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A Review on Radon and its Significance in Radioactive Mineral Exploration and Deciphering Active Tectonics and Earthquake Prediction

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ABSTRACT: Radon in soil gases is attributed to the radioactive decay of small accumulation of U/Th that is present within the mineral matter of the source rock. Radon infiltration and release is essentially a part of a dynamic feature, the out-gassing process of the earth. Wide variation in radon concentrations is thus reported in soil, air and in underground and surface waters. Concentration changes are mostly related to the uneven distribution of radioactive minerals, properties of soil affecting radon transportation, tectonic, atmosphere and metrological settings. The seismicity and tectonics of the Himalaya and earthquake prediction studies using radon is a precursor has been a subject of a spherical investigation in the NW Himalaya. The study reveals the precursory nature of radon anomalies add the total correlation index with micro earthquake is formed to be 62% for the radon network. The correlation of radon data with micro earthquake recorded by IMD network in Kangra valley shows a rising trend in both radon emanation and micro seismicity in Kangra and Chamba valley of NW Himalayas. The high concentration in fractures joints and faults lineaments springs related to the increased ratio of rock surface area to water volume and uranium mineralization in the shear zones present in close vicinity of fault and thrust. Radon concentrations in groundwater of intermountain valley forming the main aquifer consist of hydro-geological units. Radon concentration increase with drilling depth, aquifer one not mixed and that groundwater withdrawn is taking place from some water-bearing strata and is some hydro-geological units shows higher radon at shallow depth indicate that uranium-rich sandstone of middle Siwalik and sand eroded from the uranium mineralized granites rocks of lesser Himalayas have to get mixed with gravel aquifer of shallow depth. Considering metrological parameter approximately constant for a season fluctuation due to seismic events have been found this type of approach will help us to develop an earthquake alarm model from radon in near fracture. The Himalayas are known for the enrichment of radioactive elements and the anomalies have been imparted. The Himalayas are also known for the tectonic activities. The Himalayas require further investigation for as the proportion of radioactive anomalies, seismic activities and the environmental radiation health hazard are concerned.

I. INTRODUCTION

Radon is the radioactive noble gas and does not chemically react with its environment, be it rock or water. It can only be engaged in physical mechanisms. Its half-life is long enough that it can carry useful information on dynamic events. Radon is the sole alpha-emitting gas and can be detected with less chance of parasite phenomena altering the measurements. Its presence on the earth is very limited (4x10-7 in weight). It is almost completely ubiquitous.

Radon has three isotopes:-
1) Radon- 222 from the uranium- 238 chains with 3.8 days loops of half-life.
2) Radon- 220 from the thorium- 232 chains with 55 seconds half-life.
3) Radon- 219 from the uranium- 235 chains with 4 seconds half-life.

As Rn-222 is the only isotope with a sufficiently long half-life, it can migrate a significant distance from the source.

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Radon is produced within the rock grains that contain uranium and its daughter in secular equilibrium. Radon is produced through the alpha decay of its immediate parent; radium- 226. For a given radium concentration in various rock specimens, the amount of radon escapes is different depending on parameters such as grain size, previous heating. The fraction of radon atoms that escape from solid is called "emanation power" of the said solid. The basic phenomenon which allows the radon to escape is the recoiling motion of the produced nucleus due to the emission of alpha particles. Within a mineral grain, the range of recoiling of the atom is of the order of 20 to 70 nm. Other possibilities are the diffusion through the grain material and the preferential diffusion through the radiation-damaged material. Water also has an important role in radon emanation; hydrated emanation has a large tendency to exhibit greater emanating power than the un-hydrated surface. When radon is released in a porous material it moves under two different mechanisms: "DIFFUSION" within the pore fluid and "TRANSPORT", when the fluids themselves carry the radon gas. Diffusion and transport may take place alone or simultaneously.
Radon can be transported by groundwater to far larger distances than diffusion processes alone would permit. In thermal water, the radon content is usually very high and by using this fact we can identify hidden hydrothermal systems. According to Hoehm and Von Gunten, it is possible to access infiltrated groundwater radon builds up according to the laws of radioactivity. Heavy rainfall induces a decrease in radon concentration which could be explained by the dilution of radon in a water table whose volume is increased. It has been reported that exposure to the high concentration of radon causes lung cancer. So the alpha-emitting short-lived daughters, Po- 214 and Po- 218 of radon can attach to the surface of airborne particles in the inhaled air, deposit in the lungs and irradiate the tissue. So the interest has focused on the measurement of radon activity inside the domestic premises.
Detection of radon in water (ground, spring, wells, streams and lakes etc.) can also be used for uranium exploration. This is based on the analysis of water in – situ employing various techniques of separating the gases or laboratory analysis of samples of water collected in hermetically sealed containers. Radon has more recently been used as a possible tool for earthquake prediction. Radon by itself has never been used to predict an earthquake. But it has been correlated in many cases with earthquake activity and is one of the several indicators used in earthquake prediction.

II. RELATED WORK

[1] have observed that Rn^{222} concentrations in geological environment is affected by fluid dynamics of the main gas carriers which are subject to the chemical and physical relations depending on local and general pressure-volume-temperature conditions. Knowledge of the chemical frame in which noble gases get inserted is of essential importance in Rn^{222} data evaluation. A number of gases such as $Co_{2,}$ H_2S, CH_4 are present in or near geothermal areas. Detailed studies on the chemical and isotopic composition of gas samples suggest that their amounts can be formulated as a function of temperature and used as a tool in geothermal explorations. [2] It is possible to derive the geochemical model of natural hydrothermal system in which gas-water-rock equilibrium reactions occur. Knowledge of these reactions is useful in the evaluation of deep geo-thermal temperatures using surface data of gas samples and also in earthquake prediction research, as deep physical and chemical processes influence the gas mix pattern. Owing to the depth of the hypocenters and frictional heating generated during earthquakes, seismic events are to be considered "hot events" which strongly affect the por fluid pressure and deep hydrodynamic conditions. Thus knowledge of the exact deep seated gases becomes of decisive importance in the evaluation of experimental data in earthquake related research studies. [8] Estimation of Radon and Uranium in water system in India has been studied by many workers. [24]

III.DISCUSSION

In India, radon studies are confined to certain parts in which Himalayan region is highly explored. [22] reported a very high value of radon 792Bq/l from groundwater in the Kullu district of HP, India. These workers also observed very high value of radon in thermal springs as compared to other sources of water. They attributed these high values to the lithology of the area which is mainly covered by tourmaline granite and assumed to be a high source of radon. [23] observed no correlation between radon with a high concentration of uranium in Bathinda locality. [23] Observed that helium is a better precursory signal for seismic activity than radon due to strain build-up factor. Globally helium concentration in the soil – gas is 5ppm. Helium is emanated from deep layers of the crust than radon in the earthquake activity zone during the strain build up around the hypocenter. On the other hand when stress exceeds its elastic limits by rupture rate of emanation increases from upper crustal rocks marking the beginning of an earthquake. During this phase, helium is affected at deeper layers and its emanation rate increases. Hence it acts as a better precursor for seismic activities
[19] reported that radon and helium are used as a precursor for earthquake prediction studies. Radon due to its short half-life displays poor intrinsic mobility and hence low diffusivity. On the other hand, helium shows high mobility and

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low solubility in water resulting in high diffusive character with diffusion coefficient 1.68cm2/sec. due to this in comparison to radon, helium appears to be a powerful pathfinder for delineation of crustal discontinuities, faults and fractures. The survey of soil-gas concentration variation of radon and helium distribution along the profiles show as we move along MBT2 helium varies from 5.24-5.46ppm and radon varies from 37-754KBq/m3. Along the profile E, the point e3 shows the maximum value of radon >700KBq/m3 lies on the contact between subathus and alluviums which is directly above MBT2 marking the boundary between Dharamshala and Subathu formation. While point e6 shows the maximum value of helium approximately 5.47ppm. Soil-Gas flux is found to be low in Shiwalik which comprises of sandstone as a comparison to alluviums

[12] Have reported that meteorological parameters have a great influence on radon emanations. These authors observed that factors such as temperature and humidity show a positive correlation with radon while radon shows negative correlation with atmospheric pressure and wind velocity. The wind causes a decrease in soil gas radon concentration because radon being diluted and removed at the surface. There is no correlation between radon and rainfall. Sites such as MCT and MBT in Kangra (HP) locality have high radon release from the deeper sources. The lithology between MCT and MBT comprises of the lesser Himalayan zone whereas shiwaliks of Palampur area comprises of conglomerate, medium to coarse-grained sandstone with pebbles interbedded within the thin clay beds. In middle shiwaliks presence of kyanite suite of heavy minerals to this assemblage results in high uranium concentration of 3-10ppm which is more than the world's average – 2.1ppm in greywacke and 1.5ppm in arkose. Different values of radon are found to be occurred in soil-gas and groundwater due to different transport mechanisms attributed to the development of micro cracks, fissures and fractures due to the dilatancy before an earthquake. The positive anomaly in soil-gas radon concentration by an earthquake may be due to strain build-up factor in the area and negative radon anomaly may be due to the squeezing effect of compressional stress in rocks which changes porosity of soil at the micro scale [5].

In Doon valley [5] reported 92.53Bq/l of radon in groundwater. These authors have observed that radon show no correlation with temperature, pH and conductivity. However in some localities, radon shows goods correlation with depth. The uranium minerals found in sand and long residence time of water in the rock. However higher radon concentrations are found to be reported at shallow depth in the Gangs and song river catchment area. In Hamirpur valley (HP) [17] have reported radon concentration in indoor air in dwellings and varies from 260.51Bq/m3 (Nekhul village) to 875.01Bq/m3 (Galot village). The radon values recorded at the walls of dwellings is almost double the value obtained at the centre of the room and this may be due to alpha tracks caused by Rn-222 and Rn-220 (because of building material). High uranium values are also recorded in soils of Asthota village (601ppm), Galot village (614ppm) and Khiach village (21.28ppm). There is a lack of correlation between radon exhalation rate and uranium concentration due to the difference in the porosity of the material. However, [17] observed that different plant species have different uptake of uranium concentration. In Doon valley [3] have observed radon in water 10 – 154Bq/l whereas radium in selected water samples varied from 0.11 – 0.76Bq/l. these high radon values found in clusters are associated with tectonics, fault, thrust and associated mineralization. Radon concentration is controlled by the neotectonic and hydrological processes that occur in the area. The spatial distribution of radon shows areas with relatively high values are Shankarpur, Premnagar, Dhoolkot, Bindal river and Bharuwala. These clusters have radon values close to the vicinity of tectonically active fault (MBT), another E-W trending thrust close to nagsidh hill. In this area prominent NW-SE oriented fractures are reported. Radium values ranged from 0.11 – 0.76Bq/l lies in the western part of Doon valley. In sub-catchments of the surna and tons rivers radon concentration increases with drilling depth. Lithologically, the aquifers are not mixed. Below 100m depth, the aquifer is more uniform while mixing of water takes place above 100m depth. Doon gravel formation being highly porous and permeable causes natural emanations of gases into upper unsaturated zones.

[24] reported maximum soil emanation rate at jawalamukhi (HP) and minimum at Pathankot (PB).maximum no. of radon spikes before the earthquake were absent at Palampur and jawalamukhi showing the maximum sensitivity to seismic activity. Most of these radon spikes are preceded with earthquake event.Observations: - At Palampur station16 radon anomalies were encountered before 22 seismic events. Similarly 20-23 in Jwalamukhi, 8-13 in Kotla, 10-14 in Dalhousie, 12-14 in Chamba and 11-12 in Pathankot.

[21] Geochemical studies of some thermal springs in India have been carried out in recent past. The researchers have observed radon values ranging from 16 – 136Bq/l from thermal springs in Pārbati and Beas valley. The workers also reported a significant correlation of radon with helium and uranium. Geothermal springs located in NW Himalayas Kullu region are associated with seismic belts, structural features along seismically active fault systems. The workers have observed that high range of radon value found to be associated with gneisses, granite porphyroids, schists and quartzites having the composition of U-Th bearing minerals. [16] Have reported that radon level was found to be higher

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in the area comprising of granite, quartz porphyry, schist and phyllite and lowest in sedimentary rocks and quartzite. Geologically, Kumaon Himalaya is delimited by MCT in the north and MBT in the south. Between these two regional planes of separation Precambrian and Paleozoic sedimentary and metamorphic rocks are found. Radon concentration in water is measured from springs and hand pumps of this region. In south Kumaon Himalaya, the maximum value of radon concentration was reported from a water sample of hand pump (392Bq/l) and minimum from colluvial spring type (1Bq/l). While in northeastern Kumaon region, the maximum value of radon concentration was reported from a water sample of hand pump (502Bq/l) and minimum from colluvial spring type (5Bq/l). Besides the natural radioactive source geohydrological characteristics of spring also control the radon concentration in groundwater. [13] have observed that there is a weak correlation between radon and radium. They have investigated in soil and water samples of some localities in Delhi and Rajasthan. The maximum (5.03Bq/kg in Badli area) and minimum (1.74bq/kg in Smaypur) concentration of radon and radium is found in soil samples of Delhi region. While in Rajasthan region, the maximum (2.90Bq/kg in Ratnagarh) and minimum (1.97Bq/kg in Lakshmangarh). The exhalation rate of radon and radium in soil samples is 2.15-6.21mBq/kg/hr in Delhi region. While in Rajasthan,2.43-3.58mbq/kg/hr. The maximum (1.54Bq/l in Pitampura) and minimum (0.17Bq/l in Smaypur) concentration of radon has been observed in water samples of Rajasthan. [12] carried out radon measurements in soil samples of some villages of Udhampur district of J&K, India. Monitoring of any release of radioactive material to the environment is necessary for environment protection. Radon concentration in soil samples varies from 5.46(Albatica village) – 19.17Bq/kg (Jib). Uranium concentration in soil samples ranges from 2.53(Albatica) – 3.65ppm (Jib).While radon exhalation rate is found to vary from 6.42 (Albatica) – 22.47mBq/kg/hr (Jib). The workers have observed a positive correlation between uranium concentration and radon exhalation rate in soil samples and also between uranium content and radon content in soil samples of the study area.

[3] have measured radon in different springs draining from different hydrological setups and water to find the geo-hydrological control over radon concentration in groundwater emanating in the form of spring overall. The study area involves the north-central part of Kumaon lesser Himalayas (Garhwal Himalayas). The area is dominated by multiple deformations resulting in superimposed folding, repeated faulting and thrusting. The radon measurements are found to be associated with four spring types (fracture joint-related spring, fault lineament related spring, fluvial related spring and colluvial related spring) and rivers/streams. The maximum radon value is found in fracture joint-related spring I .e.887Bq/l (budhakedar area belongs to Bhatwari formation) and minimum radon value in colluvial related spring i.e. 0.2Bq/l (Sharna area belongs to Bering formation). Whereas, in rivers/streams maximum concentration of radon 26.2Bq/l is found to be associated with Balganga river from Bhatwari formation and minimum concentration 0.1bq/l Bhilangana river at Ghansali from Bering formation. The high concentration of radon in fracture joint-related spring is due to the increased ratio of rock surface area to water volume and uranium minerals in the shear zones while the minimum concentration in colluvial related spring type is due to high transmissivity and turbulent flow within such deposits leading to natural domination of gases. The researchers have observed that radon values recorded highest in springs draining through gneisses, granites and mylonites.

[15] Collected 20 water and soil samples from different locations of Bikaner and Jhunjhunu districts of Rajasthan. The radon concentration in water samples (collected from hand pumps and tube wells having depth ranging from 50-600feet) varies from 0.50Bq/l (lunkaransar area of Bikaner) – 9.8Bq/l (Mandela area of Jhunjhunu). The radon concentration in soil samples (all soil measurements have been carried out at 100cm depth) varies from 941Bq/m3 (kaloo area of Bikaner) – 10,050Bq/m3 (Khetri area of Jhunjhunu). Radon concentration in soil and water samples of the studied area is found within safe limits. It can be used for drinking and construction purposes without posing any significant radiological threat to the inhabitants. [11] Also reported problems of high radon levels from groundwater in some parts of Bangalore.

IV. CONCLUSION

Radon can be used as the precursor for the geodynamic and tectonic events Radon concentration in underground aquifers can be used for finding the groundwater movements and deciphering the linkage between the aquifers the most important aspect of the radon is in deciphering the tectonically active zones which van be future lucky for the major earthquake events. Rn^{222} and the progeny level is found to exhibit a seasonal variation peak in winter and minimum in summer and rainy season with the maximum to the minimum ration of 9.0. Diurnally radon concentration is highest in early morning hours and least in the afternoon in increased towards the sunset. Radon and helium are established as geochemical precursors for earthquake predictions studies. Helium/ radon ratio seems to be a better predictive tool in comparison to individual radon and helium. Radon because of its short half-life 3.8 days attenuates rapidly for crustal layers deep than 500 m whereas helium is a highly mobile gas and is carried by fluids deep up to 5 km without attenuation. The stress causing an earthquake builds up around the hypocenter, during this phase first helium is affected at deeper layers and its ammunition increases hence helium/ radon ratio rises sharply. When stress reaches upper crustal layer radon ammunition is enhanced from rocks under excessive strain. Therefore radon can carry geochemical signals from the deep interior before an earthquake.

V. FUTURE SCOPE

Needs for standardization of the measurements arises out of the necessity to evaluate a national average and prepare an Rn^{222} map of the country. SSNTD technique can be extensively used for indoor Rn^{222} Thoron monitoring. The measurement has to consider the seasonal, diurnal variation of indoor Rn^{222} levels for correctly estimating the loss. The presence of Thoron and its progenesis in some location is yet another factor which needs special attention for attaining an average value of indoor Rn^{222} and loss arising due to inhalation it is necessary to have a countrywide newly Rn^{222} map covering all the seasonal variation in different type of dwellings for exploration of radioactive minerals, locating oil and natural gas deposits, underground fluid motion and water resources, earthquake prediction, radiation health hazards, geothermal resources and delineation of hidden/active fault which can be the loci for the future earthquake.

Integrated gamma and radon survey may be useful in locating shallow fracture zone in hard rock terrains for groundwater potential. There is a need to take up large scale radon activity evaluation in India on the line of the USA and Europe to correlate episeismological studies with environmental radon level however no such survey has been undertaken in Asian country including India even the estimation of radon level not available. Radon gas may be the major source of public radiation exposure accounting between 5 to 20% of lung cancer death. There seems to be a correlation between radon concentration in dwelling and radium content in soil samples there is need to prepare the radium inventory map of India so the high radon rich area can be identified with the help of Radium inventory map for pinpointing the areas of detailed radon survey.

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