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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 ^{210}Pb in the soil and sediment of Hemavathi River Environment. The samples were collected in pre-monsoon and monsoon seasons and the concentration of ^{210}Pb was determined using standard radiochemical analytical method. The mean activity concentration of ^{210}Pb in soil was found to be 12.19Bqkg^{-1} and 5.41Bqkg^{-1} in monsoon and pre-monsoon respectively. The mean activity concentration of ^{210}Pb 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: polinum-210, lead-210, radiochemical method, soil, hemavathi, sediment

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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 varies radiation sources natural background radiations are important. The naturally radiation comes from terrestrial and cosmic rays, which is derived essentially from the ^{238}U and ^{232}Th series and single occurring ^{40}K. 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.[1] Among the naturally occurring radionuclides ^{210}Pb is a member of ^{238}U series, which results from the intermediate decay of ^{226}Ra to the noble gas, ^{222}Rn by alpha disintegration. It also comes from the wet precipitation or dry deposition of ^{222}Rn. This atmospheric addition of ^{210}Pb is in excess of the amount supplied by the in situ decay of ^{226}Ra. Background or supported ^{210}Pb is assumed to be in equilibrium with the decay of ^{226}Ra 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, ^{210}Pb can be released back to the water column. ^{210}Pb 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 ^{210}Pb 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 ^{210}Pb in aquatic environs is important and so an attempt was made in the present investigation to study the Seasonal variation of ^{210}Pb in the soil and sediment of Hemavathi River environ. Seasonal variations are important to understand the behavior of ^{210}Pb 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 5,410km^2, a 245km in length and is located between 12^{0}13'-13^{0}8'18" N latitudes and 75^{0}32'4" - 76^{0}38' E longitudes.[2] The river basin consists of Major drainage pattern is dendritic to sub dendritic.[3]

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).[4] 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.[5]

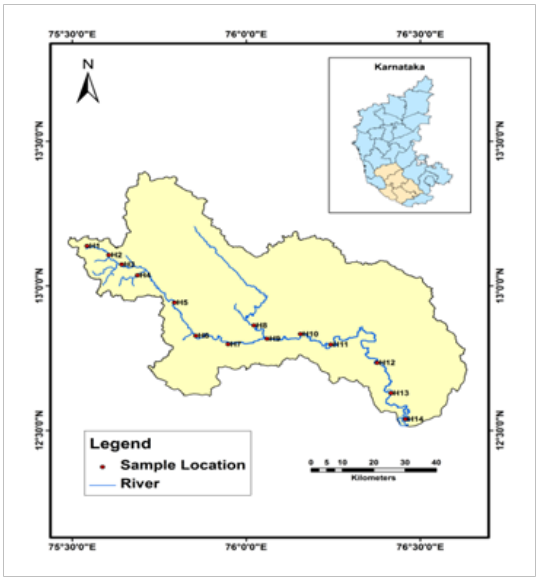

Figure 1 Hemavathi river basin map.

Physico-chemical parameters

The organic matter in the soil and sediment was measured by using the weight loss-on-ignition method[6] at an ignition temperature of 550 ºC for 24h. Other physico-chemical parameters were measured by using standard protocol.[7,8] 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 H_2O_2 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 20cm, within a time interval of 20 seconds to set the solution with the required size fraction, to determine (Silt+clay) %.[9] Based on this at room temperature of about 25-30 ºC, the solution was collected with a 20ml bulb type pipette at 5cm in the water column after allowing the settling column to stand without disturbing, for 3hours, 36 minutes. The collected 20ml gives the clay fraction (<2 microns), which is dried in a beaker.[9] The clay percentage was determined using the equation given below

$$\text{Clay}\,(\%) = \left[\frac{\text{W1}-\text{W2}}{20\times\text{m}}\right]\times 100\times 1000$$

Where, W1is the weight of the beaker after drying with clay,

W2 is weight of the empty beaker

m is the mass of the soil taken

20 represent 20ml

1000 represents the total volume of solution i.e., L

Sample processing and activity determination

The ^{210}Pb activity was determined by using chemical deposition method.[10,11] A known weight of sample was taken in a beaker 4M HNO_3. The organic matter present in the sample was removed by adding 3:1 HNO_3 and HClO4 mixture in small increments until a white residue appears. The samples were then converted into 1M HCl medium and ^{210}Po in the solution was deposited onto the brightly polished back ground counted (both sides) silver disk using magnetic stirrer at 97 ºC for 6h 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 0.005cps background and 30% efficiency. The activity of ^{210}Pb was estimated through ^{210}Po by allowing the ^{210}Po plated solution for a period of 12 months to build-up ^{210}Po from ^{210}Pb.[11,12] 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.[5]

$$A = \left(S \pm SD\right)\times\frac{100}{E}\times\frac{100}{E_P}\times\frac{1000}{W}\ \ Bqkg^{-1}$$

Where,

S is the net counts per second

SD is the standard deviation

E is the efficiency (%) of alpha counter, determined as described in Section2.3

Ep is the plating efficiency (%), determined using ^{210}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}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 10.411.01Bqkg^{-1} in monsoon and pre-monsoon, respectively. But lowest activity was found 7.510.8 Bq kg^{-1} and 2.770.52Bqkg^{-1} in monsoon and pre-monsoon respectively. The highest activity in sediment was found to be 22.551.4Bqkg^{-1} and14.881.21Bq kg^{-1} in monsoon and pre-monsoon respectively. But lowest activity was found 6.010.7Bqkg^{-1} and 2.570.50Bqkg^{-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}Pb at an individual location depends on the efficiency of removal by rain and ^{222}Rn concentration in air. Because of grandparent radioactive inert gas ^{222}Rn, it has been enter to the atmosphere from geological sources, ^{210}Pb is attached with submicron-size aerosols which are removed by precipitation and deposited on the earth's surface.[13] In sediment the activity concentration of ^{210}Pb depends on the geology of the location, weathering concentration and drainage pattern of the river,[14] while the geochemistry of the parent radionuclide and its speciation also play a significant role.[15] Kaliprasad & Narayana[3] 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 8.21and 5.27 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 1.43 and 21.16, but in monsoon it 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}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}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}Pb show correlation with correlation coefficient 0.613. ^{210}Pb activity also has shown good correlation with moisture (%). The statistics of the value corresponding to the ^{210}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 ^{210}Pb activity as compared with other region of the world is shown in Table 4. The present ^{210}Pb 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 ^{210}Pb activity in soil and sediments of Hemavathi River

Sampling Location	^{210}Pb activity (Bqkg^{-1})			
	Monsoon		Pre-monsoon	
	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
H6	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	8.08 ± 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 bold values in the table represent the better positive correlation between the variables

Pre monsoon	**Soil**	**Moisture (%)**	**Organic matter**	**PH**	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Pb**
	Moisture (%)	1						
	Organic matter	0.653	1					
	PH	0.023	-0.4	1				
	Silt (%)	0.197	0.553	-0.315	1			
	Clay (%	**0.572**	0.68	-0.225	0.143	1		
	Sand (%)	-0.556	-0.819	0.336	-0.608	-0.873	1	
	Pb	**0.855**	**0.604**	-0.153	0.153	**0.613**	-0.567	1
	sediment	Moisture (%)	Organic matter	PH	silt(%)	Clay(%)	sand(%)	Pb
	Moisture (%)	1						
	Organic matter	0.603	1					
	PH	-0.766	-0.514	1				
	Silt (%)	0.642	0.579	-0.405	1			
	Clay (%)	0.179	-0.312	-0.355	-0.185	1		
	Sand (%)	-0.669	-0.262	0.597	-0.707	-0.564	1	
	Pb	0.126	**0.544**	-0.133	0.53	-0.335	-0.205	1
Monsoon	**Soil**	**Moisture (%)**	**Organic matter**	**PH**	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Pb**
	Moisture (%)	1						
	Organic matter	0.678	1					
	PH	-0.49	-0.465	1				
	Silt (%)	0.634	0.839	-0.431	1			
	Clay (%)	0.062	0.443	0.164	0.498	1		
	Sand (%)	-0.321	-0.681	0.073	-0.79	-0.925	1	
	Pb	0.393	**0.676**	-0.292	0.341	0.065	-0.195	1
	Sediment	**Moisture (%)**	**Organic matter**	**PH**	**Silt (%)**	**Clay (%)**	**Sand (%)**	**Pb**
	Moisture (%)	1						
	Organic matter	0.3	1					
	PH	-0.278	-0.509	1				
	Silt (%)	0.345	0.169	-0.514	1			
	Clay (%)	0.314	0.259	-0.125	0.224	1		
	Sand (%)	-0.397	-0.283	0.304	-0.575	-0.926	1	
	Pb	0.187	**0.733**	-0.373	-0.137	-0.008	0.059	1

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

	^{210}Pb (Bqkg^{-1})				^{210}Pb(Bqkg^{-1})		
	Premonsoon		Monsoon		River		Reference
	Soil	Sediment	Soil	Sediment			
Mean	5.41	6.18	12.19	12.88	23-108	Padubidri	Prakash[16]
Median	4.56	4.91	11.65	11.65	8.1-71.1	Kali river	Rajashekara[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	Rajashekara KM et al.[17]
St. DEV	2.48	3.46	5.47	4.54	2.9-62.7	Netrvathi	Rajashekara KM etal.[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	22.2-122.1	Black forest	Schuettelkopf & kiefer[20]
Frequency	peaked	normal	normal	normal	3.6-45.2	Mangalore, India	Radhakrishna et al.[21]

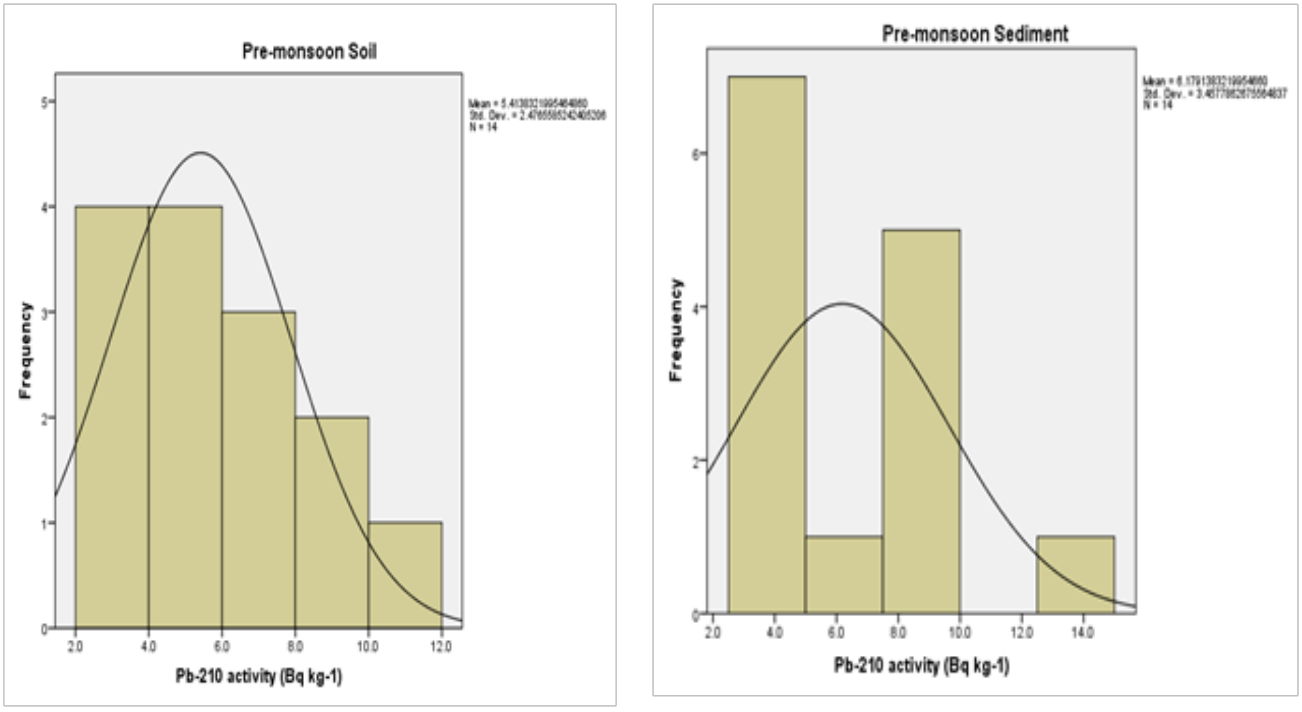

Figure 2 The frequency distribution of 210Pb activity in pre-monsoon soil and sediment.

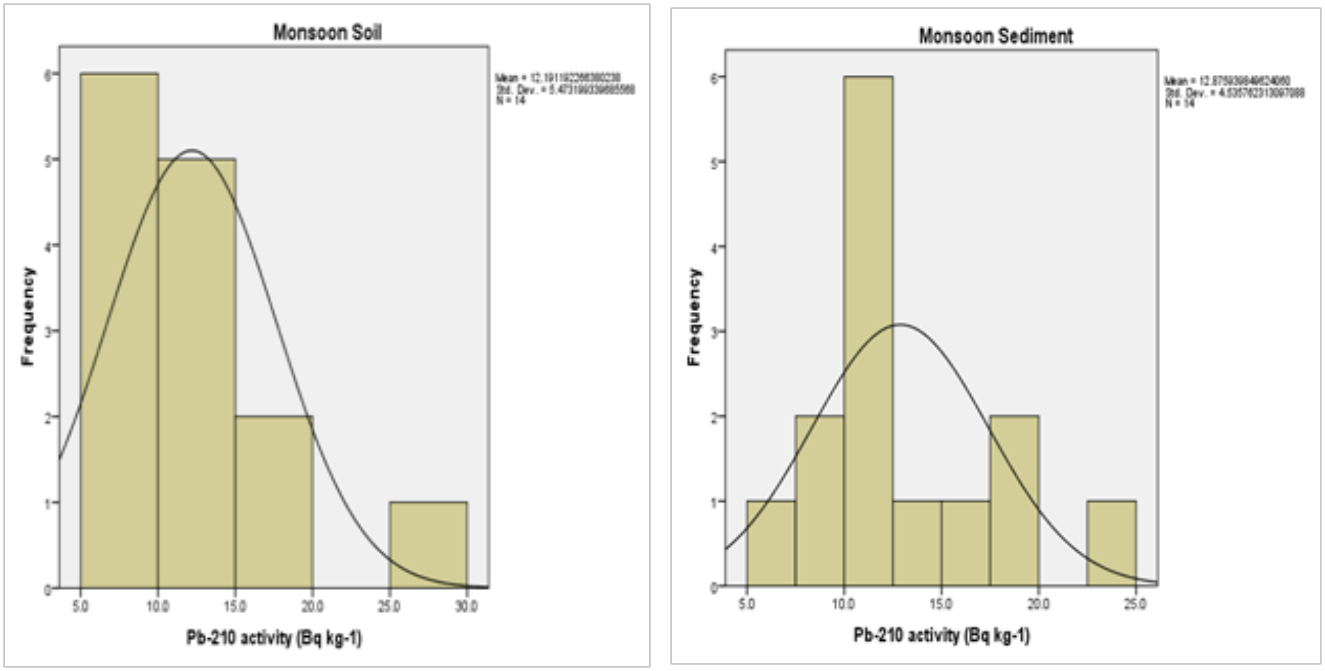

Figure 3 The frequency distribution of ^{210}Pb activity in monsoon soil and sediment.

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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