Chapter Seven

CONCLUSION AND DISCUSSION

This chapter presents a brief summary of the salient features of the work carried out during PhD studies and presented in this thesis. In the introductory part of this work, the importance of the α-radioactive nuclide radon as a health hazard and use of the etched track detectors as an effective tool for its measurement were briefly described. According to Fleischer, (1998) nuclear tracks and radon are intertwined because etched track detectors can record tracks from the α-particles emitted by radon. Etched track detectors for measuring radon are the dosimeters of choice, first, because they are passive and thus need no power supply and second because they measure total radon exposure, allowing averaging of the radon concentration over long periods of time, such as weeks, months or a year.

After reviewing the etching characteristics and track registration efficiencies of plastic track detectors it was concluded that CR-39 is the most convenient track detector because of its high sensitivity and some other characteristics as addressed in Chapter 2.

Efforts were made to discover new etchants for the CR-39 detector which have a higher efficiency and shorter etching time. This was desirable because the chemical etching techniques reported and presently in use for CR-39 detectors are time consuming. In this regard, systematic studies were carried out wherein a number of new etchants were studied. As a result, four new etchants were discovered. These included NaOH dissolved in Ethanol, NaOH dissolved in 1-Propanol, NaOH dissolved in methanol, and NaOH dissolved in methanol + water (from now onward called SMW solution). It was found that:

1. 1 M NaOH/1-Propanol Solution at 49 °C yields a maximum value of the etching efficiency of ~ 70%;
2. 1.5 M NaOH/Ethanol solution at 55 °C yields a maximum value of the etching efficiency of ~ 77%;
3. 1.5 M NaOH/ Methanol Solution at 55 °C yields maximum value of the etching efficiency of ~ 78%; and
4. SMW solution (consisting of 60% Methanol, 10% NaOH and 30% water) at 55 °C yields maximum the efficiency of ~ 81%.

All the above-mentioned four etchants are more efficient than conventionally used 6 M aqueous NaOH (i.e. 64%) at 70 °C. Besides having higher etching efficiencies, these etchants also have the advantage that they require much shorter processing time (i.e. minutes instead of hours). This is a great discovery. The introduction of these etchants in routine dosimetry will not only lower the existing detection limit but will also drastically reduce the processing time from hours to minutes for the CR-39 detector.

After the above-mentioned novel achievements, indoor radon levels and natural radioactivity were measured in selected cities of Bahawalpure Division (Pakistan). Bahawalpur is the largest division of the Punjab Province. It is larger than many countries of the world. Gamma activity from the naturally occurring radionuclides namely ^{226}Ra, ^{232}Th, the primordial radionuclide ^{40}K and the artificial radionuclide ^{137}Cs was measured in the soil of Bahawalpur Division using gamma spectrometry technique. The mean activities of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were found to be 32.9±0.9, 53.6±1.4, 647.4±14.1 and 1.5±0.2 $Bq.kg^{-1}$, respectively. The mean radium equivalent activity Ra_{eq}, external hazard index, internal hazard index and terrestrial absorbed dose rate for the area under study are 158.5±4.1 $Bq.kg^{-1}$, 0.4, 0.5 and 77.32 $nGy.h^{-1}$, respectively. The annual effective dose equivalent to the public was found to be 0.5 mSv. From the measured indoor radon concentration levels, excess lung cancer risk has been calculated using the risk coefficients recommended by EPA and UNSCEAR. Due to the unavailability of smoking data for the public in the Bahawalpur Division, lung cancer risk has been calculated using only radon exposure. According to the EPA model, the lifetime excess lung cancer risk due to the life-time exposure is found to vary from 12 per million per year to 102 per million per year in the cities surveyed. These values vary from 16 per million per year to 114 per million per year if UNSCEAR limits are applied. According to the EPA and UNSCEAR models, the overall average value of the lifetime excess lung cancer risks due to the life-time exposure in the Bahawalpur Division vary from 19–65 and 24–73 respectively.

Besides some other factors, indoor radon levels depend on the radon exhalation rate from building materials and soil beneath the house. Therefore, accurate knowledge of the exhalation rate plays an important role in characterization of the radon source strength in building materials and soil. It is a useful quantity to compare the relative importance of different materials and soil types. A majority of houses in Pakistani villages are mainly constructed from soil and sand. Therefore, studies concerning the determination of radon exhalation rate from these materials were carried out using CR-39 based NRPB radon dosimeters. In this context, samples were collected from different towns of the Bahawalpur division, Punjab and major cities of NWFP. After treatment, samples were placed in plastic containers and dosimeters were installed in them. After exposure to radon, CR-39 detectors were etched in 25% NaOH at 80 °C for 16 h. From the measured radon concentration values, ^{222}Rn exhalation rates were determined. It ranged from 1.56 to 3.33 $Bq.m^{-2}.h^{-1}$ for the soil collected from the Bahawalpur Division and 2.49 - 4.66 $Bq.m^{-2}.h^{-1}$ for NWFP. The ^{222}Rn exhalation rates from the sand samples were found to range from 2.78–20.8 $Bq.m^{-2}.h^{-1}$ for the Bahawalpur Division and from 0.99 to 4.2 $Bq.m^{-2}.h^{-1}$ for NWFP. ^{226}Ra contents were also determined in the above samples which ranged from 28–36.5 $Bq.kg^{-1}$ in the soil samples collected from the Bahawalpur Division and from 40.9 to 51.9 $Bq.kg^{-1}$ in the samples collected from the NWFP. In sand samples, ^{226}Ra contents ranged from 49.2–215 $Bq.kg^{-1}$ and 22.6–27 $Bq.kg^{-1}$ in the samples collected from the Bahawalpur Division and NWFP respectively. ^{226}Ra contents in these samples were also determined using HPGe detector. The results of both the techniques were found to be in good agreement within experimental errors.

Finally it was decided to exploit the helpful aspects of radon. Therefore, it was successfully used as a tool for determination of the uranium contents in ore samples. To do so, ore samples were placed in plastic containers with CR-39 based NRPB radon dosimeters installed in them. The containers were then hermetically sealed and the dosimeters were exposed to radon for three weeks to equilibrate the ^{222}Rn and ^{226}Ra activities. After exposure, CR-39 detectors were etched in 25% NaOH at 80 °C for 16 h. The measured track densities were then related to radon concentrations using calibration factor of 2.7 $Tracks.cm^{-2}.h^{-1}/ (kBq.m^{-3})$. From the measured radon concentration values, ^{226}Ra activities were calculated that ranged from 157–454 $Bq.kg^{-1}$. Using these activity values, assuming secular equilibrium, ^{238}U contents were calculated which ranged from 13–37 ppm in the ore samples under study. In order to verify the validity of the assumption of secular equilibrium, the above samples were analyzed with a high-resolution Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES). The results obtained from this method showed higher ^{238}U content that ranged from 356–2061 ppm, which was a clear indication that there is disequilibrium between ^{226}Ra and ^{238}U. Due to the unavailability of the ^{226}Ra standard for ICP-AES, the equilibrium factor was therefore determined using HPGe based gamma spectrometry technique. Here, specific activity of ^{226}Ra was determined using gamma line at 609.3 keV (46.1%) of ^{214}Bi. Then specific activity of ^{238}U was determined using the gamma line at 143.76 keV (10.5%) of ^{235}U. Equilibrium factor, defined as the ratio of the specific activities of ^{226}Ra and ^{238}U, was determined. The NRPB dosimeter data was then corrected for the equilibrium factor which resulted in ^{238}U contents that ranged from 229–1968 ppm.

Future Recommendations

- Our newly discovered etchants, discussed in Chapter 3, would be of great help if introduced in routine dosimetry. However, before doing so systematic studies need to be performed to determine the calibration factor for CR-39 detector (e.g. in the case of radon dosimetry).
- In order to have a clear picture of indoor radon concentration levels in any area, contribution from all the possible sources (addressed in Chapter1) should be measured systematically e.g. soil, building material and **underground water**. The contribution of underground water needs to be studied properly in Pakistan.
- The epidemiological studies of lung cancer should be carried out on national level in conjunction with medical specialists in order to calculate the proper risk coefficient in our own environment.
- While using radon as a search tool for uranium exploration, field experiments need to be carried out in order to verify the results obtained in the laboratory environment.
- Radon measurement may possibly be helpful in predicting earth quake provided that radon monitoring stations are established on fault lines running throughout the country.