NATIONAL WORKSHOP ON RADON/HELIUM PRECURSORS FOR EARTHQUAKE PREDICTION STUDIES

RADON MONITORING TECHNIQUES

The techniques used for radon monitoring fall in two categories

1.Instantaneous radon monitoring techniques

2.Time-integrated radon monitoring techniques

INSTANTANEOUS RADON MONITORING TECHNIQUES

(I) RADON EMANOMETRY

Radon emanometer, is used to measure the alpha emission from the radon in the soil-gas fraction of a sample by pumping the gas into scintillation chamber. The most widely used radon emanometers utilise silver activated zinc sulphide phosphor, ZnS(Ag), as the scintillation material. The alpha particles emitted from the decay of radon, impact the scintillator creating an energy pulse in the form of light quanta(photons). These photons are registered and amplified by photomultiplier tube until it can be detected as a single pulse.

(ii) IONISATION CHAMBER TECHNIQUE

An ionisation chamber is a gas filled electrode system designed to detect the presence of an ionising particle. In passing through the gas in the chamber, the ionising particle creates a track of pairs of electrons and positive ions. Under the influence of an electric field, the electron and positive ion are attracted in opposite directions. The chamber is operated at a voltage of 100 to 300 volts, so that recombination and multiplication of electrons and ion pairs is negligible. This type of detection system needs a fairly high radon concentration (1000 pCi/L) in order to be effective.

TIME-INTEGRATED RADON MEASUREMENT TECHNIQUES

Time-integrated devices are generally placed in the auger hole and allowed to absorb the radon or record the radon alpha activity over a specified period of time. In this technique radon is measured either directly by detecting the alpha emission or indirectly by detecting radio-active decay products of radon. A brief description of these techniques is given below:

(i) SOLID STATE ELECTRONIC DETECTOR TECHNIQUE

Alpha-logger (Alpha Nuclear Company, Trent, Canada) is a portable, battery powered, microprocessor based data acquisition and control system. The unit is designed to acquire and record the radon data upto twelve alphameter-400 probes and seven auxiliary probes

for meteorological data. The instrument detects and integrates instantaneous radon fluctuations over relatively short intervals of time and upon command of automatic logger system, transmits its data over upto 1Km. of cable for recording. Alphameter 400 is designed to measure near surface radon gas fluctuations. It consists of a silicon diffused-junction for detection of alpha particles and gives sufficient counts over 24 hrs exposure in most of the soils(Gaucher, 1976: Waren, 1977). The detector unit is placed inside a covered auger hole about 60 cm in depth. The detector is separated from the soil surface at the bottom of hole by a 6.4 cm gap and the air in the gap shields the detector from the impact of direct alpha particles generated in the soil. The detector thus records the alpha particles emanated by radon isotopes and their alpha-emitting daughters.

The new and modified version of Alpha-logger has the facility to record any number of radon alpha counts in 15 minute increment over a period of 40 days non-stop. The recorded data is retrieved with the aid of a laptop computer. In most of the soils the alpha count rate is quite low, thus counting statistics over a 15 minute interval is usually poor. The software supplied with the system can sum up any number of 15 minute counting intervals.

(ii) ALPHA TRACK-ETCH TECHNIQUE

The track-etch technique developed by Fleicher, price and walker is being used for estimation of the content of radon isotopes. This technique involves soil gas migration through inverted cups emplaced in shallow holes. These cups have alpha-sensitive plastic track detectors which record their time integrated exposure. after a sufficient period of exposure, these detectors are etched and scanned for track density measurements. it give the long term average radon detection in the soil-gas because of its negligible background of spurious signals.

(iii) RADON ADSORPTION TECHNIQUE

Radon can be measured indirectly by determination of the radon decay products or daughters present in the sample. The short lived daughters (^{214}Pb and ^{214}Bi) are beta and gamma emitters and are used to determine the amount of radon adsorbed in a material like activated charcoal. It has capacity for adsorbing and retaining radon. Canisters containing activated charcoal are placed in holes for 2-3 days exposure. The amount of radon to which it has been exposed can be determined by measuring the gamma activity of ^{214}Pb (0.295 and 0.352Mev) and ^{214}Bi(0.609Mev). These isotopes are radioactive decay products of ^{222}Rn and are essentially the only gamma emitters in the Uranium decay series after ^{222}Rn.

(iv) PARTIAL EXTRACTION OF ^{210}Pb

Another indirect method for the determination of radon is by measuring the concentration of long-lived radioactive decay products, ^{210}Pb and ^{210}Po, in natural samples. Transported radon should be a better indicator of distant uranium accumulation than total radon, which may reflect just the concentration of local uranium or radium to the sampling location. The selective determination of radon may be accomplished by measuring the ^{210}Pb or ^{210}Po in a partial extraction of a rock or soil sample with a solvent (usually a weak acidic solution). The extractable ^{210}Pb found in the soil grain should represent the mobile ^{210}Pb component deposited by its radon parent. The ^{210}Pb can be measured after

chemical separation of lead fraction by beta-counting of ^{210}Pb (0.01 and 0.05MeV) or alpha-counting of ^{210}Po. These decay products of ^{210}Pb are easier to measure than the low energy radiation emitted by ^{210}Pb itself. Alternatively, the polonium fraction can be chemically separated and ^{210}Po alpha-counted.

(v) THERMOLUMINESCENCE DETECTOR TECHNIQUE

Thermoluminescence is the process whereby light is emitted by a substance when it is heated and which can be attributed to the previous expose to ionisation radiations. When a crystal is exposed to ionizing radiation, electron-hole ionisation pairs are created. On heating, some electrons and holes are released and can combine with trapped charges and be neutralised. This process may occur with or without the emission of light. When light is emitted, the process is called thermoluminescence. The commercially available detectors, Alpha-2 TM, has a thermoluminescence detector wafer suspended in the air space of a plastic cup. By suspending the wafer, both sides of the wafer are exposed to the radon in the air space.The wafer is composed of calcium sulphate doped with dysprosium in a matrix of polytetrafluroethylene(Teflon). An alpha particle from ^{222}Rn has an energy of 5.5 MeV and range of approximately 5.5mg/cm^2 in wafer material. thus it can deposit all of its energy in the wafer.

INSTRUMENTS USED FOR RADON MONITORING

In order to monitor radon in soil-gas and groundwater for correlating it with microseismicity of the area under investigation various types of instruments have been used as a part of our research programme. A brief description of the instruments is given below:

RADON EMANOMETER

The radon emanometer, manufactured by ECIL, Hyderabad and patented by Atomic Energy Mineral Division, India, is used to measure the radon concentration. The apparatus consists of an alpha counting scintillation assembly with inverted bell shaped detector, a hand-operated rubber pump and a soil gas probe. A thick nickel coating is used in the interior of detector for the absorption of alpha particles from any contamination in the material of the detector wall and also works as optical reflector for alpha scintillation. The phosphor used is ZnS(Ag), a fine layer of which is made to adhere on the inside wall of detector with the help of silicon grease. The detector is coupled to a photomultiplier tube which is supplied with E.H.T of 1000 Volts by a group of batteries.

The soil gas probe is a metallic tube about 1.5 inch in diameter with perforations at the lower portion. It has a rubber capping on the upper half of the tube which can be inflated through one of the tubes at the top and the probe can be sealed pneumatically in an auger hole. it has outlet and inlet tubes for the circulation of the soil gas. A hand operated rubber pump is used to circulate the soil-gas in the system. This has valves fitted on the ends and allows gas to flow in one direction only.

ALPHAMETER

Alphameter made by Alpha Nuclear Company, Canada is used for continuous measurement of radon in soil-gas. This instrument is a tube 34cm long and 5.1cm in diameter. It has a silicon diffused junction detector with an active area of 400 mm^2. This type of detector is referred to as a solid ionisation chamber. The detector chamber forms an open end cavity of about 4.5cm diameter and 3.8cm deep resulting in a detector chamber volume of about 60 ml. The main function of the chamber is to detect alpha particle which must have gaseous origin. This instrument does not register any alpha particle which exhibits energy less than 1 MeV. Its sensitivity is such that a 24 hour exposure gives sufficient counts in most of the soils. Further we can integrate data of 15 minutes interval and multiples of it. It can store data upto 40 days non-stop and data can be retrieved with IBM laptop at any time.

ALPHA GUARD

Alpha Guard (PQ 2000 PRO Model) is used for short term radon measurements in soil-gas, water and indoor air. It is based on the principle of pulse ionisation chamber and can be operated in diffusion as well as flow modes.In the diffusion mode, only ^{222}Rn gas may pass through the glass fibre filter into the chamber while the radon progeny products are prevented to enter it. The filter also protects the interior of the chamber from contamination of dust particles and aerosols.Radon concentration in soil gas is measured by a specially designed soil gas unit by connecting the Alpha Guard, Alpha pump and a modified soil gas probe. The main advantages of the Alpha Guard are its fast response, higher sensitivity and a wide dynamic range which is linear over the interval $2Bq/m^3$ - $2x10^6$ Bq/m^3.In addition, it is a multisensor unit which can measure temperature, pressure, relative humidity simultaneously with radon. Software supplied with the instrument can plot them along with radon to have a permanent record.

Helium Monitoring Technique

ASM 100 HDS
HELIUM LEAK DETECTOR

The ASM 100 HDS detector is a complete helium leak detection system. It uses a sniffing technique and comprises a helium gas analyser, with a pumping system : molecular drag pump (MDP) and a set of dry pumps (with diaphragms and graphite vanes) connected to the MDP exhaust. Operation is fully automatic. The device takes the form of a case which contains all the vacuum circuits and electronic components. With the help of MDP pump and set of two dry pumps a vacuum of several millibars is obtained which is sufficient to secure proper operation.

ANALYSIS CELL

The cell is a mass spectrometer analysis cell set to m/e = 4 , where m/e = atomic weight of the particle/ number of electrons lost by ionisation.

THE PRINCIPLE

The principle of the magnetic deflection spectrometer is as follows:

Neutral molecules of the gas being analysed enter an ionisation chamber (or ion source) where they are bombarded by a beam of electrons produced by a heated tungsten filament. A large proportion of the molecules is converted into ions. These ionized particles are accelerated by an electric field. The entire analysis cell is within a magnetic field which has the effect of curving the trajectories of ions along different radii depending on the mass of ions and charge on the ion (m/e) ratio. As a result the ion beam , which contains ions of different masses, divides into several beams each containing only ions with the same m/e ratio. The helium ions (m/e = 4) are separated from the lighter (H_2^+ or H^+ , smaller radii) or heavier ions (N_2 or O_2 , larger radii).
With the magnetic field held constant (permanent magnet), the accelerating electric field is adjusted so that the helium ions (m/e = 4) follow a particular trajectory and hit the target, which is the input of a DC amplifier.
The helium ion stream is proportional to the partial pressure of helium in the system ; its magnitude indicates the flow rate of the leak that has been detected.

MAIN TECHNICAL SPECIFICATIONS

Dimensions	L 480 - W 430 - H 165 mm
Full weight of detector	20.5 Kg
Mains voltage	100- 115 - 200 - 220 - 230 - 240 V
Mains frequency	50 - 60 Hz single phase
Power consumption	250 VA
Ambient operation temperature	- 20° C to 45° C

TECHNICAL SPECIFICATIONS

Spectro cell sensitivity	3. 10^{-4} A/mbar
Reaction time constant	< 1s
Spectro pressure safety	5. 10^{-4} mbar
Triode pressure display	10^{-5} to 10^{-3} mbar
Measurement range :	
- flow	10^{-7} to 1 mbar.l/s
- concentration	0.1 ppm to 100% helium
Set point adjustment	10^{-7} to 1 mbar.l/s
Recording output (8 decades log.)	1 V / decade
Start -up time	1,5 min

SNIFFING SPECIFICATIONS

Flow sucked in by the probe	1 mbar.l/s
Detector calibration	for He flow and concentration
Air helium signal	5. 10^{-6} mbar.l/s (5 ppm)
Measurement range	10^{-7} to 1 mbar.l/s (0.1 ppm to 100% He)
For standard sensitivity	

- smallest measurable leak	1. 10^{-6} mbar.l/s (1ppm)
- for a signal / noise ratio = 1	5. 10^{-6} mbar.l/s (5ppm)
High sensitivity mode	
- smallest measurable leak	1. 10^{-7} mbar.l/s (0, 1 ppm)
Signal apparition time	
(for standard 5m probe)	1s

TECHNIQUE

Helium leak detector ASM 100 HDS (Alcatel, France) using sniffing technique is used for helium analysis in thermal springs and in soil-gas. It comprises of a helium gas analyser with a pumping system.

The main component of helium leak detector is a spectro-cell which acts as a mass spectrometer. The helium ion analysis is based on the partial pressure of helium in the system which is calibrated to yield helium concentration in ppm. In soil-gas, helium is estimated directly by a sniffing probe from an auger hole.

Thermal spring water samples were collected in air tight bottles ($100cm^3$) and kept indoor for a period of one month to get helium accumulation. A closed circuit technique is followed to estimate helium in the collected samples using two hypodermic syringes, air tight bottle containing silica gel and the helium leak detector. The calibrated logarithmic scale displays the helium concentration in ppm. The whole operation is fully automatic and helium values from 0.1ppm to 100% helium can be measured.