Seasonal variation and behavior of 210Pb in the soil and sediment of Hemavathi riverine environment

Abstract

In the present study, discuss the seasonal variation of 210Pb in the soil and sediment of Hemavathi River Environment. The samples were collected in pre-monsoon and monsoon seasons and the concentration of 210Pb was determined using standard radiochemical analytical method. The mean activity concentration of 210Pb in soil was found to be 12.19Bqkg\(^{-1}\) and 5.41Bqkg\(^{-1}\) in monsoon and pre-monsoon respectively. The mean activity concentration of 210Pb in sediment was found to be 12.87Bqkg\(^{-1}\) and 6.17Bqkg\(^{-1}\) in monsoon and pre-monsoon respectively. The activity was high in monsoon as compared to the pre-monsoon.

Keywords: polonium-210, lead-210, radiochemical method, soil, hemavathi, sediment

Introduction

The radioactivity is everywhere in the earth including the human body. All radioactive sources emit radiations which cause biological damage to the human population. Among the various radiation sources natural background radiations are important. The naturally radiation comes from terrestrial and cosmic rays, which is derived essentially from the 238U and 232Th series and single occurring 40K. The concentration of radionuclides from terrestrial sources changes with locations and altitude. The average dose rate received by population was value of 2.4mSv per year. Among the naturally occurring radionuclides 210Pb is a member of 238U series, which results from the intermediate decay of 226Ra to the noble gas, 222Rn by alpha disintegration. It also comes from the precipitation or dry deposition of 222Rn. This atmospheric addition of 210Pb is in excess of the amount supplied by the in situ decay of 226Ra. Background or supported 210Pb is assumed to be in equilibrium with the decay of 226Ra without the negligible loss of radionuclides. Lead-210 is highly reactive and is readily scavenged by organic matter and clay particles, but under anoxic conditions, 210Pb can be released back to the water column. 210Pb is removed from the water column to the sediment by scavenging. Chemical adsorption onto particulate matter facilitates transport over long distances before its final deposition in the sediment. The activity of 210Pb at the sediment surface is the result of interplay between accumulation, sediment mixing, and radioactive decay. Therefore, it is important to understand the concentration and behavior of lead in an aquatic environment. The published data on 210Pb in aquatic environs is important and so an attempt was made in the present investigation to study the Seasonal variation of 210Pb in the soil and sediment of Hemavathi River environ. Seasonal variations are important to understand the behavior of 210Pb activity with different seasons, because of heavy rain fall in rainy season and high temperature in pre-monsoon may affects the changes in activity concentration.

Materials and methods

Study area

Hemavati River is one of the major rivers in South Karnataka. The river originates at Ballala Rayana Durga in Western Ghats, which is 1,219m above the sea level. The river covers the areas of Chikmagalur, Hassan and Mysore districts before joining River Cauvery near Krishnarajasagara. Hemavathi River basin has a drainage area of about 5,410km², a 245km in length and is located between 12°13’-13°8’18” N latitudes and 75°32’4” - 76°38’ E longitudes. The river basin consists of Major drainage pattern is dendritic to sub dendritic.

Sample collection

Figure 1 shows the sampling stations along River Hemavathi. The Sampling station H1 and H14 corresponds to the upper and lower reaches of the river. The soil and sediment samples were collected from the river bank and river drainage respectively with following standard procedures (EML). For the seasonal variation “analysis” the samples were collected from January and August. The collected sample was stored in polyethylene bags and brought to the laboratory for the further processing. The samples were dried in an air circulated oven till constant dry weight is obtained.

![Hemavathi river basin map](image-url)
Physico-chemical parameters

The organic matter in the soil and sediment was measured by using the weight loss-on-ignition method at an ignition temperature of 550 °C for 24 h. Other physico-chemical parameters were measured by using standard protocol. In the present investigation the sand, silt and clay fractions were separated to find the type of soil and sediment. About 20g of sediment or soil sample was taken in a beaker; added 30% of H₂O₂ to remove organic matter and 10% acetic acid to remove carbonate material present in the samples. After washing 2 to 3 times, sand was separated through wet sieving ASTM 230 sieve. Based on Stokes law for settling particles, the solution was collected at a depth of 20 cm, within a time interval of 20 seconds to set the solution with the required size fraction, to determine (Silt+clay) %. Based on this at room temperature of about 25-30 °C, the solution was collected with a 20 ml bulb type pipette at 5 cm in the water column after allowing the settling column to stand without disturbing, for 3 hours, 36 minutes. The collected 20ml gives the clay fraction (<2 microns), which is dried in a beaker. The clay percentage was determined using the equation given below

\[ \text{Clay} (\%) = \left( \frac{W_1-W_2}{20 \text{cm}} \right) \times 100 \times 1000 \]

Where, \( W_1 \) is the weight of the beaker after drying with clay, \( W_2 \) is weight of the empty beaker, \( m \) is the mass of the soil taken, 20 represent 20 ml, 1000 represents the total volume of solution i.e., \( L \)

Sample processing and activity determination

The \( ^{210}\text{Pb} \) activity was determined by using chemical deposition method. A known weight of sample was taken in a beaker 4M HNO₃. The organic matter present in the sample was removed by adding 3:1 HNO₃ and HClO₄ mixture in small increments until a white residue appears. The samples were then converted into 1M HCl medium and \( ^{210}\text{Po} \) in the solution was deposited onto the bright-line polished back ground counted (both sides) silver disk using magnetic stirrer at 97 °C for 6 h continuously. The disk was then washed with distilled water, rinsed with alcohol, dried under an infrared lamp and then counts were noted on both sides using ZnS(Ag) alpha counter of 0.005cpm background and 30 % efficiency. The activity of \( ^{210}\text{Pb} \) was estimated through \( ^{210}\text{Po} \) by allowing the \( ^{210}\text{Po} \) plated solution for a period of 12 months to build-up \( ^{210}\text{Po} \) from \( ^{210}\text{Pb} \). The total net count was obtained from both sides of the silver planchet, for a counting time period of 2000 seconds. The activity concentration of Polonium-210 was calculated using the following equation Iyengar et al.: \(^3\)

\[ A = \left( S \pm SD \right) \times \frac{100}{E} \times \frac{1000}{E_p} \times \frac{1000}{W} \times Bq kg^{-1} \]

Where,
- \( S \) is the net counts per second
- \( SD \) is the standard deviation
- \( E \) is the efficiency (%) of alpha counter, determined as described in Section 2.3

Ep is the plating efficiency (%), determined using \( ^{210}\text{Po} \) standard and was found to be 90% and

\( W \) is the weight of the dry sample taken for analysis in gram.

Result and discussions

The activity concentration of \( ^{210}\text{Pb} \) in soil and sediment samples from Hemavathi river environment as shown in Table 1. The highest activity in soil was found to be 27.441.6 Bq kg\(^{-1}\) and 10.411.01 Bq kg\(^{-1}\) in monsoon and pre-monsoon, respectively. But lowest activity was found 7.510.8 Bq kg\(^{-1}\) and 2.770.52 Bq kg\(^{-1}\) in monsoon and pre-monsoon respectively. The highest activity in sediment was found to be 22.551.4 Bq kg\(^{-1}\) and 14.881.21 Bq kg\(^{-1}\) in monsoon and pre-monsoon respectively. But lowest activity was found 6.010.7 Bq kg\(^{-1}\) and 2.570.50 Bq kg\(^{-1}\) in monsoon and pre-monsoon respectively. The activity concentration was varied from location to location as changes with seasons. The activity was high in monsoon as compared to the pre-monsoon. The higher activity concentration in monsoon was found to be statistically significant (p<0.001). The variation is due to the deposition of \( ^{210}\text{Pb} \) at an individual location depends on the efficiency of removal by rain and \( ^{222}\text{Rn} \) concentration in air. Because of grandparent radioactive inert gas \( ^{222}\text{Rn} \), it has been enter to the atmosphere from geological sources, \( ^{210}\text{Pb} \) is attached with submicron-size aerosols which are removed by precipitation and deposited on the earth’s surface. In sediment the activity concentration of \( ^{210}\text{Pb} \) depends on the geology of the location, weathering concentration and drainage pattern of the river, while the geochemistry of the parent radionuclide and its speciation also play a significant role. Kaliprasad & Narayana reported the values of Physico-chemical parameter. The physico-chemical parameters of the samples are useful to know the behavior of radionuclides in soil and sediment. Therefore, we have measured the physico-chemical parameters such as pH, Moisture, Organic matter and granulometric content like silt, clay, sand, in soil and sediment as shown in Table 2 for pre-monsoon and monsoon respectively. The pH value of soil and sediment samples varies from 5.06 to 8.12 and 5.72 to 8.58 in pre-monsoon and it was varies from 5.17 to 9.14 and 6.24 to 10.7 in monsoon soil and sediment samples respectively. The mean organic matter content (%) in soil was 5.22 and 6.64, and it was in sediment 2.61 and 3.45, in pre-monsoon and monsoon respectively. The mean moisture (%) in pre-monsoon samples was 18.19 and 18.76 for soil and sediment respectively. The moisture (%) in soil samples of monsoon was high in due to rain as compared to pre-monsoon. The granulometric parameters of soil and sediment samples shows that soil samples are sandy loam and loamy sand type, but the sediment samples shows sand type in pre-monsoon and in monsoon it shows more clay content. The organic matter and \( ^{210}\text{Pb} \) shows good correlation in both seasons.

Using the SPSS statistical tool to analyze the correlation between physico-chemical parameters and radionuclides are shown in Table 3. The organic matter and \( ^{210}\text{Pb} \) shows good correlation with correlation coefficient 0.604 and 0.544 in pre-monsoon soil and sediment samples and it was 0.676 and 0.733 in monsoon soil and sediment respectively. The clay of pre-monsoon soil and \( ^{210}\text{Pb} \) show correlation with correlation coefficient 0.613. \( ^{210}\text{Pb} \) activity also has shown good correlation with moisture (%). The statistics of the value corresponding to the \( ^{210}\text{Pb} \) in soil and sediment has shown in Table 4. The frequency distribution graphs are shown in (Figures 2) (Figure

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3). The skewness of the soil and sediment in both the seasons showed positive. The kurtosis of pre-monsoon soil shows negative and all other samples shows positive. The values of kurtosis indicate the flat and peaked distribution as per positive and negative respectively. The values of skewness and kurtosis indicate the normal distribution. The 210Pb activity as compared with other region of the world is shown in Table 4. The present 210Pb value is less than the values reported for kali, Sharavthi and Netravathi River, but the values are higher than HBR Kerala.16–21

Table 1 Seasonal variation of 210Pb activity in soil and sediments of Hemavathi River

| Sampling Location | Monsoon 210Pb activity (Bq kg⁻¹) | Pre-monsoon 210Pb activity (Bq kg⁻¹) |
|-------------------|----------------------------------|-------------------------------------|
|                   | Soil                             | Sediment                            | Soil                             | Sediment                            |
| H1                | 27.44 ± 1.6                      | 16.91±1.2                           | 4.06±0.63                        | 2.87±0.53                           |
| H2                | 15.03 ±1.1                       | 10.33±0.9                           | 10.41±1.01                      | 14.88±1.21                          |
| H3                | 6.76 ± 0.7                       | 9.39±0.9                            | 4.66±0.68                        | 5.85±0.76                           |
| H4                | 8.45 ± 0.8                       | 17.85±1.2                           | 3.07±0.55                        | 3.47±0.58                           |
| H5                | 17.85 ± 1.2                      | 12.21±1.0                           | 9.42±0.96                        | 3.96±0.62                           |
| H6                | 7.51 ± 0.8                       | 13.15±1.1                           | 6.05±0.77                        | 3.37±0.57                           |
| H7                | 7.51 ± 0.8                       | 11.09±1.0                           | 3.47±0.58                        | 3.86±0.61                           |
| H8                | 12.96 ± 1.1                      | 18.79±1.3                           | 8.23±0.90                        | 8.33±0.90                           |
| H9                | 12.21 ± 1.0                      | 6.01±0.7                            | 6.15±0.78                        | 9.62±0.97                           |
| H10               | 11.46 ± 1.0                      | 22.55±1.4                           | 4.36±0.65                        | 7.83±0.88                           |
| H11               | 14.09 ± 1.1                      | 10.52±0.9                           | 2.77±0.52                        | 2.57±0.50                           |
| H12               | 9.39 ± 0.9                       | 9.02±0.9                            | 4.46±0.66                        | 7.93±0.88                           |
| H13               | 11.84 ± 1.0                      | 12.21±1.0                           | 2.48±0.49                        | 3.96±0.62                           |
| H14               | 8.98 ± 0.8                       | 10.15±0.9                           | 6.15±0.78                        | 7.93±0.88                           |
| Mean              | 12.19                            | 12.87                               | 5.41                             | 6.17                                |

Table 2 Physico-chemical parameters of Hemavathi river soil and sediment in monsoon

| H-mon | Moisture (%) | Organic Matter (%) | pH | Silt (%) | Clay (%) | Sand (%) |
|-------|--------------|--------------------|----|----------|----------|----------|
| Soil  | Range        | 7.8-49.38          | 2.81-15.45 | 5.17-9.14 | 6.00-20.00 | 11.31-40.88 | 32.54-82.69 |
| Mean  | 18.19        | 6.64               | 6.63 | 16.23    | 26.68    | 57.09    |
| Median| 16.49        | 5.70               | 6.34 | 14.80    | 22.42    | 63.16    |
| Stdev | 10.40        | 3.71               | 1.40 | 7.28     | 11.76    | 16.63    |
| Sediment | Range       | 3.48-39.77         | 0.62-7.03 | 6.24-10.7 | 1.2-8.81 | 10.6-39.4 | 51.39-85.39 |
| Mean  | 18.76        | 3.45               | 8.59 | 6.12     | 15.62    | 78.26    |
| Median| 17.08        | 2.70               | 8.30 | 5.21     | 13.26    | 80.26    |
| Stdev | 9.11         | 2.59               | 1.24 | 3.29     | 7.15     | 8.52     |

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Table 3 Pearson correlation matrix among the variables 

|                | Pre monsoon Soil | Moisture (%) | Organic matter | PH       | Silt (%) | Clay (%) | Sand (%) | Pb       |
|----------------|-----------------|--------------|----------------|----------|----------|----------|----------|----------|
| Moisture (%)   | I               | I            |                |          |          |          |          |          |
| Organic matter | 0.653           | I            |                |          |          |          |          |          |
| PH             | 0.023           | -0.4        | I              |          |          |          |          |          |
| Silt (%)       | 0.197           | 0.553       | -0.315         | I        |          |          |          |          |
| Clay (%)       | 0.572           | 0.68        | -0.225         | 0.143    | I        |          |          |          |
| Sand (%)       | -0.556          | -0.819      | 0.336          | -0.608   | -0.873   | I        |          |          |
| Pb             | 0.855           | 0.604       | -0.153         | 0.153    | 0.613    | -0.567   | I        |          |

|                | Pre monsoon Sediment | Moisture (%) | Organic matter | PH       | Silt (%) | Clay (%) | Sand (%) | Pb       |
|----------------|----------------------|--------------|----------------|----------|----------|----------|----------|----------|
| Moisture (%)   | I                    | I            |                |          |          |          |          |          |
| Organic matter | 0.603                | I            |                |          |          |          |          |          |
| PH             | -0.766               | -0.514      | I              |          |          |          |          |          |
| Silt (%)       | 0.642                | 0.579       | -0.405         | I        |          |          |          |          |
| Clay (%)       | 0.179                | -0.312      | -0.355         | -0.185   | I        |          |          |          |
| Sand (%)       | -0.669               | -0.262      | 0.597          | -0.707   | -0.564   | I        |          |          |
| Pb             | 0.126                | 0.544       | -0.133         | 0.53     | -0.335   | -0.205   | I        |          |

|                | Monsoon Soil | Moisture (%) | Organic matter | PH       | Silt (%) | Clay (%) | Sand (%) | Pb       |
|----------------|--------------|--------------|----------------|----------|----------|----------|----------|----------|
| Moisture (%)   | I            | I            |                |          |          |          |          |          |
| Organic matter | 0.678       | I            |                |          |          |          |          |          |
| PH             | -0.49       | -0.465      | I              |          |          |          |          |          |
| Silt (%)       | 0.634       | 0.839       | -0.431         | I        |          |          |          |          |
| Clay (%)       | 0.062       | 0.443       | 0.164          | 0.498    | I        |          |          |          |
| Sand (%)       | -0.321      | -0.681      | 0.073          | -0.79    | -0.925   | I        |          |          |
| Pb             | 0.393       | 0.676       | -0.292         | 0.341    | 0.065    | -0.195   | I        |          |

|                | Monsoon Sediment | Moisture (%) | Organic matter | PH       | Silt (%) | Clay (%) | Sand (%) | Pb       |
|----------------|----------------|--------------|----------------|----------|----------|----------|----------|----------|
| Moisture (%)   | I              | I            |                |          |          |          |          |          |
| Organic matter | 0.3           | I            |                |          |          |          |          |          |
| PH             | -0.278       | -0.509      | I              |          |          |          |          |          |
| Silt (%)       | 0.345        | 0.169       | -0.514         | I        |          |          |          |          |
| Clay (%)       | 0.314        | 0.259       | -0.125         | 0.224    | I        |          |          |          |
| Sand (%)       | -0.397       | -0.283      | 0.304          | -0.575   | -0.926   | I        |          |          |
| Pb             | 0.187        | 0.733       | -0.373         | -0.137   | -0.008   | 0.059    | I        |          |

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Table 4 Statistical analysis and comparison of \(^{210}\)Pb activity with other area

|                  | \(^{210}\)Pb (Bq kg\(^{-1}\)) |                  | \(^{210}\)Pb (Bq kg\(^{-1}\)) |                  |
|------------------|-----------------|-----------------|-----------------|-----------------|
|                  | Premonsoon      | Monsoon         | River           | Reference       |
| Soil             | Sediment        | Soil            | Sediment        | Padubidri       |
| Mean             | 5.41            | 6.18            | 12.19           | 12.88           | 23-108          | Prakash\(^{14}\) |
| Median           | 4.56            | 4.91            | 11.65           | 11.65           | 8.1-71.1        | Kali river      | Rajashekar\(^{17}\) |
| Maximum          | 10.42           | 14.88           | 27.44           | 22.56           | 5.7-15.1        | HBR, Kerala     | Narayana et al.\(^{18}\) |
| Minimum          | 2.48            | 2.58            | 6.77            | 6.02            | 8-113.1         | Sharvathi       | Rajashekar KM et al.\(^{17}\) |
| St. DEV          | 2.48            | 3.46            | 5.47            | 4.54            | 2.9-62.7        | Netrvathi       | Rajashekar KM et al.\(^{17}\) |
| Skewness         | 0.85            | 1.23            | 1.78            | 0.79            | 29.6-253.4      | Goa region      | Avadani et al.\(^{19}\) |
| Kurtosis         | -0.19           | 1.64            | 4.01            | 0.1             | 22.1-122.1      | Black forest    | Schuettelkopf & kiefer\(^{20}\) |
| Frequency        | peaked           | normal           | normal           | normal           | 3.6-45.2       | Mangalore, India | Radhakrishna et al.\(^{21}\) |

Figure 2 The frequency distribution of \(^{210}\)Pb activity in pre-monsoon soil and sediment.
Seasonal variation and behavior of $^{210}$Pb in the soil and sediment of Hemavathi riverine environment

Conclusion

The activity concentration of $^{210}$Pb was measured in the soil and sediment of Hemavathi river compared with the other reported values. Studies were conducted to study the seasonal variations. The seasonal variation is statistically significant. The mean activity in monsoon was higher than pre-monsoon in both soil and sediment. A good correlation observed between organic matter and the activity concentration of $^{210}$Pb in soil and sediment of both the seasons. $^{210}$Pb was increased with increase organic matter and clay, moisture also influence to increase the activity concentration. The data will helpful to understand the basic dynamics of radionuclides in soil and sediment phase of different seasons.

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Conflict of interest

The authors declare no conflict of interest.

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Figure 3 The frequency distribution of $^{210}$Pb activity in monsoon soil and sediment.

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