving force using Keithley 2400 Series Source Measurement Unit.

3. RESULTS AND DISCUSSION

Electrical conduction of electrolyte through cylindrical pores of TEM can be represented as equation (1) which is derived using Ohm's law and explained elsewhere [20]. This equation illustrates that electrical conduction is directly proportional to the porosity and exposed area of aperture $\bar{A}$, and is inversely proportional to length of the cylindrical pores which is equal to thickness of the TEM.

$$I = \frac{1}{k\rho} \left(\frac{P\bar{A}}{L} \right) V, \quad (1)$$

where, ρ is the specific resistance of the electrolyte,

k is aperture size dependent constant and is inversely proportional to exposed area of TEM,

P is the porosity of TEM,

L is the length of the pores equal to thickness of the TEM, and

$\bar{A}$ is exposed area of the aperture in electrochemical cell.

Porosity for membrane having cylindrical pores can be expressed as

Porosity (P) - Pore Density (D) $\times$ Pore Area (A)

If, r is the radius of the pores of TEM, the equation (2) can be rewritten as equation (3)

$$P = D(\pi r^2) \quad (3)$$

Substituting the value of porosity from equation (3) to equation (1), it becomes as follows

$$I = \frac{\pi \bar{A}}{k_p} \left(\frac{D r^2}{L} \right) V \quad (4)$$

The mathematical model expressed by equation (1) for electrical conduction of electrolyte through cylindrical pores of TEM infers that conduction is directly dependent on porosity. The current is same if porosity is constant besides variability of embodied factors of pore density and pore size, because porosity is a cumulative characteristic of both factors. Equation (4), suggests that conduction is directly proportional to pore density and square of pore radius [27], when constant porosity is not taken into account.

The figure 1 illustrates the I-V characteristics representing the electrical conduction behaviour of 0.5 M KCl electrolytic solution across polycarbonate TEMs of average pore size 0.16 μm and 0.2 μm having same pore density but different porosity using conductometric technique. It is evident from the graph that there is increase in electrical conduction of electrolytes through the micro porous TEM with increase in pore size comprising same pore density. The experimentally observed electrical current increases proportional to almost square of the pore radius as theoretical derived in mathematical equation (4).

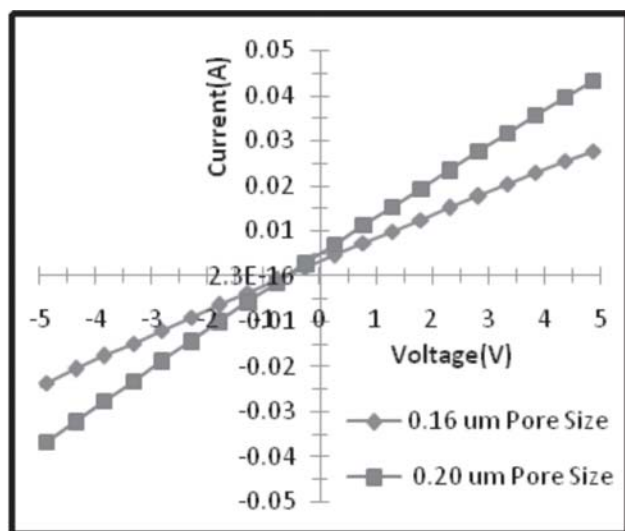


Fig.1: Electrical conduction across TEMs with same pore density having different pore size and porosity

The figure 2 depicts the I-V characteristic for similar electrolyte conduction studies across the commercially available polycarbonate TEMs of pore size 0.2 μm and 0.4

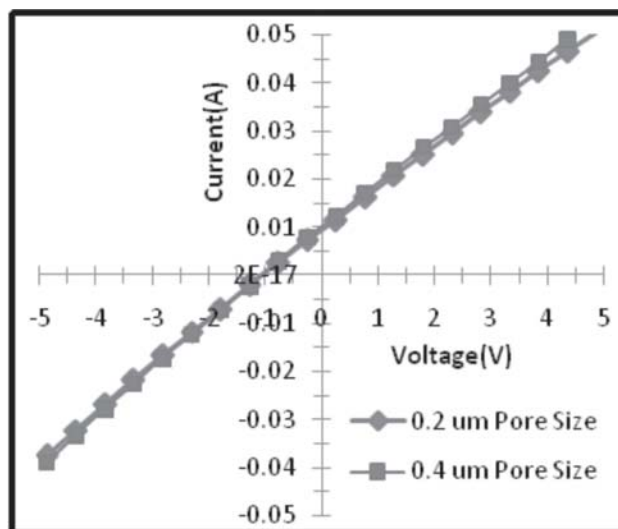


Fig. 2: Electrical conduction across TEMs with different pore size and pore density having same porosity

μm with same porosity but having different pore density. The graph illustrate that there is no significant difference in electrical conduction of electrolytes through the micro porous TEMs of different pore size and density but with same porosity. Mathematical equation (1) corroborates this experimental observation that the electrical conduction is same if the porosity is same besides variability of embodied factors of pore density and size.

It is also observed from the I-V characteristics that the conduction current does not achieve the zero value and also does not cross the origin when the applied potential difference (driving force) becomes zero while changing its polarity from forward bias to backward bias. This may be understood by taking into account the contribution of developed negative charges on the inner wall surface of the pores. During etching process of latent tracks in TEMs, carboxylic groups (R-COOH) are formed that attach to the inner pore wall surface. The electrically neutral carboxylic groups ($-\text{COOH}$) bonded to the polymer chains (R) dissociate into mobile hydrogen ions (H^+) and sessile carboxylic groups (R-COO^-) during the electrical conduction of electrolyte. The mobile hydrogen ions are susceptible to applied electric driving force generating the negative charge along the inner pore surface [2, 26] and thus the membranes become selective for the flow of cations. Some of the cations may become attracted towards the negatively charged pore surface and get accumulated, which results to generate a potential barrier to the flow of ions. Hence, some threshold potential of driving force is required to overcome the developed potential barrier within pores for conduction of electrolyte when applied potential (driving force) changes its polarity instantly from forward bias to backward bias.

As the cylindrical pores are symmetrical, forward and backward resistance offered by the membrane pores to electrolyte conduction is same, due to which I-V characteristics are linear and symmetrical in first and third quadrant.

This study suggests an easy and low cost method to measure any of the parameters- pore density or average pore size of the membrane having cylindrical pores, if other parameter and conductivity of electrolyte are known for a given aperture $\bar{A}$ for conduction in the electrochemical cell. This conductometric method is simple, easy, fast and low cost to estimate the porosity, pore density or average pore size and may become reliable with further more investigations in future with comparison to scanning electron microscopy technique.

4. CONCLUSION

Experimental observations corroborate the theoretical considerations that electrolytic transport through pores increases with increase in pore size of TEMs having same pore density, but different porosity and is independent of the pore size for the TEMs having same porosity but different pore density. Forward and backward conduction is found significantly same for the cylindrical pores of track etch membranes. The conductometric technique is a simple, fast and low cost method and may become a reliable method to estimate the porosity, pore density or average pore size of membranes with further investigations in future.

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RADIOLOGICAL IMPACT OF EXPOSURE TO RADON-THORON AND THEIR PROGENY PRESENT IN THE ENVIRONMENT OF FLY ASH DUMPING SITE IN FARIDABAD (HARYANA)

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ABSTRACT

Radon-Thoron and their progeny monitoring was carried out in dwellings near fly ash dumping sites in Faridabad (Haryana), as it is very important from health and hygiene point of view of the occupants. For the measurements, the track etch technique was used. The dosimeter employed for the measurement consisted of twin chamber systems with LR-115 Type II SSNTDs placed on the two sides of the central partition inside the cup and a bare film placed outside it. The detectors were exposed in the mixed field of radon-thoron in the environment of dwellings. The detectors were placed in about 100 dwellings and the choice of the dwelling was random. The value radon, thoron concentration and PAEC due to radon and thoron in the dwellings near fly ash dumping sites in District Faridabad (Haryana) varied from 10.30 Bqm⁻³ to 129.91 Bqm⁻³ with an average value of (44.85±11.77) Bqm⁻³, 1.67Bqm⁻³ to 65.08 Bqm⁻³ with an average of (22.73±5.82) Bqm⁻³ and 1.1 mWL to 14.04 mWL with an average of 4.85±1.27 mWL, 0.05 mWL to 1.76 mWL with an average of 0.61±0.16 mWL respectively. The annual exposure, inhalation dose and annual effective dose vary from 0.05 WLM to 0.65 WLM, 0.31 mSv/y to 4.96 mSv/y with an average of 1.72±0.45 mSv/y and 0.18 mSv to 2.45 mSv with an average of 0.85±0.22 mSv respectively. The measurements indicate that the radon concentration was below the safety levels (action levels) as recommended by various regulatory bodies. The maximum value of 129.91 Bqm⁻³ was found in a cave inside a temple, where there was no ventilation. The different values of radon concentrations are due to different ventilation conditions and house structures. The radon concentration was found to decrease with the increase in distance of the dwelling from the fly ash dumping site.

Keywords: Radon, LR-115 type-II SSNTDs, Fly ash dumping sites, Dwellings.

1. INTRODUCTION

In recent decades, the industrialization is going all over the world. Apart from the need of industrialization, there is its negative impact on the global environment and social life. Most important ill effect of these global processes has been the generation of large quantities of industrial waste. In order to meet the growing energy demand of the country, coal based thermal power generation shall continue to play a dominant role in the future also [1]. Fly ash is technologically important material generated during the combustion of coal in thermal power plant [2]. The fly ash produced in the thermal power plant needs to be disposed outside the plant premises. These fly ash dumping sites affect the surrounding environment because Coal fly ash contain enhanced levels of radionuclide's along with other toxic elements.

Fly ash is potential carcinogen containing heavy metals, hazardous compounds and ²²⁶Ra which decay to form chemically inert radioactive gas ²²²Rn [3]. Radon (²²²Rn) is one of the most pervasive and serious global indoor air concerns. Radon becomes an indoor air pollution problem when it penetrates into dwellings near dumping sites directly from the air and ground water contaminated due to fly ash [4]. Therefore, the problems related with their safe management and disposal has become a major challenge to environmentalists and scientist.

In the present study, Radon Thoron and its progeny levels were measured in the dwellings near the fly ash dumping sites. This study was important from health and hygiene point of view.

Table 1
Radon and thoron concentration, progeny level at fly ash dumping sites.

Location	Radon concentration (Bq m ⁻³)	Thoron concentration (Bq m ⁻³)	PAEC (Rn) (mWL)	PAEC (Th) (mWL)
FFAD-1	129.91	65.08	14.04	1.76
FFAD-2	76.98	39.39	8.32	1.06
FFAD-3	60.2	28.5	6.51	0.77
FFAD-4	51.64	22.05	5.58	0.6
FFAD-5	40.29	20.88	4.36	0.56
FFAD-6	30.73	17.34	3.32	0.47
FFAD-7	20.45	14.58	2.21	0.39
FFAD-8	15.3	12.18	1.65	0.33
FFAD-9	12.71	5.58	1.37	0.15
FFAD-10	10.3	1.67	1.11	0.05
Av±SE*	44.85±11.77	22.73±5.82	4.85±1.27	0.61±0.16

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

Table 2
Radon and thoron annual exposure, inhalation dose and annual effective dose in high rise building.

Location	Annual exposure (Rn) (WLMx10 ⁻¹)	Annual exposure (Th) (WLMx10 ⁻²)	Annual exposure (Rn+Th) (WLM)	Inhalation dose (mSv/y)	Annual effective dose (mSv)
FFAD-1	5.78	7.25	0.65	4.96	2.45
FFAD-2	3.42	4.39	0.39	2.96	1.45
FFAD-3	2.68	3.17	0.3	2.26	1.13
FFAD-4	2.3	2.46	0.26	1.88	0.96
FFAD-5	1.79	2.33	0.2	1.55	0.76
FFAD-6	1.37	1.93	0.16	1.22	0.59
FFAD-7	0.91	1.62	0.11	0.88	0.4
FFAD-8	0.68	1.36	0.08	0.69	0.31
FFAD-9	0.56	0.62	0.06	0.47	0.24
FFAD-10	0.45	0.19	0.05	0.31	0.18
Av±SE*				1.72±0.45	0.85±0.22

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

2. EXPERIMENTAL TECHNIQUE

For the measurement of radon, thoron and their progeny levels twin cup dosimeter has been employed in the different dwellings near fly ash dumping sites. Dosimeter is shown in the fig 1. These cups have three modes: filter mode, membrane mode and bare mode to register the tracks due to radon, Thoron and progeny respectively.

These detectors were hanged for 100 days in different dwellings near fly ash dumping sites. To register the tracks LR-115, type-II Solid state nuclear track detector cut into the pieces of 2.5x2.5 cm and fixed in the twin cup in three different chambers [5]. Detector were mounted vertically and the location were so selected that the dust collection on the detector to be minimum. LR-115 is a strippable film, consists of a 12-13 μ m thick alpha-sensitive layer of red dyed cellulose nitrate plastic deposited on a 100 μ m thick polyester base.

After the exposure of 100 days, the detectors were retrieved and collected in the laboratory for further analysis. Now, the films were etched in 2.5N NaOH solution at 60°C for 90 minutes with the help of constant temperature bath. After

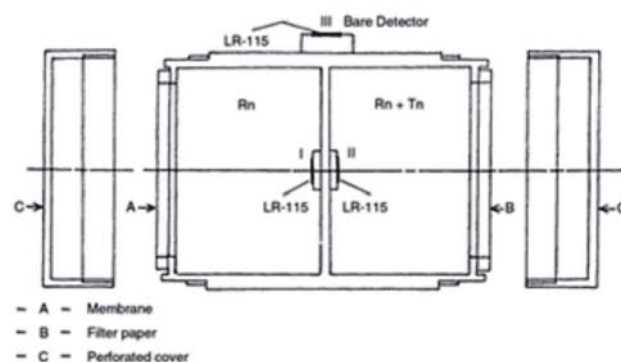


Fig. 1: Twin cup dosimeter

the etching detector should be washed under the running water. The film after the removal from the base was recorded by calibrated spark counter for the counting of tracks [6].

3. RESULT AND DISCUSSION

Track density measured was converted into potential alpha energy concentration (PAEC) in mWL and then into radon concentration (EEC value) in Bq/m³ [7].

The concentrations of radon (C_R) and Thoron (C_T) were calculated by using the following relations [8].

$$C_R (\text{Bq m}^{-3}) = T_m / d \times S_m$$

$$C_T (\text{Bq m}^{-3}) = T_f - d C_R \times S_{ff} / d \times S_{ff} ,$$

Where C_R and C_T is concentration of radon and thoron, T_m and T_f is track density in membrane and filter compartment and d is exposure time.

The inhalation dose in mSv/y was estimated using the formula.

$$D_{in} = \{(0.17 + 9F_R)C_R + (0.11 + 32F_T)C_T\} \times 7000 \times 10^{-6} ,$$

where F_R and F_T is equilibrium factor for radon and thoron respectively. The progeny concentrations in terms of Working Level (WL) were calculated as:

$$C_R (\text{Bq/m}^3) = \text{PAEC (WL)} \times 3700/F ,$$

where F is equilibrium factor and its value is 0.4 and 0.1 for radon and thoron respectively. For measurement 10 different locations have to be selected for 100 dwellings according to the varying distances from dumping sites.

The values of radon and thoron concentration and progeny level (PAEC) varied from 10.30 Bq m⁻³ to 129.91 Bq m⁻³ with an average 44.85 ± 11.77 Bq m⁻³, 1.67 Bq m⁻³ to 65.08 Bq m⁻³ with an average of 22.73 ± 5.82 Bq m⁻³, 1.10 mWL to 14.04 mWL with an average value of 4.85 ± 1.27 mWL, and 0.05 mWL to 1.76 mWL with an average value of 0.61 ± 0.16 mWL respectively as shown in table 1.

The value of radon and thoron annual exposure, inhalation dose and annual effective dose varied from 0.05 WLM to 0.65 WLM, 0.31 mSv/y to 4.96 mSv/y with an average value of 1.72 ± 0.45 mSv/y and 0.18 mSv to 2.45 mSv with an average value of 0.85 ± 0.22 mSv respectively as shown in table 2. The maximum value of 129.91 Bq m⁻³ was found in a cave inside a temple, where there was no ventilation.

4. CONCLUSION

The measurements indicate that in the dwellings near the fly ash dumping sites, concentration of radon is below the safety levels (action levels) as recommended by various regulatory bodies. The maximum value of radon concentration was found to be 129.91 Bq m⁻³ in a cave inside a temple, as there was no ventilation. The different values of radon concentrations are due to different ventilation conditions and house structures. Measurements show that the level of radon concentration decreases with the increase in distance of the dwelling from the fly ash dumping site.

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EFFECT OF GAMMA EXPOSURE ON Cu NANOWIRES SYNTHESIZED VIA TEMPLATE-ASSISTED ELECTRODEPOSITION

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ABSTRACT

The template synthesis is a simple and innovative way to fabricate one-dimensional nanostructures. In the present study, via template-assisted electrodeposition technique Copper (Cu) nanowires of 80nm diameter were synthesized electrochemically (using polycarbonate track-etch membranes) from aqueous acidic solution of copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) at room temperature ($29 \pm 1^\circ\text{C}$). The synthesized nanowires were exposed to gamma rays using Co-60 source with different fluence at Inter University Accelerator Centre, New Delhi. These nanowires were characterized using X-ray Diffractometer (XRD) and I-V Keithley source meter, before and after gamma exposure. The XRD study revealed the crystalline nature of all the nanowires and no variation was observed in the relative "2 theta" position when spectra of irradiated nanowires were compared with the pristine case. I-V measurements of exposed copper nanowires showed modified behaviour and a variation was observed in the electrical conductivity of the copper nanowires with the exposure dose.

Keywords: Template Synthesis, Nanowires, Gamma rays, I-V characteristics, XRD.

1. INTRODUCTION

The development of more powerful devices depends on the progress of miniaturizing their components and this stimulated a surge of interest in nanoscale materials and devices. Nanomaterials, which are defined with at least one dimension between 1–100 nanometers, grab a lot of attention due to their special structures, properties and applications superior to those of their bulk counterpart. When the physical characteristic lengths get constrained in two dimensions, then the physical and chemical properties show modifications due to quantum or finite size statistical mechanical effects; such systems called one-dimensional nanostructures.

Nanowire is the promising building block among different morphologies of one-dimensional nanostructure, having one unconfined direction available for electrical conduction with other two quantum-confined directions. Synthesis and characterization of nanowires, which are the main focus of this study, have attracted immense interest for developing

new generation nanodevices [1] with high performance. Nanowires provide ideal systems for studying transport processes of one-dimensionally confined objects and related fundamental phenomena.

The template synthesis approach entails the fabrication of a variety of nanostructures of desired morphology. The template serves as a scaffold against which materials with acquired morphology are synthesized. The pores of templates are filled with different methods such as sol-gel, electrodeposition or other chemical method. Among these, electrodeposition is a simple, convenient and versatile technique to synthesize the nanostructures using templates. Electrodeposition is most widely used technique due to numerous advantages viz. higher deposition rate, low cost, ability to produce nanostructures with feature size and more [2,3]. In electrodeposition technique, various factors like current density, applied potential, temperature, mechanical agitation, pH of the electrolyte and more, affected the growth of nanostructures.

Radiation on the living and non-living things are rooted in the head most events. There are pros and cons of the irradiation; therefore, the analysis of irradiation effects on the properties of materials is necessary for their practical utility [4,5]. During elementary acts of the interaction of energetic particles like electrons, neutrons, gamma rays and more with matter produced primary radiation defects. Taking a utilitarian rather than a fundamental view, the purpose to study the radiation effect on materials is to predict the performance of the materials and devices in different environmental and operating conditions.

Irradiation phenomenon has been recognized as a valuable tool to tailor the properties of nanostructures, as required for a particular application. In this context, a great deal of work has been carried out on bulk materials, thin film or CNTs till date [6,7]. But a little effort has been made to investigate the irradiation effect on metallic nanowires either experimentally or theoretically [8,9]. Present study has been carried out to investigate the influence of gamma rays irradiation on the structural and transport properties of copper (Cu) nanowires of 80nm diameter.

2. EXPERIMENTAL DETAILS

2.1 Synthesis

Electrodeposition using template-assisted approach is one of the most widely used methods to form the uniform and crystalline nanowires of different diameter and morphology due to low fabrication cost, high deposition rates and high aspect ratio [10,11]. A two-electrode electrochemical cell was used for electrodeposition that was poured with aqueous solution of 1M $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. pH of the solution adjusted with the help of H_2SO_4 . Conducting copper tape with track-etch polycarbonate membrane as an overlay worked as cathode and a copper rod acted as anode. At room temperature, the experiment was carried out for 15 min. at applied potential of 0.35V. After the deposition, electrolyte drained out from cell and the samples were removed from the cathode carefully, rinsed with distilled water and dried in air for some time.

2.2 Irradiation Parametrs

Cu nanowires were irradiated with gamma rays using Co-60 source at Inter University Accelerator Centre, New Delhi, India. The activity of gamma source at the time of exposure was 6.3 kGy/hour. The time of exposure for different doses calculated from the relation; $\text{Time} = \text{Dose}/\text{Activity of the source}$.

2.3 Characterization

The electrical and structural properties of pre- and post-irradiated copper nanowires were investigated using Keithley 2400 series source meter and Rigaku MiniFlexII X-

ray diffractometer respectively. For I-V characteristics measurement, sample was stuck on copper substrate which acted as one electrode, while the fine tungsten tip of diameter 10 μm worked as another electrode. The tip placed on embedded standing nanowires within the membrane. The morphology of nanowires was examined by Scanning electron microscopy (SEM) using JEOL JSM-6390LV at NIT Kurukshetra, India. For SEM characterization, samples were dipped in di-chloromethane solution to dissolve polycarbonate membrane then washed with ethanol and de-ionized water and dried in air for some time.

3. RESULTS AND DISCUSSION

SEM image of the copper nanowires showed the array of nanowires of cylindrical shape (fig. 1). Image revealed the uniform and homogenous growth of nanowires of identical diameter equal to diameter of pores of template.

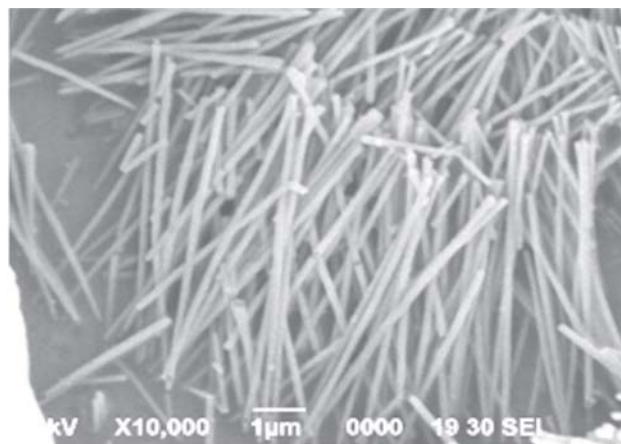


Fig. 1: SEM Images of Copper nanowires

The structural properties of the pristine and gamma irradiated copper nanowires of 80nm diameter were examined by XRD using $\text{CuK}\alpha$ radiation (wavelength) 1.5406 $\text{\AA}$ (fig.2). The Miller indices of diffraction peaks indexed as (111), (200), (220), (311), (222), (400) and (331) were observed in the XRD patterns that matches with the standard JCPDS cards-04-0836 (Cu) and it confirmed the cubic structure of copper nanowires. When XRD spectra of post-irradiated nanowires were compared with the pristine, it revealed no shifting in the “2 theta” position of diffraction peaks. Hence, after irradiation, no modification occurred in the shape and size of the unit cell of copper. Irradiated nanowires also sustained the polycrystalline nature of cubic lattice geometry with lattice parameter 3.615 $\text{\AA}$.

The average grain size of copper nanowires were calculated using Scherrer formula [12] represented by equation (1),

$$d = 0.9 \lambda / \beta \cos \theta \quad (1)$$

where d is the average grain size; λ is the characteristic wavelength of the CuK_α radiation; β is full width at half maxima (FWHM) in radians and θ is the bragg's angle. The grain size (g) is almost constant in pre- and post-irradiation cases i.e. 40, 38, 38, 40, 44nm in case of zero (pristine), 50, 150, 250 and 350 KGy of dose.

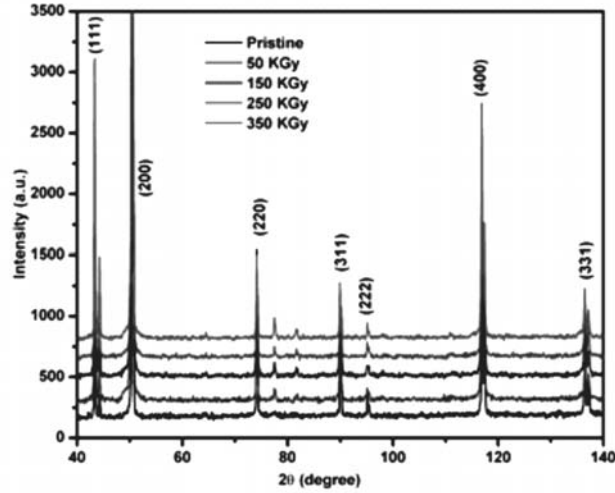


Fig. 2: XRD spectra of pristine and gamma irradiated copper nanowires

For the gamma-ray energies of this source (1.173 MeV and 1.332 MeV), Compton effect dominates over other interaction mechanisms. In Compton effect, an amount of the energy of incident photon gets transferred to the atomic electron and recoiled electron and photon are scattered in different directions with change in energy. In most of the interactions recoiled electron does not get sufficient energy from photons to be knocked out of atom from its position. According to Binary Cascade Approximation, there is a minimum energy required to displace the atom from their lattice position, therefore, the observed pre- and post-irradiated XRD spectra demonstrated that the atom sustained at its lattice site and hence, no shifting in 2 theta positions were observed.

I-V characteristics (IVC) of pre- and post-irradiated nanowires were drawn using a two probe set-up (fig. 3). Measurements were made before the dissolution of the template because the template acts as a buttress for the vertically aligned nanowires. IVC of pristine nanowires show the ohmic behavior. However, IVC of irradiated nanowires were showed dissimilar behavior from ohmic nature. The length of nanowires is much larger than the Fermi electron wavelength and electron mean free path of the material, so transport properties of the nanowires follow the classical relation;

$$\sigma = \frac{L}{R \cdot A} = \frac{dI}{dV} \cdot \frac{L}{A}$$

As length (L) and cross-sectional area (A) of nanowires are constant parameters, so electrical conductivity (σ) is directly proportional to the slope of I-V characteristics. The electrical conductivity of a single copper nanowire comes out to be $0.0588 \times 10^8 \text{ } \Omega^{-1} \text{ m}^{-1}$, while for bulk material it was $0.596 \times 10^8 \text{ } \Omega^{-1} \text{ m}^{-1}$. About ten times decrement in the electrical conductivity of the copper was observed as we approached from bulk to nanoscale.

In case of post-irradiated nanowires, the I-V characteristics appear to be drastically affected (Fig. 3). At gamma dose 50 kGy, I-V curves of copper nanowires sustained their linear characteristics but, at further doses I-V characteristics deviated from its ohmic behavior and traced the non-linear path.

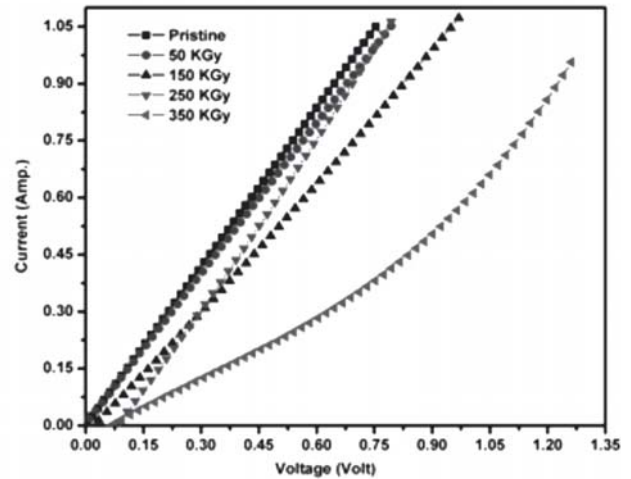


Fig. 3: I-V graph of pristine and gamma irradiated Cu nanowires

Nanowires exhibit ballistic and diffusive phenomenon of charge carrier transportation, that depend on the wire length and diameter. A ballistic transport phenomenon is associated with the carrier flow without any scattering, when the carrier mean free path is longer than that of the wire length. This mechanism is normally observed at the contact junction of nanowire or in breaking contacts and in other external circuits [13]. When the diameter of nanowire becomes comparable to the electron Fermi wavelength, the phenomenon of conductance quantization ($G=2e^2/h$) takes place [14]. It is found that the conductance of nanowires strongly depends on their crystalline structure [15]. Point defects disrupt the number of such conductance channel and may cause variation in the conductance.

For qualitative analysis, Mayadas & Shatzkes (MS) [16] was used to explain the electron conduction in the low dimensional systems. MS model suggested that the scattering of the electrons from the grain boundaries, depends on various parameters such as electron mean free path, grain size and reflection coefficient at the grain boundaries, may attribute to the reduction in the conductivity. As in our case diameter of copper nanowires (80 nm) is greater than the mean free path of electrons. So contribution in resistivity of the nanowires was explained by MS model.

Grain size of the nanowires are of the order of mean free path of electrons (39 nm), therefore, scattering from the boundaries of the grains affect the conductivity of the nanowires. Grains extended between both surfaces of wires, therefore lower and upper surface do not affect the conductivity; grain boundaries normal to the plane of film affect the conductivity. The contribution towards resistivity due to grain boundary scattering could be evaluated on the basis of the MS model from the following equation:

$$\rho = \rho_0 \left[1 + \frac{3 \lambda_0}{2 g} \left(\frac{R}{1-R} \right) \right]$$

Where; λ_0 is the electron mean free path; g, grain size and R is the probability of the reflection of electrons at grain boundaries.

The grain boundaries are itself a high resistance region than the intra-grain region. These boundaries act as a potential barrier in the flow of the charge carriers and the tunneling of charge carriers through boundaries depends on the reflection coefficient of these grain boundaries or potential barriers. The exposure of gamma rays might have increased the reflection coefficient (R) of grain boundaries. Increased value of R would decrease the component of forward transfer of momentum of charge carriers' (i.e. specular scattering) or it would alternatively increase the component of diffusive scattering of charge carriers from grain boundaries. The decreased specular scattering (or increased diffusive scattering) represents a decrease in the rate of flow of charge carries with applied potential difference across the two ends of a nanowire and hence the electrical conductivity of nanowires.

4. CONCLUSION

Evaluation of the electrical and structural properties of the pre- and post- irradiated copper nanowires was carried out on the basis of XRD spectra, SEM and I-V characteristics.

The I-V characteristics of the irradiated nanowires get modified in a non-linear manner as compare to ohmic behavior of pristine nanowire. The linear portions in the IVC's of irradiated nanowires signify the strength of Ohm's law even in case of irradiated nanowires but only up to an extent. The gamma ray exposure induced changes in granular properties and the tunneling of electrons through these grain boundaries. Hence, a relative assessment of decrease in the electrical conductivity was observed with increase in dose of gamma-ray photons.

5. ACKNOWLEDGEMENT

The authors wish to thank to the Director, IUAC, New Delhi, India for providing irradiation facility and the Director, NIT Kurukshetra, India for providing SEM and XRD facilities.

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STUDY OF RADON CONCENTRATION IN GROUND WATER AND ITS POTENTIAL HEALTH HAZARDS IN GRANITE REGIONS OF RAMANAGARA DISTRICT OF KARNATAKA STATE

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ABSTRACT

Measurement of radon concentration in drinking water has been conducted by many countries in all over the globe, because of the hazardous effect of radon on health of the human beings. The concentration of radon in drinking water causes radiation related health hazards both through inhalation and ingestion. The presence of radon content in groundwater sources depends on the radium concentration in the rock of the aquifer. Transport of radon through soil and bedrock by water depends mainly on the percolation of water through the pores and along fractured planes of bedrocks. The concentration of radon has been determined by collecting the various drinking water samples from different locations of bore wells and hand pumps around Ramanagara (Bangalore rural) district and were measured by using radon Emanometry technique. The radon concentration in groundwater has been found vary from $2.9 \pm 0.1 \text{ Bq.l}^{-1}$ to $198.5 \pm 4.2 \text{ Bq.l}^{-1}$ with an average value of $76.11 \pm 3.1 \text{ Bq.l}^{-1}$. The inhalation and ingestion dose vary from $7.1 \mu\text{Svy}^{-1}$ to 0.501 mSvy^{-1} with an average value of 0.191 Bq.l^{-1} and $0.01 \mu\text{Svy}^{-1}$ to 0.041 mSvy^{-1} with an average value of 0.016 mSvy^{-1} respectively. The present study data shows that 80% of the ground water samples have radon concentration were found to be higher than the EPA recommended maximum contamination level (MCL) of 11 Bq.l^{-1} and remaining 20% of the ground water samples below the action level.

Keywords: Ground water, Radiation, Emanometry, Inhalation, Ingestion.

1. INTRODUCTION

Environmental radioactivity comes from various radionuclides present in soil, rocks, air, water and building materials in variable amounts. Radon, a decay product of ^{226}Ra , is the main contributor to the environmental radioactivity [1]. Radon is continuously formed by the decay of ^{226}Ra present in aquiferous rocks and is trapped in porous rocks, and it percolates to occupy and dissolves in groundwater. Fractures and joints serves as the plumping system for groundwater flow in many areas and they are routs by which groundwater can move through gneisses, metamorphic and sedimentary rocks. The concentration of radon and risk due to ingestion is higher with the higher activity of radium and uranium in groundwater.

The concentration of radon in groundwater is influenced by several factors such as presence of shear zones, degree

of metamorphic rocks, soil porosity, permeability and activity of radium [2-3]. Radon is present in groundwater and typically exceeds the concentration of other natural radionuclides by the order of magnitude.

A large number of measurements of environmental radon has been made by investigator all over the globe concerned with the health risk, exploration of uranium and earthquakes [4]. High concentration of radon in groundwater water poses a potential health risks in two ways by inhalation and ingestion.

High concentration of radon in indoor environment and drinking water constitutes a major health hazards to the mankind, because of its carcinogen effect. Evaluation and management of these risks can be improved through a better understanding of the factors, which control radon

concentration particularly in those areas with elevated radon levels [5, 6].

Almost every country on the planet is prone to radon related health hazards. In this context, this study is to estimate radon levels in water samples and the radiation doses to the general public of the study area.

2. STUDY AREA

The area of the study is the granitic region of Ramanagar district. Ramanagara district is located in the south-eastern part of State. The flat topped lateritic hills are seen in the north-eastern part of the district. Geologically the area belonged to peninsular gneisses, younger and older granites, dolerite and amphibolite dykes, laterite, charnockite and amphibolite's and politic schist. In addition to these plenty of granite quarries and crushing plants are spread over the entire district, Granite quarrying and crushing is going on for the past three decades and density of crushing plants in the district is high. The quarrying activities cause air and water pollution. The crushing and mining activities are responsible for the emission of dust leading to the redistribution of associated radioactivity in different matrices of the environment.

3. MATERIALS AND METHODS

3.1. Estimation of radon level in water samples

The activity concentration of ^{222}Rn in ground water was estimated by the Emanometry [7 - 8]. Schematic diagram of Radon bubbler is as shown in Fig. 1. The bore well and hand pump water samples were collected from different selected locations in and around Tumkur districts during February and March 2013. In order to obtain fresh water from bore well, the water was allowed run fully at least five or ten minutes before the sample was taken. About 100 ml of water samples were collected in air tight plastic bottle with minimum disturbance. The plastic bottles were filled completely in a gentle manner, so that zero head space was present. Care was taken to see that no air bubbles were seeing inside the container and also to avoid aeration during the sampling processes, which might lead to out gassing [9]. After collecting the water samples by using the standard procedure, the samples were brought to the laboratory with minimal loss of time and were analyzed immediately. In this method, about 40 to 60 ml of the water samples was transferred into the bubbler by the vacuum transfer technique. The dissolved radon in the water was transferred into pre-evacuated and background counted scintillation cell. The scintillation cell was stored for 180 minutes to allow radon to attain equilibrium with its daughters and then it was coupled to a photomultiplier and alpha counting assembly and finally, concentration of radon samples have been measured using the relation [7].

$$^{222}\text{Rn} (\text{BqL}^{-1}) = \frac{6.97 \times 10^{-6} \times D}{V \times E \times (1 - e^{-\lambda t}) \times e^{-\lambda T} \times e^{-\lambda \theta}} \quad (1)$$

where, D = Counts above background, V = Volume of water, E = Efficiency of the scintillation cell (74%), λ = Decay constant for radon ($2.098 \times 10^{-6} \text{ s}^{-1}$), T = Counting delay after sampling, t = counting duration (s) and θ = build up time in the bubbler (s).

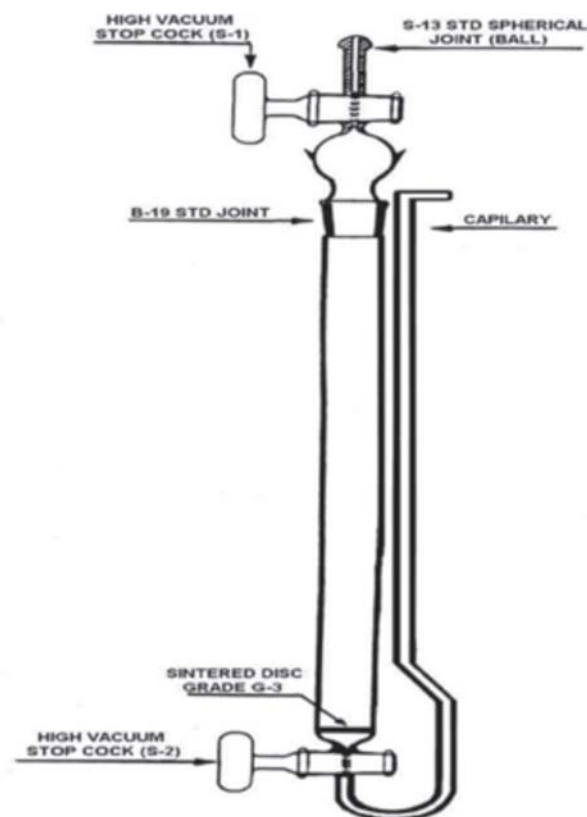


Fig. 1: Schematic diagram of Radon bubbler

3.2. Estimation of dose due to radon in water samples

The dose due to radon can be divided into two types, namely, the dose from inhalation and the dose from ingestion. The effective dose to the ingestion mainly depends upon the amount of water consumed by a human being in a day. However, radon gas present in the drinking water can also escapes into the indoor air during showering and other domestic uses and can cause a significant increase in the risk of lung cancer due to the radon inhaled. Radiation dose to the public from waterborne radon is thought to be a higher threat than all other contaminants in

water. The annual mean effective doses for inhalation and ingestion from radon in water have been calculated by using the parameter established in the UNSCEAR report 2000 [1] as

$$D_{in} (\text{mSv.y}^{-1}) = C_{RnW} \times R_{aW} \times F \times I \times DCF \quad (2)$$

Where, D_{in} is the effective dose for inhalation, C_{RnW} is the radon concentration in water (Bq.L^{-1} or kBq.m^{-3}), R_{aW} is the radon in air to the radon in water (10^{-4}), F is the equilibrium factor between radon and its progenies (0.4), I is the average indoor occupancy time per individual (7000 h.y^{-1}) and DCF is the dose conversion factor for radon exposure ($9 \text{ nSv (Bq.h.m}^{-3})^{-1}$).

$$D_{ig} (\text{mSv.y}^{-1}) = C_{RnW} \times C_w \times EDC \quad (3)$$

Where, D_{ig} is the effective dose for ingestion, C_{RnW} is the radon concentration in water (Bq.L^{-1}), C_w is the weighed estimate of water consumption (60 L.d^{-1}) and EDC is the effective dose coefficient for ingestion (3.5 nSvBq^{-1}), respectively.

4. RESULTS AND DISCUSSION

The concentration of radon in bore well water has been studied in and around the granite regions of Ramanagara district and the range of radon concentration, effective dose are summarized in Table 1. The radon concentration in groundwater has been found vary from $2.9 \pm 0.1 \text{ Bq.L}^{-1}$ to

$198.5 \pm 4.2 \text{ Bq.L}^{-1}$ with an average value of $76.11 \pm 3.1 \text{ Bq.L}^{-1}$. The inhalation and ingestion dose vary from $7.1 \mu\text{Sv.y}^{-1}$ to 0.501 mSv.y^{-1} with an average value of 0.191 Bq.L^{-1} and $0.01 \mu\text{Sv.y}^{-1}$ to 0.041 mSv.y^{-1} with an average value of 0.016 mSv.y^{-1} respectively.

Radon in water depends on the local geology, radium and uranium dissolved in water and hydro geological conditions and rock of the aquifer [10]. The higher radon concentrations were observed at Maralebekuppe, Raghuvanahalli, T Bekuppe, Somanahalli and Ramanahalli. These areas are attributed by gray pink granite rocks; these rocks contain higher activity of radionuclides. They are younger than altered and gray granite rocks. A high concentration of radon in bore well water was detected in granites and metamorphic rocks [5-6]. The minimum ^{222}Rn concentrations were observed at Mahimanahalli, Karrirayaradoddi and Madapura gate. This is due to the fact that all the locations are attributed by gray granites and dolerites, these rocks contains lower activity of radionuclides when compared to gray pink granites.

In the other parts of the study area such as Ramagiri, Kebballi, Therenadoddi and Kallugopanahalli, in these regions there is no significance variation of ^{222}Rn , these regions have higher activity concentrations than the regions of minimum radon concentration. Because these regions are attributed by gray granites contain slightly lower activity of radionuclides when compared to pink gray granite

Table 1
The average radon concentration and average annual effective dose from different ground water samples in different locations of Ramanagara district.

Sl. No.	Locations	^{222}Rn (Bq.L^{-1})	Dose (mSv.y^{-1})		Total dose (mSv.y^{-1})
			Inhalation	Ingestion	
1	Ramanagar	64.0 ± 0.9	0.161	0.013	0.174
2	Somanahalli	120.1 ± 3.7	0.302	0.025	0.327
3	Madapura gate	8.5 ± 2.1	0.021	0.001	0.022
4	Maralebekuppe	198.5 ± 4.2	0.501	0.041	0.542
5	Maharaje katte	82.9 ± 2.8	0.208	0.017	0.225
6	Karrirayara doddi	8.14 ± 1.3	0.021	0.001	0.022
7	Mahimanahalli	2.9 ± 0.1	0.007	0	0.007
8	Kallugopanahalli	42.2 ± 2.9	0.106	0.008	0.114
9	Kanakapura	18.9 ± 2.3	0.047	0.004	0.051
10	T.bekuppe	187.2 ± 3.7	0.471	0.039	0.51
11	Kebballi	62.6 ± 1.7	0.157	0.031	0.188
12	Raghuvanahalli	129.2 ± 4.97	0.325	0.027	0.352
13	Ramagiri	25.6 ± 3.0	0.064	0.005	0.069
14	Therenadoddi	33.5 ± 2.6	0.084	0.007	0.091
15	Ramanahalli	157.3 ± 5.1	0.396	0.033	0.429
	Average	76.11 ± 3.1	0.191	0.016	0.208
	Minimum	2.9 ± 0.1	0.007	0	0.007
	Maximum	198.5 ± 4.2	0.501	0.041	0.542

rocks. Higher concentrations of ^{222}Rn have been observed near the granitic quarries. The rock of these regions contains higher activity of radionuclides. Due to the mining activity, the bed rocks are fissured and fractured. In the bed rock aquifer's groundwater occurs and flows in fractures. Radium rich minerals present along the surface of fractures decay and released a ^{222}Rn into the groundwater. Since, the recoil distance as well as the diffusion length of ^{222}Rn is small, it is widely accepted that only those minerals flying on the surfaces of fractures in direct contact with the ground water, contribute to increase ^{222}Rn levels in groundwater.

Slightly lower radon concentration in groundwater was found from schist bed rock in Ramanagara regions. The highest ^{222}Rn concentration in groundwater was from granitic bed rocks. It is generally accepted that high ^{222}Rn levels found in terrain of high grade metamorphic and granite rocks. The UNSCEAR has suggested a value of radon concentration in water for human consumption between 4 and 40 Bq.l⁻¹ [11-12]. It has been observed that except 6 drinking water samples from the study area, have radon concentration higher than the UNSCEAR recommended level of 4 and 40 Bq.l⁻¹. The measured radon concentration values were compared with the allowed MCL for radon concentration in water (which is 11 Bq.l⁻¹) proposed by USEPA, it has been observed that, except 3 remaining all drinking water samples from the study area, have radon concentration higher than the MCL of 11.1 Bq.l⁻¹. From this, it is evident that 80% of the drinking water samples from the study area have radon concentration higher than the MCL recommended by EPA [2].

The World Health Organization [12] and the EU Council [13] recommend the determination of reference level of the annual effective dose received from drinking water consumption at 0.1 mSv.y⁻¹. According to WHO, if total annual effective dose is lower (or equal) than 0.1 mSv, then, the water is suitable for drinking purpose and no further action is necessary. However, if dose is higher than 0.1 mSv, then remedial measures are needed to reduce it. In the present study except 60%, the remaining all drinking water samples from the study area are well below the reference level of 0.1 mSv.y⁻¹ of WHO and hence do not pose any health problem from radon dose received from drinking water in the study area.

5. CONCLUSION

From the above study it is conclude that Radon concentration in groundwater mainly depends on the local geology, hydro logical characteristics. The radon concentration in groundwater has been found to vary from $2.9 \pm 0.1 \text{ Bq.l}^{-1}$ to $198.5 \pm 4.2 \text{ Bq.l}^{-1}$ with an average value of $76.11 \pm 3.1 \text{ Bq.l}^{-1}$. Elevated levels of radon concentration in

groundwater samples were found in the pink gray granite regions of Maralebekuppe, Ramanahalli and T.bekuppe. The present study data shows that 80% of the ground water samples have radon concentration were found to be higher than the EPA recommended maximum contamination level (MCL) of 11 Bq l⁻¹ and we can conclude that except 60%, the remaining all drinking water samples from the study area are well below the reference level of 0.1 mSv.y⁻¹ of WHO.

6. ACKNOWLEDGEMENT

Authors would like to express their sincere thanks to the University Grant Commission (UGC) for granting funds to carry out this research work.

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STUDY OF RADON EXHALATION RATES USING SOLID STATE NUCLEAR TRACK DETECTORS IN STONE MINING AREA OF ARAVALI RANGE IN PALI REGION, DISTRICT FARIDABAD

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ABSTRACT

It is well established that indoor radon-thoron and daughters are the largest contributors to total radiation dose received by populations. They account for more than 50% of the total dose and the radiation exposure beyond permissible levels can lead to deleterious effects on health. This fact necessitates extensive studies of natural radioactivity levels in the stone mining area of Aravali range in Faridabad. The stone mining area of Aravali Range in Pali, District Faridabad bears significant geological features. Radon exhalation from ground plays an important role in enhanced indoor radon levels and can pose grave health hazards to the workers and the residents. Exhalation rates (mass and surface) from stone samples of the area have been studied using LR-115, Type II nuclear track detectors. The mass and surface exhalation rates from crushed stone samples, also called stone dust varied in the range 3.41 - 9.11 mBq kg⁻¹ h⁻¹ and 75.9 - 202.7 mBq m⁻² h⁻¹, respectively. The study has revealed substantial presence of radionuclides in the samples collected from the mining area.

Keywords: Radon, Exhalation rate, Health, Environment, Stone.

1. INTRODUCTION

Natural radio activity is wide spread in the earth environment and it exists in soil, rocks, water and air. Radon-thoron and its daughter products are the largest contributors to total radiation dose received by people. Emanation of radon (²²²Rn) is associated with the presence of radium and uranium in the ground, these elements present in all types of rocks and soils. The concentrations of radon vary with specific sites and geological materials.

A radon is an inert gas, can move freely through the soil from its source. Radon concentration variations depend on time, place and height above the ground. If uranium rich material lies close to the surface of the earth, there can be high radon emanation rates, resulting in high radon exposure hazards.

The increased interest in measuring radon concentration in the environment of mines is due to its associated health hazards and environmental pollution and is of concern with the control and minimization of such radiation exposure.

Mining of stone is being carried out since long and a large number of workers are involved in this industry. Stone is technologically important material being used in houses in flooring and on walls. The stone mining area of Aravali Range in Pali, District Faridabad bears significant geological features, so extensive studies of natural radioactivity levels in the stone mining area of Aravali range in Faridabad had been carried out to measure the radon concentration.

Radon exhalation from ground in this area affects health of the workers and the residents. The inhalation of short lived daughter products of naturally occurring radon for a long time leads to pathological effects such as cancer. Alpha radiation emitted by radon has the potential to damage the DNA of the lung cells. The damage being localized to lung cells, the lung cancer is the only potential hazard known by radon in indoor air.

The stone mining area of Aravali Range in Pali, District Faridabad bears significant geological features (proximity to fast developing sub urban areas). Geographic coordinates of Faridabad are Latitude: 28°25' 59" N,

Longitude: 77°19'20.03" E. So extensive studies of natural radioactivity levels in the stone mining area of Aravali range in Faridabad had been carried out to measure the radon concentration.

2. MATERIALS AND METHODS

For the measurement of radon concentration, CAN technique have been used. Different samples of stones and soils based on their different physical appearance were collected from each site. A known amount of stone and soil samples (crushed, filtered through a sieve and oven dried) were placed in plastic cans. LR-115 type-II plastic track detectors were fixed on the bottom of the lid of each can with tape such that sensitive side of the detector faced the specimen. The cans were tightly closed from the top and sealed. The geometrical parameters of the detectors were: LR-115 type- II plastic track detectors (2cm×2cm). The exposure time of the detectors was 100 days. At the end of the exposure time, the detectors were removed and subjected to a chemical etching process in 2.5N NaOH solution at 60°C for one and half-hour. The detectors were then washed and dried. The tracks produced by the alpha particles, were then observed and counted using spark counter, the spark counter is pre sparked at 900V and operated at 450V.

Following expression gives the exhalation rate

$$Ex = CV\lambda/A[T + 1/\lambda\{e^{-\lambda T} - 1\}] \quad (1)$$

Where Ex is the radon exhalation rate in Bqm⁻² h⁻¹, C is the integrated radon exposure as measured by LR-115 type II plastic track detector in Bqm⁻³h, V is the effective volume of Can in m³, λ is the decay constant for radon in h⁻¹, T is the exposure time in h and A is the area covered by the Can in m².

Table 1

Radon exhalation rates in some stone samples from Aravali range

Sample Code	Mass(g)	Radon Mass Exhal. Rate (mBq/Kg/h)	Radon Surface Exhal. Rate (mBq/m ² /h)
SA-1	150	3.41	75.9
SA-2	150	4.03	89.7
SA-3	150	3.98	88.5871
SA-4	150	9.11	202.771
SA-5	150	6.82	151.8
SA-6	150	8.98	199.8774
SA-7	150	5.98	133.1032
SA-8	150	5.43	120.8613
SA-9	150	4.78	106.3935
SA-10	150	5.78	128.6516
Avg±SE		5.83±0.6277	129.76±13.97

3. RESULTS AND DISCUSSION

The mass and surface exhalation rates from crushed stone samples, also called stone dust varied in the range 3.41 – 9.11 mBq kg⁻¹h⁻¹ and 75.9 – 202.7 mBq m⁻²h⁻¹, respectively. The study reveals the substantial presence of radionuclides in the samples collected from the mining area.

4. CONCLUSION

The measurements indicate normal level of radon concentration emanated from stone and soil samples collected from Aravali range of hills of north India.

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ESTIMATION OF EQUILIBRIUM FACTORS OF RADON AND ITS PROGENY USING SSNTDS IN THE DWELLINGS OF HYDERABAD, INDIA

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ABSTRACT

Equilibrium factors play an important role in the estimation of effective dose in the indoor environment due to Radon and its progeny. Generally, the dose estimation is made taking UNSCEAR suggested equilibrium factor (EF) of 0.4 for the radon and its progeny. But in practice the concentration of radon and its progeny vary significantly with local environmental conditions and time. Subsequently, the equilibrium factor EF also changes and hence affects the effective dose estimation of a particular dwelling. So, the UNSCEAR EF value does not reflect the actual effective doses. With this in view, the present study is carried out to estimate the equilibrium factors in different types of dwellings in the urban Hyderabad using SSNTDs. It is found that, the equilibrium factors in the urban Hyderabad vary from 0.01 to 0.71 with an average of 0.32 ± 0.23 . The average EF value of urban Hyderabad is found to be relatively lower than Indian average and global average. The reasons for the lower equilibrium factor values in the study area have been discussed in this paper.

Keywords: Radon, Progeny, Equilibrium factors, Effective doses.

INTRODUCTION

The studies on uranium miners established the risk of occurrence of lung cancers in the miners exposed to high levels of ^{222}Rn and its progeny [1]. In the middle of 20th century, significant exposure to radon daughters rather than inhalation of radon gas itself was established and it is believed that progeny nuclides are predominant causative agents for the observed excessive lung cancers [2, 3]. The alpha emitting decay products of radon entering the lungs directly through breathing ionise the tissues and can cause damage to the lungs. In the dwellings, radon gas accumulates as a result of emanation from the soil below and from the building materials. This concentration varies widely and depends on radium content, porosity of soil and ventilation. Generally in the dose estimation, the concentration of radon gas is determined first and an assumed equilibrium factor (EF) between the radon and its progeny is then applied. However, in practice the concentration of radon and its progeny vary significantly with time and place due to the persisting variance in the radon and its progeny concentrations. Therefore an assumed EF can not reflect the actual conditions. The

present study is an attempt to estimate the EF values using SSNTDs for various types of dwellings of urban Hyderabad and it is important for risk assessment to know the normal range of the EF values for a particular region.

MEASUREMENT PROCEDURE

Passive dosimeters were used for the measurement of ^{222}Rn and its progeny in the dwellings of Hyderabad. The details of dosimeters and its methodology have been discussed elsewhere [4, 5]. The dosimeters were installed in different locations and retrieved in a stipulated time. The films were etched in a standard chemical procedure [5] to estimate the tracks in membrane mode, filter mode and bare mode. Using the calibration factors for the membrane and bare mode, the radon and its progeny concentrations, respectively, were calculated.

RESULTS AND DISCUSSION

The equilibrium factors, EF, is derived using formula

$$EF_{\text{Rn}} = (WL/R_{\text{cn}}) \times 3700,$$

where WL working level representing the progeny concentration and R_{cn} is radon concentration. The estimated average EF values of radon for urban Hyderabad is shown in table below.

	F- values of radon
Range	0.01 to 0.71
Average	0.32
SD	0.23
GM	0.21

It is found that the EF values in the urban Hyderabad vary from 0.01 to 0.71 with an average value of 0.32 ± 0.23 (geometric mean of 0.21), whereas in the Indian dwellings the EF values are ranging from 0.21 to 0.67 with an average value of 0.52 [6]. The average EF value of urban Hyderabad is lower than the Indian average and global average of 0.4 [7]. The variation of F in the different rooms in dwellings is shown in Fig.1 and it was found that the F values are higher in kitchen when compared to those of front rooms, bed rooms and halls. This may be due to the higher humidity and more aerosol concentration in kitchens. Generally in urban areas, the front rooms are opened only at the time of entering into the dwellings so that the ventilation rates are relatively lower than those of halls and bed rooms.

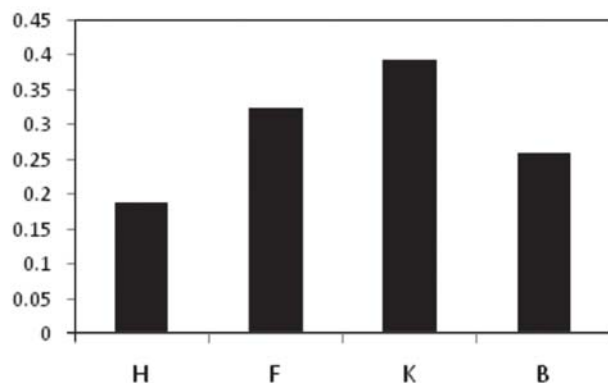


Fig. 1: Room wise variation of EF (H:Hall, F:Front Room, K:Kitchen, B:Bed Room)

In the present study, an attempt is also made to estimate the EF values for different types of roofs and floors, the values of which are shown in the table below.

Roof		Floor	
Type	F-Value	Type	F-Value
RCC	0.35	Mud	0.2
Asbestos	0.16	Mosaic	0.16
Tiled	0.31	Concrete	0.34
		Stone	0.3

The variation of EF values in different dwellings may be due to the spatial and temporal fluctuations of environmental parameters of the particular area of dwelling, such as ventilation, aerosol concentration, surface deposition, occupation factor, etc. So, the indoor air environmental parameters are to be monitored carefully in the estimation of EF values.

From this study, it can be concluded that an assumed EF value can not reflect the actual condition for many realistic situations in the evaluation of effective dose. Therefore it is suggested that the equilibrium factor is to be estimated at each location to calculate the effective dose. The variation of dose values estimated in study area using the EF value suggested by UNSCEAR varied from 0.46 to 8.20 $mSv\cdot y^{-1}$ with an average of $1.63mSv\cdot y^{-1}$, whereas the same values estimated using calculated EF value (0.32) varied from 0.08 to 4.94 $mSv\cdot y^{-1}$ with an average of $1.17mSv\cdot y^{-1}$ (5).

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