Introduction

Literature survey is done in connection with the objectives of the studies. Majority of researchers from India and different places of the world measured the activity of radium and radon in ground water, $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ from the environmental samples like in rock, soil and building materials, ambient gamma radiation levels of the different environments and also physicochemical parameters of ground water. Different types of techniques applied by the various researchers for the analysis of natural radionuclides in rock, soil and building materials like granite, cement, marble, tiles, paints, brick and sand samples and also radium, radon and physicochemical parameters of ground water. In the present study a review of literature is made on the following topics.

- Ambient $\gamma$-radiation level in the atmosphere
- Studies on radon and radium in ground water.
- Distribution of activity of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in soil, rock and building materials.
- Radon in ground water and physicochemical parameters.
- Concentration of radon in indoor atmosphere.

2.1. Ambient $\gamma$-radiation level

Surinder Singh et al (2001) have reported the gamma activity near the wall in the dwellings of Kulu area, Himachal Pradesh, India as 10.5 to 28.5$\mu$Rh$^{-1}$ using environmental dosimeter $^{[1]}$.

Sreenivasa Reddy et al (2002) have measured the natural background radiation level in the dwellings of river basin of Godavari, Khammam, Andrapradesh, India using Thermo luminescence Detectors (TLDs) and reported the average value of natural background radiation level as 185.6±26.5nGy.h$^{-1}$.$^{[2]}$

Sivakumar R et al (2002) have measured Indoor gamma radiation dose rates inside residential buildings in Gudalore using a CaSO$_4$: Dy thermo luminescent dosimeter the maximum dose rate is observed during summer and less in winter. The dose rates observed were between 77.9 and 229.3nGy h$^{-1}$.The calculated mean annual effective
dose equivalent rates range between 477.6 microSv y$^{-1}$, for the inhabitants of mud houses to 1406.3 microSv y$^{-1}$, for those living in terrace houses made of cement and brick [3].

**Vinay Kumar Reddy et al (2003)** have reported natural background levels varied from 87.9 to 456.0 nGy.h$^{-1}$ in to around Lambapur to Peddagatutto areas of Nalgonda district, tora Pradesh using Thermo luminescence Detectors [4].

**Ramola et al (2004)** have measured natural radiation level in both the indoor to outdoor atmosphere using environmental radiation dosimeter in TehriGarhwal, Uttaranchal to report the value of the gamma activity varied from 29.74 to 41.19 μRh$^{-1}$ with a mean of 36.5 μRh$^{-1}$ for indoor environment to 28.76 to 43.46 μRh$^{-1}$ with a mean of 30.1 μRh$^{-1}$ for outdoor environment [5].

**Asha Rani et al (2005)** have reported an average outdoors terrestrial gamma dose rate as 83.28 nGy.h$^{-1}$ in Himachal Pradesh using gamma scintillometer [6].

**Brahmanandhan et al (2006)** have estimated the total dose due to natural background radiation around Kudankulam nuclear power plant (Radhapuram and Nanguneri taluks) using TLD and reported mean value of indoor gamma dose rate as 305±48 nGy.h$^{-1}$ and 273±50 nGy.h$^{-1}$ in Radhapuram and Nanguneri taluks respectively[7].

**Narayana et al., (2007)** have reported the median values of gamma absorbed dose rates in air as 44 nGy.h$^{-1}$, 35 nGy.h$^{-1}$ and 57 nGy.h$^{-1}$, in the Kali, Sharavathi and Netravathi riverbanks, respectively using a portable plastic scintillometer and distribution of radionuclide’s using NaI(Tl) gamma ray spectrometer [8].

**Sonkawade et al (2008)** have reported variation of absorbed dose as in the range of 23 to 185 nGy.h$^{-1}$ and the indoor annual effective dose in the range of 0.11 to 0.91 mSv with the outdoor annual effective dose ranged from 0.03 to 0.23 mSv using scintillometer [9].

**M.S.Negi et al (2009)** have measured the gamma radiation around the Tehri Dam Project in Uttarakhand state by using Environmental Radiation Dosimeter. The recorded gamma dose rate in the indoor atmosphere was found to vary from 25.1 μRh$^{-1}$ to 67 μRh$^{-1}$ with a mean value 38.6 μRh$^{-1}$[10].
Mohankumari and B N Anandaram (2013) have measured the outdoor and indoor environmental gamma radiation level in several parts of Sagara and Soraba taluk, Shimoga district, Karnataka, INDIA, using a calibrated radiation gamma survey monitor. The measurement was made during winter and summer seasons. The gamma radiation dose rate in outdoor environment is range from 43.5nGy h\(^{-1}\) to 287.1nGy h\(^{-1}\). Gamma radiation dose rate in indoor atmosphere varied from 43.5nGy h\(^{-1}\) to 261nGy h\(^{-1}\). The higher dose rate was recorded in the houses having granitic flooring and lower dose rate in the houses having white marble flooring\[11\].

N. Karunakara and Yashodhara (2014) have calculated the gamma dose rates in and around uranium mining region of Gogi using gamma dose survey meter. The ratio of indoor to outdoor dose rate is 1.09 with the geometric mean values of indoor and outdoor gamma dose rates were 104nGy h\(^{-1}\) and 97nGy h\(^{-1}\) respectively\[12\].

2.1.a. World scenario.

Karahan and Bayulken (2000) studied the gamma absorbed dose rate in Istanbul, Turkey and they have reported mean value of gamma absorbed dose rate as 65nGy.h\(^{-1}\)[13].

Vaupotic (2001) reported the values of gamma radiation level ranged between 0.47 and 2.06 mSv.y\(^{-1}\) for indoors, and 0.62 and 1.07 mSv.y\(^{-1}\) for outdoors in schools on the territory of the abandoned uranium mine 'Zirovskivrh'[14].

Shahbazi-Gahrouei (2002) has reported an average exposure rate of 49 nGyh\(^{-1}\) and annual average effective dose as 0.49±0.04 mSv using scintillation detector in Chaharmahal and Bakhtiari province, south west of Iran [15].

Isomura (2003) has estimated the regional distributions of natural gamma ray radiation in Hyogo Prefecture and space radiation dose using scintillation spectrometry and the mean spatial dose rate reported as 68.7nGy.h\(^{-1}\). They have the observed lowest level of 24.5nGy.h\(^{-1}\) at serpentinite area in Ooya and Sekinomiya town and highest level was 177.6nGy.h\(^{-1}\) at granite area in Mt. Rokko [16].

Sundaland Strand (2004) has reported an arithmetic mean of indoor gamma dose rate of 200 nGy.h\(^{-1}\) and a maximum of 620 nGy.h\(^{-1}\) in wooden dwellings located directly on the most thorium-rich of Norwegian [17].
Colmenero Sujo et al (2004) have estimated the value of annual effective dose of gamma radiation from the soil and radon inhalation as 3.83 mSv in soil samples taken from areas surrounding the city of Aldama, in Chihuahua using high-resolution gamma spectrometry.\(^{[18]}\)

Fayez H.H and Al-Ghorabie (2005) have reported an average outdoor gamma radiation dose rate from terrestrial gamma rays ranged from 14 to 279 nGy.h\(^{-1}\) for the period of 2001-2002 in At-Taif city, Al-Haba village and Ash-Shafa village of western region of the Kingdom of Saudi Arabia using CaSO\(_4\) : DyThermo Luminescence Dosimeters (TLD-900). They have reported indoor gamma radiation dose ranged from 90 to 221 nGyh\(^{-1}\) for the period of 2002-2003.\(^{[19]}\)

Gorjánácz et al (2006) have measured the terrestrial gamma activity in both the indoor and the outdoor environment in the vicinity of Hungarian uranium mine and the reported value from 62 to 233 nGy.h\(^{-1}\) and 93 to 27 5nGy.h\(^{-1}\) in Kövágószöllös and Cserkút, respectively.\(^{[20]}\)

Xinwei Lu and Xiaolan Zhang (2007) have observed mean outdoor gamma absorbed dose rate due to primordial radionuclides as 69.7 nGy.h\(^{-1}\) in Mountain National Geological Park of China using NaI(Tl) detector.\(^{[21]}\)

Mujahid et al (2008) have calculated the absorbed dose rate of gamma in air and the annual effective dose were in the range from 18.54 ± 1.17 to 52.90 ± 3.31 nGy.h\(^{-1}\) and 0.09 ± 0.01 to 0.26±0.02 mSv, respectively in Pakistan using high-purity germanium detector.\(^{[22]}\)

Degerlier et al (2009) reported the value of outdoor gamma dose rates as 67 nGy.h\(^{-1}\) using portable gamma scintillation detector in air 1m above ground level in Turkey and the value of estimated annual effective dose to the public as 82μSv.\(^{[23]}\)

Erol Khan et al (2010) have measured the outdoor gamma radiation in air around the Canakkale, Turkey by using plastic scintillators. The average gamma absorbed dose rate was found to be 66.4nGy/h and corresponding to an annual effective dose of 81.4μSv.\(^{[24]}\)

A.A Sadiq and E.H Agba (2012) have investigated the ambient radiation levels in Keffi, Nigeria by using a halogen-quenched GM detector. Some areas were found to have a relatively higher indoor dose, while others had a higher outdoor dose.
equivalent rate ranging from 0.81 to 1.27 mSv/yr and 0.21 to 0.28 mSv/yr for the outdoor and the indoor radiation levels respectively. The mean outdoor and indoor radiation levels were found to be 0.25 and 1.08 mSv/yr respectively [25].

Muhammad Rafique (2013) has measured the ambient indoor/outdoor gamma dose rates in Muzaffarabad city, the state capital of Azad Kashmir using a portable Ludlum Model 19 Micrometer. For the outdoor measurements, minimum and maximum gamma dose rates were found as 533±4.33 and 1,143±0.96 μGy y⁻¹, while for the indoor environment minimum and maximum gamma dose rate value were found as 533 ± 4.33 and 979±3.2 μGy y⁻¹. Average values of indoor and outdoor gamma dose rates were found as 761±3.62 and 710±3.75 μGy y⁻¹[26].

Flex B et al (2015) have measured the gamma radiation in Microbiology and physics laboratories all of Plateau State University Bokkos by using gamma ray spectrometer. The mean equivalent dose rate per hour for indoor background radiation for the laboratories was found to be 0.256 Sv/hr⁻¹ while the outdoor was 0.249 Sv/hr⁻¹. The mean annual equivalent dose rate of the laboratories were compute for indoor and outdoor background radiation level to be 1.54 mSv yr⁻¹ and 0.44 mSv yr⁻¹ respectively, and are in a good proportion below the world wide average dose of 2.4 mSv yr⁻¹ [27].

The Indian average value for gamma absorbed dose rate is 55 nGy h⁻¹ at outdoor. The world average at indoor is 84 nGy h⁻¹ and outdoor is 58 nGy h⁻¹ according to UNSCEAR report. About 95% of the world’s population is assumed to live in areas of normal background radiation with outdoor exposure ranging from 24 to 160 nGy h⁻¹ [28]. The national indoor values are ranged from 20 to 190 nGy h⁻¹ with average of 80 nGy h⁻¹ and outdoors are varied from 20 to 1105 nGy h⁻¹ with an average value of 56 nGy h⁻¹.
2.2. Distribution of activity of radionuclides in soil and rock samples.

Many investigators have carried out the work on the distribution of radionuclides in relation to their mineral composition in soil and rock. In addition to the useful applications, it is possible to detect contamination instantly and thus appropriate measures against the risk of human health and environment from radiation can be taken.

This section explains brief earlier studies, associated with activity of $^{226}$Ra, $^{232}$Th and $^{40}$K, from soil, rock, and building materials. This gives significant amount of information about the study carried by various researchers in the different parts of the world. The data is published in the national and international journals.

2.2.a Indian scenario

Mishra and Sadasivan (1971) have measured the $^{226}$Ra activity in Indian soils by using gamma spectrometry and they have reported 2.6 – 26.3 Bq.kg$^{-1}$[29].

Ramachandran and Mishra (1989) have measured the natural radioactivity levels in Indian foodstufs by using gamma spectrometry. The activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in food items for the population of Bombay environment ranged from 45.9 to 649.03 Bq.kg$^{-1}$, 0.01 Bq.kg$^{-1}$ to 1.16 and 0.02 to 1.26 Bq.kg$^{-1}$ respectively[30].

Selvasekarapandian et al (2000) have reported the mean concentration of $^{232}$Th, $^{238}$U and $^{40}$K as 75.3±44.1, 37.7±10.1 and 195.2±85.1 Bq.kg$^{-1}$, respectively in soil samples of Gudalore Taluk in the Udagamandalam district using gamma ray spectrometry[31].

Karunakara N et al (2001) have studied the distribution of radio-nuclides in the environment of Kaiga, in the south west coast of India, by using gamma spectrometry. The activity of $^{226}$Ra was found to vary between 15.5 to 61.2 Bq.kg$^{-1}$ with an average value of 31.3 Bq kg$^{-1}$, that of $^{232}$Th varies between 11.4 to 41.9 Bq.kg$^{-1}$ with an average value of 27.5 Bq.kg$^{-1}$ and of $^{40}$K between 78.3 to 254.8 Bq.kg$^{-1}$ with an average value of 159.9 Bq.kg$^{-1}$[32].

Kannan et al (2002) have observed the concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in soil samples collected from Kalpakkam and the values varied from 5 to 71, 15 to 776 and 200 to 854 Bq.kg$^{-1}$, respectively using gamma ray spectrometry. In beach sand
samples, $^{238}$U, $^{232}$Th and $^{40}$K contents varied from 36 to 258, 352 to 3872 and 324 to 405Bq.kg$^{-1}$, respectively [33].

Sannappa et al (2003) have done the studies on background radiation and reported that the average values radon and thoron concentrations were found to be 23.17 and 22.19Bqkg$^{-1}$, respectively. The authors concluded that the radon concentration, gamma radiation and $^{226}$Ra and $^{232}$Th activity in the soils are lower than the global average value [36].

Ramasesamy et al (2004) have measured the activity concentrations of radionuclides in beach-rock samples of southeast coast of Tamilnadu using gamma ray spectrometry. They found that average values of activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K were 29.25Bq kg$^{-1}$, 144.18Bq kg$^{-1}$ and 267.48Bq kg$^{-1}$, respectively [37].

Sannappa et al (2005) have been carried out an extensive study on radionuclides in soil samples collected from different locations of Mysore region using gamma ray spectroscopy method with HPGe detector. They found activity of $^{226}$Ra and $^{232}$Th in soils were varied from 10 to 15Bq.kg$^{-1}$ for $^{226}$Ra with an average value of 14Bq.kg$^{-1}$ and from 8.5 to 20Bq.kg$^{-1}$ for $^{232}$Th with an average of 16.5Bq.kg$^{-1}$ [38].

Khanna et al (2006) have been reported the activity of radionuclides ranged from Below-Detectable-Level to 613.24Bq kg$^{-1}$, BDL to 229.86, and 32.03 to 567.76Bq kg$^{-1}$, respectively in Agastheeswaram taluk of Kanyakumari district by $\gamma$-ray spectrometry using NaI(Tl) detector. The total absorbed dose rate due to the distribution of these elements had been reported as 112.97nGy.h$^{-1}$[39].

Rohit Mehra et al (2007) have observed the values of activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in the soil samples collected from Malwa region of Punjab using HPGe detector based on high-resolution gamma spectrometry. It was varied from 18.37 to 53.1Bq.kg$^{-1}$, 57.28 to 148.28Bq.kg$^{-1}$ and 211.13Bq.kg$^{-1}$ to 413.27Bq.kg$^{-1}$ with overall mean values of 35, 80 and 317Bq.kg$^{-1}$, respectively [40].

Ramola et al (2008) have measured the activity concentrations of primordial radionuclides in the soil samples collected from different lithological units of the Thauldar and Budhakedar regions of Garhwal Himalaya, India using gamma ray spectrometry and reported values of $^{226}$Ra, $^{232}$Th and $^{40}$K varied from below detection level to 131±18, 9±6 to 384±53 and 471±96 to 1406 ± 175Bq.kg$^{-1}$, respectively [41].
V.R.K. Murtya, N. Karunakara (2008) have been carried out the experiment to measure the activity of primordial radionuclides in soil samples of Botswana by using gamma spectrometry. The activity of $^{226}$Ra was found to vary in the range 6.1 to 97.4 Bq kg$^{-1}$ with a mean value of 34.8 Bq kg$^{-1}$, $^{232}$Th in 7.4 to 110.0 Bq kg$^{-1}$ with a mean value of 41.8 Bq kg$^{-1}$ and that of $^{40}$K between 33.5 and 1085.7 Bq kg$^{-1}$ with a mean value of 432.7 Bq kg$^{-1}$ in surface soils. The mean value of effective dose, due to the $^{238}$U series, $^{232}$Th series and $^{40}$K in soil, was 0.07 mSv $^{[42]}$.

Ningappa and Sannappa (2008) have reported the natural radiation levels and radionuclides concentration in the Bangalore rural by using HPGe Detector and Scintillometer. It was found that the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples were found to vary from 32.4 to 55.2, 39.9 to 214.3 and 485.4 to 1150.2 Bq kg$^{-1}$ respectively and the corresponding arithmetic mean values of 40.7, 93.1 and 750.4 Bq kg$^{-1}$ and activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in rocks were varied from 32.2 to 163.6, 128.3 to 548.6 and 757.4 to 1418.4 Bq kg$^{-1}$, respectively and the corresponding arithmetic mean values of 93.2, 306.2 and 1074.4 Bq kg$^{-1}$ $^{[43]}$.

Singh J et al (2009) have studied the natural radioactivity levels in soil of Upper Siwaliks of Kala Amb, Nahan and Morni Hills, Northern India, using gamma-ray spectrometry. The concentration of natural radionuclide contents in soil were varies from 28.3±0.5 to 81.0±7 Bq kg$^{-1}$, 61.2±1.3 to 140.3±2.6 Bq kg$^{-1}$ and 363.4±4.9 to 1002.2±11.2 Bq kg$^{-1}$ respectively $^{[44]}$.

M. Sowmya1, B. Senthilkumar1(2010) have measured the activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples from the Madras atomic power station, Kalpakkam, South India using gamma-ray spectroscopy. The average activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples were found to be 22.6±12.6 to 92.8±44.3 and 434.1±131.1 Bq kg$^{-1}$, respectively. 74.6±30.8 nGy h$^{-1}$ was the outdoor gamma absorbed dose rate and annual effective dose was 91.5±37.8 mSv y$^{-1}$ respectively $^{[45]}$.

Christa E P et al (2011) have studied the radiation levels of $^{238}$U, $^{232}$Th and $^{40}$K in soil samples of Kollam district of Kerala by using gamma-ray spectroscopy. The activities of $^{238}$U, $^{232}$Th and $^{40}$K was found to vary from 17 to 3081 Bq kg$^{-1}$, 54 to 11976 Bq kg$^{-1}$ and BDL 67.4 Bq kg$^{-1}$ to 216 Bq kg$^{-1}$ respectively and outdoor gamma dose rates varied from 49 to 9244 nGy h$^{-1}$ $^{[46]}$. 

44
Badhan K et al (2012) have estimated the activity concentration and absorbed gamma dose rates due to primordial radionuclides $^{238}$U, $^{232}$Th and $^{40}$K for the soil of different villages of Ludhiana district of Punjab, India using a high-purity germanium detector. The average activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in the soil samples were found to be 28.58, 50.95 and 569.59 Bq kg$^{-1}$ and the total gamma dose rate contribution of 68.50 nGy h$^{-1}$ [47].

Dhawal Sj et al (2013) have measured the activity due to radionuclides, $^{238}$U, $^{232}$Th and $^{40}$K, in 50 soil samples collected from South Konkan, Maharashtra, India. The mean activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K are 44.97 ± 1.22 Bq kg$^{-1}$, 59.70 ± 2.17 Bq kg$^{-1}$ and 217.51 ± 8.75 Bq kg$^{-1}$ respectively, measured from all the soil samples studied. The good correlation between activity concentration of $^{238}$U, $^{232}$Th and $^{40}$K as well as between activity concentration of $^{232}$Th and $^{40}$K was observed. The average calculated absorbed dose rate in air (68.08 nGy h$^{-1}$) was found to be higher than the world average of 57 nGy h$^{-1}$ [48].

I Yashodara, and N. Karunakar (2013), have estimated the activity concentration of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the soil samples in the Gogi region measured by the HPGe gamma spectrometer method. The activities of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the soil were varied in the range of 5-176 Bq kg$^{-1}$, 9-686 Bq kg$^{-1}$, and 81-1493 Bq kg$^{-1}$ with corresponding median values of 36 Bq kg$^{-1}$, 85 Bq kg$^{-1}$ and 859 Bq kg$^{-1}$ respectively [50].

B.C. Shivakumar et al (2014) have studied the concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in rock and the surrounding soil was carried out in the Mandya district, Karnataka, India by using HPGe gamma spectrometry. In rock samples the geometric mean activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th were 1143.8 Bq kg$^{-1}$, 77.1 Bq kg$^{-1}$ and 142.22 Bq kg$^{-1}$ respectively and in soil the geometric mean values were 639.92 Bq kg$^{-1}$, 40.57 Bq kg$^{-1}$ and 72.76 Bq kg$^{-1}$ respectively [51].

P. Shahul Hameed and G. Sankaran Pillai (2014) have measured the activity concentrations and absorbed dose rate of primordial radionuclide’s ($^{238}$U, $^{232}$Th and $^{40}$K) in the rock samples collected from 14 sedimentary rocks and 9 igneous rocks in Tiruchirappalli district by using gamma ray spectrometry. In sedimentary rocks the geometric mean activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K were found to be 7.4, 29.5 and 233.6 Bq kg$^{-1}$, respectively and in igneous rocks geometric mean activity...
concentrations of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were distinctly higher and found to be 13.1, 105.7 and 888.8 Bq kg$^{-1}$ respectively.$^{[52]}$

**Manjulata Yadav and Mukeshrawat (2015)** have measured the activity level due to the presence of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in soil samples of Purola area in Garhwal Himalaya region, using HPGe. The measured activity of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in collected soil samples of Purola was found to vary from 13±10 to 55±10 Bq kg$^{-1}$ with an average of 31±2 Bq kg$^{-1}$, 13±10 to 101±13 Bq kg$^{-1}$ with an average 30±3 Bq kg$^{-1}$ and 150±81 to 1310±154 Bq kg$^{-1}$ with an average 583±30 Bq kg$^{-1}$, respectively and the radium equivalent activity were found to vary from 47 to 221 Bq kg$^{-1}$ with an average of 115 Bq kg$^{-1}$. The total absorbed gamma dose rate in this area was found to vary from 22 to 93 nGy h$^{-1}$ with an average of 55 nGy h$^{-1}$.\[53]

**2.2b World scenario:**

**Karahan and Bayulken (2000)** have studied the activity concentrations of radionuclides in soil samples collected from Istanbul, Turkey using gamma-ray spectrometry and reported mean values of concentrations of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ as 21, 37 and 342 Bq kg$^{-1}$ respectively.$^{[54]}$

**N.K Ahmed et al (2001)** have been carried out the study on natural radioactivity concentrations in some Egyptian rock phosphate samples using HPGe gamma spectrometer and reported values of concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ varied from 41.4 ± 3 to 1873.0 ± 137 Bq kg$^{-1}$, 1.5 ± 0.3 to 9.0 ± 3 Bq kg$^{-1}$ and 11.5 ± 3 to 54.8 ± 8 Bq kg$^{-1}$ with average value of 479 ± 222, 6.0 ± 5 and 28.0 ± 13 Bq kg$^{-1}$.\[55]

**Jamal Al-Jundi (2002)** have observed the values of activity concentrations of radionuclide’s ranged from 48.3 to 523.2 Bq kg$^{-1}$ for $^{238}\text{U}$, 8.7 to 27.1 Bq kg$^{-1}$ for $^{232}\text{Th}$ and 44 to 307 Bq kg$^{-1}$ for $^{40}\text{K}$.$^{[56]}$

**Tzortzis (2003)** have estimated the values of activity concentration varied from 1 to 906 Bq kg$^{-1}$, 1 to 588 Bq kg$^{-1}$ and from 50 to 1606 Bq kg$^{-1}$ for $^{232}\text{Th}$, $^{238}\text{U}$ and $^{40}\text{K}$, respectively in granite rock samples imported to Cyprus for use in the building industry using high-resolution gamma ray spectroscopy.$^{[57]}$

**Matiullah (2004)** have reported the mean activity concentration levels of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in the soil samples collected from Bahawalpur division, Pakistan, using gamma spectrometry technique. It was found that mean activity concentration levels
of $^{226}$Ra, $^{232}$Th and $^{40}$K were varied from $32.9 \pm 0.9$, $53.6 \pm 1.4$ and $647.4 \pm 14.1$ Bq kg$^{-1}$, respectively [58].

*Tahir (2005)* have reported the mean activity concentrations of $^{232}$Th, $^{226}$Ra and $^{40}$K in soil samples collected from Punjab Pakistan, by using P-type coaxial high purity germanium (HPGe) based gamma–ray spectrometer. The activity concentrations $^{232}$Th, $^{226}$Ra and $^{40}$K were varied from 41 to 8, 35 to 7 and 615 to 143 Bq kg$^{-1}$, respectively [59].

*Isinkaye and Ajayi (2006)* have studied the concentration of radionuclides in Nigeria using highly sensitive HpGe detector and reported the mean activity concentrations values of $^{40}$K, $^{226}$Ra and $^{228}$Ac are $585.50 \pm 17.40$ Bq kg$^{-1}$, $66.91 \pm 5.23$ Bq kg$^{-1}$ and $48.91 \pm 2.10$ Bq kg$^{-1}$ in rock samples $113.89 \pm 5.64$ Bq kg$^{-1}$, $21.47 \pm 5.14$ Bq kg$^{-1}$ and $14.20 \pm 1.07$ Bq kg$^{-1}$ in sediment samples, respectively collected around Ikogosi warm spring of Nigeria [60].

*Xinwei Lu and Xiaolan Zhang (2007)* have reported the concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in the rock samples collected from Mountain National Geological Park of China by using NaI (TI) detector. It was found that concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K varied from 10.7 to 34.8, 19.9 to 53.6 and 642.7 to 1609 Bq kg$^{-1}$ with an average of 20.4, 30.1 and 1009.5 Bq kg$^{-1}$, respectively [61].

*K. M. Dabayneh (2008)* have measured the activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in soil samples collected from diverse zones in the southern area of West Bank, Palestine using gamma-ray spectroscopy. The measured activities of $^{238}$U, $^{232}$Th and $^{40}$K were found to range from 32.9 to 104.7, 14.5 to 76.6 and 297 to 962 Bq kg$^{-1}$ with averages value of 68.7, 48.0 and 630 Bq kg$^{-1}$, respectively. The obtained values of activity concentrations are higher than the world average of 35, 30 and 500 Bq kg$^{-1}$ for $^{238}$U, $^{232}$Th and $^{40}$K, respectively [62].

*Ajayi OS et. al (2009)* have measured the activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in surface soil samples of Nigeria by means of gamma spectroscopy with a high-purity germanium detector. It was found that activity concentration values of $^{40}$K, $^{226}$Ra and $^{232}$Th were varied from $34.9 \pm 4.4$ to $1,358.6 \pm 28.5$ Bq kg$^{-1}$; $286.5 \pm 308.5$ Bq kg$^{-1}$; $9.3 \pm 3.7$ to $198.1 \pm 13.8$ Bq kg$^{-1}$ with a mean value of $54.5$ Bq kg$^{-1}$ and a standard deviation of $38.7$ Bq kg$^{-1}$, while that of were varied from $5.4 \pm 1.1$ to
502.0 ± 16.5Bq kg⁻¹ with a mean value of 91.1Bq kg⁻¹ and standard deviation of 100.9Bq kg⁻¹[63].

**Canbaz et al (2010)** have reported natural gamma-emitting radionuclides and activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K in rocks and soils from the Ezine plutonic area by HPGe gamma spectrometry. The activity concentrations of $^{226}$Ra ranged from 94 to 637Bq kg⁻¹, those of $^{232}$Th ranged from 120 to 601Bq kg⁻¹ and those of $^{40}$K ranged from 1074 to 1527Bq kg⁻¹ in the analysed rock samples from different parts of the pluton[64].

**D. Otwoma et al (2012)** have measured the radioactivity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in rock and soil samples collected from Homa Mountain area in southwestern Kenya, by using p-type intrinsic hyper pure germanium (HpGe) coaxial detector. The average values of $^{40}$K, $^{226}$Ra and $^{232}$Th were 915.6, 195.3 and 409.5Bq kg⁻¹, respectively. The range of the annual effective dose for a person living in Homa Mountain area was varied from 28.6 to 1681.2 with a mean of 470.4μSv[65].

**Matthew(2013)** have studied the activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in tailing enriched soil and sediment samples collected from two mining sites in southwestern Nigeria by using gamma spectrometry with low background NaI(Tl) detector. The activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in all the measured samples were varied from 249.66 to 1459.25Bq/kg, 7.62 to 50.31Bq/kg and 12.68 to 234.18Bq/kg, respectively in soil samples and for sediment samples, the values were varied from 241.86 to 1590.40Bq/kg, 9.86 to 74.8Bq/kg and 15.47 to 145.46Bq/kg for $^{40}$K, $^{226}$Ra and $^{232}$Th, respectively. The results show that the mean activity concentrations of the radionuclides in soil and sediment of the study area are higher than their world-wide average crustal values[66].

**Maurice Moyon Ndontcheng et al (2014)** have been carried out the experiments to study the natural radioactivity levels of $^{226}$Ra, $^{232}$Th, and $^{40}$K in soil samples in Douala-Bassa zone of Littoral Region, by using gamma spectrometry based broad energy germanium detector (BEGe 6350). The obtained mean values of $^{226}$Ra, $^{232}$Th, and $^{40}$K in the two campuses were 25.48Bq/kg, 65.96Bqkg⁻¹, and 39.14Bqkg⁻¹ for Campus 1 and 24.50 Bqkg⁻¹, 66.71Bqkg⁻¹, and 28.19Bqkg⁻¹ for Campus 2, respectively[67].
The activity of primordial radionuclides such as $^{226}$Ra, $^{232}$Th and $^{40}$K in the Indian soils are varied from 7 to 81, 14 to 160 and 38 to 760 with the mean values of 29, 64 and 400, respectively. The average values of $^{226}$Ra, $^{232}$Th and $^{40}$K concentrations reported for normal background areas of Indian soils are 15 Bq.kg$^{-1}$, 18.36 Bq.kg$^{-1}$ and 369.6 Bqkg$^{-1}$ and the corresponding world average are 30, 45 and 420 Bq.kg$^{-1}$ respectively [2].

2.3. Activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in Building materials.

2.3a. Indian scenario:

Kant et al (2001) studied the concentration of radon and in the samples of coal and fly ash collected from different thermal power stations of Northern India and cement samples collected from Ballabgarh, Haryana using LR 115 type-II plastic detector and reported concentration of radon varied from 433 ± 28 to 2086 ± 28Bq.m$^{-3}$ for coal samples and 748 ± 28 to 1417±111Bq.m$^{-3}$ for fly ash samples and 158 to 1810Bq.m$^{-3}$ for cement samples [68].

Chauhan and Chakravarti (2002) have reported the average value of radon emanation in the coal, fly ash soil and water samples collected from thermal power plants of North India varied from 433±28 to 2086±36Bq.m$^{-3}$using SSNTDs. Their reported average radon concentration in the atmosphere of thermal power plants varied from 558±40 to 682±60Bq.m$^{-3}$[69].

Nain et al, (2006) have done the studies on radioactivity in cement samples using gamma-ray spectrometry and reported that the radon and radium concentration in various brands varied between 333±9.9 to 506±13.3Bqm$^{-3}$ and 3.7±0.1 to 5.6±0.2Bqkg$^{-1}$ while in various cementations finishing materials it was found to be 378±19.7 to 550±9.8Bqm$^{-3}$ and4.2±0.2 to 6.1±0.1Bqkg$^{-1}$ respectively. The authors concluded that there is marginal variation of the concentration of radium and radon in various brands of cement in India and the concentration levels are lower than that of average global values [70].

Mahur et al (2008) have studied the concentration of radionuclides in Jharkhand State, India and reported the values of activity concentrations of uranium varied from 123 ± 7Bq.kg$^{-1}$ to 40,858 ± 174Bq.kg$^{-1}$, 162 ± 11Bq.kg$^{-1}$ to 9024 ± 189Bq.kg$^{-1}$ for
potassium and no significant values for thorium in the rock samples collected from Singhbhum shear zone of Jharkhand State situated in eastern India\cite{71}.

**Sonkawade et al (2008)** have been reported the radio nuclides activity concentration in Northern India ($^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$) varied from 29±1 to 98 ± 4Bq.kg$^{-1}$, 20 ± 2 to 112 ± 2.8Bq.kg$^{-1}$, and 200 ± 8 to 1908 ± 15.6Bq.kg$^{-1}$, respectively in commonly used building construction materials, radiation shielding bricks, hematite aggregate and other materials\cite{72}.

**Kant et al (2010)** have done the studies on radon activity and exhalation rates in Indian fly ash samples using gamma ray spectrometer and the concentration of $^{238}\text{U}$, $^{226}\text{Ra}$ and $^{40}\text{K}$ were varied from 99 ± 2 to 203 ± 4Bqkg$^{-1}$, 145 ± 2 to 288 ± 4Bqkg$^{-1}$ and 355 ± 5 to 516 ± 6Bqkg$^{-1}$ respectively. The radon exhalation rate was varied from 7.8 to 21.6mBqkg$^{-1}$h$^{-1}$ and absorbed dose rate were 143 to 277nGyh$^{-1}$\cite{73}.

**Gupta and Chauhan (2011)** have estimated the radiation dose and concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ from soil, stone and sand samples, used as building materials in North-Eastern Haryana state of India by means of gamma ray spectrometry. It was found that the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were varied from 18±1.5 to 156± 6Bqkg$^{-1}$, 23±1 to 300±5Bqkg$^{-1}$ and 32±0.5 to 1705±14Bqkg$^{-1}$ respectively\cite{74}.

**Y. Raghu and Ravishankar R (2015)** have been studied the natural radioactivity concentration of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in building materials (brick, sand, clay, soil, cement) in Pachal of Tiruvannamalai District, Tamilnadu by using gamma ray spectrometry. It was found that the minimum concentration of $^{226}\text{Ra}$ is 7.47Bq/kg measured in sand while the highest value is 31.26Bqkg$^{-1}$ measured in cement. The lowest value for $^{232}\text{Th}$ is 27.09Bqkg$^{-1}$ was recorded in sand sample and the highest value is 77.8Bqkg$^{-1}$ obtained in clay sample. The lowest and highest values for $^{40}\text{K}$ were measured to be 233.92Bqkg$^{-1}$ and 419.7Bqkg$^{-1}$ in cement and soil respectively. The distribution of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in building materials is not uniform\cite{75}.
2.3b. World scenario:

Muhammad Iqbal et al (2000) have done the studies on measurement of natural radioactivity in marble and the reported activity concentration of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ vary from 4 to 63, 9 to 40 and 7 to 105 Bq kg$^{-1}$ respectively. The radium equivalent activity ranged from 25 to 99 Bq kg$^{-1}$ and the average values of external and internal hazards indices were 0.19 and 0.26 respectively. The authors concluded that the marble mined from the various geological sites in Pakistan is safe for use as a construction material [76].

Hewamanna et al (2001) have measured the specific radioactivity concentrations of radionuclides in clay brick samples from kiln sites using gamma ray spectrometry with an HPGe detector. It was found that specific radioactivity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ were 35, 72, and 585 Bq kg$^{-1}$, respectively [77].

Walley et al (2001) have observed the radium equivalent activity in building materials collected from both Egyptian and foreign by using hyper-pure germanium (HPGe) detector. It was varied from 5.46±0.16 to 150.52±4.52 Bq kg$^{-1}$ for marble samples and from 229.52±6.89 to 92.16±2.76 Bq kg$^{-1}$ for granite [78].

Kovler et al (2002) have reported the activity concentrations of $^{226}\text{Ra}$ in the samples of industrial by-products used in construction building in Israel by hyper-pure germanium (HPGe) detector. It was found that $^{226}\text{Ra}$ varied from 158.8 to 18.8 Bq kg$^{-1}$ in the samples of building products, 74.3 to 17.5 Bq kg$^{-1}$ in the samples of building binders, 164.5 to 17.7 Bq kg$^{-1}$ in the samples of aggregates, and 761.4 to 241.6 Bq kg$^{-1}$ [79].

Neman et al (2003) have made the survey of indoor $^{222}\text{Rn}$ and its daughters at Campinas Brazil using CR-39 and reported the $^{222}\text{Rn}$ daughter distribution is influenced by environmental factors and the building materials used for the construction of the houses. They observed the higher concentrations of $^{222}\text{Rn}$ and its daughter’s products in the houses having cement floors [80].

Freitas A C (2004) have been studied the activity concentration of $^{232}\text{Th}$ and $^{238}\text{U}$ series and $^{40}\text{K}$ radionuclides in sand of two Island beaches in south-eastern Brazil, by using gamma-ray spectrometry. The average activity concentration of primordial radionuclide’s $^{232}\text{Th}$, $^{238}\text{U}$ and $^{40}\text{K}$ at Preta beach, they were 239, 121 and 110 Bq kg$^{-1}$,
while at Dois Rios beach they were 48, 39 and 412Bq kg\(^{-1}\), respectively. The absorbed dose rate in air, observed at 1 m above the ground, ranged from 54 to 228nGy h\(^{-1}\) at Preta beach and from 39 to 110nGy h\(^{-1}\) at Dois Rios beach\[^{[81]}\].

**Ademola J A et al (2005)** have reported that the radioactivity concentrations of the natural radionuclide’s in the samples of concrete building blocks from different block making industries in Ibadan, by using gamma-ray spectrometry with a NaI(Tl) detector. The radioactivity concentrations were varied from 6.2 to 57.5Bq kg\(^{-1}\), 12.4 to 64.9Bq kg\(^{-1}\) and 95.3 to 766.1Bq kg\(^{-1}\) for \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K, respectively. The radium equivalent activities of the 32 samples varied from 51.3 to 175.7Bq kg\(^{-1}\)[82].

**A M El-Arabi et al (2006)** have studied the concentrations of radon in the rock samples in Nile valley using portable radon monitor Prassi. Their reported values of radon concentration varied from 36.1±2 to 96.4±6, 17.8±3 to 73.6±4 and 18.0±2 to 188.1±15Bq.m\(^{-3}\) for samples collected from BirElsid, Wadi El-Gemal and samples from Germany, respectively\[^{[83]}\].

**Quirino et al (2007)** estimated the concentrations of indoor \(^{222}\)Rn in the State of Zacatecas using gamma ray spectrometry of radon decay products adsorbed into charcoal canisters. The average, minimum and maximum concentrations are 67, 26 and 511Bq.m\(^{-3}\), respectively\[^{[84]}\].

**Mujahid S A et al (2008)** have been estimated the concentrations of radionuclides of \(^{232}\)Th, \(^{238}\)U and \(^{40}\)K in different brands of cement available in Pakistan using high-purity germanium detector. The range of activity concentrations were found for \(^{226}\)Ra from 25.10±1.55 to 52.60±3.20Bq kg\(^{-1}\), for \(^{232}\)Th from 10.30±0.65 to 30.40±1.70Bq kg\(^{-1}\) and for \(^{40}\)K from 17.25±1.55 to 292.95±23.05Bq kg\(^{-1}\). The estimated value of radium equivalent concentration was from 11.16±2.60 to 114.98±7.11Bq kg\(^{-1}\). The radon exhalation rates from different brands of cement were found in the range from 3.3±0.7 to 8.1±1.7mBqkg\(^{-1}\) h\(^{-1}\)[85].

**Ismail et al (2009)** have been investigated the levels of natural radioactivity and associated radiation hazard in some Malaysia’s sand used in building constructions using gamma-ray spectrometry. The activity concentration of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K were found in the range of 6.45 to 107.90Bqkg\(^{-1}\), 7.78 to 96.67Bqkg\(^{-1}\) and 31.05 to 1105.53Bqkg\(^{-1}\) respectively. The mean range of annual equivalent doses to dwellers were in the range of 0.059 ± 0.005mSvyr\(^{-1}\) to 0.738 ±0.018mSvyr\(^{-1}\)[86].
Elham Bavarnegin et al., (2012) have done the analytical study of radionuclide concentration of 226Ra, 232-Th, and 40K and 222Rn exhalation rate in building materials of ramsara northern city of Iran, using HPGe gamma-ray and an active radon gas analyser. It was found that the 222Rn exhalation rate varied from below the minimum detection limit of 0.01 to 0.31Bqm$^{-2}$h$^{-1}$ with an average of 0.08Bqm$^{-2}$h$^{-1}$. The concentrations of 226Ra, 232-Th, and 40K were varied from below the minimum detectable activity up to 73.5, 169.0 and 1.350Bqkg$^{-1}$, with the average value of 16±6, 25±11, and 280±101Bqkg$^{-1}$, respectively [87].

Leanandro et al (2014) have measured the activity concentrations of the naturally occurring radionuclides 226Ra, 232-Th and 40K in 15 Brazilian economic wall paints samples, by using high resolution gamma-ray spectrometry. The activities concentrations in the studied samples were ranged from 1.3±0.2 Bq/kg to 23.4±0.7 Bq/kg for 226Ra; from 2.5±0.4Bqkg$^{-1}$ to 45.8±1.5Bq/kg for 232Th and from 5.8±2.1Bq/kg to 157±22Bq/kg for 40K. The radium equivalent index, calculated from the 226Ra, 232-Th and 40K concentrations, varied from 1.30Bq/kg up to 95.9 Bq/kg, below the value of 370Bqkg$^{-1}$[88].

United Nations Scientific Committee on the Effects of Atomic Radiation Sources (UNSCEAR -2000) has given the mean radioactivity concentration of the three primordial radionuclides in soil samples for India and world. The world average value is 33, 45 and 420 Bqkg$^{-1}$ for 226Ra, 232-Th and 40K respectively, and the Indian average value is 29, 64 and 400 Bqkg$^{-1}$ for 226Ra, 232-Th and 40K, respectively. The average concentration of 238U in Indian soil is 29Bq.kg$^{-1}$ and the world average is 35Bq.kg$^{-1}$. It is observed from the literature review the activity of primordial radionuclides such as 226Ra, 232-Th and 40K in the Indian soils are varied from 7 to 81, 14 to 160 and 38 to 880Bq/kg with the mean values of 29, 64 and 400Bq/kg. The activity concentration of radionuclide’s such as 226Ra, 232-Th and 40K in cement are varied from 16 to 377, 2 to 385 and 130 to 1390Bq.kg$^{-1}$, respectively, in Brick 21 to 48, 26 to 126 and 130 to 1309Bq.kg$^{-1}$, respectively. And in granite varies from 4 to 98, 103 to204 and 76 to 1380Bq.kg$^{-1}$, respectively.
2.4. Concentration of radon and radium in ground water

The section is related to the earlier observations briefly, and also gives significant amount of information about the study carried by various researchers in different parts of the world. The data are published in national and international journals.

2.4.a. Indian scenario.

R.P. Chauhan and K. Kant (2001) have carried out the experiment in the different areas to measure the radium and radon concentration in different ground water near the thermal power plants in northern parts of India, by using alpha sensitive LR-115type2 track detector. It was found that the radium concentration varies from 1.11 to 3.11Bq/l, and the radon concentration varies from 10.64 to 29.78pCi/l. The radon mass exhalation rate varies from 8.95 to 25.08mBqkg⁻¹hr⁻¹ and surface exhalation rates vary from 245.21 to 690.2mBqm⁻²hr⁻¹ in different water samples [89].

V.M. Choubeya and S.K. Bartaryaa (2003) have estimated the radon concentration in groundwater of Doon valley in Outer Himalaya by using Zns coated detector. The consistency of radon concentration in tube wells and hand pumps varies from 25.4±1.8 to 92.5±3.4Bq l⁻¹ with an average of 53.5±2.6Bq l⁻¹ [90].

K.M. Rajashekaraa and Y. Narayanaa (2006) have reported concentration of radon in ground and surface water samples from two major rivers of coastal Karnataka (Kali and Sharavathi) by using an Alpha Guard PQ2000Pro. ²²²Rn concentration in bore well and open well water was found to vary in the range of 0.91 to 15.86Bq l⁻¹ and 0.33 to 9.70Bq l⁻¹ in catchment areas of Kali river. The ²²²Rn concentrations were found to vary in the range of 1.07 to 10.72 q l⁻¹ and 2.01 to 10.02Bq l⁻¹ in the bore well and open well water respectively. Then the same was found in the catchment areas of Sharavathi River subsequently. ²²²Rn concentration in the surface water of Kali river and sharavathi rivers was found to vary in the range of 0.16 to 1.79Bq l⁻¹ and 1.19 to 9.92Bq l⁻¹, respectively [91].

Vishal Arora et al (2008) have measured the activity concentration of radon in ground water samples of seismically active areas of N-W Himalayas, Himachal Pradesh and the water samples were collected from the different sources and wide range of the Himalayan villages of the Zone-I, II and III respectively. The average
values of radon concentration in water samples collected from Zone-I, II and III have been found to be 61.2Bq/l, 50.8Bq/l, and 23.2Bq/l respectively [92].

**Prasad and Ganesh (2009)** have measured the Radon concentration in ground water by using RAD7 in the Budhakedar area of Tehri Garhwal, India. It was found to vary from 8 to 3047Bq.l⁻¹ with an average value 510Bq.l⁻¹ in summer and 26 to 2311Bq.l⁻¹ with an average value 433Bq.L⁻¹ in winter. It shows a positive correlation of radon concentration in water in summer season [94].

**Rani A, Mehra et al (2012)** have studied the concentration of radon in groundwater around the different areas of the districts of Sri Ganganagar, Hanumangarh, Sikar and Churu in northern Rajasthan by RAD7, was used to estimate the radon concentration in groundwater. Radon concentration in the ground water varies from 0.5±0.3Bql⁻¹ (Chimanpura) to 85.7±4.9Bql⁻¹ (Khandela) with an average value of 9.03±1.03Bq l⁻¹. The estimated total annual effective dose of adults ranged from 1.34 to 229.68μSv y⁻¹ [95].

**Primal D’Cunha, and Y.Narayana (2013)** have traced the concentration of $^{222}$Rn in drinking water in coastal regions of Kerala. The $^{222}$Rn concentrations in water were measured using the emnometery.It was found to vary from 0.03 to 1.31Bq/l. The associated effective dose was computed for the population of the region and it varies from 0.25 to 9.53μSv y⁻¹ with mean value of 2.15μSv y⁻¹ [96].

**B.C. Shiva Kumar and M.S.Chandrashekar (2014)** have carried out the experiment to measure the activities of radionuclides $^{226}$Ra and $^{222}$Rn in ground water around Mandya district, Karnataka State, India, by using Emanometery method. It was found that the concentration of $^{222}$Rn in bore well water varies from 6.44±0.20 to 44.83±0.54Bq l⁻¹ with geometric mean 16.42±0.31Bq l⁻¹ and. $^{226}$Ra concentrations varies from 14.26±0.32 to 81.06±0.99mBq l⁻¹ with geometric mean 27.61±0.43mBq l⁻¹. The ingestion and inhalation together total dose varies from 26.31 to 178.53μSv y⁻¹ with a geometric mean of 65.94μSv y⁻¹, which is below the prescribed dose limit of 100μSv y⁻¹ by WHO [97].
Parminder Singh and et al (2015) have conducted the experiment to measure the $^{238}$U and $^{222}$Rn concentrations in drinking water samples collected from Hamirpur and Kangra districts of Himachal Pradesh and adjoining areas of Jammu and Kashmir, India, by using Laser Fluorimetry technique. The concentration of $^{238}$U and $^{222}$Rn were found in the range of $0.26 \pm 0.1$ to $29.5 \pm 2.5\mu g\ l^{-1}$ and $0.86 \pm 0.12$ to $7.62 \pm 0.64\ Bq\ l^{-1}$ respectively[^98].

2.4b. World scenario

Abdulrahman I. et al. (1996) have studied the concentration of radon in the capital city of Saudi Arabia, Riyadh by using Liquid scintillation counter, and all samples have shown low radon levels with an average concentration of $0.2\ Bq\ l^{-1}$ and a range value of 0.1 to $1.0\ Bq\ l^{-1}$ [99].

N. Zouridakis, et al., (2001) have found the concentration of radon ($^{222}$Rn) and uranium ($^{238}$U) in the ground water by using Liquid Scintillation Analyzer (LSA) and SRAFION NMRR, in situ. The measured $^{222}$Rn activity concentrations were from background level up to $160\ Bq\ l^{-1}$ [100].

Walter D’Alessandro et al (2002): have reported that concentration of radon in ground water in active volcanic area of Mt. Etna by using a Lucas scintillation chamber. Estimated activity values range from 1.8 to $52.7\ Bq\ l^{-1}$. About 40% of the samples exceed the maximum contaminant level of $11\ Bq\ l^{-1}$ proposed by the USEPA in 1991 [101].

Tadeusz Andrzej Przylibski a et al., (2003) have measured the Radon concentration in ground water of the Polish part of the Sudety Mountains, Poland by using Lucas-type scintillation chamber, within the range of 0.2 to $1645\ Bq/m^{3}$, with the arithmetic mean at $240.0\ Bq/m^{3}$ and the geometric mean at $106.7\ Bq/m^{3}$. The largest number of radon concentrations found in the Sudetic ground waters ranged between ca. 3 to 6 and $1000\ Bq/m^{3}$ [102].

Almeida Rm et al (2004) have studied and analyzed the concentrations $^{226}$Ra, $^{228}$Ra, $^{222}$Rn, $^{238}$U in the Ground water from Região dos Lagos, a coastal area of Rio de Janeiro state by using Lucas-type scintillation chamber. Concentrations values ranged from 0.002 to $0.492\ Bq\ l^{-1}$ for $^{226}$Ra, from 0.01 to $1.50\ Bq\ l^{-1}$ for $^{228}$Ra, and from
0.1mBq l\(^{-1}\) to 0.8mBq l\(^{-1}\) for \(^{238}\)U, and \(^{222}\)Rn concentrations were found to be greater than 3Bq l\(^{-1}\)[103].

**Marcus and Luiza (2005)** have analysed the radionuclide content in over 350 Brazilian groundwater samples in areas with quite different geologies by using scintillation chamber. The observed values of \(^{228}\)Ra, \(^{226}\)Ra, \(^{222}\)Ra, \(^{210}\)Pb and \(^{238}\)U content in ground water. And found the geometric means were 0.045BqL\(^{-1}\), 0.014BqL\(^{-1}\), 57.7BqL\(^{-1}\), 0.040BqL\(^{-1}\) and 1.2μgL\(^{-1}\) respectively. They have also revealed the origin of \(^{210}\)Pb in ground water is the presence of dissolved\(^{222}\)Ra in water[104].

**Villalba et al (2006)** have studied about the natural radioactivity in groundwater, throughout the state of Chihuahua ((Mexico) by using scintillation chamber. The activity concentration of \(^{222}\)Rn and \(^{226}\)Ra and total uranium in groundwater samples were analysed and found that, the total uranium activity concentration is varied from 0.03 to 1.34 BqL\(^{-1}\). Radon activity concentration is varied from 1.0 to 39.8BqL\(^{-1}\). A linear correlation between \(^{238}\)U and \(^{222}\)Rn dissolved in groundwater of individual wells was observed near Chihuahua City[105].

**F.Oner et al (2008)** have reported the radon \(^{222}\)Rn concentrations in drinking water and river water, in the city of Amasya, inner parts of the Median Black sea region in Turkey and the Yesilirmak River, by using WG-1001 Vacuum Water Degassing System and the AB-5R Radiation Monitor. It was found that the concentrations in tap water, spring water and the Yesilirmak River water in Amasya ranged from 0.42±0.14 to 2.4±0.32BqL\(^{-1}\), 0.39±0.19 to 1.17±0.21BqL\(^{-1}\)and 0.28±0.04 to1.08±0.30Bq L\(^{-1}\) respectively. The average effective dose equivalent from radon in tap water has been estimated as 5.87mSv y\(^{-1}\)[106].

**Ajayi and Adesida (2009)** have studied the radioactivity in some sachet of drinking water samples produced in Nigeria by using scintillation counter and measured the activity concentration values varied from 0.57±0.21 to 34.08±5.61BqL\(^{-1}\), 2.22±0.97 to 15.50±4.51BqL\(^{-1}\) and 0.04±0.01 to 7.04±1.16BqL\(^{-1}\) for the radio nuclides respectively[107].

**Binesh et al (2011)** have studied on radioactivity and dose assessment of heavy radioactive pollution, \(^{226}\)Ra and\(^{228}\)Ra from water sources of three northern regions in Iran by using alpha scintillation chamber. The reported \(^{226}\)Ra levels were higher than
Khalid Abdulaziz Aleissal et al (2012) have determined the concentration of $^{222}$Rn well waters located in and around the city of Riyadh in Saudi Arabia by using an ultra-low level liquid scintillation spectrometer. The measured $^{222}$Rn activities of deep wells ranged from 0.34±0.05 to 3.52±0.30Bq\textsuperscript{l}-1 and the shallow wells ranged from 0.72±0.08 to 7.21±0.58Bq\textsuperscript{l}-1\cite{109}. Ali AbidAboJassim (2013) has found the radon concentrations in drinking water in Al-Najaf cities, using RAD-7. It was found that the radon concentrations varied from (2.43±0.879Bq/m\textsuperscript{3}) to (225.5±12.657Bq/m\textsuperscript{3}), and the mean annual effective dose of Ingestion and Inhalation had varied from0.017739μS.y\textsuperscript{-1} to 1.64μS.y\textsuperscript{-1} and 0.088μS.y\textsuperscript{-1} to 0.704μS.y\textsuperscript{-1} respectively\cite{110}. Asia H. Al-Mashhadani, Adel Mehdi Sale (2015) have been carried out the experiment to measure the concentration of radioactivity in drinking water from Al-Sader city in Baghdad, Iraq by using RAD-7. The activity concentration values range were 1.400 to55.79Bq\textsuperscript{l}-1 for $^{226}$Ra, 0.0 1 to11.95Bq\textsuperscript{l}-1 for $^{232}$Thand 6.3800 to 253.86Bq\textsuperscript{l}-1 for and $^{40}$K respectively. Radium Equivalent activity was calculated and it was range from 6.8807Bq\textsuperscript{l}-1 to 63.521Bq\textsuperscript{l}-1. The absorbed dose rate in air was also calculated for the samples and it ranges from 3.1524nGyh\textsuperscript{-1} to 29.697nGyh\textsuperscript{-1}\cite{111}. From the literature survey, it is observed that radon concentration value obtained from water samples was compared with those reported by the other investigators in different parts of the world and found that, the value of radon concentration lies above the range reported by other investigators. The United Nations Scientific Committee on the Effects of Atomic Radiation(UNSCEAR) has suggested a value of radon concentration in water for human consumption between 4 to 40Bqm\textsuperscript{-3}.World Health Organization (WHO) has recommended 100Bq l\textsuperscript{-1} of radon activity in water as a safe limit for drinking purposes the allowed maximum contamination level for radon concentration in water is 11Bq\textsuperscript{l}-1 and for $^{226}$Ra the guidance value of 740mBq/l proposed by the US Environmental Protection Agency, USEPA. World Health Organization [WHO] and EU Council [EU] recommended the safe limit of the annual effective dose received from drinking water consumption to be 0.1mSv.y\textsuperscript{-1} from these $^{226}$Ra, $^{232}$Thand $^{40}$K radioisotopes.
2.5. Physiochemical parameters in ground water.

The pollutants are being added to the ground water systems through human activities and natural processes. Such as calcium, magnesium, sodium, potassium, carbonates, nitrate, bicarbonates, chloride, sulphate, total dissolved solids, total hardness, pH, iron and Radon, a natural radioactive gas.

Measurements of radon concentration and physicochemical parameters in ground water have been carried out in some places of the world. The pollution control board and mines and geology are conducted countrywide measurement of physicochemical parameter in India. Number of researchers have been studied the water quality of various groundwater from different sources. A few of them has been listed.

V.M. Choubeya and S.K. Bartaryaa (2003) have been estimated the radon concentration in groundwater of Doon valley in Outer Himalaya by using Zns coated detection chamber. Radon variation in tube wells and hand pumps varies from 25.4±1.8 to 92.5±3.4Bq\textsuperscript{-1} with an average of 53.5±2.6Bq\textsuperscript{-1}. In addition to radon and \textsuperscript{226}Ra other physicochemical parameters of water like temperature, pH and conductivity were also measured by using a portable water-analysis kit. However, no correlation was found between radon concentration and temperature, pH and conductivity\textsuperscript{112}.

Nnamdi Norbert et al (2010) have determined the activity concentrations of \textsuperscript{40}K, \textsuperscript{226}Ra and \textsuperscript{232}Th and physicochemical parameters of ground water in and around Abeokuta, Nigeria by using γ-ray spectroscopy. The total annual ingestion effective doses were found to vary between 115.00±1.15μSv and 1362.30±438.02μSv. The nitrate and phosphate levels in the ground water higher than the prescribed standard safe limits\textsuperscript{112}.

HajoIdriss et al (2011) have measured the radon concentration in wells of Khartoum State by using HPGe-detector. Radon activity concentration was found in the range of 1.58 to 345.10Bq\textsuperscript{-1} with an average value of 59.20±6.60Bq\textsuperscript{-1}. No correlation was noted between radon concentration and physicochemical parameters.\textsuperscript{113}.

Nagaiah et al (2013) have conducted the experiment to measure the concentration of uranium in the ground water in Bangalore city, India, by using Laser-Induced Fluorimetry. The concentration of uranium in the collected water samples is found to
be in the range 0.24μg/l to 770.1μg/l, with a geometric mean (GM) value of 18.9μg/l. About 35% of the water samples show the concentration of uranium above the safe limit of 30μg/l. Few physicochemical parameters of water such as pH, Total dissolved solids (TDS), major cations, major anions, and trace elements were also measured [114].

**Latife et al (2013)** have measured the concentration of radium and radon in drinking water samples collected from various locations of Kutahya city, Turkey by using collector chamber method. Physicochemical parameters such as pH, conductivity and temperature of the water. The radon concentration ranges between 0.1 and 48.6±1.7Bq/l, while the radium concentration varies from a minimum detectable activity of 0.02 to 0.7±0.2Bq/l in Kutahya city. The resulting contribution to the annual effective dose due to radon ingestion varies between 0.3 and 124.2mSv y⁻¹; the average radiation exposure from drinking water is less than 73.6mSv y⁻¹ [114].

From the literature review, it was observed that in most of the locations the quality of water is exceeding the prescribed limits of drinking water. As most of the water samples do not meet the water quality standards. So, it affects the health of the public. As per the specification fixed by the Bureau of Indian Standards (IS10500:2003) and EPA for the following elements i.e., the permissible limits of the sulphate for drinking purposes is 200 milligrams/liter to 400 milligrams/liter, chloride is 250 milligrams/liter to 1000 milligrams/liter, fluoride for drinking purposes is 1.0 milligrams/liter to 1.5 milligrams/liter. Total hardness for drinking purposes is 300 milligrams/liter to 600 milligrams/liter. The safe limit for pH as recommended by WHO is 7.0-8.5. The TDS in water is usually less than 500mg/l. The acceptable limit of the Nitrate is 45mg/l and maximum permissible limit is 100 mg/l. From the literature, it was observed that significant positive correlation between radon concentration and water temperature and fluoride. There were no correlation between radon concentration and pH value, TDS and nitrate.
2.6. Radon, thoron and their progeny

This section explains brief earlier studies, associated with concentration of $^{222}\text{Rn}$, $^{220}\text{Rn}$ and their progeny. The Baba Atomic Research Centre (BARC), Mumbai conducted countrywide measurement $^{222}\text{Rn}$, $^{220}\text{Rn}$ and their progeny levels in India. Many numbers of researchers all over the country are actively participated in measuring $^{222}\text{Rn}$, $^{220}\text{Rn}$ and their progeny. This gives the significant amount of information about the study carried by various researchers in different parts of the world. The data are published in national and international journals.

2.6a. Indian scenario:

Ramola [1997] has measured the concentration of radon in TehriGarhwal using SSNTDs and reported the mean value of radon concentration as 113.5Bq.m$^{-3}$. They also reported annual geometrical mean values of radon as 104Bq.m$^{-3}$ and 123Bq.m$^{-3}$ inside the cemented and mud houses, respectively $^{[115]}$.

Sarita [1998] has studied the concentration of radon and thoron in Rajasthan using SSNTDs. Their reported values of radon and thoron concentration varied from 6.9 to 103.7Bq.m$^{-3}$ and 1.3 to 73.2Bq.m$^{-3}$, respectively $^{[116]}$.

Virk et al (1999) have studied the concentration of indoor $^{222}\text{Rn}$/ $^{220}\text{Rn}$ in Hamirpur and Una districts of Himachal Pradesh and observed the high concentration during winter and low during summer and rainy seasons. The mean values of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ concentrations during these seasons were reported as 81.6Bqm$^{-3}$ and 39.0Bqm$^{-3}$, respectively $^{[117]}$.

Negi et al (2001) have measured the concentration of radon and thoron using SSNTDs in Garwal homes and Kumaun homes. The values reported the concentration of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ varied from 11.3Bq.m$^{-3}$ to 129.7Bq.m$^{-3}$ and 1Bq.m$^{-3}$ to 97.7Bq.m$^{-3}$, respectively in Garwal homes and 6.7Bq.m$^{-3}$ to 63.5Bq.m$^{-3}$ and from 1Bq.m$^{-3}$ to 156Bq.m$^{-3}$ respectively in Kumaun homes. The reported values of levels of $^{222}\text{Rn}$ and $^{220}\text{Rn}$ daughter varied from 0.1mWL to 21mWL and 0.1mWL to 833.6mWL, respectively in Garwal houses and 1.00mWL to 17.2mWL and 1.2mWL to 210.6mWL in Kumaun homes, respectively $^{[118]}$. 
Sarvanan et al (2002) measured the $^{222}$Rn levels in Madurai, India, using LR–115 SSNTDs and reported the low value of $^{222}$Rn concentration as 5Bq.m$^{-3}$ and high value as 184Bq.m$^{-3}$. They have observed seasonal variation and the average value of $^{222}$Rn concentration in summer as 38.5Bq.m$^{-3}$ and in winter 69.9Bq.m$^{-3}$ and yearly average as 57.6Bq.m$^{-3}$[119].

Manikandan et al (2002) reported the potential alpha-energy concentrations of the radon and thoron progeny ranged from 0.97 to 12.72mWL and from 1.63 to 15.83mWL with a geometric mean of 6.02 and 7.89mWL, respectively, taking all seasons into account measured in Udagamandalam Taluk of Nilgiris. They reported inhalation dose due to radon progeny as 1357mSv.y$^{-1}$ and the corresponding annual effective dose equivalent value as 2.13mSv.y$^{-1}$[120].

Sreenath Reddy et al (2004) reported indoor thoron concentration levels varied from 8 to 330Bq.m$^{-3}$ with the geometric mean value 37.3Bq.m$^{-3}$ and an average of 55±57Bq.m$^{-3}$ in Hyderabad city using Solid State Nuclear Track Detector (SSNTD) based dosimeters. They observed higher thoron levels in dwellings with mud flooring[121].

Ramola (2005) has measured the levels of radon, thoron, and their progeny were in the houses of Garhwal and Kumaun Himalaya using LR-115 plastic track detectors. Their reported values of radon and thoron concentrations varied from 7 to 191Bq.m$^{-3}$ and from 1 to 145Bq.m$^{-3}$, respectively and dose rate due to radon, thoron, and their decay products varied from 0.35 to 16.56mSv.y$^{-1}$ with an average of 8.41mSv.y$^{-1}$[122].

Sannappa et al (2006) have reported radon and thoron concentrations in old and new types of buildings using SSNTDs. They reported radon and thoron concentrations, which are varied from 9.0±1.6 to 89.9±5.8Bq.m$^{-3}$ and 6.0±1.7 to 48.0±8.3Bq.m$^{-3}$[123].

Ramachandran T V et al (2006) have studied the indoor radon and thoron levels in the country wide, initiated by the Bhabha Atomic Research Centre, using SSNTD method. Indoor radon levels varied from 4.6 to 147.0 Bq.m$^{-3}$ with a geometric mean (GM) of 23.3 Bq.m$^{-3}$ (GSD 2.61) and thoron levels were found to be less than the radon levels and vary between 3.6 to 42.8Bq.m$^{-3}$ with a geometric mean (GM) of 12.2 Bq.m$^{-3}$ (GSD 3.22). Mean annual inhalation dose rates due to radon, thoron and their progeny were estimated to be 0.97mSv.y$^{-1}$(GSD 2.49)[124].
Upadhay et al (2007) have measured the levels of radon, thoron and their progeny using LR-115 SSNTDs. Their reported activity concentrations varied from 7.78±2.02 to 59.01±5.57Bq.m⁻³ for radon and 1.16±0.28 to 65.08±5.09Bq.m⁻³ for thoron. The inhalation dose varied from 0.23 to 2.29mSv.y⁻¹. The level of radon varied from 0.84 to 6.38mWL and the concentrations of thoron progeny from 0.03 to 1.76mWL \[125\].

Ramola et al (2008) have measured the activity concentration of radon by using CR-LR difference technique (surface traps) and the reported values of radon concentration based on \(^{210}\)Po varied from 36 to 1173Bq.m⁻³ with an average of 304Bq.m⁻³\[126\].

Singh et al (2010) have reported the \(^{226}\)Ra and \(^{222}\)Rn exhalation rate in some solid samples of some area of santhalpargana, Jharkhand using LR-115 Type II SSNTDDetector. They reported that the values of \(^{226}\)Ra concentration and \(^{222}\)Rn exhalation rate were found to be maximum in Jamatara district and minimum in Godda district. It is also observed that values were found to be more in soil compared with rock and sand samples \[127\].

Ramachandran et al (2011) have estimated the concentration of \(^{220}\)Rn varied from 5.7 to 42.2Bqm⁻³ with a GM of 12.2Bq m⁻³ whereas Inhalation dose rate due to \(^{220}\)Rn and its progeny varied from 0.047 to 0.39mSv y⁻¹ with GM of 0.14mSv y⁻¹\[128\].

Deepak Varma and M.ShakirKhan (2013) have been determined the levels of radon, thoron and their progeny in the dwellings of Northern India by using twin chamber dosimeter cups. The radon and thoron concentrations were found to vary from 16.62–155.12Bq/m³ and 4.16–24.93Bq/m³. Their progeny concentrations were found to vary from 1.80–16.7mWL and 0.112–0.674mWL. The values of life time fatality risk and annual effective dose were found to vary from 0.24x10⁻⁴–1.21 x10⁻⁴ and 0.31–2.78mSv/y, respectively \[129\].

Anil Sharma and Ajay kumar (2015) have estimated the Radon and Thoron gas concentration levels in the environmental air of normal background radiation area in thirty one dwellings of Dwarka city of New Delhi, India by using SSNTD. \(^{222}\)Rn concentration levels were found to vary from 4.4±1.6 to 29.8±3.8 Bqm⁻³ whereas a thoron concentration is found to vary from 2.8±0.5 to 13.6±1.7 Bqm⁻³. The annual effective dose from radon were found to vary from 0.12 to 0.86mSv whereas from thoron found to vary from 0.01 to 0.07mSv \[130\].
2.6b. World scenario:

**Vaupotic (2001)** have been studied the concentration of radon and reported instantaneous indoor $^{222}$Rn concentrations in winter ranged from $22\pm8\text{Bq.m}^{-3}$ to $3700\pm100\text{Bq.m}^{-3}$ in schools on the territory of the abandoned Uranium mine in Slovenia\textsuperscript{[131]}.

**Nobuyuki et al (2002)** have been estimated the outdoor radon concentration in Japan using passive type radon monitor during 1997 and 1999 and reported mean outdoor $^{222}$Rn concentration as $6.1\text{Bq.m}^{-3}$, which was about 40% of the indoor $^{222}$Rn concentration in Japan. Their estimated values of $^{222}$Rn concentration in study area ranged from $3.3\text{Bq.m}^{-3}$ (Okinawa region) to $9.8\text{Bq.m}^{-3}$ (Chugoku region). They have observed seasonal variation of outdoor $^{222}$Rn concentration lowest in July to September, and highest in October to December. The estimated effective dose to the general public due to $^{222}$Rn and its progeny reported as $0.45\text{mSv.y}^{-1}$\textsuperscript{[132]}.

**Neman et al (2003)** have made the survey of indoor $^{222}$Rn and its daughters at Campinas Brazil using CR-39 and reported the $^{222}$Rn daughter distribution is influenced by environmental factors and the building materials used for the construction of the houses. They observed the higher concentrations of $^{222}$Rn and its daughter’s products in the houses having cement floors\textsuperscript{[133]}.

**ColmeneroSujo et al (2004)** have estimated radon concentration in the city of Aldama, in Chihuahua. The values of indoor radon levels ranging from 29 to $422\text{Bq.m}^{-3}$ and in 76% of the homes tested, the values of radon concentrations exceeded $148\text{Bq.m}^{-3}$\textsuperscript{[134]}.

**Maged et al (2005)** have reported the concentration of indoor radon in Egypt using solid state alpha track detectors. The values are ranged from 24 to $55\text{Bq.m}^{-3}$ in common building materials used for construction of houses, CR-39 plastic detectors. The reported value of effective dose equivalent ranged for the indoor varied from 0.6 to $1.4\text{mSv.y}^{-1}$\textsuperscript{[135]}.

**Abumurad and Al-Tamimi (2005)** have been carried out to measure radon levels indoor and in soil using closed- and open-can techniques during three different seasons (fall, winter and spring) in Soum area northwest of Jordan. They reported an
average radon concentration was 144Bq.m$^{-3}$, which is below the indoor radon concentration action level recommended by ICRP\textsuperscript{[136]}. 

**Rahman et al (2006)** have reported maximum indoor radon concentration of 323±5Bq.m$^{-3}$ in district Charsadda and minimum value of 13±6Bq.m$^{-3}$ in the district Swabi of North West Frontier Province and federally administered tribal areas of Pakistan. They observed the maximum radon concentration level 281±Bq.m$^{-3}$ in drawing rooms like bedrooms in District Charsadda and minimum level of 21±8Bq.m$^{-3}$ reported in a drawing room of District Mardan\textsuperscript{[137]}. 

**Abo-Elmagd et al (2007)** have carried out the measurements of radon and its related parameters using passive (CR-39) and active (Alpha-Guard analyzer) techniques inside seven ancient Egyptian tombs of the Valley of the Kings in Luxor throughout the winter and summer seasons. They reported an average radon concentration inside the tombs ranged from 86.4 ± 13.8 to 6102.8 ± 573.6Bq.m$^{-3}$ in summers\textsuperscript{[138]}. 

**Ferdoas S. Al-Saleh (2008)** have reported indoor 222$^{\text{Rn}}$ concentration city in Saudi Arabia using CR-39 detector during 2004 to 2005 ranged from 2 to 69Bq.m$^{-3}$ with an average of 18.4Bq.m$^{-3}$ and the effective annual dose as 0.46mSv.y$^{-1}$ at dwellings of Riyadh\textsuperscript{[139]}. 

**N.Ali and E.U.khan (2010)** have studied the different samples of water, indoor air and soil gas have been collected from Islamabad by using RAD-7 and it was estimated the total mean annual effective doses from water and indoor air of Islamabad and Murree regions are 2.023 and 0.733mSv.y$^{-1}$ respectively. These doses are within the recommended limits of the world organisations\textsuperscript{[140]}. 

**Abd El-ZaherM (2011)** has studied indoor radon concentration in Alexandria city, Egypt by using LR-115 detectors. The estimated annual average indoor radon concentration varied from 45±8 to 90±13 Bqm$^{-3}$ with an overall average value of 65±10Bq m$^{-3}$. The season/annual ratios for different type of dwellings varied from 1.54 to 2.50. The mean annual estimated effective dose received by the residents of the studied area was estimated to be 1.10mSv. The annual estimated effective dose is less than the recommended action level 3-10mSv y$^{-1}$\textsuperscript{[141]}.

**Bayram can et al (2012)** have measured the levels of indoor radon gas in 204 houses in Kilis, Osmaniye and Antakya using passive nuclear track detectors. It was found
that average indoor radon activity concentrations for Kilis, Osmaniye and Antakya were 50Bq/m$^3$ (1.26mSv/y), 51Bq/m$^3$ (1.29mSv/y) and 40Bq/m$^3$ (1.01mSv/y), respectively. An international recommended value of absorbed dose rate in indoor air is 55nGy h$^{-1}$\cite{142}.

This is observed from the literature survey that a large amount of work has been done on ambient gamma level, physicochemical parameters, radon and radium in ground water, activity concentrations of radionuclides in soil, rock, cement, granite, marble, sand, paint etc (building materials). Reviews made in the journals and publications reveal that statistical study on water quality will be helpful as rapid method of water quality monitoring and prediction. Such work was not done previously in the Tumkur and Ramanagar and Bangalore districts. Hence it was felt necessary to carry out the studies on Physiochemical parameters, ambient gamma level, radon and radium in ground water, activity concentrations of radionuclides in soil, rock and building materials and concentrations of radon, thoron and their progenies in this region.
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