CHAPTER 2

REVIEW OF EARLIER WORK

2.1 Ambient gamma radiation exposure level

Iyengar et al (1994) have measured the ambient gamma radiation level in the Kalpakkam beach and the surrounding areas using NaI (Tl) Scintillometer. They have reported the dose rates ranging from 43.5 - 3480 nGy h\(^{-1}\) on the beach and 52.2 - 330.6 nGy h\(^{-1}\) in the villages away from the beach. Lakshmi et al (1995) have reported the ambient gamma radiation level along East Coast of Tamilnadu using NaI(Tl) scintillometer as 17.4-2175 nGy h\(^{-1}\). They have also reported the high exposure rate near Kanyakumari as 4350 nGy h\(^{-1}\).

Shaheed et al (1996) have measured the ambient gamma radiation level in Kaveri river ecosystem using Scintillometer. They have reported the dose rate ranging from 43.5 - 235 nGy h\(^{-1}\). They have found that the radiation level decreased with increasing distance from the river. The gamma radiation survey carried out by Lakshmi et al (1990) using scintillometer around Kundankulam showed the dose rate ranging from 261 to 2697 nGy h\(^{-1}\).
Somasundaram et al (1996) have reported the ambient gamma radiation level at 5 selected sampling sites of Gulf of Mannar to range from 87 - 3915 nGyh⁻¹. A similar type of study has been carried out by Muguntha et al (1998) using the G M tube type Environment radiation dosimeter. They have reported exposure rate in 39 various locations of Gudalor taluk, Tamilnadu to range from 55.7 - 266 nGyh⁻¹.

Nagaiah and Venkataramaiah (1994) have reported the background radiation around Mysore using a NaI(Tl) scintillometer as 50 to 200 nGyh⁻¹. A similar study has been reported by Radhaknshna et al (1993) along the coastal belt of Mangalore, Karnataka. They have found a high background radiation level in the Ullal beach where dose rate range from 44 - 2102 nGyh⁻¹ and dose rate ranging from 53-123 nGyh⁻¹ in the normal background areas.

Ramachandran et al (1994) have carried out the ambient gamma radiation survey in high background radiation areas of Kerala using scintillometer and TLD's. They have found radiation level of 87 - 7177.5 nGyh⁻¹ inside the house and 130.5 - 10570.5 nGyh⁻¹ outside the house in Chavra region and 52.2 -1679.1 nGyh⁻¹ inside the house and 52.2 - 1862 nGyh⁻¹ and outside the house in the Thazhava panchayat.
Paul et al (1994) have measured the variation of radiation exposure in the high background radiation area of Manavalakurichi using G.M.Survey metre and TLD's. They have reported the radiation field varying from 3000-5000 nGyh\(^{-1}\), before mining and 200-300 nGyh\(^{-1}\) after mining. Paul et al (1982) have reported the ranges of external radiation field as 1740 - 4350 nGyh\(^{-1}\), 4350 - 6090 nGyh\(^{-1}\), 870 - 2610 nGyh\(^{-1}\), 261 - 522 nGyh\(^{-1}\), 348 - 522 nGy.h\(^{-1}\) for Manavalakurichi (proper), Manavalakuncru (settlement), Manavalakurichi Periavilai, Rajakkamangalam and Laxmipuram locations of Kerala, respectively.

Avadhani et al (1998) have measured the gamma radiation level in the environs of Goa covering an area of 3700 sq.km using the plastic scintillometer. They have reported the external gamma dose rates ranging from 30 - 87.8 nGyh\(^{-1}\) with a geometric mean of 70.3 nGyh\(^{-1}\).

Raghuvanshi et al (1994) have carried out airborne gamma spectrometric survey over the parts of Singhbhum district, Bihar. They have reported the gamma dose rate to range from 75.7 to 200.1 nGyh\(^{-1}\). Further they have found higher dose rates near granitic rocks.

Mishra and Sadasivan (1971) have reported the Indian average for external gamma dose from soil as 41.4 nGyh\(^{-1}\) based on the concentration of
\(^{232}\text{Th},^{238}\text{U}\) and in soil. A similar study has been done by Kamath et al (1996) by collecting the samples from 19 various stations showed the range of gamma dose as 31.4 - 128.6 nGy h\(^{-1}\). Nambi et al (1987) have carried out the countrywide radiation monitoring using TLD's in India. They have reported the Indian average dose rate of 89.6 nGy h\(^{-1}\)

Yu-Ming Lin et al (1987) have measured the ambient gamma exposure level in 153 sites of Taiwan using the NaI(Tl) scintillometer. They have reported the absorbed dose rate in air to range from 20 - 90 nGy h\(^{-1}\) with a mean of 54 nGy h\(^{-1}\). Bruno Sansoni (1982) has measured the natural gamma radiation level around Fichtelgebirge a granitic mountain district belonging to FRG, using the dose meter based on plastic scintillator. The reported range lies between 130.5 to 609 nGy h\(^{-1}\).

Quindos et al (1994) have reported the overall terrestrial gamma dose in Spain as 53.3 nGy h\(^{-1}\) based on the radionuclide concentration in soil. A similar study by Shenber (1997) in the Tripoli metropoliton showed an average dose rate of 23 nGy h\(^{-1}\).

Mc Aulay et al (1980) reported the gamma exposure rate in Ireland as 43.7 - 192 nGy h\(^{-1}\) with an average of 72 nGy h\(^{-1}\). They have observed an average exposure rate of 105 nGy h\(^{-1}\) in 19 measurements of all granites.
Tschirf (1980) has reported the gamma dose rate for outdoor environs of Austria, using G M counters to lie between 20- 150 nGy h\(^{-1}\).

Vaz carreiro et al (1988) have measured the natural background radiation exposure to Portuguese population in 312 measuring sites using the G M tube based radiation meter. They have reported the gamma dose rate range as 40-250 nGy h\(^{-1}\) with an average of 121 nGy h\(^{-1}\). Further they have found a higher dose rates near Granites. Nikl et al (1988) have measured the indoor and outdoor-gamma exposures over 123 sites in Hungary using TLD's. They have reported a mean dose rate of 54.8 nGy h\(^{-1}\) and 74.4 nGy h\(^{-1}\) in the outdoors during 1983 - 85 and 1986 respectively.

Grasty et al (1984) have reported the absorbed gamma dose rate measured using aerial survey scintillation detectors to range from 18-44 nGy.h\(^{-1}\) for the outdoor environments of Canada. Vassilev (1991) has made 3670 measurements of the gamma dose rates using Ground survey scintillation detector in Bulgaria. He has reported the range as 48-96 nGy h\(^{-1}\) with an average of 70 nGy h\(^{-1}\) for the outdoor and 57 - 93 nGy h\(^{-1}\) with an average of 75 nGy h\(^{-1}\) for the indoor environs.

Thomas 1 Cullen (1977) reported the radiaion levels in the beaches of Guarapari, Brazil to range from 322- 17400 nGy h\(^{-1}\). UNSCEAR (1993) has
summarised the absorbed dose rates in air as 18 - 44 nGy h$^{-1}$ in Canada, 26 - 53 nGy h$^{-1}$ in Cuba, 5 - 100 nGy h$^{-1}$ in Japan, 8 - 89 nGy h$^{-1}$ in UK, 13 - 100 nGy h$^{-1}$ in US, etc.

Olarinoye et al (2010) have measured the background radiation level at the vicinity of three campuses of two major tertiary institutions in Minna, Nigeria, using a portable Geiger-Mueller tube - based environmental radiation dosimeter. They have reported the dose rate ranging from 0.125 – 0.184 μSv/hr. They have also reported the annual effective dose as 0.189 mSv/hr.

Maharana et al (2010) have measured gamma radiation levels (indoor and outdoor) in the villages surrounding the uranium-enriched regions around Jaduguda, India, using card-based CaSO(4):Dy thermoluminescent dosemeters. They have reported the annual indoor and outdoor gamma dose values as 980 and 924μGy h$^{-1}$, respectively.

Gerald Pinto et al (2010) have measured the gamma absorbed dose rates in Udupi and Karkala taluks of coastal Karnataka, India, using the GM-Survey meter. They have reported the dose rate ranging from 70 to 123 nGy h$^{-1}$
WENG Jianqing et al (1992-2004) have measured the ambient gamma radiation level in Qinshan Nuclear Power Plants (QNPP) Base, the northeast of Zhejiang Province using thermoluminescent dosimeter (TLD). They have reported the dose rate ranging from 84 - 113 nGyh^{-1}, with an average of 96nGyh^{-1} in the 13 years.

Idrish Miah (2003) has measured Indoor gamma dose rate in air using TLDs in the Dhaka district, Bangladesh. He has reported the average annual effective dose and the collective dose equivalent for the residents, respectively as, 0.86 mSv and 172.2 man-Sv.

Sreenath Reddy et al (2010) have measured the natural background gamma radiation levels in the Hyderabad and its surroundings, India, using thermoluminescence (TL) dosimeters and Geiger-Muller based μR-survey meter. They have reported the dose rate ranging from 226 - 506 nGyh^{-1} for urban Hyderabad and 190- 462 nGyh^{-1} for surroundings of Hyderabad.

Mohanty et al (2003) have measured The external gamma dose rate level of Erasama coastal Region, eastern coast of Orissa, India. They have reported the absorbed gamma dose rates in air due to the naturally occurring radionuclides ranging from 650 - 3150 nGyh^{-1}, with a mean value of 1925±718 nGyh^{-1}.
Senthilkumar et al (1996) have measured Gamma absorbed dose rates in air outdoors from soil samples collected from Thanjavur (Tamil Nadu, India) using γ-ray spectrometry. They have reported the dose rate ranging between 32 nGy.h\(^{-1}\) and 59.1 nGy.h\(^{-1}\), with an arithmetic mean of 43.3 ± 9 nGy.h\(^{-1}\).

Sriharsha et al (2008) have measured the gamma exposure rate in Mysore and Chamaraj Nagar district, Karnataka, India using Environmental radiation dosimeter. They have reported the dose rate varying 122.7 to 231.4 nGy.h\(^{-1}\) inside the temples and between 141.8 to 340.2 nGy.h\(^{-1}\) outside the temples of the region. They have also reported the indoor dose rate varying 112.2 to 197.5 nGy.h\(^{-1}\), with a median of 127.0 nGy.h\(^{-1}\), and outdoor dose rate varying 140.9 to 298.4 nGy.h\(^{-1}\), with a median of 216.2 nGy.h\(^{-1}\).

### 2.2 Radionuclides in soil (\(^{226}\)Ra, \(^{232}\)Th, \(^{40}\)K, \(^{210}\)Po and \(^{210}\)Pb)

Ramachandran et al (1994) have measured the activity of \(^{238}\)U and \(^{232}\)Th in soil samples collected from Chavara panchayat and Thazhava panchayat, Kerala using the NaI(Tl) spectrometer. They have reported 122.4-5834.4 Bq kg\(^{-1}\) and 37.08-741.6 Bq kg\(^{-1}\) as the activity ranges of \(^{232}\)Th and respectively in 24 sampling stations of Chavara panchayat. The
similar activity range reported in 12 sampling stations of Thazhava panchayat lies between 81.6 - 163.2 Bqkg\(^{-1}\) and 7.42-61.8 Bqkg\(^{-1}\).

Iyengar et al (1994) have reported the ranges of 36 - 237 Bqkg\(^{-1}\), 352 - 2969 Bqkg\(^{-1}\) and 324-368 Bqkg\(^{-1}\) as the activity of \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K respectively in beach sands of Kalpakkam. The corresponding activity ranges in soils lies between 11-14 Bqkg\(^{-1}\), 35-91 Bqkg\(^{-1}\) and 109-577 Bqkg\(^{-1}\) respectively. The measurements were made using the HPGe gamma ray spectrometer.

Radhakrishna et al (1993) have measured the \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K content in the soil samples collected from Ullal beach using HPGe detector. They have reported the average activity of \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K as 546 Bqkg\(^{-1}\), 2971 Bqkg\(^{-1}\), and 268 Bqkg\(^{-1}\) respectively. The corresponding activities in sand samples reported are 374 Bqkg\(^{-1}\), 1842 Bqkg\(^{-1}\) and 158 Bqkg\(^{-1}\). They have attributed the high activities of these radionuclides is due to the existence of patches of monazite in beach sands. Lakshmi et al (1990) have reported the activity of \(^{238}\)U as BDL, \(^{232}\)Th as 614 Bqkg\(^{-1}\) and \(^{40}\)K as 7.32 Bqkg\(^{-1}\) in the beach soils from Kundankulam village.

Rao et al (1983) have reported the \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K activity in Bombay soils to range from 5.2 - 33.7 Bqkg\(^{-1}\), 7.4-21.5 Bqkg\(^{-1}\) and 37-571.7
Bq kg$^{-1}$ respectively. The corresponding activities reported in the soils from Nandadevi area are 83.3 - 150.2 Bq kg$^{-1}$, 68.8 - 132.5 Bq kg$^{-1}$ and 561.3-876.5 Bq kg$^{-1}$. A similar study has been carried out by Nageswara Rao (1989) in Rajasthan using NaI(Tl) detector. An average activity of 43.8 Bq kg$^{-1}$, 112.6 Bq kg$^{-1}$ and 108.5 Bq kg$^{-1}$ in dune sands has been reported.

Avadahani et al (1998) have reported the geometric mean of activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in the soil samples collected from 12 sampling stations of Goa as 39.7Bq kg$^{-1}$, 33.3 Bq kg$^{-1}$ and 138.4 Bq kg$^{-1}$ respectively. The activity range of $^{238}$U, $^{232}$Th and $^{40}$K as BDL - 47.3 Bq kg$^{-1}$, 18.8 - 272.1 Bq kg$^{-1}$ and 37.5 - 555.9 Bq kg$^{-1}$ has been reported by Muguntha et al (1998) in the soil samples collected from 39 sampling stations of Gudalor, Tamil Nadu.

Sarita Mittal et al (1998) have measured the $^{226}$Ra, $^{232}$Th and $^{40}$K concentration in soil samples and in granite samples collected from five cities of Rajasthan employing the gamma spectrometry. They have reported the activity range of 37.04 - 63.3 Bq kg$^{-1}$ for $^{226}$Ra, 43.27 - 85.2 Bq kg$^{-1}$ for $^{232}$Th and 76.71-125.2 Bq kg$^{-1}$ for $^{40}$K in soil samples. Further they have found that the natural radioactivity levels due to these nuclides in various
granite samples are twice compared to that of soils samples collected from the same area.

Raju and Singh (1995) have measured potassium, uranium, and thorium content in sediments of six river basins in southern Kerala using NaI(Tl) flat crystal detector. They have reported activity range of 10-49 ppm, 25-133 ppm and 9 - 43 ppm for thorium in low lands, midlands and high lands respectively of all rivers. The corresponding activity range of 1-4 ppm, 2-12ppm and 0-4 ppm for uranium whereas the potassium concentration to range from 1.5-3.4%, 1.3-2.8% and 1.5-3.7% respectively has been reported.

Mishra and Sadasivan (1971) have carried out the detailed study on the $^{238}$U, $^{232}$Th and $^{40}$K content in Indian soils by collecting the samples from 35 locations all over India. They have reported the country wide average taking into consideration the normal background area as 14.8 Bqkg$^{-1}$ for $^{238}$U, 18.33 Bqkg$^{-1}$ for $^{232}$Th and 433.6 Bqkg$^{-1}$ for $^{40}$K.

Lakshmi et al (1995) have reported the activity of $^{232}$Th in beach sands of Kanyakumari and Pondicherry as 300 Bqkg$^{-1}$ and 2000Bqkg$^{-1}$ respectively. Kamath et al (1996) have reported activity range of $^{226}$Ra as 6.4-84 Bqkg$^{-1}$, $^{232}$Th as 13.2 - 165.2 Bqkg$^{-1}$ and $^{40}$K as 33.6 - 819.7 Bqkg$^{-1}$ in
the soil samples collected from 19 cities in India. They have found a uniform
distribution in the activity of natural radionuclides with respect to depth.

Narayana et al (1994) have measured $^{238}$U, $^{232}$Th and $^{40}$K content in
Netravathi river sediments and marine sediments near Ullal employing
HPGe spectrometer. They have reported the activity range as 108.96-254.96
Bq kg$^{-1}$, 6.68-35.9 Bq kg$^{-1}$ and 4.9 - 63.34 Bq kg$^{-1}$ of $^{40}$K, $^{238}$U and $^{232}$Th
respectively in Netravathi river sediments. They have observed highest
activity of $^{238}$U and $^{232}$Th in the sea sediments during monsoon. They have
also reported that the activity of $^{238}$U and $^{232}$Th decreases with depth in soil
and sand samples collected from Ullal beach. They have observed the
enrichment of radionuclides in 125 - 250μm fractions in these samples.

Karunakara et al (1996) have measured the activity of $^{238}$U, $^{232}$Th and
$^{40}$K in soil samples of Kaiga. They have reported a geometric mean of 29.8
Bq kg$^{-1}$, 22.8 Bq kg$^{-1}$ and 109.2 Bq kg$^{-1}$ as the activities of $^{238}$U, $^{232}$Th and $^{40}$K
respectively. Kannan et al (1992) have reported 1856 - 3878 Bq kg$^{-1}$ as the
activity range for the thorium series in the monazite sands of Kalpakkam.

Nagaiah (1996) has reported the activity of $^{238}$U, $^{232}$Th and $^{40}$K in soils
of Mysore to range from 4.1 -130.6 Bq kg$^{-1}$, 13.1-159.7 Bq kg$^{-1}$ and 86.5 -
1216.6 Bq kg$^{-1}$ respectively.
Quindos et al (1994) have measured the natural radioactivity in Spanish soils using HPGe detector. They have reported the median value of $^{226}$Ra, $^{232}$Th and $^{40}$K over 900 sampling sites as 31.6 Bq kg$^{-1}$, 35.7 Bq kg$^{-1}$ and 480 Bq kg$^{-1}$ respectively. A similar study has been done by Delaune et al (1986) in Louisiana soils. They have reported the average activity of $^{40}$K as 472 Bq kg$^{-1}$ and $^{226}$Ra as 64 Bq kg$^{-1}$ in finely grained samples.

Megumi et al (1988) have reported the activity range of $^{40}$K as 75 - 400 Bq kg$^{-1}$ and that of $^{226}$Ra as 5 - 230 Bq kg$^{-1}$. They have observed the lowest concentration of radionuclide in the soils containing Quartz, amphibole and Chlorite and the highest activity was observed in soils containing albite and biotite.

Myrick et al (1983) have reported the countrywide average activity of $^{226}$Ra and $^{232}$Th in surface soil of US as 40.7 Bq kg$^{-1}$ and 36.3 Bq kg$^{-1}$ respectively. An average activity of 30 Bq kg$^{-1}$, 44 Bq kg$^{-1}$ and 431 Bq kg$^{-1}$ of $^{238}$U, $^{232}$Th and $^{40}$K respectively has been reported by Yu-Ming Lin et al (1987) in 40 soil samples collected from Taiwan. Mollah et al (1990) have studied the distribution of gamma radionuclides in soils at the atomic energy research establishment in Bangladesh. They have reported the ranges of
activity of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ as 46.8 - 82.5 Bqkg$^{-1}$, 39.2 - 61.9 Bqkg$^{-1}$ and 10 - 29.6 Bqkg$^{-1}$ respectively.

Mc Aullay et al (1988) have reported the mean value of 60 Bqkg$^{-1}$ for $^{226}\text{Ra}$, 26 Bqkg$^{-1}$ for thorium series and 350 Bq.kg$^{-1}$ for $^{40}\text{K}$ in soil samples from republic of Ireland. Shenber (1997) has measured the natural radioactivity levels in soils from Tripoli using HPGe detector and reported the activity range of 8.67 - 12.8 Bqkg$^{-1}$, 7.65 - 9.73 Bqkg$^{-1}$ and 265 - 282 Bqkg$^{-1}$ for $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ respectively.

Bonka (1982) has measured the concentration of $^{232}\text{Th}$ and $^{238}\text{U}$ in the dark and light sands of Northern Germany. He has reported the range of concentration of $^{238}\text{U}$ and $^{232}\text{Th}$ as 3.7 - 14.8 Bqkg$^{-1}$ and 5.57 - 14.8 Bqkg$^{-1}$ in light sand and 18.5 - 740 Bqkg$^{-1}$ and 37 - 1110 Bqkg$^{-1}$ in dark sands. Soto et al (1988) have reported the average concentration of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ as 25Bqkg$^{-1}$, 26Bqkg$^{-1}$ and 440 Bqkg$^{-1}$ in soil samples collected from Cantabria and 70 Bqkg$^{-1}$, 35 Bqkg$^{-1}$ and 800 Bqkg$^{-1}$ in the soil samples collected from Arribes duero regions of Spain.

Jasinska et al (1982) have studied the correlation between the soil parameters and natural radioactivity. They have measured the concentration of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ using Ge(Li) gamma ray spectrometer. They have
observed a good correlation between the concentration of radionuclides and the percentage of floating fraction.

UNSCEAR (1993) reports the activity range of natural radionuclides in various types of soils in the Nordic countries as 600 - 1200 Bq kg⁻¹, 5-25 Bq kg⁻¹ and 4 - 30 Bq kg⁻¹ for \(^{40}\text{K}, \(^{226}\text{Ra}\) and \(^{232}\text{Th}\) respectively in sand and silt. The corresponding activity range of 600 - 1300 Bq kg⁻¹, 20 - 120 Bq kg⁻¹ and 25 - 80 Bq kg⁻¹ in clay, 900 - 1300 Bq kg⁻¹, 20 - 80 Bq kg⁻¹, 20 - 80 Bq kg⁻¹ in Moraine and 600- 1000 Bq kg⁻¹, 100-1000 Bq kg⁻¹ and 20-80 Bq kg⁻¹ in soils containing alum shale respectively have been reported.

Vinogradov (1959) has reported the \(^{226}\text{Ra}\) activity in various types of soils in Erstwhile, USSR as 33.3 Bq kg⁻¹ in Podzols, 37.1 Bq kg⁻¹ in gray forest soils, 29.6 Bq kg⁻¹ in loamy black earth soils, etc.

Klement (1964) has reported the ranges of concentration of \(^{226}\text{Ra}\) in Germany, Ireland, Poland and USA as 13-18.1 Bq kg⁻¹, 48.1 - 107 Bq kg⁻¹, 37 - 51.8 Bq kg⁻¹ and 29.6 - 104 Bq kg⁻¹ respectively. Khademi et al (1980) has reported the radium activity of soil from Ramsar to range from 777 - 36963 Bq kg⁻¹.

Sutherland and de Jong (1990) have measured the \(^{238}\text{U}, \(^{232}\text{Th}\) and \(^{40}\text{K}\) in soil samples of three fields of southern Saskatchewan, Canada, using
HPGe detector. They have reported median $^{238}\text{U}$ activity between 31.4-34.1 Bq kg$^{-1}$, $^{232}\text{Th}$ concentrations between 29.6-31.2 Bq kg$^{-1}$ and $^{40}\text{K}$ concentrations between 471 -502 Bq kg$^{-1}$. They have found that the variability in the concentration of radionuclides with respect to depth in a given field was low having the coefficient of variation less than 10% and $^{137}\text{Cs}$ has greater variability ranging from 18 % - 23 %.

Koster et al (1988) have formulated a linear regression model for natural radioactivity levels in Dutch soils. They have reported that activity range of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ as 19 - 47 Bq kg$^{-1}$, 22 - 77 Bq kg$^{-1}$ and 490 - 700 Bq kg$^{-1}$ respectively in alluvial clay, 27-38 Bq kg$^{-1}$, 33 - 53 Bq kg$^{-1}$ and 410-666 Bq kg$^{-1}$ in sea clay, 5-27 Bq kg$^{-1}$, 11-55 Bq kg$^{-1}$ and 120 - 460 Bq kg$^{-1}$ in peat soils, 11-15 Bq kg$^{-1}$, 12 - 26 Bq kg$^{-1}$ and 230 Bq kg$^{-1}$ in acidic sand, 18.41 Bq kg$^{-1}$, 31-62 Bq kg$^{-1}$, 620 - 640 Bq kg$^{-1}$ in loess, etc. They have found that the activity of radionuclides decreases with grain size of the soil. Also they concluded that pH, sampling depth, organic matter and lime do not contribute significantly to the radioactivity of the soil.

Kazuko Megumi and Tetsuo Mamuro (1977) have studied the concentration of uranium series nuclides in soil particles in relation to their size using Ge(Li) detectors. They have observed the increase in the
concentration of radionuclides with decrease in the particle size. Surbeck and Voelkel (1988) have carried out a similar investigation for six soil samples. They have also observed the decrease in the specific activity of uranium and thorium series nuclides with the increase of grain size.

Kazuko Megumi et al (1982) have examined the concentration of uranium series nuclides, thorium series nuclides and potassium in soil of a granitic belt in relation to their surface area of soil, clay mineral composition and the $\text{SiO}_2$ contents. They have found that the concentration of $^{238}\text{U}$, $^{226}\text{Ra}$, $^{210}\text{Pb}$, Ra and $^{40}\text{K}$ contents increase with an increase in the $\text{SiO}_2$ content. They have also found increase in concentration of $^{238}\text{U}$, $^{226}\text{Ra}$, $^{210}\text{Pb}$ and $^{228}\text{Ra}$ with increase in surface area in the homologous soils resulting from progressive weathering. They have noticed the decrease in the content with increasing surface area in homologous soils.

Schuttelkopf and Kiefer (1982) have reported the concentration range of $^{226}\text{Ra}$, $^{210}\text{Pb}$ and $^{210}\text{Po}$ as $14.8 - 448.7$ Bq$\cdot$kg$^{-1}$, $22.2 - 122.1$ Bq$\cdot$kg$^{-1}$ and $33.3 - 207.2$ Bq$\cdot$kg$^{-1}$ in the soil samples collected from black forest of Germany. Kodaira et al (1980) have measured the $^{210}\text{Pb}$ concentration in the soil from Japan. They have reported the activity range of $53.65 - 125.8$ Bq$\cdot$kg$^{-1}$ in the soil collected from 0-2 cm depth, $53.28 - 222$ Bq$\cdot$kg$^{-1}$ in the soil collected
from 2 - 16 cm depth and 8.51 - 55.5 Bq.kg\(^{-1}\) in the soil collected from 15 - 25 cm depth.

US Atomic Energy Commission has reported the \(^{210}\)Po activity of different types of soils from USA as 33.3 Bq.kg\(^{-1}\) in brown soils, 58.09 Bq.kg\(^{-1}\) in bounizen soils, 55.87 Bq.kg\(^{-1}\) in gray brown soils, 45.5 Bq.kg\(^{-1}\) in ground water podozol soil, 28.86 Bq.kg\(^{-1}\) in podozol soil and 58.3 Bq.kg\(^{-1}\) in red yellow podozol soils. It has also reported the \(^{210}\)Po concentration in 17 top soils of USA to range from 8.14 - 128.29 Bq.kg\(^{-1}\). Parfenov (1974) has reported world range of \(^{210}\)Po as 8.14-219Bq.kg\(^{-1}\).

Karunakara et al (1993) have reported geometric mean of 97.89 Bq.kg\(^{-1}\) as the activity of \(^{210}\)Po in soil samples from Kaiga. Siddappa et al (1991) has reported the activity range of \(^{210}\)Po in the soils of coastal karnataka as 1.3-13.7 Bq.kg\(^{-1}\). Iyengar et al (1990) have reported the activity of \(^{210}\)Po to be 44.4 Bq.kg\(^{-1}\) in the soils of Kalpakkam.

Santos et al (1990) have reported the activity range of \(^{210}\)Po as 27 - 74 Bq.kg\(^{-1}\) and 45.9 - 70 Bq.kg\(^{-1}\) in Join Ville and CIPC, Brazil. Nagaiah (1996) has reported the activity range of \(^{226}\)Ra, \(^{210}\)Po and \(^{210}\)Pb as 2-12.9 Bq.kg\(^{-1}\), 7.6 -37.3 Bq.kg\(^{-1}\) and 7.2-38.6 Bq.kg\(^{-1}\) respectively in the soils from Mysore.
Somasundaram et al (1996) have measured the $^{210}$Po and $^{210}$Pb content in the sediments of Gulf of Mannar. They have reported the activity range of $^{210}$Po as 35.6 - 386.1 Bq kg$^{-1}$ and $^{210}$Pb as 27.6 - 45.4 Bq kg$^{-1}$. Sahul hameed et al (1996) also carried out a similar study in the Kaveri river ecosystem and they have reported the concentration of $^{226}$Ra to range from 4.5-7 Bq kg$^{-1}$, $^{210}$Po from 15.4-28.3 Bq kg$^{-1}$ and $^{210}$Pb from 11.2-18.5 Bq kg$^{-1}$ in the Kaveri river sediments.

Neena Raman (1994) has reported the activity of $^{210}$Po in soils and sands of Ullal as 24.7 Bq kg$^{-1}$ and 19.7 Bq kg$^{-1}$ respectively. An activity range of 11.1-55.4 Bq kg$^{-1}$, 6.24-43.24 Bq kg$^{-1}$ and 10.7-19.5 Bq kg$^{-1}$ for $^{226}$Ra, $^{210}$Pb and $^{210}$Po respectively has been reported by Narayana et al (1995) in the soils of coastal Karnataka.

Alam et al (1999) have measured the $^{226}$Ra, $^{232}$Th and $^{40}$K in beach sand minerals from the Plant of the Beach Sand Exploitation Center (BSEC) and soils from the tourist zone of Cox’s Bazar, Bangladesh, using $\gamma$-ray spectrometry. They have reported the average activity concentrations of the corresponding nuclides were 6439, 1324 and 472 Bq kg$^{-1}$ for zircon; 348, 388 and 59.7 Bq kg$^{-1}$ for ilmenite; 22.0, 43.1 and 293 Bq kg$^{-1}$ for magnetite; 3951, 7903 and 213 Bq kg$^{-1}$ for garnet; 6643, 11670 and 182 Bq kg$^{-1}$ for
rutile; 2582, 4684 and 639 Bq kg\(^{-1}\) for heavy sand and 110, 213 and 501 Bq kg\(^{-1}\) for light sand, respectively.

Mandakini Maharana et al (2010) have measured the activity concentrations of \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K in surface soil samples around selected villages of Jaduguda, India, using, HPGe detector with 50% relative efficiency. They have reported the average estimated activity concentrations of \(^{238}\)U, \(^{232}\)Th, and \(^{40}\)K in the surface soil were 53.8, 44.2 and 464.2 Bq kg\(^{-1}\) respectively.

Johan et al (2010) have measured soil gamma-ray concentration at four spots along the volcano’s caldera located at the village of Cemorolawang, District of Probolinggo, Indonesia, just 2 km east of the crater, using ATOMTEX AT6101D (ATOMTEX, Belarus) gamma spectrometer. They have found \(^{226}\)Ra concentration as 31.9±4.2 Bqkg\(^{-1}\), \(^{232}\)Th concentrations as 57.0±6.8 Bqkg\(^{-1}\) and \(^{40}\)K concentrations 760.8±84.6 Bqkg\(^{-1}\).

Nada et al (2009) have measured Distribution of radionuclides in soil samples from a petrified wood forest in El-Qattamia, Cairo, Egypt, using, high-resolution gamma spectrometry. They have reported the mean activity concentrations of \(^{238}\)U, \(^{232}\)Th and \(^{40}\)K as, 65.26±12.99, 23.66±0.95 and 146.33±1.50 Bq kg\(^{-1}\), respectively.
Rohit Mehra et al (2007) have measured the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples collected from thirty different locations of Malwa region of Punjab, India, using, HPGe detector. They have found $^{226}$Ra concentration to vary between 18.37 - 53.11 Bq kg$^{-1}$, $^{232}$Th concentration to vary between 57.28 - 148.28 Bq kg$^{-1}$ and $^{40}$K concentration to vary between 211.13 - 413.27 Bq kg$^{-1}$ with overall mean values as 35 Bq kg$^{-1}$, 80 Bq kg$^{-1}$ and 317 Bq kg$^{-1}$, respectively, for the above radionuclides.

Diab et al (2008) have measured the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in the soil samples collected from a cultivated area, where phosphate fertilizers produced by Abu-Zabal factory, Egypt, using, HPGe detector. They have found $^{226}$Ra concentration to vary between 6.0± 1.2 to 87.5 ± 4.5 Bq kg$^{-1}$, with an average value of 31.12 ± 2.22 Bq kg$^{-1}$, $^{232}$Th concentration to vary between 3.8 ± 1.2 to 14.2 ± 3.3 Bq kg$^{-1}$ with an average value of 10.96 ± 1.89 Bq kg$^{-1}$ and $^{40}$K concentration to vary between 71.8 ± 24 to 543.2 ± 26.5 Bq kg$^{-1}$ with an average value of 264.1 ± 11.94 Bq kg$^{-1}$.

Akhtar et al (2004) have measured the activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K barren and cultivated soil of Bio saline Research Station in Pakka Anna, established by Nuclear Institute for Agriculture and Biology (NIAB) in 1990, 34 km. away from the city of Faisalabad, in the Punjab.
province of Pakistan, using, HPGe detector. They have reported activity concentration of $^{40}\text{K}$, for virgin and cultivated saline soil was 500–610.2 and Bq/kg 560.2–635.6 respectively, for $^{238}\text{U}$, 26.3–31.6 and 30.3–38.7 Bq/kg, and for $^{232}\text{Th}$, 50.6–55.3 and 50.6–64.0 Bq/kg respectively.

Ramola et al (2008) have measured the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in soil samples collected from different lithological units of the Thauldhar and Budhakedar regions of Garhwal Himalaya, India, using gamma ray spectrometry. They have found activity concentrations of $^{226}\text{Ra}$ $^{232}\text{Th}$ and $^{40}\text{K}$ to vary from below detection level (BDL) to 131 ± 18 Bq kg$^{-1}$, 9 ± 6 to 384 ± 53 Bq kg$^{-1}$ and 471 ± 96 to 1406 ± 175 Bq kg$^{-1}$, respectively.

Huy et al (2005) have measured the activity concentrations of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in 106 samples of surface soil collected in Southern Vietnam. They have found the mean values of mass activity of radionuclides $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ for Southern Vietnam as 28.6, 50.7 and 292.6 Bq kg$^{-1}$, respectively.

Ningappa et al (2007) have measured the activity of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in soil samples of granite quarries of Kanakapura, Ramanagara Taluks and Bidadi Hobli in Bangalore rural District and Bangalore city using HPGe gamma-ray spectrometer and have found $^{226}\text{Ra}$ concentration to vary between 32.4 to 55.2, Bq kg$^{-1}$, $^{232}\text{Th}$ concentration to vary between 39.9 to
214.3 Bq kg\(^{-1}\) and \(^{40}\)K concentration to vary between 485.4 to 1150.2 Bq kg\(^{-1}\), respectively.

Jabbar et al (2009) have measured the activity concentrations of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K in soil samples, collected from southern Rechna interfluvial region, Pakistan. They have found the mean radioactivity levels of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K for Southern Vietnam as 50.6 +/- 1.7, 62.3 +/- 3.2 and 662.2 +/- 32.1 Bq kg\(^{-1}\), respectively.

Korenkov et al (2000) have measured the \(^{210}\)Po content in the superficial soil layer of Moscow. They have reported the activity range of \(^{210}\)Po as 30-50 Bk/kg.

Vaaramaa et al (2010) have measured the Vertical distribution and activity contents of \(^{210}\)Po and \(^{210}\)Pb in forest soils from seven different locations in Finland. They have reported the mean total inventory in the soil profile, up to 20 cm, of \(^{210}\)Pb as 4.0 kBq m\(^{-2}\) with range 3.1-5.0 kBq m\(^{-2}\) and \(^{210}\)Po as 5.5 kBq m\(^{-2}\) with range 4.0-7.4 kBq m\(^{-2}\).

Ashraf E.M. Khater and H.A. AL-Sewaidan (2008) have measured the \(^{210}\)Po content in the selected phosphate fertilizers samples used in Saudi Arabia. They have reported the activity range of \(^{210}\)Po as 0.5–110 Bq kg\(^{-1}\) with a mean value of 25 Bq kg\(^{-1}\).
Che Abdul Rahim Mohamed et al (2006) have measured the $^{210}\text{Po}$ and $^{210}\text{Pb}$ content in sediment around the Sabah water at Teluk Brunei, Sipitang, Teluk Kimanis, Kota Kinabalu and Kuala Penyu in Malaysia. They have reported the activity range of $^{210}\text{Po}$ as 0.413 dpm/g to 8.491 dpm/g and $^{210}\text{Pb}$ as 0.023 dpm/g to 2.767 dpm/g.

Neame et al (1982) have measured the vertical distribution of $^{210}\text{Po}$ and $^{210}\text{Pb}$ content in undisturbed sediments in a uranium mining area of northern Saskatchewan, Canada. They have reported the activity range of Pb-210 from 0.8 to 931 pCi g$^{-1}$.

Raja and Shahul Hameed (2010) have measured the $^{210}\text{Po}$ and $^{210}\text{Pb}$ content in the sediments of Parangipettai Coast, South East Coast of India. They have reported the activity concentration of $^{210}\text{Po}$ and $^{210}\text{Pb}$ in sediments as 4.38 Bq/kg and 2.31Bq/kg respectively.

Marbaniang et al (2010) have measured the $^{210}\text{Po}$ content in the soil samples at Domiasiat uranium deposit area, West Khasi Hills, Meghalaya, India. They have reported the the mean activity of $^{210}\text{Po}$ in soil as124.8 +/- 5.7 Bq/kg.
Narayana et al (2013) have measured the $^{210}$Po and $^{210}$Pb content in the monazite sands in high background radiation areas of coastal Kerala, India. They have reported the activity range of $^{210}$Po as 1.85 to 31.27 Bq kg$^{-1}$ and $^{210}$Pb as 9.77 to 132.30 Bq kg$^{-1}$.

Prakash et al (2013) have measured the $^{210}$Po and $^{210}$Pb content in the environment of Mangalore, South west coast of India. They have reported the activity range of $^{210}$Po in the soil samples as 1.5 to 26.9 Bq kg$^{-1}$ and $^{210}$Pb as 7.6 to 67.5 Bq kg$^{-1}$.

Jha (2013) has measured the $^{210}$Po content in the terrestrial environment around uranium deposit area, West Khasi Hills, Meghalaya, India and reported the activity range of $^{210}$Po in the soil samples as 123.97 to 132.72 Bq kg$^{-1}$.

Yashodhara et al (2013) have measured the $^{210}$Po and $^{210}$Pb content in soil samples around Gogi Uranium mining region in North Karnataka, India. They have reported the activity range of $^{210}$Po in the soil samples as 19.4 to 257.4 Bq kg$^{-1}$ and $^{210}$Pb as <0.7 to 231.6 Bq kg$^{-1}$.

Shivakumar et al (2012) have measured the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples collected from Srirangapattana, India using gamma ray
spectrometry. They have reported the mean activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K as 21.8, 46.5 and 532.2 Bqkg$^{-1}$, respectively.

Rajeshwari et al (2012) have measured the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples collected from Donimalai-Sandur region of North Karnataka, India using HPGe detector. They have reported the mean activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K as 13.9, 20.6 and 341.2 Bqkg$^{-1}$, respectively.

Dhanya Balakrishnan et al (2007) have measured the activity of $^{232}$Th, $^{238}$U and $^{40}$K in soil samples of Eloor Island, Kerala using 5X4” NaI(Tl) gamma-ray spectrometer and have found $^{232}$Th concentration to vary between 44.8 to 792.8, Bqkg$^{-1}$, $^{238}$U concentration to vary between 12.6 to 445.5 Bqkg$^{-1}$ and $^{40}$K concentration to vary between 129 to 1160.5Bqkg$^{-1}$, respectively.
2.3 Radionuclides in water

R.C. Ramola et al (1997) measured the radon in drinking water of Garhwal, Himalaya region. They have reported the highest value of 880kBq m\(^{-3}\) and lowest value of 27kBq m\(^{-3}\).

Hess et al (1982) have measured radon in about 2000 samples from public and privately drilled wells in Maine, USA and reported values ranging from 7.4-185kBq m\(^{-3}\) for water. The average values obtained from 10 different granite bodies ranged from 55.5-1443kBq m\(^{-3}\). The minimum and maximum values for radon concentration in waters of Sweden and Nova Scotia are summarized in a report by NCRP (1984) as 18.5kBq m\(^{-3}\) and 6290kBq m\(^{-3}\) respectively.

Khan and Rossen (1997) have reported that the radon in ground water supplies in Appalachian Piedmont province to range from 10\(^3\)-10\(^4\)kBq m\(^{-3}\). Kannan et al (2001) have measured radon concentration in ground waters of Kalpakkam and have reported the value to range between 0.15-3.84Bq l\(^{-1}\).

Pachocki et al (1996) have measured Radon-222 concentration in surface water and wells water in the main towns and villages which are located in area of Karkonoskie Plateau and reported radon concentration
(below 10 Bq/l) for surface water and the values ranging from 87.5 Bq/l to 818.1 Bq/l for ground water.

Komal Badhan et al (2010) have measured radon concentration levels in ground water in the environs of National Institute of Technology, Jalandhar, Punjab, India, using electronic radon meter (RAD7). They have reported values ranging from 560 to 7750 Bqm$^{-3}$ with an average value of 5143.33 Bqm$^{-3}$ for drinking water.

Abdulrahman I. Alabdula’aly (1999) has measured radon concentration levels in eight water supply municipalities of the Central Region of Saudi Arabia. Samples were collected from 77 wells and reported the well water radon level was in the range of 0.89–35.44 Bq/l with an overall weighted geometric mean value of 8.80 Bq/l.

Ramola et al (2004) have measured Radon concentrations in groundwater and soil–gas the different geological formation of Kumaon Himalaya, India, and reported Radon concentrations to vary from 1 to 392Bq/l with a mean of 50Bq/l in water and 398Bq/m$^3$ to 25.8kBq/m$^3$ with a mean value of 5.867kBq/m$^3$ in soil–gas, respectively.

Vishal Arora et al (2011) have measured the activity concentration of radon in ground water samples of seismically active areas of N-W
Himalayas, Himachal Pradesh, India, and reported Radon concentrations to vary from 8.4Bq/l to 314Bq/l with an average value of 61.2 Bq/l, 14.4Bq/l to 140Bq/l with an average value of 50.8 Bq/l and 9.3Bq/l to 77.8Bq/l with an average value 23.2 Bq/l, respectively for the three important zones, viz. Zone-I, Zone-II and Zone-III in the study area.

Ramola et al (1999) have measured Radon concentrations in the water samples taken from the tube wells and hand pumps of the Dehradun city, India. They have reported Radon concentration to vary from 27 to 154 Bq.l" with an average of 67 Bq.l" in the water samples of hand pumps and radon concentration to vary from 26 to 129 Bq.l" with an average of 59 Bq.l" in the water samples of tube wells.

Mahesh et al (2001) have measured radon concentration in Groundwater (open well and bore well) samples from various locations of coastal Karnataka and Kaiga, India and reported radon concentration ranging from 0.14-25.4 Bq L(-1) with a median value of 3.74 Bq L(-1) for open well waters and redon concentration ranging from 0.22-197.0 Bq L(-1) with a median value of 5.75 Bq L(-1) for the bore well waters.

Bhushan Gokhale and Solomon Leung (2010) have measured radon concentration in Groundwater samples collected from eight wells in remote
Antelope Creek valley, Idaho. They have reported a very high radon concentration of 11 Bq/L (300 pCi/L) in seven locations of their study area.

Samer M. Abdallah et al (2007) have measured radon concentration in spring and well water sources using the E-PERM method at sites ranging from sea level to 1200 m above sea level and across several geologic formations within Lebanon, and reported radon concentration ranging from a low of 0.91 Bq L$^{-1}$ in a coastal well source to a high of 49.6 Bq L$^{-1}$ for a spring source in a mountainous region.

Manzoor et al (2008) have measured radon concentration in municipal supply drinking water in metropolitan Lahore city of Pakistan and reported radon concentration ranging from $2.0 \pm 0.3$ to $7.9 \pm 2.1$ Bq l$^{-1}$ with a mean value of annual effective dose for an individual consumer as $16.5 \pm 12.8$ $\mu$Sv y$^{-1}$.

Shashikumar et al (2011) have measured radon concentration in water samples of Mysore city, Karnataka, India and have reported the activity of $^{222}$Rn to be 434.60 Bq l$^{-1}$ in the bore well water sample of Chamundi Hills.

Shivakumar et al (2012) have measured radon concentration in natural ground water samples of Mandya District, India and have reported the $^{222}$Rn concentration ranging from 0.60 to 539.26 Bq l$^{-1}$ with an average value of
115.27 Bq l⁻¹. They have also reported the average annual dose due to ²²²Rn in such waters as 1.47 X 10⁻⁴ Sv/y.

2.4 Radionuclides in Granites and minerals

Ferodoas S. Al-Saleh et al (2007) have measured the activity of ²²⁶Ra, ²³²Th and ⁴⁰K in marbles and granites of Riyadh region employing high resolution γ-ray spectrometry and have found ²²⁶Ra concentration to vary between 0.36-32.4 Bq kg⁻¹ in marbles and between 0.03-147.0 Bq kg⁻¹ in granites, ²³²Th concentration to vary between 0.10-32.0 Bq kg⁻¹ in marbles and between 0.02-186.40 Bq kg⁻¹ in granites, ⁴⁰K concentration to vary between 0.68-897.1 Bq kg⁻¹ in marbles and between 0.28-1531.7 Bq kg⁻¹ in granites.

A. El-Taher et al (2007), have measured activity of ²²⁶Ra, ²³²Th and ⁴⁰K in granites of Egypt (From Aswan to Wadi-El-Allaqi) employing 3in X 3in NaI(Tl) detector and have found there highest concentrations as 24, 31.28 and 589.95 Bq kg⁻¹.

Ahmed et al (2006) have measured the ²²⁶Ra, ²³²Th and ⁴⁰K activity concentration (Bq/kg) in igneous and metamorphic rock samples from different locations of Egypt and Germany, using HPGe detector. They have
found $^{226}$Ra concentration to vary between 3.9 - 57.4 Bq kg$^{-1}$ in Egypt and 5.1 - 76 Bq kg$^{-1}$ in Germany, $^{232}$Th concentrations to vary between 3.2 - 53.4 Bq kg$^{-1}$ in Egypt and 3.4 - 70 Bq kg$^{-1}$ in Germany and $^{40}$K concentrations to vary between 202 - 1211 Bq kg$^{-1}$ in Egypt and 10 - 2070 Bq kg$^{-1}$ in Germany.

Muhammad Iqbal et al (2005) have measured the $^{226}$Ra, $^{232}$Th and $^{40}$K activity concentration (Bq/kg) in marble from various geological formations in Pakistan, using a NaI(Tl) gamma-ray spectrometer with a matrix-inversion-based spectral stripping technique. They have found $^{226}$Ra concentration to vary between 4-63 Bq kg$^{-1}$, $^{232}$Th concentrations to vary between 9-40 Bq kg$^{-1}$ and $^{40}$K concentrations to vary between 7-105 Bq kg$^{-1}$.

Nada (2002) has measured the $^{238}$U, $^{232}$Th and $^{40}$K activity concentration (Bq/kg) for Miocene iron ochre region at Um-Greifat area, eastern desert of Egypt (clastic-carbonate sediments), using gamma-ray spectrometry. They have found $^{238}$U concentration to vary between 1858 to 4062 Bq kg$^{-1}$, $^{232}$Th concentrations to vary between 29 and 151 Bq kg$^{-1}$ and $^{40}$K concentrations to vary between 46 and 409 Bq kg$^{-1}$.

UNSCEAR (1988) reports the activity range of natural radionuclides in copper ore as 30-80 Bq kg$^{-1}$, 23-110 Bq kg$^{-1}$ for $^{238}$U and $^{232}$Th, respectively.
Ajayi (2000) has measured the natural radioactivity in some rock samples in Ikogosi-Ekiti, Southwestern Nigeria by employing a very sensitive gamma spectroscopic system consisting of a 76 mm x 76 mm NaI(Tl) scintillation detector system coupled to a versatile Canberra Series 10 plus multichannel analyzer. He has found the average concentrations of $^{238}\text{U}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in the samples as, 57.9 +/- 28.1 Bq kg$^{-1}$, 81.6 +/- 23.8 Bq kg$^{-1}$ and 1203.1 +/- 687.2 Bq kg$^{-1}$, respectively.

Michalis Tzortzis et al (2003) have measured the gamma radiation in samples of a variety of natural tiling rocks (granites) imported in Cyprus for use in the building industry was measured, employing high-resolution $\gamma$-ray spectroscopy and have found $^{238}\text{U}$ concentration to vary between 1 to 588 Bq kg$^{-1}$, $^{232}\text{Th}$ concentration to vary between 1 to 906 Bq kg$^{-1}$, $^{40}\text{K}$ concentration to vary between 50 to 1606 Bq kg$^{-1}$, respectively.

A. El-Shershaby (2001) have measured the activity of $^{238}\text{U}$ and $^{232}\text{Th}$ in granites in Gable Gattar II, which is located in the north eastern desert of Egypt using a hyper-pure germanium spectrometer and have found $^{238}\text{U}$ concentration to vary between 165+5 to 27851+836 Bq kg$^{-1}$, $^{232}\text{Th}$ concentration to vary between 71+2 to 274+8 Bq kg$^{-1}$ respectively.

Ningappa et al (2007) have measured the activity of $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ in rock samples of granite quarries of Kanakapura, Ramanagara Taluks and
Bidadi Hobli in Bangalore rural District and Bangalore city using HPGe gamma-ray spectrometer and have found $^{226}\text{Ra}$ concentration to vary between 32.2 to 163.6 Bq kg$^{-1}$, $^{232}\text{Th}$ concentration to vary between 128.3 to 548.6 Bq kg$^{-1}$ and $^{40}\text{K}$ concentration to vary between 757.4 to 1418.4 Bq kg$^{-1}$.

Kerur et al (2010) have measured the activity of $^{232}\text{Th}$, $^{238}\text{U}$ and $^{40}\text{K}$ in rock samples collected from Gadag, Gulbarga and Kottur, in north Karnataka, India using HPGe detector. They have reported the mean activity concentrations of $^{232}\text{Th}$, $^{238}\text{U}$ and $^{40}\text{K}$ as 73.54, 47.32 and 114.76 Bq kg$^{-1}$ for Gadag, 7.2, 4.9 and 121.8 Bq kg$^{-1}$ for Gulbarga and 20.96, 42.2 and 875 Bq kg$^{-1}$, for Kottur samples, respectively.

Aydarous et al (2010) have measured the $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ activity concentration (Bq/kg) in different types used granite tiles collected from Jeddah province, Saudi Arabia, using HPGe detector. They have found $^{226}\text{Ra}$ concentration to vary between 9.7 to 133 Bq kg$^{-1}$, $^{232}\text{Th}$ concentrations to vary between 4.9 to 144 Bq kg$^{-1}$ and $^{40}\text{K}$ concentrations to vary between 9.7 to 133 Bq kg$^{-1}$, respectively.

Buket Canbaz et al (2007) have measured the $^{226}\text{Ra}$, $^{232}\text{Th}$ and $^{40}\text{K}$ activity concentration (Bq/kg) in granitoid samples from from the Ezine plutonic area, Turkey, using HPGe detector. They have found $^{226}\text{Ra}$ concentration to vary between 94 to 637 Bq kg$^{-1}$, $^{232}\text{Th}$ concentrations to vary between 120 to...
601Bqkg⁻¹ and ⁴⁰K concentrations to vary between 1074 to 1527Bqkg⁻¹, respectively.

Ademola et al (2010) have measured the activity of ²²⁶Ra, ²³²Th and ⁴⁰K in granite samples collected from five different quarry industries in Ondo State, Nigeria, using, gamma-ray spectrometry and have found the mean activity concentrations for each industry to range between 16.7-85.4, 62.4-113.6 and 1315-1551Bq.kg⁻¹ for ²²⁶Ra, ²³²Th and ⁴⁰K radionuclides, respectively.

Xinwei et al (2006) have measured the activity of ²²⁶Ra, ²³²Th and ⁴⁰K in commercial granites of China, using, NaI(Tl) gamma-ray spectrometer with a matrix inversion-based spectral stripping technique, and have found the activity concentrations to range between 14.5-204.7, 16.7-186.7 and 185.7-1745.6Bq.kg⁻¹ for ²²⁶Ra, ²³²Th and ⁴⁰K radionuclides, respectively.

Safia H. Q. Hamidalddin and Afaf A. Fakeha (2012) have measured the activity of ²²⁶Ra, ²³²Th and ⁴⁰K in copper ores and iron ores in the Arabian shield, the western part of the Saudi Arabia by employing a high resolution γ-ray spectrometry and have found ²²⁶Ra concentration to vary between 2.50 to 386.30Bqkg⁻¹ in iron ore and between 57.41 to 1048.01Bqkg⁻¹ in copper ores, ²³²Th concentration to vary between 1.50 to 183.90 Bqkg⁻¹ in iron ores
and between 43.66 and 44.41 Bq kg\(^{-1}\) in copper ores and \(^{40}\)K concentration to vary between 2.70 to 186.99 Bq kg\(^{-1}\) in iron ores and 48.92 and 191.33 Bq kg\(^{-1}\) in copper ores.

Zubair et al (2013) have measured the activity of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K in rock samples collected from Lalitpur, India using gamma-ray spectrometry and have found the activity concentrations to range between BDL-65.25, BDL-4.06 and BDL-550.2 Bq kg\(^{-1}\) for \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K radionuclides, respectively.

Shivakumar et al (2012) have measured the activity of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K in rock samples collected from Srirangapattna, India using gamma ray spectrometry. They have reported the mean activity concentrations of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K as 13.9, 46.8 and 950.9 Bq kg\(^{-1}\), respectively.

Rajeshwari et al (2012) have measured the activity of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K in the building materials collected from Donimalai-Sandur region of North Karnataka, India using HPGe detector. They have reported the mean activity concentrations of \(^{226}\)Ra, \(^{232}\)Th and \(^{40}\)K as 54.4, 48.9 and 960 Bq kg\(^{-1}\), respectively.

From the above literature survey it is clear that the extensive study carried out by various investigators from different parts of the world...
regarding the natural background radiation level, distribution of radionuclides in environmental matrices like soil, water, various types of rocks, minerals and granites etc., vary from place to place. Several places in India as well as some parts of the world are known to form high background radiation regions. Till to date, no data is available on the environmental radioactivity in the Granite and Sand quarries present in and around Malnad biosphere. Hence an attempt has been made to provide a radiation map of this area and to know the distribution of radionuclides in soil, garnites, water, minerals, etc., and hence to assess the resulting radiation dose to the population working at such units. This type of study has not been carried out so far in this part of the country and hence happens to be the first of its kind in this area.