MRP Title "*Estimation of radium content of and radon Exhalation rates from some soil samples*"

UGC 12th Plan

December 2015

By –

Dr. Hiranya Kumar Sarma, M.Sc., Ph.D

Principal

Suren Das College, Hajo

Kamrup, Assam

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No. F.5-369/2014-15/MRP/NERO/22-02

February, 2015

17 FEB 2015

The Principal,
Baosi Banikanta Kakati College, P.O. - Nagaon - 781 311, Dist. - Barpeta, Assam.

Sub. : Financial Assistance to Teachers working in the colleges for undertaking **Minor Research Project (MRP)** on "**Estimation of Radiation ..... some soil samples**".

Sir/Madam,

With reference to the MRP submitted by Dr. Hiranya Kumar Sarma, Department of Physics of your college for financial assistance under the above scheme, this is to inform you that the University Grants Commission has approved a grant of Rs.**4,68,000/- (Rupees Four Lakh and Sixty Eight Thousand)** only for undertaking the above research project for the items listed below:-

Recurring Items	Amount (Rs)	Non-Recurring Items	Amount(Rs)	Total(Rs)
Chemical and Glass Works	50,000/-	Books & Journals	40,000/-	90,000/-
Field Works and Travel	30,000/-	Equipments	2,98,000/-	3,28,000/-
Contingency including special needs	30,000/-			30,000/-
Any other items	20,000/-	Any other items	-	20,000/-
		Grand Total		Rs. 4,68,000/-

Terms & Conditions

1. **The Principal Investigator (P.I.) is requested to submit acceptance certificate as per the format of the UGC Guidelines within 15 days from the date of issue of this letter.**
2. Date of implementation of project will be the received date of 1st installment of grant.
3. The Research Project has to be completed within a period of 24 months. No extension in tenure is permissible in any circumstances.
4. The second installment of grant 40% will be released on receipt of the progress report of the work done, utilization certificate item wise statement of expenditure duly certified by the Principal Investigator/ Registrar/ Principal/ Head of the institution.
5. The detailed terms and conditions of availing Minor Research Project (12th Plan) may be seen at www.ugc.ac.in
6. The suggestions given by the subject expert/s (if any) are enclosed for the benefit of investigator.

(Dr. Mohammad Arif)
Joint Secretary

Copy to:-

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2. The Director, College Development Council, Gauhati University, GopinathBordoloi Nagar, Guwahati-781014, Assam, India.
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Education Officer

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CONTENTS

1.1. INTRODUCTION:

There are many known and unknown gases within or around our home, in which radon gas is one of the health concerns. Radon is a naturally occurring radioactive gas found in soils, rock, water everywhere that has the symbol Rn having atomic number 86. Radon was discovered in 1900 by Friedrich Ernst Dorn, who called it radium emanation. In 1908 William Ramsay and Robert Whytlaw-Gray, named it niton (Latin *nitens* meaning "shining"; symbol **Nt**) and isolated it, determined its density, and determined that it was the heaviest known gas. It has been called "radon" since 1923. Its position in the periodic table is in VIII $^{th.}$ group of VI$^{th.}$ period. Its specific gravity, boiling point and freezing point are 9.73, 211 K and 202 K respectively (Lange, 1961). It is one of the noble gases and so should have been inert. However, some investigators (Stein, 1969, 1970 and 1972) have reported that like xenon, radon (though a noble gas) too has been successfully reacted with liquid bromine trifluoride and some solid complexes of antimony halides. When cooled below the freezing point radon exhibits a brilliant phosphorescence which becomes yellow as the temperature is lowered and orange-red at the temperature of liquid air. The volume corresponding to an activity of 1 picocurie (Pci) of radon is about 6.7 $\times$ 10^{-19} cm^3 and the corresponding partial pressure is less than 10^{-18} atmosphere (Evans, 1969). The average atmospheric concentration of radon is of the order of 6×10^{-18} % by volume (Clark, 1959). It is colourless, odourless and tasteless and can only be studied using special equipment.

After emanation when radon enters an enclosed space, it can sometimes accumulate to unacceptably high concentrations. In open air it is quickly diluted to harmless concentrations.

There are twenty known isotopes of radon. The most stable isotope is ^{222}Rn, which is a decay product (daughter product) of ^{226}Ra, has a half-life of 3.823 days and emits alpha particles. ^{220}Rn is a natural decay product of thorium and is called “thoron.” It has a half-life of 55.6 seconds and also emits alpha radiation. ^{219}Rn is derived from actinium, is called “actinon,” is an alpha emitter and has a half-life of 3.96 seconds.

Radon is produced by the natural radioactive decay of uranium and thorium. Since uranium is essentially ubiquitous in the earth's crust, radium-226 and radon-222 are present in almost all rock, soil, and water. Both uranium and thorium are ubiquitous in the ground and their important isotopes are ^{238}U, ^{232}Th and ^{235}U. The decay chains for these nuclides are given in Fig.1.1, Fig.1.2. and Fig.1.3 and their half lives are shown in Table 1.1, Table 1.2 and Table 1.3 (Sharma, 1996). In terms of radioactivity, ^{238}U and ^{232}Th are in approximately equal abundance and are also in approximate activity equilibrium with their daughter nuclides. At a given site in the ground, however, the levels of uranium and thorium present depend on local geology. Within both the uranium and thorium decay chains, the element Rn, an inert gas, is produced. ^{222}Rn, commonly known as radon, is produced from the decay of ^{226}Ra in the ^{238}U decay chain, and ^{220}Rn, commonly known as thoron, is produced

Fig1.1 : ^{238}U decay chain, including ^{222}Rn and its decay products (Sharma B.K., 1996)

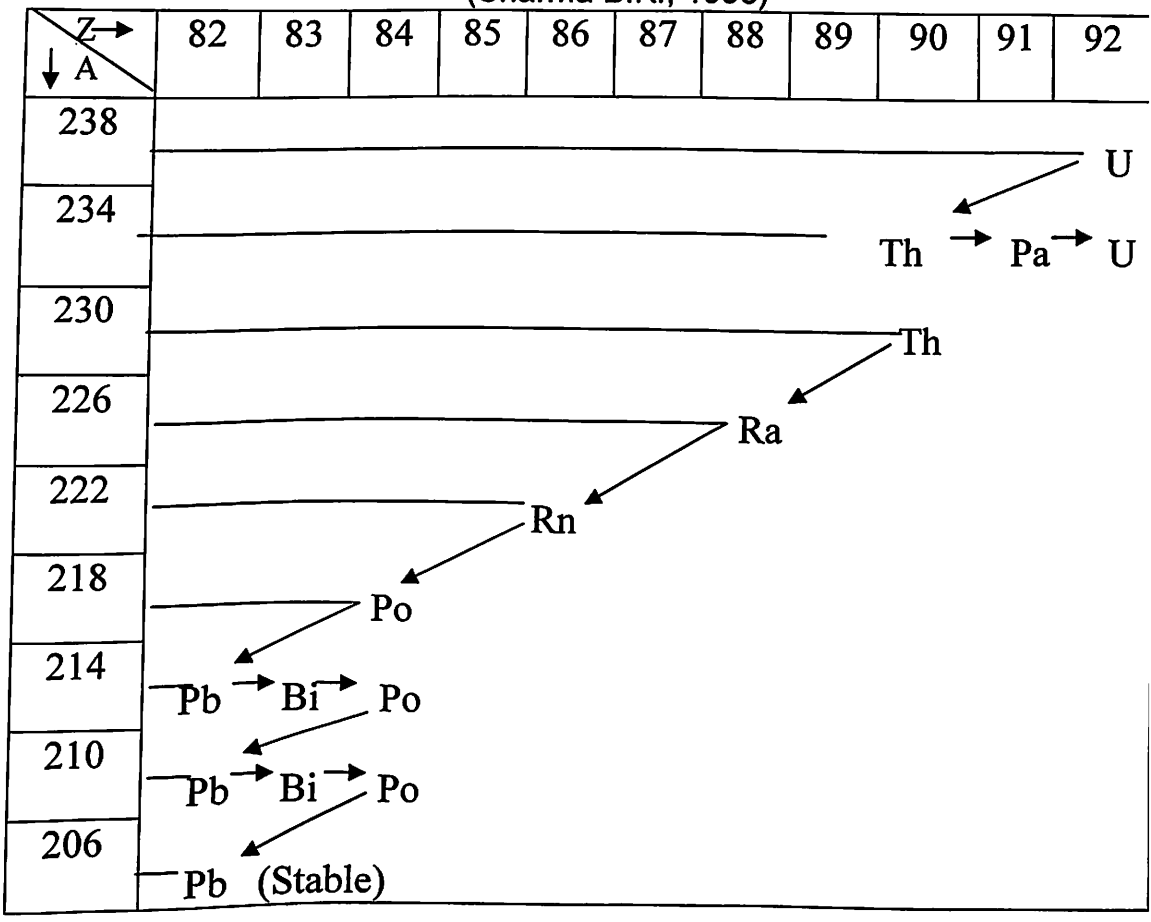


Table1.1: Radioactive series of ^{238}U(Sharma B.K., 1996)

NAME AND SYMBOL	ATOMIC WEIGHT	ATOMIC NUMBER	RADIATION	HALF LIFE PERIOD
Uranium (U)	238	92	α	4.5×10^9 years
Thorium (Th)	234	90	β	24.6 days
Protactinium (Pa)	234	91	β	1.14 min.
Uranium (U)	234	92	α	2.7×10^5 years
Thorium (Th)	230	90	α	8.3×10^4 years
Radium (Ra)	226	88	α	1590 years
Radon (Rn)	222	86	α	3.8 days
Polonium (Po)	218	84	α	3.0 min.
Lead (Pb)	214	82	β	26.7 min.
Bismuth (Bi)	214	83	β	19.7 min.
Polonium (Po)	214	84	α	1.5×10^{-4} sec
Lead (Pb)	210	82	β	22 years
Bismuth (Bi)	210	83	β	4 days
Polonium (Po)	210	84	α	140 days
	206	82	-	Stable

Fig 1.2 : ^{232}Th decay chain, including ^{220}Rn and its decay products (Sharma B.K., 1996)

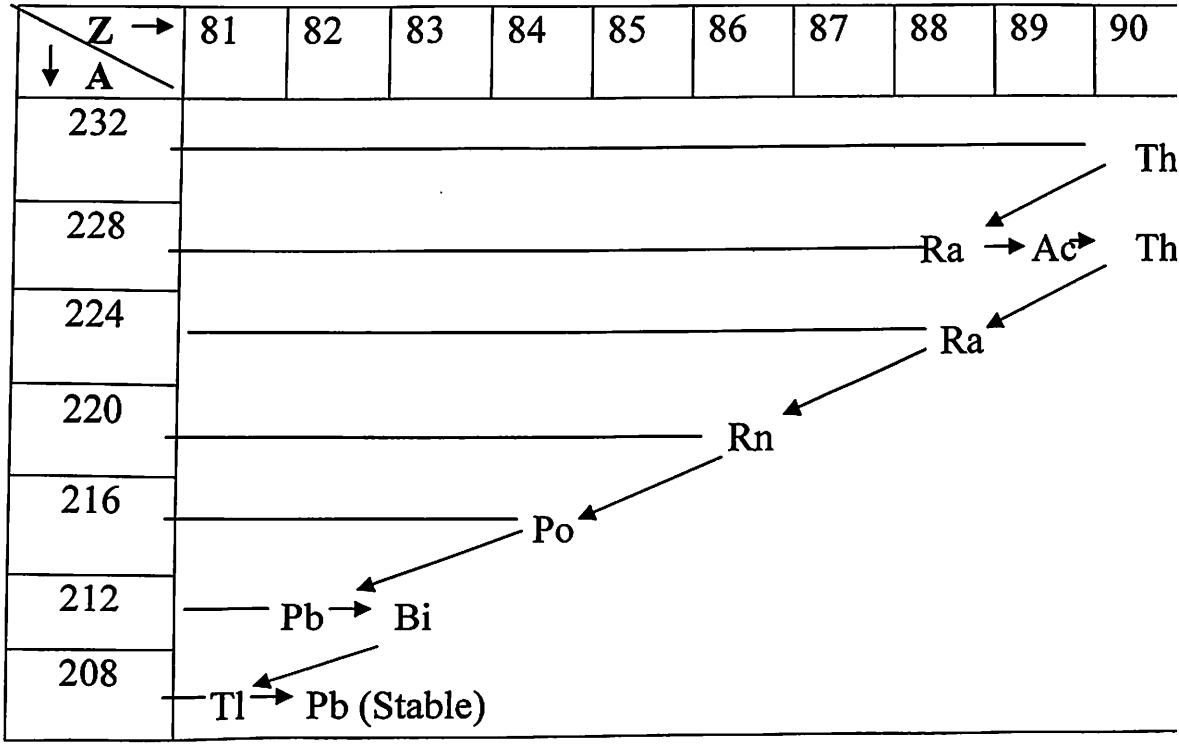


Table1.2 : Radioactive series of ^{232}Th (Sharma B.K., 1996)

NAME AND SYMBOL	ATOMIC WEIGHT	ATOMIC NUMBER	RADIATION	HALF LIFE PERIOD
Thorium (Th)	232	90	α	1.4×10^{10} years
Radium (Ra)	228	88	β	6.7 years
Actinium (Ac)	228	89	β	6.13 hours
Thorium (Th)	228	90	α	1.9 years
Radium (Ra)	224	88	α	3.65 days
Radon (Rn)	220	86	α	55 sec
Polonium (Po)	216	84	α	0.16 sec
Lead (Pb)	212	82	β	10.6 hours
Bismuth (Bi)	212	83	α	1 hour
Thallium (Tl)	208	81	β	3.1 min
Lead (Pb)	208	82	-	Stable

Fig 1.3 : ^{235}U decay chain, including ^{219}Rn and its decay products (Sharma B.K., 1996)

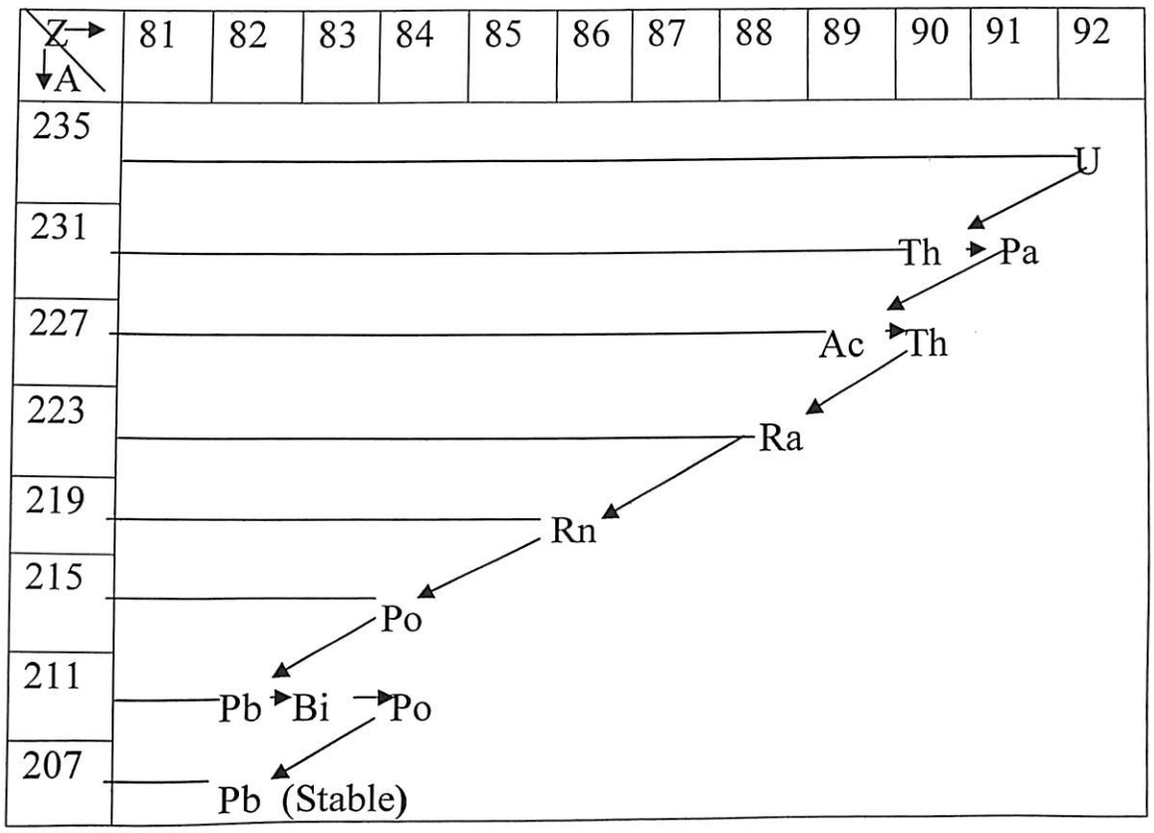


Table 1.3 : Radioactive series of ^{235}U (Sharma B.K., 1996)

NAME AND SYMBOL	ATOMIC WEIGHT	ATOMIC NUMBER	RADIATION	HALF LIFE PERIOD
Uranium (U)	235	92	α	7.3×10^8 years
Thorium (Th)	231	90	β	25.6 hours
Protoactinium(Pa)	231	91	α	3.28×10^4 years
Actinium (Ac)	227	89	β	21.6 years
Thorium (Th)	227	90	α	18.17 days
Radium (Ra)	223	88	α	11.68 days
Radon (Rn)	219	86	α	3.92 sec
Polonium (Po)	215	84	α	1.83×10^{-3} sec
Lead (Pb)	211	82	β	36.1 min
Bismuth (Bi)	211	83	β	2.16 min
Polonium (Po)	211	84	α	0.52 sec
Lead (Pb)	207	82	-	Stable

from the decay of ^{224}Ra in the ^{232}Th decay chain. The dispersion of these gases in the ground is quite different owing to their different half lives, 3.8 days for radon compared with 55 secs. for thoron. In contrast to thoron, radon is able to move considerable distances from its parent during its lifetime.

It can diffuse readily out of surface soil into the atmosphere and into the basements and living areas in houses. In terms of environmental alpha-radioactivity, ^{238}U decay chain and radon are considered to be more important than the ^{232}Th decay chain and thoron. In dry non-metallic solids and still air, the movement of radon is purely by diffusion, whereas in the ground the situation is more complex. Here the movement is by a combination of diffusion and convection or pressure-driven flow. Sources of Uranium not only lie deep underground but also in soils. Its presence in soils, even in very small amount contributes to the amount of radon rising to the surface and in to the air above.

1.2. SCOPE OF RADON STUDIES:

Radon emanation and migration in the earth and in the atmosphere have been the subjects of numerous studies.

1.2.1. Hydrologic studies

Because of radon's rapid loss to air and comparatively rapid decay, radon is used in hydrologic research that studies the interaction between ground water and streams. Any significant concentration of radon in a stream is a good indicator that there are local inputs of ground water.

1.2.2. Geologic studies

Some researchers have looked at elevated soil-gas radon concentrations, or rapid changes in soil or groundwater radon concentrations, as a predictor for earthquakes (Liu et al., 1975; Noguchi and Wakita, 1977; Mogro-Campero et al.,1980; Ramola et al., 1990; Virk and Sing, 1993; Virk, 1996). Anomalous radon changes in ground water and soil gas have been reported for a number of earthquakes at stations located several hundred kilometres from their epicentre (Ulomov and Mavashev, 1967; Sadovsky et al., 1972). Results have been generally unconvincing but may ultimately prove to have some limited use in specific locations.

Radon soil-concentration has been used in an experimental way to map buried close-subsurface geological faults, because concentrations are generally higher over the faults. Similarly it has found some limited use in geothermal prospecting.

1.2.3. Atmospheric studies

Radon emanation from the soil varies with soil type and with surface uranium content, so outdoor radon concentrations can be used to track air masses to a limited degree. This fact has been put to use by some atmospheric scientists.

Radon is a known pollutant emitted from geothermal power stations, though it disperses rapidly, and no radiological hazard has been demonstrated in various investigations. The trend in geothermal plants is to

reinject all emissions by pumping deep underground, and this seems likely to ultimately decrease such radon hazards further.

Radon has been used in variety of ways in medicine also. Published reports on the use by the USA military in nasopharyngeal irradiation in World War II are excellent case studies (Warlic, 1996).

1.3. HEALTH EFFECTS AND EPIDEMIOLOGY

Radon levels in the outdoor air are relatively low however, when Radon enters a house it can build up to levels which pose a significant health risk to the occupants. Radon is one of the earliest known occupational carcinogens among the radioactive elements (Phillips and Denman, 1997).

Radon gas is chemically unreactive. It does not react with body tissues. While some inhaled Radon does dissolve in the body fluids, the resulting concentration is so low that the radiation dose from the Radon gas itself is negligible. It is the Radon decay products that cause the damaging health effects when breathed in. The greater the amount of Radon in the air, the greater is the potential of developing lung cancer

When Radon undergoes the process of radioactive decay, new particles like Polonium, radioactive Lead and Bismuth are created. These Radon decay products are also called "Radon daughters" and unlike to the Radon gas they are solid particles. The problem is, that the Radon daughters are radioactive substances, too! Most of the Radon daughters

become attached to tiny dust particles (aerosols) in the indoor air. When these particles are inhaled, a fraction of them is deposited in the lungs. Inside the lung, Radon daughters emit alpha particles that are absorbed in the nearby lung tissues. The resulting radiation dose increases the risk of lung cancer.

The build up of these radon daughter in the lung and their subsequent movement through the body of the lymphatic system and blood vessels may result not only in lung cancer but other cancers also throughout the body. The smoking may be considered an addition to the inhalation of radon daughters. Henshaw et al. (1990) claimed that indoor radon exposure is associated with the risk of leukemia and certain other cancers such as melanoma and cancers of kidney and prostrate. The tissues at risk from exposure to Rn and its progeny include the epithelium of bronchi, Segmental bronchioles and alveolar membranes The most important tissue is the bronchiode epithelium, which is the site of most lung cancers thought to be induced by radiation.

Over the last two decades a quite few studies on association between indoor radon level and lung cancer incidence have been made. Although some studies are inconclusive, some others indicate a positive correlation between radon levels and lung cancer (Archer et al.,1973; Waxweiler et al.,1981; Sevc et al., 1988; Henshaw et al., 1990; Pershagen

et al., 1993; Bochicchio et al., 1998; Fisher et al., 1998; Field et al., 2000; Ahad et al., 2003). Some other studies, on the other hand have shown an absence of any such correlation (Cohen,1987; Toth et al., 1998; Luckey, 2000).

All of the environmental radon epidemiology studies have serious methodological problems. One problem involves uncertainties in dosimetry. This arises from difficulty in locating former residences, in measuring the cumulative dose to assign to each individual in case:control studies, as well as the very important question as to what dose to assign to the TBE cell from which radon-induced lung cancer is thought to arise. The new methods being used for radon measurements should provide some help on the data collection side. Remaining major problems common to all epidemiology studies are the difficulty in identifying and controlling for the presence of confounding variables, such as smoking (active and passive), along with the problems in identifying and correcting for various selection and ascertainment biases.

Because of the uncertainties, the size of the study group needed to establish statistical confidence is so large that the power of the statistical tests is often too weak to establish a significant difference between no risk from residential radon and increased risk at the level found in miner studies. A reasonable conclusion from these studies is that deleterious effects of naturally-occurring background levels, if present, are too small to detect in most residential radon epidemiology studies. Evidence derived from

ecologic studies has been critically reviewed recently with special relevance to radon. (Stidley C.A. and Samet J.M., 1993). The authors conclude that the 15 largest ecologic studies they reviewed did not contribute to better understanding of the quantitative risks of indoor radon.

1.4. SOURCES OF RADON

The Original source of Rn^{222} is from the natural radioactive decay of U^{238} and Ra^{226}, which are commonly occuring elements in the crust of the earth.

1.4.1. Soils and Rocks as the source of Radon

Certain soils and rocks that contain high levels of uranium also store natural deposits of radon.These are

a)Granite

b)Phosphate

c)shale

d) Pitchblende

Radon is continually being formed in soil and released to air as a result of the extended half-lives of uranium and radium and their abundance in the earth's surface. Atmospheric radon is not an issue of health concern because the radon is rapidly diluted to low levels by circulation throughout outdoor air.

There are no sinks for radon, and it is estimated that only negligible quantities escape to the stratosphere. As a result, the ultimate and sole fate of $radon^{222}$ is transformation or degradation through radioactive decay.

Radon decays only through normal radioactive processes, meaning, an atom of radon emits an alpha particle resulting in an atom of Po^{218}, which in turn, also undergoes alpha particle emission to produce other radon progeny.

The radon concentration in the soil is a function of

a) The radium concentration

b) The soil moisture content

c) The soil particle size.

d) The rate of exchange of soil-entrapped air pockets with the atmosphere.

The normal soil gas-radon measurements are in the range of 270-675 Pci radon ^{222}/L of air.

After radon is produced at the soil particulate level from the radioactive decay of radium, it is released into small air or water containing pores between soil and rock particles.

This transportation of radon throughout soil is primarily accomplished through alpha recoil and the mechanical flow of air and water throughout the soil.

Transporation throughout soil and within these pores is also somewhat facilitated by diffusion and convection, the diffusion constants for radon in air and water, 10-2cm 2/sec and 10-5cm 2/sec, respectively, indicate that diffusion of radon is a relatively slow process and the movement of radon is therefore not significantly effected by this mechanism.

After radon is released into the pore spaces, the efficiency of its eventual release into ambient air, termed exhalation,is a function of

a) The soil porosily

b) The concentration of radon in the soil/gas pore.

c) Meteorological factors, including precipitation and atmospheric pressure.

Following the release into ambient air, the dispersion of radon is primarily determined by atmospheric satellite, including vertical temperature gradients and direction of wind's force, and turbulence.

1.4.2. Water as the source of radon

Ground water that is in contact with radium containing rock and soil will be a receptor of radon emanating from the surroundings.

In ground water,radon transportation in determined primarily by :

a) Diffusion patterns

b) The direction of the water's mechanical.

The solubility of radon in water is relatively low,and with its short radioactive half life, much of it will decay before it has the opportunity of release from the groundwater.

When radon containing ground water reaches the surface by natural or man-made forces, the radon will inevitably be outgassed into the atmosphere.

Although the majority of radon present in groundwater will decay prior to its arrival at the surface, groundwater is nevertheless considered the

second most prominent source of environmental radon and has been estimated to contribute approximately 5x 108 Ci radon –222 per year to the atmosphere . Radon is also minimally released from water located at or slightly beneath the ocean's surface.

Radon concentrations in surface water supplies are usually relatively low. Since municipal water supplies are typically aerated the result in diminished radon levels.

Rural household wells may have potentially high levels of radon contamination .Deep aquifers have highly variable radon levels. Levels depend on:-

a) Uranium content of the rock

b) Distribution of the aquifer relative to the rock.

c) Groundwater flow patterns.

1.4.3. Natural gas as the source of radon

Natural gas may also be a source of radon. Like ground water, natural gas can accumulate Rn gas from Radium content in the rock structures, surrounding the gas formation. It is estimated that at a typical residential gas use and air exchange rates, even for unventilated gas appliances, the contribution to indoor Rn from natural gas is less than 4 $Bq.m^{-3}$ (Ramachandran and Subba Ramu, 1990).

1.4.4. Building materials as the source of radon

Building materials are more easily characterised as indoor radon source than the soil or rock. Table 1.4 gives the radoactivity content in

building materials used for building construction in India (Ramachandran T.V., 1998). Ingersoll in 1983 has measured the Rn emanation rates for a number of building materials. In concrete , the estimated emanation rate (average) is 7.7×10^{-6} $Bq.Kg^{-1}.Sec^{-1}$. For gypsum, it was found to be about 6.3×10^{-6} $Bq.Kg^{-1}.Sec^{-1}$ (Ingersoll, 1983).

Table 1.4: Radioactivity content in building materials used for building construction in India (Ramachandran, 1998)

Material	Activity in $Bq.Kg^{-1}$			
	K^{40}	Ra^{226}	Th^{232}	Radium Equivalent
Cement	5 - 385	16 - 377	8 - 78	40 - 440
Brick	130 – 1390	21 - 48	26 - 126	88 - 311
Stone	48 - 1479	6 - 155	5 - 412	24 - 221
Sand	5 - 1047	1 - 5017	4 - 2971	22- 7759
Granite	76 – 1380	4 - 98	103 - 240	25 - 525
Clay	6 - 477	7 - 1621	4 - 11	11 – 1865
Fly ash	6 - 522	7 - 670	30 - 159	56 - 773
Lime stone	6 - 518	1 - 26	1 - 33	5 - 148
Gypsum	70 - 807	7 - 807	1 - 152	59 - 881

1.5. HOW RADON ENTERS A BUILDING

The radon entry points for the pressure driven flow of Rn bearing soil gas depend on a number of factors, like the types of house substructures, construction practice used, the age on the structure integrity of the house (Ramachandran and Subba Ramu, 1990).

Because Radon is a gas, a fraction of the Radon produced in the soil can find its way into a building through cracks in the foundation, loose-fitting pipe penetrations, sump openings, crawl spaces etc. During colder seasons when windows are closed and heaters are on the difference in temperature between the indoor air and the outdoor air causes a thermal stack effect. Warm air rises in a house and creates a vacuum in the lower portions of the building. This suction on the lower level, such as a basement, draws Radon gas from the soil into the building.

The concentration of Radon and Radon daughters in the indoor air depends on:

- the amount of radium in the soil
- cracks in the walls and foundation of the building
- loose-fitting pipe penetrations
- the impermeability between the different floors
- the existence of a concrete floor in the cellar

The concrete floor and walls in the basement slow down the movement of Radon from the soil into the building. However, cracks in the

floor, wall slab joints, and openings around plumbing and electrical conduits allow Radon to enter a building.

1.5.1. Radon-Resistant Features at Home

Radon-resistant techniques (features) may vary for different foundations and site requirements. EPA's Model Standards (and architectural drawings) explain the techniques to the builders. According to this Standard Model, a house to be built to be radon-resistant, it will include the followings basic elements (Fig. 1.4):

A. **Gas-Permeable Layer:** This layer is placed beneath the slab or flooring system to allow the soil gas to move freely underneath the house. In many cases, the material used is a 4-inch layer of clean gravel. This gas-permeable layer is used only in homes with basement and slab-on-grade foundations; it is not used in homes with crawlspace foundations.

B. **Plastic Sheeting:** Plastic sheeting is placed on top of the gas-permeable layer and under the slab to help prevent the soil gas from entering the home. In crawl spaces, the sheeting (with seams sealed) is placed directly over the crawlspace floor.

C. **Sealing and Caulking:** All below-grade openings in the foundation and walls are sealed to reduce soil gas entry into the home.

D. **Vent Pipe:** A 3- or 4-inch PVC pipe (or other gas-tight pipe) runs from the gas-permeable layer through the house to the roof, to safely vent radon and other soil gases to the outside.

E. **Junction Boxes:** An electrical junction box is included in the attic to make the wiring and installation of a vent fan easier. For example, you decide to activate the passive system because your test result showed an elevated radon level (4 pCi/L or more). A separate junction box is placed in the living space to power the vent fan alarm. An alarm is installed along with the vent fan to indicate when the vent fan is not operating properly.

Generally speaking, to avoid a state of low pressure inside the house, which may lead to the suction of Radon gas from the soil into the building.

The main reasons for low pressure inside a building are:

- Windows which are opened at the lee side of the house
- Mechanical exhaust devices in kitchens, bathrooms...
- Drawing chimneys
- Insufficient air supply to burners for oil, gas or wood

Indoor Radon can be reduced to safe levels by means of appropriate techniques which in many cases are simple and inexpensive to accomplish. Of course, the method for Radon reduction (also called: Radon mitigation) is dependent on the degree of Radon that was found through precise measurements.

1.6. A BRIEF REVIEW ABOUT RADON STUDIES

In the recent past environment scientists have been expressing concern about the radiation hazards from radon and its decay products

inside dwellings (Cliff, 1978; Nero, 1983). It has been recognized that radon daughters are the probable causative agents of the high levels of lung cancer found in Uranium miners. The U.S. Environmental Protection Agency estimates 10,000 deaths per year in the U.S. from indoor radon.

A larger number of indoor radon surveys carried out in several countries (UNSCEAR 1977, 1988, 1993) reveal the extremely large variation in the radon levels in the houses, covering a range from a few Bqm^{-3} to 100,000 Bqm^{-3}. Almost all the countries in the world are engaged in the measurement of radon levels in the environs of different geological areas. These include radon measurements in soil, rocks, atmospheric air and the dwellings. Numerous measurements of the activity concentrations of ^{222}Rn and its short lived decay products in different countries have been published in recent years (Keller et al., 1982, Straden et al., 1979, Swedjemark, 1978, Nazaroff and Doyle, 1985, Liu et al., 1993 papastefanou et al., 1994, khan et al., 1997). Many groups in India too are engaged in the study of indoor radon measurements in dwellings for health risk assessments and its control. A large group of workers at BARC have been actively engaged for radon mapping all over the country (Subba Ramu et al., 1990; Eappen, 1994; Raghavayya, 1994; Paul et al., 1994; Eappen et al., 2001; Ramachandran et al., 2006). Apart from BARC, presently, several active groups of workers are engaged in radon studies in India. They are from Guru Nanak Dev University, Amritsar (Ramola et al.,1987; Singh et al., 1991; Ramola et al.,1992; Kumar et al.,1994; Virk, 1997; Singh et al., 1998), Aligarh Muslim

University (Khan et al., 1987; Khan et al., 1989; Azam et al., 1998), Regional Engineering College (REC), Kurushetra (Chauhan et al., 2001), Defence Laboratory, Jodhpur (Mittal et al., 1998), North Eastern Hill University, Shillong (Dwivedi et al., 1996; Sen et al., 1998; Dwivedi et al., 2001), Garhwal University (Ramola et al.,1995; Ramola et al., 1997, Ramola et al.,2003), Gauhati University, Guwahati (Das et al., 1997; Deka et al.,2001; Deka et al.,2003a; Deka et al.,2003b), Osmania University, Hyderabad (Reddy et al., 1998).

There are also numerous groups to study radium content in soil samples and radon exhalation rates from soil samples (Sannappa J. et al., 1999; Azam Amir et al., 2006; Chauhan R. P. et.al., 2006; Kumar Rajesh et al., 2006; Singh et al., 2007).

1.7. HIGH LEVEL RADON AREAS AND DWELLINGS WORLD WIDE

There are many areas around the world where exceptionally high level radon concentrations have been observed. For examples

1) In Tuwa region of India, the radon levels were up to 420 $KBqm^{-3}$ in dwellings (Joshi and Mishra, 1980).

2) Radon concentrations of more than 300 $Bqm^{-3.}$ were found in some villages of Amritsar, Panjab (Malhotra R.,2000).

3) In a village in Alpine region of western Tyrol, Austria very high levels of radon have been reported (Ennemoser et al., 1994). The measurements made indoors, for example during the period January-April,

1992, showed radon concentrations of 20 to 88,000 Bqm^{-3} on the ground floor and 21 to 210,000 Bqm^{-3} in the basement.

4) An extremely high radon level, exceeding 410 $KBqm^{-3}$, has been measured in the basement of a house in Prescott. In the state of Arizona, which had a well opening in the basement with extremely high radon concentration of 3.5 M Bqm^{-3} in the well water has been reported (Kearfott, 1989).

The major motivation for initiating such studies are to assess the risk to human population from indoor Rn^{222}. The seventh generation decay product of uranium - radon, in indoor environment, contributes somewhat more than one half of the collective effective dose received by human population from all sources of exposure. Precisely out of 98% of average radiation dose received by man from natural sources, about 52% is due to breathing of radon, thoron, and progeny present in the dwellings (UNSCEAR,1993).

1.8. AIMS AND OBJECTIVES OF THE PRESENT WORK:

With the growing understanding of the role of radon and its daughter products as a major source of radiation exposure, the importance of large number of estimation of radon concentration in various parts of the country is realized. There are many Federal, State, university, and private organizations now performing measurements or planning measurement programs. It is important for these different groups to follow consistent procedures to assure accurate and reproducible measurements and to enable valid intercomparison of measurement results from different studies. Although results of indoor radon level measurements in various parts of

North Eastern Region of our country (, Dwivedi and Ghosh, 1991; Dwivedi et al, 1995;; Dwivedi et al, 1996; Mishra et al., 1998; Das et al., 1997; Deka et al.,2001; Deka et al.,2003a; Deka et al.,2003b; Deka et al.,2006)have been reported, the information about the contributions to radon levels from different sources like soil, rocks, different types of building materials is still scanty in literatute. Nero et al. (1990) estimated that soil contributes more than 90% of Rn in houses. Thus the main objectives of the present work will be to estimate the radon exhalation rates from some soil samples collected from different areas of Noonmati, Numaligarh and Duliajan areas of Assam.

If uranium rich material lies close to the surface of earth there can be high radon emanation rates, resulting in high radon exposure hazards. The measurement of radon thus necessitates the need for radium estimation in the parent source for the public health risk assessments. Hence one of the objectives of the present study to estimate radon content in the soil samples collected from different areas of Noonmati, Numaligarh and Duliajan areas of Assam. From these measurements it can be made of co-relation between radium content in soil and radon exhalation rates if any.

Another objective of this study is to generate primary data, which will help further studies in different aspects of radon studies.

2.1. INTRODUCTION

Track-etch technique using Solid State Nuclear Track detectors (SSNTDs) is considered to be the most reliable method for time-integrated and long term measurements due to its simplicity and low cost (Alter and Price, 1972; Frank and Benton, 1977; Mishra and Ramachandran, 1995). In the present investigation Particle Track Analysis technique is used. Hence a brief description of the method is given below.

SSNTDs are dielectric materials like mica, glasses, synthetic plastic etc., which record and permanently store the trajectory of the fast moving particles with high linear energy transfer (LET) and fast moving neutrons. Most of the plastic detectors do not have a fading problem and are insensitive to beta and gamma rays. These characteristics are very attractive for the purpose of their use in the field of radiation protection.

2.2. PARTICLE TRACK ANALYSIS METHOD:

This method is based on the changes in physical and chemical properties of matter by passage of charged particles through an insulating solid by creation of radiation damage, the tracks. These regions distinguish themselves from the surrounding undamaged bulk in the from of pits or holes and are preferentially attacked by suitable chemical reagents, called etchants. These etched pits are enlarged to a diameter of 10^{-4} to 10^{-3} cm and can be conveniently observed as particle tracks under an optical microscope. Each insulator, used as a solid State Nuclear Track Detector (SSNTD) shows tracks only for incident ions which produce primary

ionization along the path as a rate which is greater than a characteristic critical value for it (Fleischer et al., 1967) Thus it is possible to use this effect selectively to detect highly ionising particles even in the presence of large amounts of other radiations. This method was applied for uranium estimation in water by Fleischer and Lovette (1968) and in plants and soil by Goswami et al. (1977)

2.2.1. Characteristics of Track Storing Materials:

Almost any insulating material can store tracks of particles; but no tracks have been observed in any metal or good conductors. Materials with electrical resistivity of about 2,000 ohm-cm or more are capable of recording tracks indefinitely. Metals and semi conductors have electrical resistivity of the order of 10^{-6} ohm-cm and 2,000 ohm-cm. They can not store tracks (Fleischer et al., 1965).

One of the most striking features of all the track-recording materials is their specific threshold for recording tracks of various ions. A series of measurements reveals that there exists both a charge and an energy threshold for a given detector (Fleischer et al., 1967; Fleischer et al., 1964; Fleischer et al., 1969).

The usefulness of the threshold characteristics can be visualized by considering Fig. 2.1 (Fleischer et al., 1975), where the damage density in various nonconducting solids are plotted as a function of velocity and of energy per nucleon for a number of nuclei. The figure indicates a wide variation in response of various detectors to different nuclei. Thus heavy nuclides at energies 100 MeV/nucleon leave tracks in all detectors,

while alpha tracks (He-tracks) are observable only at low energies in CN and at very low energies in lexan. The proton tracks have been observed (Fisher, 1975; Fleischer et al., 1969) only in CN. Though the thresholds for detectors CR-39 and LR-115 (type-II) are not shown in the figure, they lie near the CN detector.

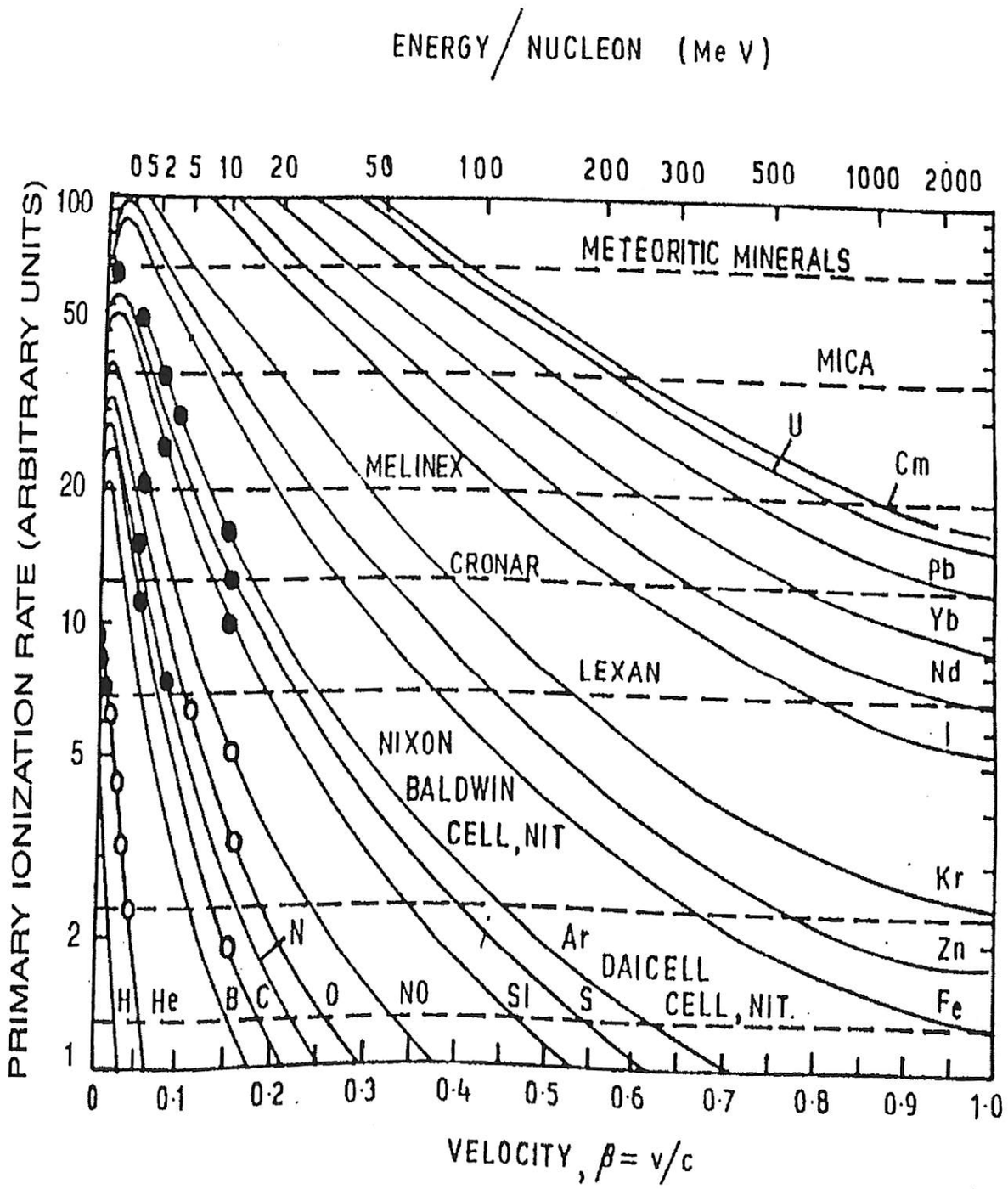


Fig. 2.1: Damage vs. Velocity for different charged particles. Each detector has a level below which no tracks are etched and one above which all particles create tracks. The experimental points for accelerator ions in Lexan Polycarbonate are given as open circles for zero registration and as filled circles for 100 %.Thresholds for other detectors are also indicated (Fleischer et al., 1975).

Due to the threshold selectivity of the detectors, one can suitably choose them for specific experiments to avoid background problems. In the present case α-from Rn and Tn decays are only observed. They have energies 1.0 to 4.0 MeV (Ramachandran et al., 1989)

2.2.2. Track formation in solids:

Most tracks are ionisation induced defects – the results of the interaction of a charged particle with the electron attached to the atom in the detector. They are narrow (~ 50 Å radius), stable, chemically reactive sites of strains, composed mainly of displaced atoms. A fast atom of atomic no Z passing through a solid would soon turn in to an ion due to its interaction with the surrounding electrons. The ion acquires a net positive charge which is given as (Fleischer et al., 1975).

$$Z^* = Z\,(1 - e^{-130\beta/z^{2/3}})$$

Where β is the speed of the ion relative to that of the light. The type of collision of the ion inside the solid depends on its velocity. At high velocities, the dominant interaction is the electrical force between the ion and electrons attached to the atoms within the solid. The effect of this force is either (a) to excite electrons to higher energy levels, or (b) to loosen them from their atoms and eject them.

The ejected electrons, called delta rays, can produce further excitation and ionisation if it is carrying enough energy. The original

ionisation and excitation occur close to the path of the ion, while secondary excitation and ionisation can spread to larger areas. However, most of the ejected electrons are confined around the core of the track region.

When an ion slows down in a solid, it captures orbital electrons one by one and its velocity becomes comparable to the orbital velocities of less tightly bound electrons. Thus below about 50 KeV/amu, the more abundant mode of energy loss is interactions between the moving ions with whole atoms or ions in the stopping medium. The damage produced by atomic collision consists of displaced atoms and the resultant vacancies.

A quantitative calculation of total damage along a track depends on the relative importance of (a) the primary damage that results from the excitation and ionisation caused directly by the heavy ions and (b) of that part of the secondary damage which is caused by the delta-rays during their passage close to the path of the ion. Experiments show that in inorganic solids, the major source of radiation damage is the primary ionisation, while in polymers; both primary and secondary ionisation and excitation contribute in track formation. Excitation can lead to chain breaks in polymers and hence to a reduced molecular weight, which in turn, helps to increase the etching rate in them (Fleischer et al., 1975).

2.2.3. Track formation mechanism:

The theoretical framework for the track formation mechanism has not yet been fully worked out nor universally agreed upon. There are many theories to explain the mechanism of track formation, the validity of each model may be judged by critical appraisal of parameters such as charge,

mass and the energy of the incident particles which are able to form etchable tracks.

Track formation in solids depends upon the total rate of energy loss (dE/dx) of the track forming particles. For each solid there is a critical rate of energy loss such that particles losing energy more rapidly than this value produce continuous tracks with unit efficiency, while, those depositing appreciably less energy per unit length produce no track. The value of this critical energy loss varies from solid to solid; but in a given material, it is the same for all particles (Fleischer et al., 1967)

Particles loss energy in different ways as it passes through a solid. Several methods have been put forward to explain track formation mechanism in SSNTDS, predicting different modes of energy loss, which involve the conception of deposition of energy in a highly restricted region. These models (Fleischer et al., 1975) are:

(i) Direct atomic displacement model,

(ii) Thermal spike model,

(iii) Total energy loss model,

(iv) Secondary energy loss model,

(v) Restricted energy loss model,

(vi) Primary & secondary energy loss model.

(vii) Primary ionization model or ion explosion model.

Some of these models unrealistic and some are not quite adequate to explain the experimental data. The primary ionization model or ion

explosion spike model is quite satisfactory. Fleischer et al. (1965) describes the various conditions to be fulfilled for track formation by ion explosion model.This model is based on the postulate that the particle first loses energy to the electrons of the atoms in its path in the solid.The energized electrons leave the region as positive ions which repel each others. This causes the alteration on to the structure of the solid.

2.2.4. Ion Explosion Spike or Primary Ionization Model :

When a charged particle passes through a solid, there is a burst of ionizations along its path resulting in the formation of an electrostatically unstable array of adjacent ions. These ions displace one another from their normal sites into interstitial position (Fig 2.2a). Thus a local electrostatic stress is produced in the region (Fig 2.2b). The elastic relaxation (Fig 2.2c), that follows spread the strain mode widely to create long range strains.

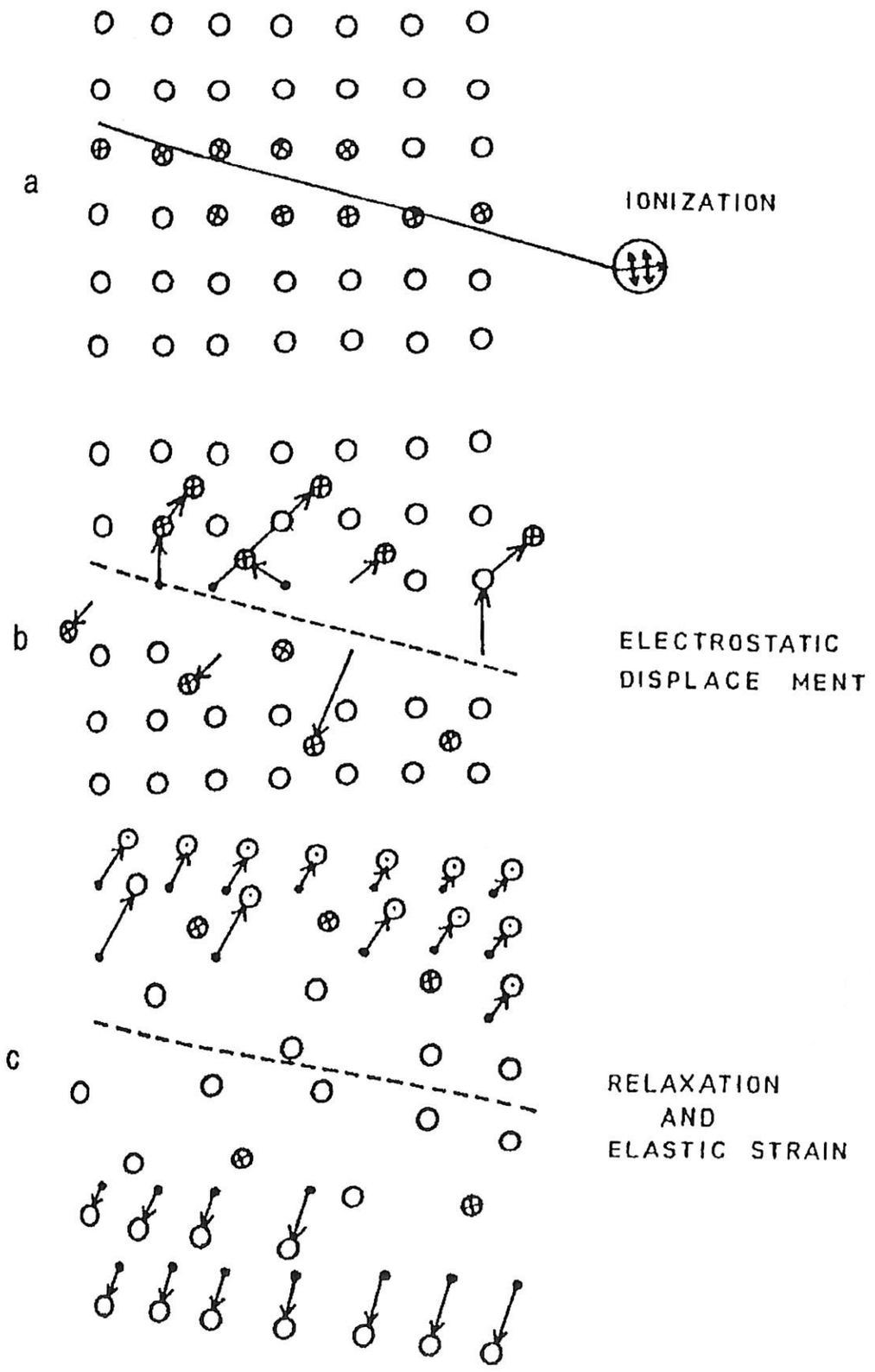


Fig. 2.2: The ion explosion Spike model for track formation in inorganic solids. (Fleischer et al., 1975)

Fleischer et al. (1965) describes the various conditions to be fulfilled for track formation by ion explosion model.

I) The coulomb repulsive forces within the ionized regions must be greater than the lattice binding forces i.e. the local electrostatic stress must be greater than the local mechanical strength. Mathematically this condition can be expressed as

$$n^2 > s = E\varepsilon_0 a_0^4 / 10e^2 \qquad (2.1)$$

Where n = average charge on the ion

e = electric charge

a_0 = interatomic spacing

ε_0 = dielectric constant

E = Young's modulus

s = stress ratio

II) The second condition describes that the tracks can be formed only if the electrons can not drain into the region from which the positive ions have been displaced by repulsion in less than one vibration time i.e. 10^{-13} seconds. This explains that the track will form in the insulators and not in metals. If the density of free electrons is n_e and the number of ionization per atomic plane is n_a then according to Fleischer et al. (1965) the radius of the region to be drained is given by

$$\pi R^2 a_0 n_e = n_a \qquad (2.2)$$

The time for electron to diffuse a distance R is R^2/D where D is diffusion constant and is given by Einstein relation

$$D = \mu_e KT/e$$

where μ_e = electron mobility.

Thus tracks will be formed only if

$$n_e < en_a / \pi a_0 \mu_e KTt \qquad (2.3)$$

where K = Boltzman's constant

T = absolute temperature

t = diffusion time i.e.Lattice vibration time.

III) According to authors of this ion-explosion model the tracks will not be formed in those materials whose hole mobility is greater than $\cong$ $10cm^2$/volt.sec. If μ_p is greater than R^2e / 4KTt, where R is the track radius of the holes will diffuse in the track radius and the tracks will not be formed.

The following equation derived by Bethe (Bethe, 1930) for primary ionization produced by charged particles while passing through atomic hydrogen accounts for all the etching rate measurements made so far (Price and Fleischer, 1971)

$$J = az^{*2}/\beta^2 [\{\ln \beta^2/1-\beta^2\} + k - \beta^2 - \delta(\beta)] \qquad (2.4)$$

where z^* = effective charge of the particles,

a = a constant depending on the nature of the medium,

k = a constant depending on the plastic and etching condition,

β = ratio of the velocity of the particle to that of light,

$\delta(\beta)$ = a relativistic correction term on account of polarisation of the medium by the electromagneticfield of the moving particle.

2.2.5. Restrictions in track formation :

Track formation will not be possible if electrons from the adjacent material can attach themselves to the ionized atoms formed due to the passage of an energetic charged particle along its path. Due to large abundance of free electrons (~10^{20} cm^{-3}) in metals, this is actually the case, hence no track will be formed in metals and good semiconductors.

The ionized region along a track is essentially a region of high concentration of holes, which may move away, there by suppressing permanent track formation. It is seen that at room temperature, if in a material, the track mobility is less than about 10^2 cm^2/v/Sec, tracks can be formed. This is why metals and many semiconductors including silicon and germanium, are not track storing materials.

2.2.6. Track formation in Plastic detectors:

Dielectric materials, such as glass, mica and plastic have been extensively used as solid state Nuclear Track Detectors for particle identification and estimation of concentrations. While the former two are used for fission fragments, various organic materials- polycarbonates and polymers (plastics) are used for studies of both fission fragments and alpha

particles. The most widely used plastics are cellulose nitrate (Diacell, LR-115, CA-80), Cellulose acetate butyrate, Lexan and Macrofol polycarbonate.

CN i.e. Cellulose nitrate ($C_6H_8O_9N_2$) is known to record the tracks of low energy protons, deuterons, titrons and alpha particles(Fleicher et al., 1975). This plastic is known for the following original properties (Pilione and Carpenter, 1981; Fantini, 1985)

(i) A high sensitivity with minimum detectable ratio (Z/β~30)

(ii) An easy and very simple etching possibility.

(iii) A very high precision of sheet thickness (<1 μm)

(iv) An excellent flexibility, permitting to fill exactly non-plane surfaces.

(v) Good reproducibility regarding different batches.

2.2.7. Charged Particle Tracks in Polymers:

The passage of heavily charged particles results in the scission of some of the polymeric chains (Fig. 2.3). A thermal spike along the trajectory of the charged particles causes localized melting, and this, together with excitation caused by the ionization, leads to chain breaking and production of new chain ends. This also produces highly reactive species such as free radicals, which may be quite long-lived. When the detector is subsequently treated with an appropriate etchant, the area of scission is dissolved and the resulting hole can become enlarged by factors of 10^2-10^3. The damage trails thus become quasi-continuous as well as permanently fixed as tracks.

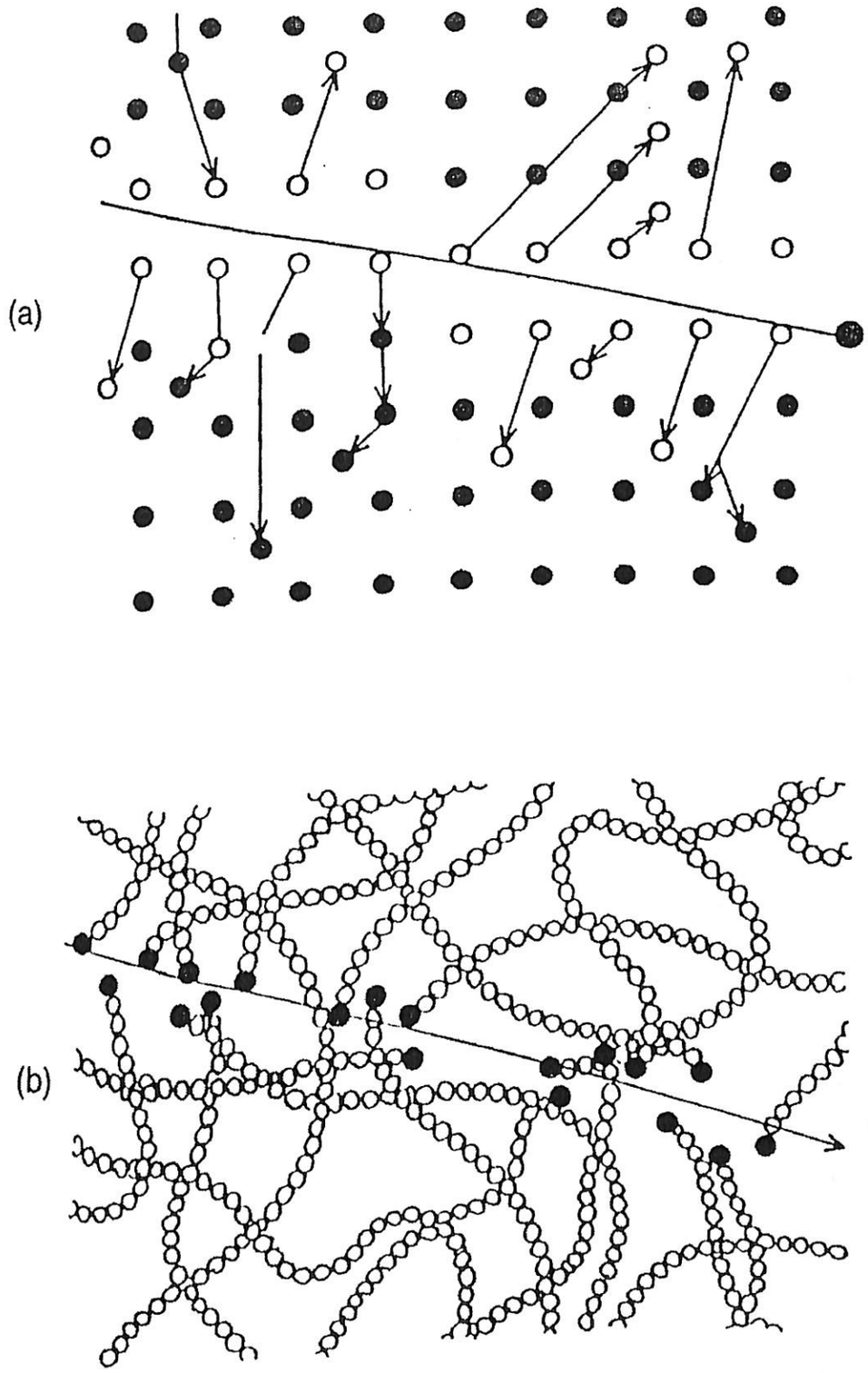


Fig.2.3: the atomic character of a particle track in (a) a crystal and (b) a polymer. In the crystal, the damage is continuous disorder, composed of vacant lattice sites and interstitial ions or atoms. In the polymer, new chain ends and other chemically reactive sites are formed (Fleischer et al., 1975).

The amount of damage, and hence the etchability and size, etc., of the etched track, depend on the rate of linear energy transfer of the charged particle over its trajectory.

2.3. OBSERVATION OF PARTICLE TRACKS AND BASIC OF TRACK ETCHING:

The most general and useful method for observing the particle tracks in solids is the technique of subjecting the film to a chemical attack to enlarge the tracks. The damage trails created by fragments from the fission of ^{235}U, first seen in mica by Silk and Barnes (Silk and Barnes, 1959) by an electron microscope, faded away by constant bombardment of electrons. The same was first revealed by Price and Walker (Price and Walker, 1962) by using hydrofluoric acid as etchant. Subsequent works by Fleischer and Price established the general realisation of track etching by proper choice of chemical reagents.

The technique of enlarging the latent trails of radiation damage with suitable chemical reagent is called chemical etching. As a charged particle traverses a dielectric, it leaves a trail of damaged material along the track. In mineral and inorganic materials, the passage of these charged particles causes a cylindrical region of imperfection which is easier to be attacked by an etching reagent than the surrounding undamaged materials. In the case of polymers, charged particles can cause radiolytic scission of polymer chains into shorter fragments. This would produce reactive low molecular weight radiolytic products, which are more easily dissolved by the etchant

than the surrounding undamaged bulk plastic. Fig. 2.4 gives the schematic representation of the basic relations between irradiated track etching and track visualization process.

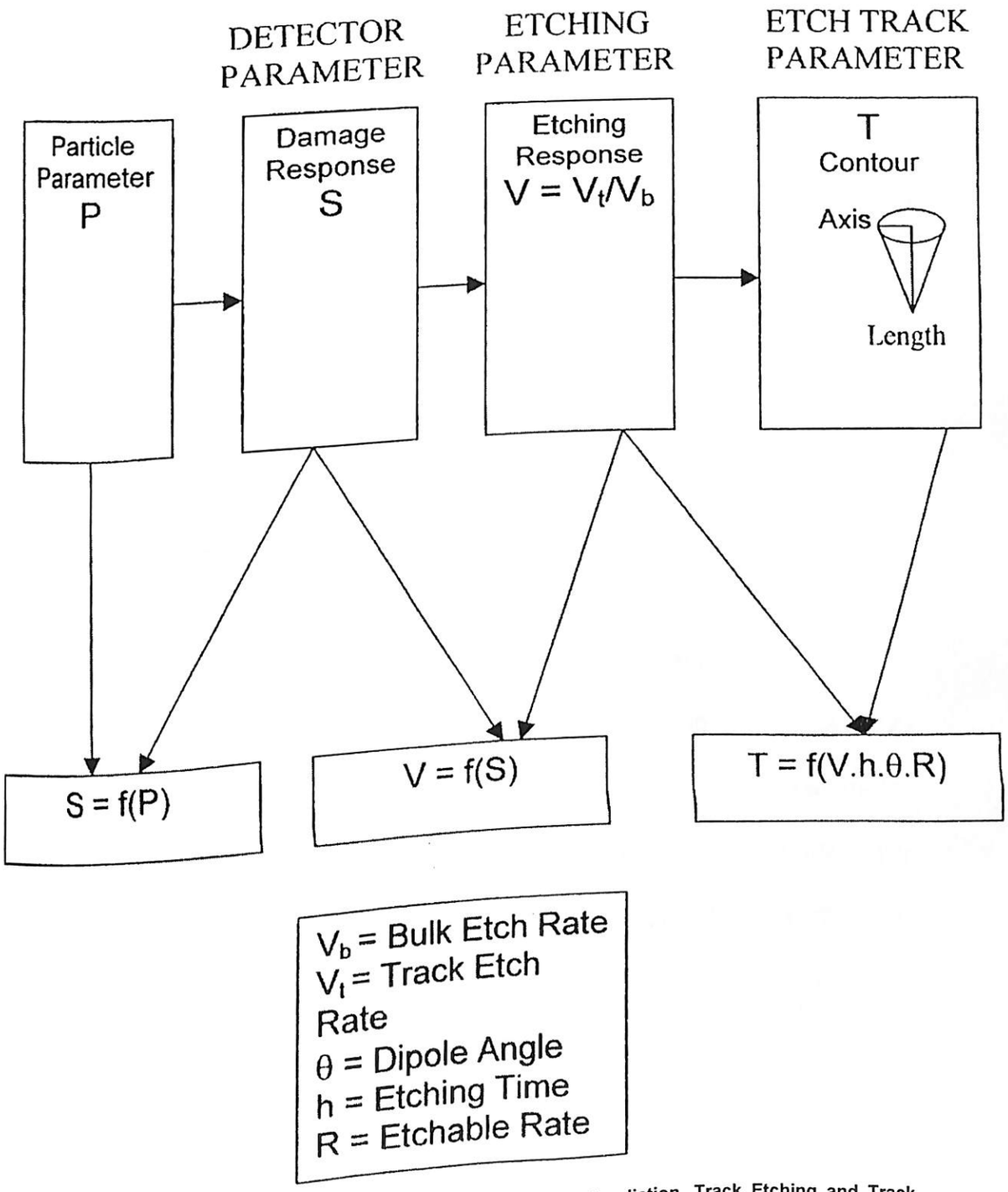


Fig. 2.4: Schematic Representation of the Basic relations of the Irradiation, Track Etching and Track Visulization Phases

With a suitable etching reagent, the rate of removing the damaged materials along the track V_t is faster than that of removing the undamaged materials (bulk etch rate, V_b). A track pit would be developed along the track as the chemical is applied to the sample for a suitable period of time t. For the formation of track by chemical etching, the rate of etching along the track , V_t must be greater than the rate of etching of the bulk materials V_b , which means that

$$V_t / V_b > 1$$

This ratio is an important parameter which denotes the degree of preferential etching along the particle trajectory. it has been observed that the region effected by the etching is not more than 70 Å across even for particles which are as intensely ionized as full energy fission fragments.

The track development by the chemical etching has shown two important characteristics. Viz., (a) after the incubation period necessary for the penetration of the solvent, the transverse dimension of the tracks vary linearly with time; (b) the track length does not increase during etching. In fact, this length tends to decrease as a consequence of surface erosion of the insulator.

2.3.1. Etching Conditions:

The etching conditions are largely based on trial and error method; yet certain guidelines are to be followed (Fleischer et al., 1975).

(a)The etchant should be so chosen that it slowly dissolve away the material at a constant rate. Since the tracks are to be enlarged to optically visible sizes, bulk attack is necessary.

(b)The attack rate, which is controlled by temperature and concentration of the etchant, can be varied by changing the concentration or by adding other chemicals to the etchants and also by changing the temperature.

(c) Etchants capable of revealing dislocation can reveal tracks also.

(d) Stirring the etchant during etching ensures uniformity of temperature of the etchant, and hence, is important.

(e)The surface to be etched should be optically smooth in order that submicroscopic cracks or scratches may not obscure tracks or produce confusion.

In the present study special track detectors LR-115 (type -II) have been used as passive detectors of alpha particles coming from radon and its daughters.

3.1. INTRODUCTION:

The " Particle track analysis " method using SSNTDs, described in the previous chapter has been used for the estimation of radon exhalation rates from soil samples and radium content in soils collected from different areas. A brief description of the various types of materials and instruments used in the present study and also the various stages of the experimental procedure are given below.

3.2. SOLID STATE NUCLEAR TRACK DETECTORS

In the present work I have used the solid state nuclear track detectors for radium estimation and radon exhalation rate measurements. The first nuclear track in dielectric solid was observed by Young (1958) in the thick sample of Lithium (LIF) under an optical microscope after suitable etching. A year later Silk and Barners (1959) observed the latent damage trails produced in mica by the fission fragments of ^{235}U using transmission election microscope. But it was Price and Walker (1962) who apparently unaware of Young's work, showed that etching solutions preferentially attack the damaged regions, producing enlarged pits that can be easily observed under an optical microscope, appearing similar to tracks in nuclear emulsions. Since then etchable tracks have been observed in many crystals, in glasses and in wide variety of plastics (Fleischer at al., 1975) Different materials vary considerably in their sensitivity, the mineral and glasses being the least sensitive and organic materials the most sensitive. The PADC, also known as CR-39 is by for the most sensitive material which is capable

of recording alpha particles with a wide range of energies (Cart wright et. Al., 1978; Henshaw et al.,1982; Durrani and Bull, 1987).

Afterwards, the considerable amount of work has been done by various investigators to systematize this pool of information and the knowledge accumulating in this field. (McCorkell,1974; Fleischer et al., 1975). During this period the workers not only developed and put the technique on firm footing, but also applied it very successfully in diverse fields (Fleischer et al., 1975). The physics applications include the studies of nuclear fission and spallation reactions (Cieslak et al., 1965), measurement life times of heavy unstable nuclei (Fleischer at al., 1963; Prevo et al., 1964; Fleischer et al., 1965). In earth sciences, these detectors have been extensively used in geo-chronology estimation and revelation of geothermal history of geological eras (Brill et al., 1964; Fleischer and Price 1964a, 1964b; Nagpaul et al., 1974; Virk and Koul, 1975; Singh and Virk 1978). In space sciences, these detectors find applications in the study of cosmic rays and that extraterrestrial materials(Fleischer et al., 1967; Virk 1977, 1979; Virk and McCorkel, 1979). In medical sciences, selectively etched tracks in thin layers of plastics have been used as fine sieves for filtration of cancer blood cells (Seal; 1964).

Some types of the plastic retain damages caused by a passing nuclear particle, this damage can be enhanced by chemical etching and made visible with help of an optical microscope. Polymers are more sensitive than inorganic materials for registering the tracks. Not only the

heavy ions but also fast protons with energies up to several MeV and above a threshold of a few tenth of a MeV (Cartwright et al., 1978) can be detected with these detectors. In the present work we have used cellulose nitrate plastic detectors LR-115 type II manufactured by Kodak-Pathe of France for the measurement of radon exhalation rates from soil samples collected from Namrup and Bongaigaon areas of Assam and also the radium content in those soil samples.

3.2.1. Cellulose Nitrate (LR-115) Plastic Track Detector

The cellulose nitrate film used is commercially known as LR-115 type II (Kodak Pathe) which has the sensitive thin layer of 12μm red cellulose nitrate coated on unetchable 100μm thick polyester base. LR-115 can easily register alpha particle tracks by chemical etching processes. LR detectors should not be exposed in the direct sun light. In particular locations close to sources of heat and draughts should avoided. It has been shown (Homer and Miles, 1986) that heat and humidity in the presence of oxygen in the air can affect the sensitivity of etched-track detectors while they are being used to measure radon. Open detectors are more sensitive than closed detectors to record radon and its decay products in the air. Kodak (LR-115) is often used for open detectors. This material has the property of detecting only those alpha particles whose energies lie within a range of about 1.7-4.8 MeV (Johnsson, 1981). Accordingly, the plate out of radon daughters on the surface of LR-115 will not register because their alpha energies (6.00 and 7.68 MeV) from ^{218}Po and ^{214}Po, respectively will be more than its upper

threshold energy and therefore will not produce etchable tracks in the surface layer. The detection efficiency as determined by Nakahara et al. (1980) and Demkjear (1986) is above 50% for energies between 1.5 MeV and 4.8 MeV. At normal incidence, LR-115 films are not affected by electrons or by radiations in the electromagnetic spectrum. Characteristics of the alpha sensitive track detector LR-115 (type II) is shown in table: 3.1.

Table-3.1: Characteristics of the detector used in the present study. (Ramachandran, 1998)

Detector Composition	Density (gm/cc)	Trade Name	Proposed Etching Condition	V_g (μm/h)
Cellulose Nitrate ($C_6H_8O_9N_2$)	1.52	CN85 LR115 Type II	2.5 N NaOH, at 60°C for 90 min.	3.2

Table3.2: Typical limits of detectable alpha-particle energies for these detector materials (Mishra et al., 1995)

Type of detector	E (Min) in MeV	E (Max) in MeV
Cellulose Nitrate($C_6H_8O_9N_2$)	0.1	4 - 6

3.2.2. Background measurements:

Unexposed detector may contain few tracks because of radon impinging on it during its transportation and storage for a long period at a place other than the selected site. Background measurements are necessary for getting accurate track density value at the location i.e. when it

is exposed in the required position. We measured the background of a statistically significant number of unexposed detectors from each batch for the entire measurement system. Finally the background count is subtracted from the field sample results.

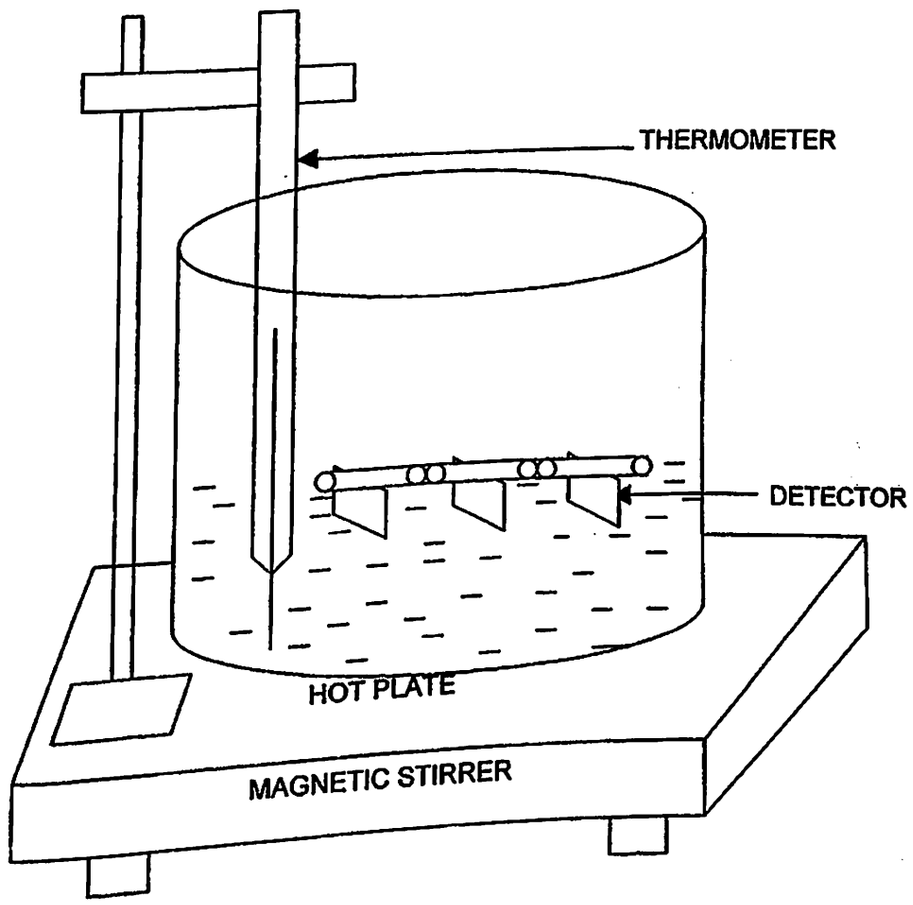
3.3. ETCHING APPARATUS:

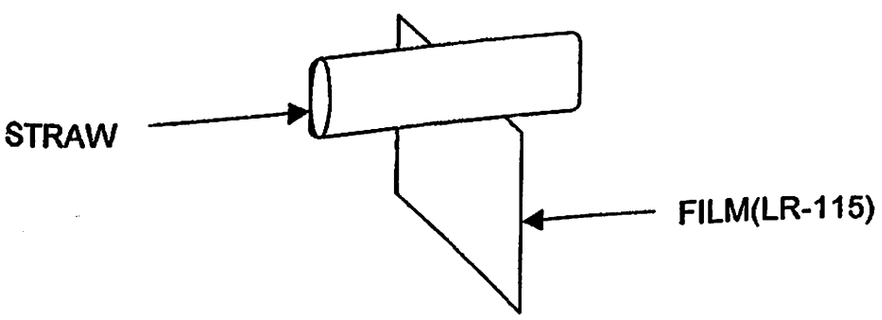
Chemical etching is the important step to make tracks in solid state nuclear track detectors observable by optical microscope. By the method of etching using a suitable chemical etchant, the latent tracks can be enlarged to microscopically visible size. The transformation of a latent track to a visible track is determined by the simultaneous action of two etching processes: a) chemical dissolution along the path of the alpha particle at a faster rate, b) chemical dissolution of the bulk material at a slower rate.

In the present study the exposed films of LR-115 are etched in 2.5 N NaOH solution at (60±1)°C for 90 minutes. The solution is kept in a glass beaker of 1000 ml. Now to suspend the detectors in the solution a straw of length 2 cm is taken. In this straw a fine incision is made by a sharp razor blade and in this incision one edge of the detector piece is inserted. This straw is allowed to float in the solution. When the straw floats, the detector inserted in it remains suspended vertically as shown in the Fig. 3.1. Normally 6 to 9 detectors are etched at a time in this manner. To ensure uniform etching of the films the solution is subjected to very mild stirring

using a magnetic stirrer. The arrangement for etching the detectors is shown in Fig. 3.1.

Fig.3.1:


THERMOMETER
DETECTOR
HOT PLATE
MAGNETIC STIRRER


STRAW
FILM(LR-115)

After etching, the films are taken out from the solution and thoroughly clean in a jet of distilled water. Then the films are allowed to dry slowly and after that kept in a Desicator. Using an optical microscope performs the measurements of optically visible tracks.

3.4. OPTICAL MICROSCOPE:

An optical microscope (Olympus-BH-2) was used to scan the chemically etched tracks. Various magnifications could be made by using different combinations of objectives and eyepieces. Magnification used for the track density measurement in the present study was 400X. The eye piece was fitted with a square graticle which was used to count the tracks randomly all over the detector surface, for 100 fields of view to obtain a representative value. The area of each field of view was 0 .0025 cm^2.

3.5. ESTIMATION OF RADIUM CONCENTRATIONS IN SOIL SAMPLES AND RADON EXHALATION RATE

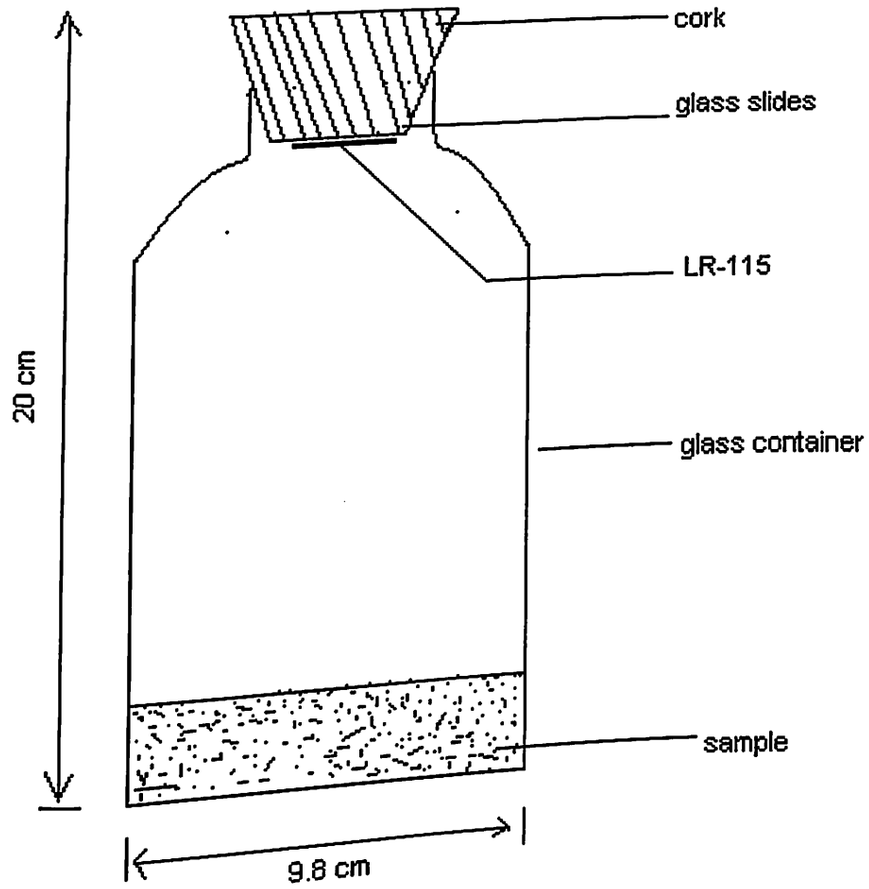


Fig.3.2: The Can technique used for the study of radium content and radon exhalation rate of soil samples.

The "Can technique' (Alter & Price, 1972; Abu-Jarad, 1988, Somogyi, 1990; Khan, Prasad & Tyagi, 1992) is used for the measurement of radium and radon exhalation rate in some soil samples from different villages of the study area. The dried samples collected from different villeges are finely powered and sieved through a 200 mesh sieve. The fine powder (250g) of samples from each site is placed in different glass bottles and

scaled with thin polyethylene sheets for 30 days so as to attain the equilibrium. After one month, LR-115 (type II) plastic track detectors are fixed on the lower side of cork lids, which are then gently pressed against the polyethylene sheets on the glass bottles (acting as emanation chambers) as shown in Fig. 3.2 so that the equilibrium is not disturbed or there is minimum possible disturbance, if any. The bottles are then sealed and left as such for 90 days so that the detectors can record α Particles resulting from the decay of radon. The exposed detectors are etched in 2.5N NaOH solution at 60^0C for 90 minutes as discussed in 3.3. The tracks are counted using an optical microscope at 400X magnification.

The "Can technique" proposed by Alter and Price (1972) and later developed by Somogyi (1990) is used to calculate the radium concentration in soil samples. The radium concentration in soil samples is calculated using the relation:

$$C_{RA} = \rho hA / KT_eM \qquad (3.1)$$

Where C_{RA} is the effective radium content of the given sample ($Bqkg^{-1}$), ρ □is the track density (track cm^{-2}), M is the mass of the sample (250 g), A is the area of cross section of bottle (7.085×10^{-3} m^2), h is the distance between the detector and the top of the sample (0.135 m), K is the sensitivity factor, which is equal to 0.0245 tracks $cm^{-2}d^{-1}$per Bqm^{-3} (Azam, Naqvi, & Srivastava, 1995) and T_e is the effective exposure time (in days)

which is related with the actual exposure time T and decay constant λ □for ^{222}Rn with the relation :

$$T_e = T - 1/\lambda\,(1 - e^{-\lambda T}) \qquad (3.2)$$

The radon exhalation rate in terms of area is calculated from the equation (Abu-Jarad,1988; Khan et al, 1992)

$$E_A = CV\lambda / A\,[T+1/\lambda\,(e^{-\lambda T} - 1)] \qquad (3.3)$$

Where E_A is the radon exhalation rate in terms of area ($Bq.m^{-2}hr^{-1}$); C is the integrated radon exposure as measured by LR-115 plastic detector ($Bq.m^{-3}hr$); V is the volume of the can (m^3); λ (= 7.5×10^{-3} hr^{-1}) is the decay constant for radon; A is the area of the can (m^2). This formula is also modified to calculate the radon exhalation rate in terms of mass ($Bq.Kg^{-1}\,hr^{-1}$) :

The radon exhalation rate in terms of mass is calculated from the expression :

$$E_M = CV\lambda/M[T+1/\lambda(e^{-\lambda T}-1)] \qquad (3.4)$$

Where E_M is the radon exhalation rate in terms of mass and M is the mass of the sample (250 gm).

The value of λ can be calculated with the help of the formula:

$$T = 0.693/\lambda \qquad (3.5)$$

Where T = half life of radon = 3.825 days.

The integrated Radon concentration can be calculated with the help of the formula

$$C_R = T_R / dK \qquad (3.6)$$

Where T_R is the number of tracks $cm^{-2}d^{-1}$, d is the time of exposure, K is the calibration factor (Sensitivity factor) = 0.0245 Tracks cm^{-2} d^{-1}/Bq.m^{-3}.

4.1. INTRODUCTION

. Measurement of radon exhalation rates and radium concentrations from soil samples collected from different areas of Assam namely, Noonmati, Numaligarh and Duliajan were carried out by using Can Technique method as discussed in chapter 3. The observed results of the radon exhalation rates and radium content in soil samples collected from different locations of the study areas are reported in this chapter.

4.2. Results And Discussions:

4.2.1 Noonmati Areas:

For Noonmati areas, soil samples are collected from different locations, Viz, i) Sankardev Nagar, ii) Bishnurava Nagar and iii) Salbari. These areas are located within the range of 14 Kms. The values of radon exhalation rates from soil samples and radium content in soil samples collected from different locations of Noonmati areas of Guwahati are given in table 4.1. It is evident from the table 4.1, that the radon exhalation rate in terms of area varies from 117.48 to 139.85 $mBqm^{-2}h^{-1}$ with an average value of 125.88 $mBqm^{-2}h^{-1}$ in soil samples collected from Sankardev Nagar. The radon exhalation rates in terms area for Bishnurava Nagar, and Salbari vary from 120.27 to 140.97 $mBqm^{-2}h^{-1}$, and 121.95 to 134.82 $mBqm^{-2}h^{-1}$ with the average value of 129.17 $mBqm^{-2}h^{-1}$, and 128.41 $mBqm^{-2}h^{-1}$ respectively. The Grand mean value of radon exhalation rate in terms of area of Noonmati is 127.81 $mBqm^{-2}h^{-1}$.

For Sankardev Nagar, radon exhalation rate in terms of mass varies from 3.32 to 3.96 $mBqkg^{-1}h^{-1}$ with an average of 3.56 $mBqkg^{-1}h^{-1}$. The radon exhalation rates in terms of mass for Bishnurava Nagar and Salbari vary from 3.40 to 3.99 $mBqkg^{-1}h^{-1}$, 3.45 to 3.82 $mBqkg^{-1}h^{-1}$ with the average values of 3.65 $mBqkg^{-1}h^{-1}$, and 3.63 $mBqkg^{-1}h^{-1}$ respectively.

The Grand mean value of radon exhalation rate in terms of mass of Noonmati is 3.61 $mBqkg^{-1}h^{-1}$.

The variation of the radium content in soil samples collected from different areas of Noonmati areas are also shown in table 4.1. The radium content in soil varies from 5.34 to 6.35 $Bqkg^{-1}$ with an average value of 5.71 $Bqkg^{-1}$ in soil samples collected from Sankardev Nagar. For Bishnurava Nagar and Salbari radium content in soil samples vary from 5.46 to 6.40 $Bqkg^{-1}$ and 5.54 to 6.13 $Bqkg^{-1}$ with the average values of 5.86 $Bqkg^{-1}$, and 5.83 $Bqkg^{-1}$ respectively.

The Grand mean value of radium content of Noonmati is 5.79 $Bqkg^{-1}$.

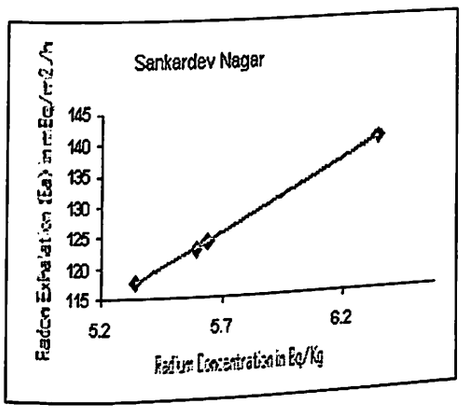
It can be seen from the table 4.1 that the radon exhalation rate varies from one place to another. This variation may be due to the differences in radium content and porosity of the soil.

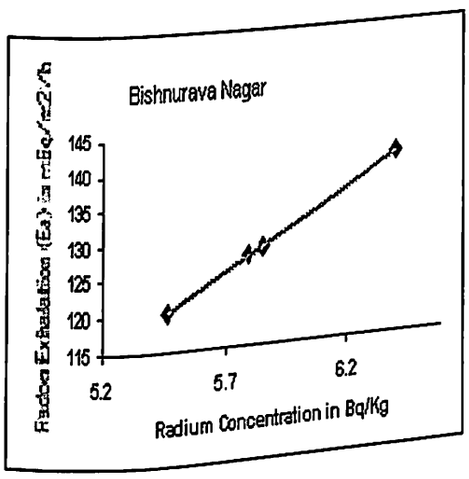
Figs. 4.1 and 4.2 shows the variation of radon exhalation rates in terms of area and mass respectively with the variation of radium concentration in soil samples collected from different areas of Noonmati. The figures show that as the radium concentration increases, radon exhalation rate also increases with a positive correlation observed between radium concentration and radon exhalation rate in soil samples.

Table.4.1: Values of Radon Exhalation Rates and Radium Content in Soil Samples Collected from Different Areas of Noonmati

Location	Sl. No.	Track density (Tracks cm^{-2})	Radon concentration ($Bq.m^{-3}$)	Radium content in $BqKg^{-1}$	Mean Radium content in $BqKg^{-1}$	Radon Exhalation Rates in terms of area(E_A) in $mBqm^{-2}hr^{-1}$	Mean Radon Exhalation Rates in terms of area(E_A) in $mBqm^{-2}hr^{-1}$	Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}hr^{-1}$	Mean Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}hr^{-1}$
Sankardev Nagar	1	840	380.95	5.34	5.71±0.04	117.48	125.88±0.9	3.329	3.56±0.02
	2	880	399.90	5.59		123.075		3.487	
	3	888	402.72	5.64		124.194		3.519	
	4	1000	453.51	6.35		139.858		3.963	
Bishnurava Nagar	1	860	390.02	5.46	5.86±0.03	120.278	129.17±0.8	3.408	3.65±0.02
	2	912	413.60	5.79		127.598		3.614	
	3	920	417.23	5.85		128.669		3.646	
	4	1008	457.14	6.40		140.977		3.995	
Salbari	1	872	395.46	5.54	5.83±0.02	121.950	128.41±0.6	3.456	3.63±0.01
	2	892	404.53	5.67		124.754		3.535	
	3	948	429.93	6.02		132.586		3.757	
	4	964	437.19	6.13		134.823		3.820	

Fig 4.1 Variation of Radon Exhalation Rates in terms of Area with Radium content





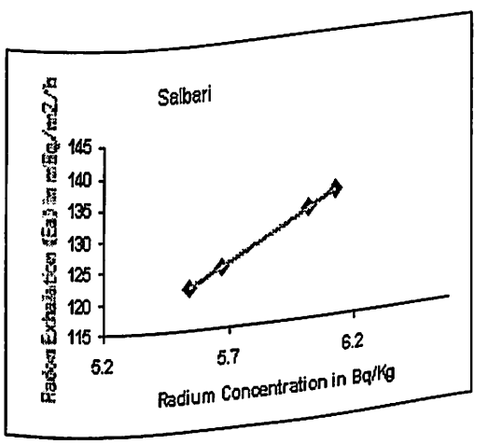
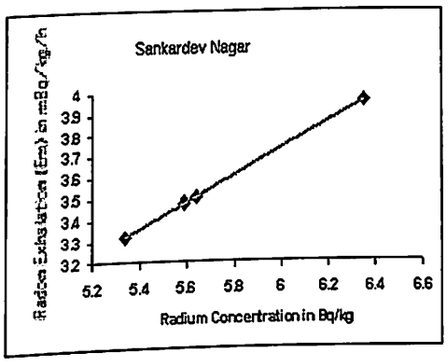
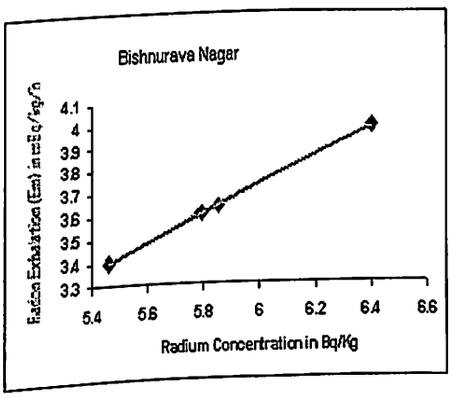
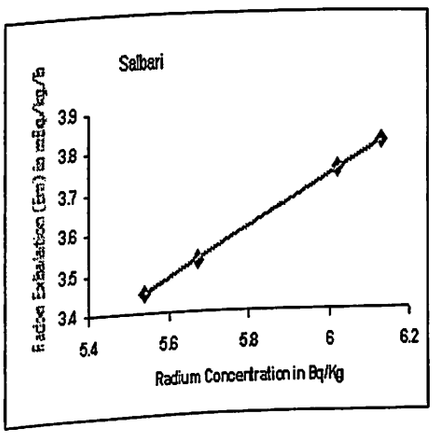


Fig 4.2 Variation of Radon Exhalation Rates in terms of Mass with Radium content







4.2.2. Numaligarh:

For Numaligarh areas, soil samples are collected from different locations, Viz, i) Township, ii) Telgaram and iii) Latukijan. These areas are located within the range of 10 Kms. The values of radon exhalation rates from soil samples and radium content in soil samples collected from different locations of Numaligarh are given in table 4.2. It is evident from the table 4.2, that the radon exhalation rate in terms of area varies from 54.25 to 121.11 $mBqm^{-2}h^{-1}$ with an average value of 81.48 $mBqm^{-2}h^{-1}$ in soil samples collected from Township. The radon exhalation rates in terms area for Telgaram, and Latukijan vary from 45.21 to 85.21 $mBqm^{-2}h^{-1}$, and 65.13 to 122.24 $mBqm^{-2}h^{-1}$ with the average value of 66.17 $mBqm^{-2}h^{-1}$, and 87.69 $mBqm^{-2}h^{-1}$ respectively.

The Grand mean value of radon exhalation rate in terms of area of Numaligarh is 77.90 $mBqm^{-2}h^{-1}$.

For Township, radon exhalation rate in terms of mass varies from 1.62 to 3.09 $mBqkg^{-1}h^{-1}$ with an average of 2.20 $mBqkg^{-1}h^{-1}$. The radon exhalation rates in terms of mass for Telgaram and Latukijan vary from 1.30 to 2.61 $mBqkg^{-1}h^{-1}$, 1.90 to 3.43 $mBqkg^{-1}h^{-1}$ with the average values of 1.94 $mBqkg^{-1}h^{-1}$, and 2.53 $mBqkg^{-1}h^{-1}$ respectively.

The Grand mean value of radon exhalation rate in terms of mass of Numaligarh is 2.22 $mBqkg^{-1}h^{-1}$.

The variation of the radium content in soil samples collected from different areas of Numaligarh areas are also shown in table 4.2. The radium content in soil varies from 2.79 to 4.96 $Bqkg^{-1}$ with an average value of 3.74 $Bqkg^{-1}$ in soil samples collected

from Township. For Telgaram and Latukijan radium content in soil samples vary from 2.31 to 4.62 $Bqkg^{-1}$ and 3.05 to 5.90 $Bqkg^{-1}$ with the average values of 3.18 $Bqkg^{-1}$, and 4.17 $Bqkg^{-1}$ respectively.

The Grand mean value of radium content of Numaligarh is 3.67 $Bqkg^{-1}$.

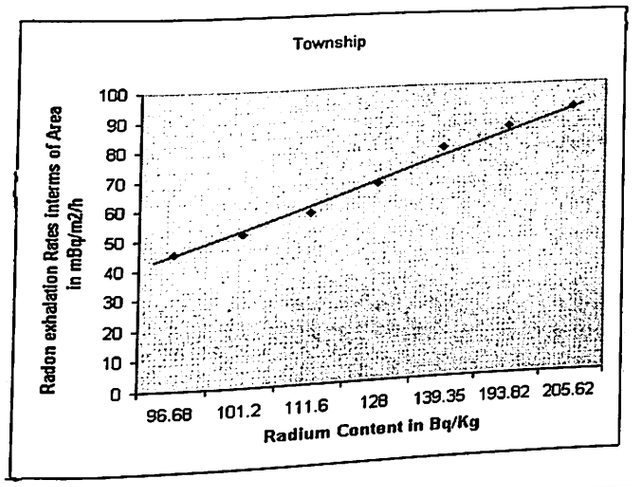
It can be seen from the table 4.2 that the radon exhalation rate varies from one place to another. This variation may be due to the differences in radium content and porosity of the soil.

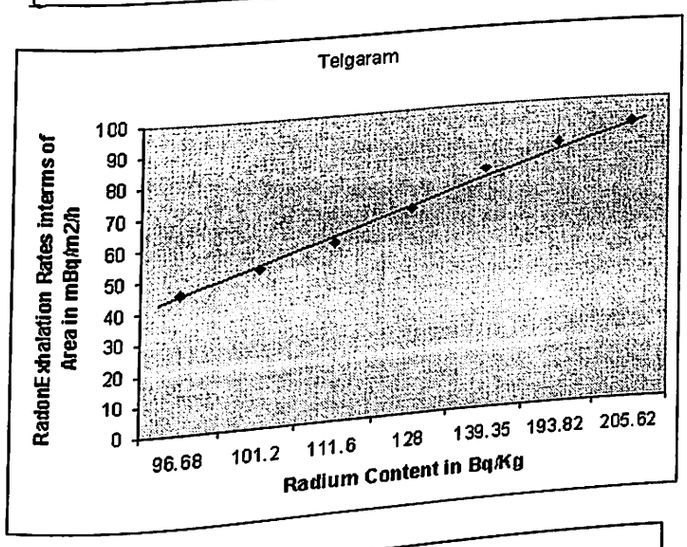
Figs. 4.3 and 4.4 shows the variation of radon exhalation rates in terms of area and mass respectively with the variation of radium concentration in soil samples collected from different areas of Numaligarh with positive correlation observed between radium concentration and radon exhalation rate in soil samples.

Table 4.2: Values of Radon Exhalation Rates and Radium Content in Soil Samples collected from different Areas of Numaligarh

Location	House No	Track density(Tracks cm^{-2})	Radon Concentration ($Bq.m^{-3}$)	Radium Content in Bq/.Kg	Mean Radium Content in $Bq.Kg^{-1}$	Radon Exhalation Rates in terms of Area(E_A) in $mBqm^{-2}h^{-1}$	Mean Radon Exhalation Rates in terms of Area(E_A) in $mBqm^{-2}h^{-1}$	Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}h^{-1}$	Mean Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}h^{-1}$
Township	1	258	117.10	2.79	3.74±0.09	54.25	81.48±2.4	1.62	2.2±0.05
	2	270	122.56	2.92		62.32		1.82	
	3	293	133.00	3.17		71.25		2.01	
	4	317	143.89	3.43		82.32		2.32	
	5	432	196.09	4.83		93.41		2.62	
	6	446	202.45	4.86		106.29		2.87	
	7	458	207.89	4.96		121.11		3.09	
Telgaram	1	213	96.68	2.31	3.18±0.1	45.21	66.17±1.7	1.30	1.94±0.05
	2	223	101.20	2.34		51.46		1.45	
	3	246	111.60	2.64		58.18		1.64	
	4	282	128.00	3.05		67.13		1.97	
	5	307	139.35	3.33		78.52		2.21	
	6	427	193.82	4.62		85.21		2.61	
	7	453	205.62	4.96		91.41		2.89	
Latukijan	1	282	128.10	3.05	4.17±0.1	65.13	87.69±2	1.90	2.57±0.05
	2	303	137.53	3.28		72.16		2.04	
	3	324	147.07	3.51		77.20		2.26	
	4	340	154.33	3.68		86.23		2.56	
	5	470	213.34	5.08		95.41		2.94	
	6	528	239.67	5.72		109.31		3.24	
	7	545	247.38	5.90		122.24		3.43	

Fig 4.3: variation of Radon Exhalation rates in terms of Area with Radium Content





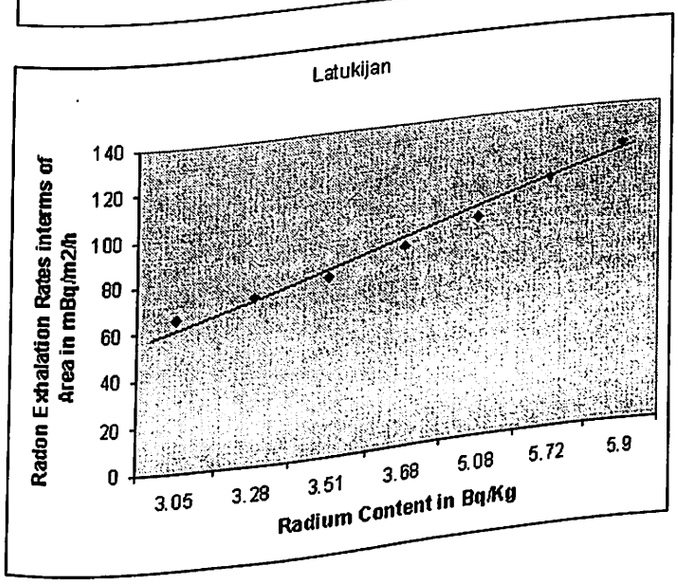
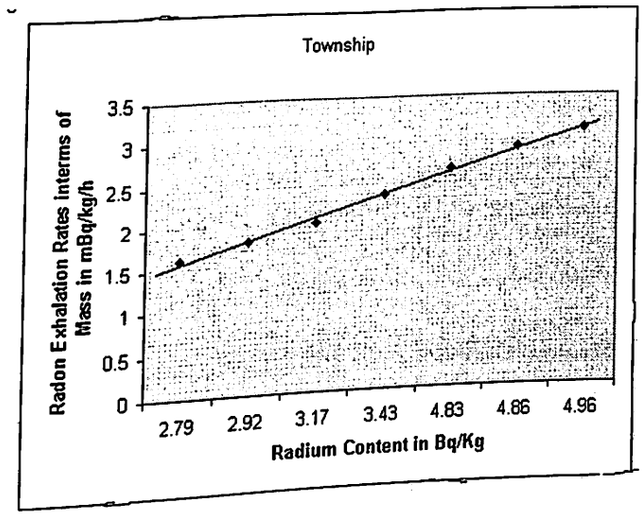
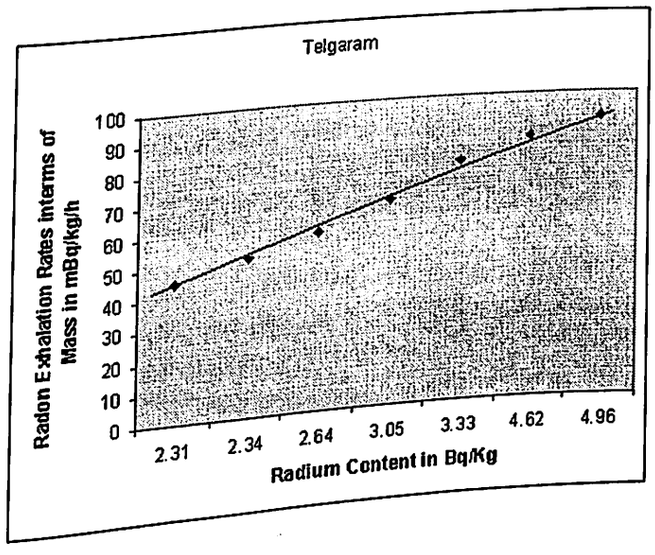
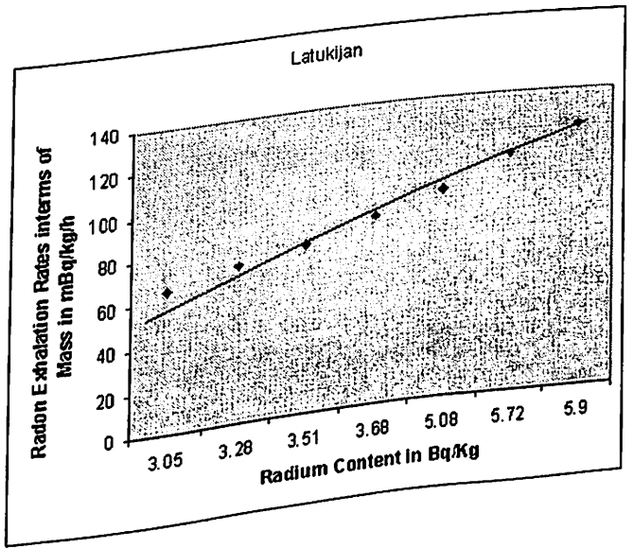


Fig 4.4: Variation of Radon Exhalation Rates in terms of Mass with Radium Content







4.2.3. Duliajan:

For Duliajan area, soil samples are collected from the locations Viz, i) Township. This area is particularly the Oil India Ltd, residential area within the range of 6-10 Kms. The values of radon exhalation rates from soil samples and radium content in soil samples collected from Township area of Duliajan are given in table 4.3. It is evident from the table 4.3, that the radon exhalation rate in terms of area varies from 57.06 to 128.66 $mBqm^{-2}h^{-1}$ with an average value of 97.27 $mBqm^{-2}h^{-1}$ in soil samples collected from Township.

For Township, radon exhalation rate in terms of mass varies from 1.61 to 3.64 $mBqkg^{-1}h^{-1}$ with an average of 2.69 $mBqkg^{-1}h^{-1}$

The variations of the radium content in soil samples collected from Township area of Duliajan are also shown in table 4.3. The radium content in soil varies from 2.59 to 5.85 $Bqkg^{-1}$ with an average value of 4.24 $Bqkg^{-1}$ in soil samples collected from Township.

It can be seen from the table 4.3 that the radon exhalation rate varies from one place to another. This variation may be due to the differences in radium content and porosity of the soil.

Figs. 4.5 and 4.6 show the variation of radon exhalation rates in terms of area and mass respectively with the variation of radium concentration in soil samples collected from Township area. The figures show that as the radium concentration increases, radon exhalation rate also increases with positive correlation observed between radium concentration and radon exhalation rate in soil samples.

Table 4.3: Values of Radon Exhalation Rates and Radium Content in Soil Samples collected from Township of Duliajan

Location	House No.	Track density (Tracks cm^{-2})	Radon Concentration ($Bq.m^{-3}$)	Radium Content in Bq./Kg	Mean Radium Content in $Bq.Kg^{-1}$	Radon Exhalation Rates in terms of Area(E_A) in $mBqm^{-2}h^{-1}$	Mean Radon Exhalation Rates in terms of Area(E_A) in $mBqm^{-2}h^{-1}$	Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}h^{-1}$	Mean Radon Exhalation Rates in terms of Mass(E_M) in $mBqKg^{-1}h^{-1}$
Township	1	239	108.39	2.59		57.06		1.61	
	2	258	117.10	2.79		61.53		1.74	
	3	303	137.00	3.28		72.16		2.04	
	4	317	143.76	3.43		75.52		2.14	
	5	357	161.90	3.67		97.34		2.32	
	6	368	166.89	3.86		85.03		2.41	
	7	371	168.25	3.92		101.11		2.45	
	8	392	177.71	4.12		108.21		2.64	
	9	394	178.68	4.24		93.42		2.72	
	10	404	183.21	4.35		110.12		2.75	
	11	408	185.03	4.41		115.23		2.80	
	12	415	188.21	4.42		97.34		2.88	
	13	425	192.74	4.5		99.01		3.04	
	14	427	193.65	4.62		101.81		3.12	
	15	451	204.53	4.88		107.41		3.18	
	16	472	214.05	5.11		112.87		3.32	
	17	493	223.58	5.34		117.48		3.32	
	18	519	235.37	5.62		123.63	97.27±9.7	3.51	2.69±0.09
	19	528	239.45	5.72		125.87		3.56	
	20	540	244.89	5.85	4.24±0.09	128.66		3.64	

Fig 4.5: Variation of Radon Exhalation Rates in terms of Area with Radium Content

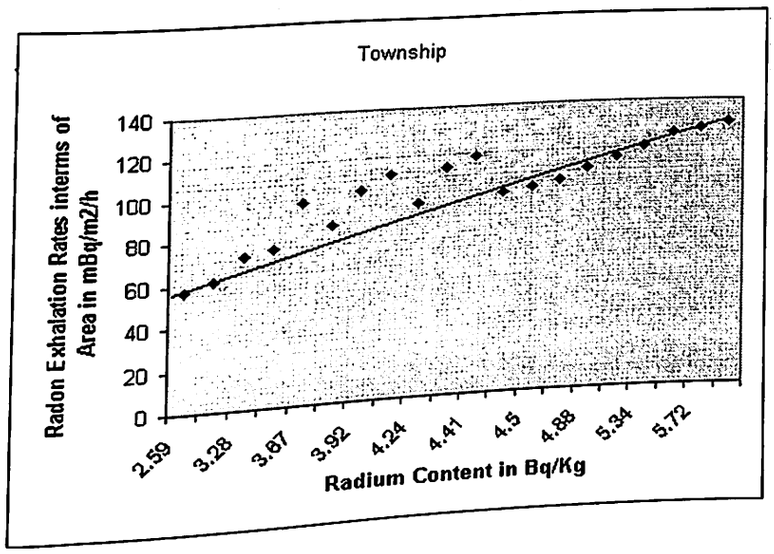
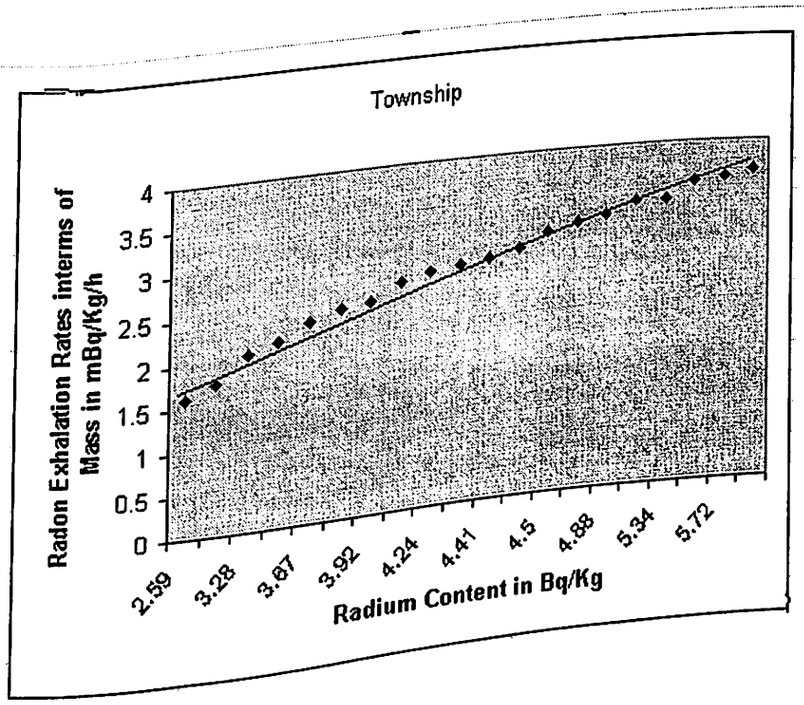


Fig 4.6: Variation of Radon Exhalation Rates in terms of Mass with Radium Content



5: Conclusions:

1. In the present investigation, it is observed that radium concentration in soil samples are much lower than the permissible value 370 $Bq.Kg^{-1}$ (OECD, 1979).
2. The observed values of radium activity in soil samples in the present study are less than the maximum permissible value and much lower than the global value 30 $BqKg^{-1}$ (UNSCEAR, 1993).
3. We have observed a positive co-relation between radium content in soil and radon exhalation rates from soil as expected.
4. The radium concentrations and radon exhalation rates are comparatively higher in Noonmati areas than in Numaligarh and Duliajan areas.
5. The results reveal that the areas are safe as for as the health hazard effects of radium is concerned.

Future Scope:

One should not take it for granted that radon study ends here. There are many aspects of this interesting problem to be investigated meticulously. Two of there may be as mentioned below

i) Correlation between indoor radon concentration and soil radon exhalation rate can be studied. But for this study a systematic protocol must be maintained while studying the indoor radon concentration of a particular house to that of soil radon exhalation rate of that particular house.

ii) Another important aspect may be the study of Uranium, Thorium abundances in Soil samples by sophisticated instrument like Gamma Spectrometer.

However solution of a problem may lead to another set of problems requiring further study.

Thus we hope that the present study may generate a series of studies in future.

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