Transport of ^{210}Po and ^{210}Pb in the Kali, Sharavathi and Netravathi river ecosystems of coastal Karnataka

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The concentration of ^{210}Po and ^{210}Pb has been measured by the chemical deposition method in surface water samples from the major rivers of coastal Karnataka: Kali, Sharavathi and Netravathi. Measurements of ^{210}Po and ^{210}Pb in surface water from these rivers are important because river water is the main source of potable water in this region due to inadequate supply of treated water. The mean activity of ^{210}Po and ^{210}Pb in the surface water of Kali is respectively 1.28 ± 0.2 and 1.37 ± 0.2 Bq l^{-1}, that for Sharavathi is 1.30 ± 0.2 and 1.44 ± 0.2 Bq l^{-1} and for the Netravathi it is 1.00 ± 0.2 and 1.22 ± 0.2 Bq l^{-1}. From the measured concentration of ^{210}Po and ^{210}Pb, the internal committed effective dose (CED) to the population of the study region was calculated. The activity ratio of ^{210}Po and ^{210}Pb and correlation between the activities of these radionuclides were studied and the internal CED to the population of the study region is also discussed in this communication.

Keywords: Transportation, ^{210}Po and ^{210}Pb, surface water, riverine environment, coastal Karnataka.

SURFACE water is the immediate recipient of land run-off, industrial and municipal effluents, fertilizers and pesticides. River water can be contaminated by surface run-off of rain water that transports leached radionuclides from cities, mine waste, soil weathering, agricultural areas and so on[1,2]. The radionuclides, if present in significant levels in water, may pose a health hazard to the public due to direct ingestion through drinking water or through diet. In sense of life, health and environmental pollution, determination of the radioactivity concentration in surface water is useful because the same water is used for drinking and agricultural irrigation. The radionuclides, ^{210}Pb and ^{210}Po occur widely in the environment and constitute an important component of the natural background radiation. ^{210}Po is an alpha emitter in the naturally occurring uranium series and it is produced by decay of ^{210}Pb. These radionuclides dissolve in water and enter the human body easily through food or water. The naturally occurring radionuclides ^{210}Po and ^{210}Pb are important because of their contributions to the internal dose to man[3]. Therefore, an attempt has been made to study the transport and enrichment of these radionuclides, and the ingestion doses due to ^{210}Po and ^{210}Pb through drinking water were calculated in the Kali, Sharavathi and Netravathi rivers of coastal Karnataka, the results are presented and discussed here.

The surface water samples were collected during monsoon season in 2006 from the selected stations from the Kali, Sharavathi and Netravathi rivers (Figure 1). The rivers in the Western Ghats region generally originate at an elevation ranging from 400 to 1600 m above the mean sea level, close to the Western Ghats ridge. The rivers are very steep in the upper reaches and fairly steep in the middle reaches. It is only near the sea that the rivers have relatively flat gradients and form some sort of a flood plain. The Kali originates in the Western Ghats, flows westward for 184 km and discharges into the Arabian Sea along coastal Karnataka. The Sharavathi originates in Western Ghats, flows due east or northeast initially, then takes a sudden turn to the west, flows down the steep western slopes of the ghats and after meandering through the short plateaus joins the sea, passing through the coastal plain. The length of the Sharavathi is 128 km. The Netravathi originates in Charmadi Ghats, that is part of the Western Ghats flowing westward for 94 km and discharges into the Arabian Sea along coastal Karnataka. The lithology of the study area consists largely of greywackes in the upstream catchment area, whereas tonalitic gneisses occur in the downstream segment. The principal

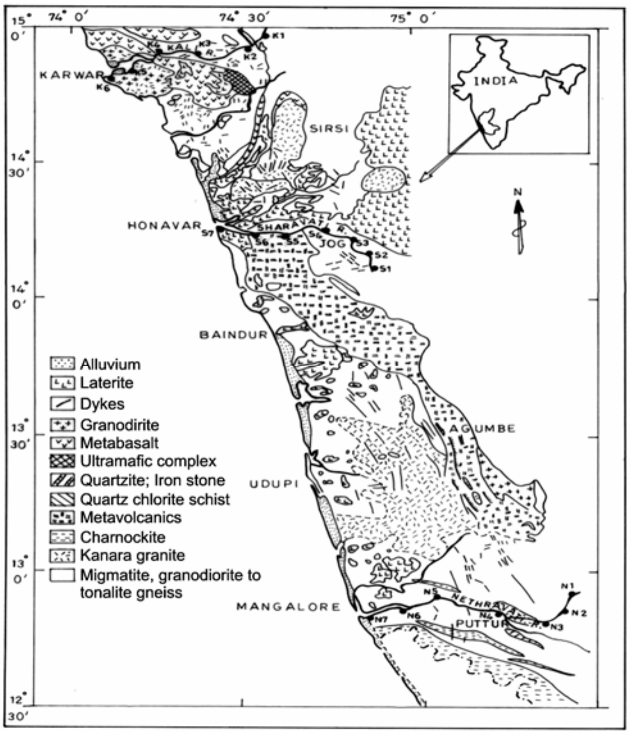

Figure 1. Map of the rivers and sampling stations.

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rock types found in these river basins are Precambrian gneisses, granites, granite gneisses, schists, charnockites, laterites, quartzite, metavolcanics, metasediments and felsic and mafic dykes[4]. Some of these rocks are rich in minerals such as kaolinite and muscovite, due to which the soils weathered from these rocks contain more potassium. The Precambrian gneisses, granites, granodirites, greywackes, laterites and shales contain accessory minerals of monazite and zircon and hence record relatively high radioactivity.

Chemical deposition method was employed for the determination of ^{210}Po activity[5]. For the analysis of water samples, about 40 l of water was collected from each selected sampling station and made acidic (pH ~ 2) by adding HCl. About 5 ml of iron carrier was added to about 40 l sample and stirred for about 30 min. Ammonia solution was added till the solution became basic (pH ~ 9). A thick ferric hydroxide precipitate was formed. The precipitate was dissolved in 1 N HCl and the solution was ready for plating. The concentration of ^{210}Po in the solution was deposited on to a silver disc being stirred at 97°C for 6 h. The silver disc was then counted on both the sides for the α-activity, using ZnS (Ag) detector of 30% counting efficiency. The activity of ^{210}Pb was estimated through ^{210}Po, by allowing the ^{210}Po-plated solution for a period of 12 months for build-up of ^{210}Po from ^{210}Pb (ref. 6).

The variations of ^{210}Po- and ^{210}Pb-activity in surface water of the Kali, Sharavathi and Netravathi from origin to estuary are shown in Figures 2. The activity of ^{210}Po and ^{210}Pb in the surface water of the Kali varies respectively from 0.42 ± 0.1 to 1.67 ± 0.3 Bq l^{-1} with mean value of 1.28 ± 0.2 Bq l^{-1} and 0.46 ± 0.1 to 1.76 ± 0.3 Bq l^{-1} with mean value of 1.37 ± 0.2 Bq l^{-1}. The activity of ^{210}Po and ^{210}Pb in the Sharavathi surface water respectively varies from 0.88 ± 0.2 to 1.62 ± 0.3 Bq l^{-1} with mean value of 1.30 ± 0.2 Bq l^{-1} and 1.16 ± 0.2 to 1.71 ± 0.3 Bq l^{-1} with mean value of 1.44 ± 0.2 Bq l^{-1}. In Netravathi, the activity of ^{210}Po and ^{210}Pb respectively varies from 0.35 ± 0.1 to 1.67 ± 0.3 Bq l^{-1} with mean value of 1.00 ± 0.2 Bq l^{-1} and 0.79 ± 0.2 to 1.71 ± 0.3 Bq l^{-1} with mean value of 1.22 ± 0.2 Bq l^{-1}. Higher values of ^{210}Po and ^{210}Pb were observed in the Sharavathi compared to that of the Kali and Netravathi. In Sharavathi, the activity of ^{210}Pb and ^{210}Po is not in good order due to differential erosion, highly dissected landscape, river capture and existence of waterfalls of great magnitude. The activity of ^{210}Pb is high compared to the activity of ^{210}Po in most of the samples. Earlier studies revealed the higher concentration of ^{210}Pb compared to ^{210}Po in soils of the catchments areas and sediment samples of these rivers[6]. This could be the reason for the higher concentrations of ^{210}Pb in river water. Sediments have been widely used as environmental indicators and they play an important role in the assessment of radioactivity contamination in natural waters.

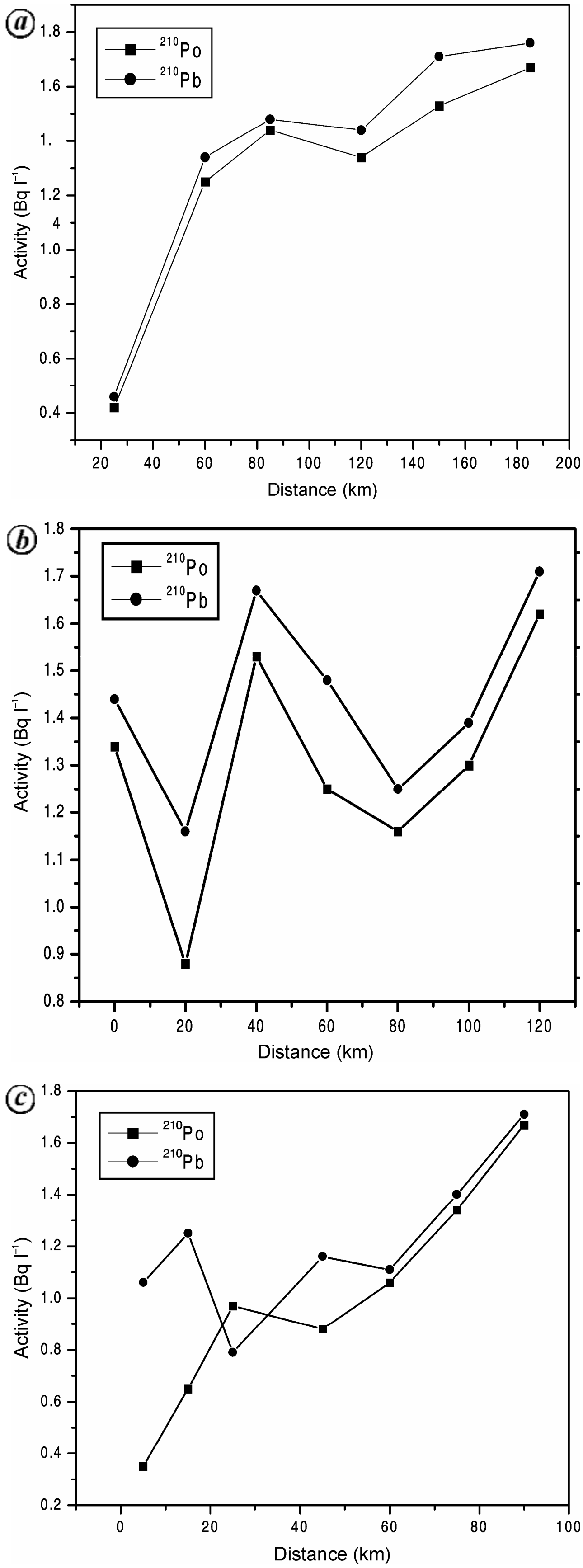

Figure 2. Variation of ^{210}Po and ^{210}Pb activity in surface water of the Kali (***a***), Sharavathi (***b***) and Netravathi (***c***) rivers from origin to estuary.

Table 1. Activity ratios of ^{210}Po and ^{210}Pb in surface water of the Kali, Sharavathi and Netravathi rivers

Sampling stations (see Figure 1 for locations)	Kali $^{210}Po/^{210}Pb$	Sharavathi $^{210}Po/^{210}Pb$	Netravathi $^{210}Po/^{210}Pb$
1	0.91	0.93	0.92
2	0.93	0.76	0.13
3	0.97	0.92	1.23
4	0.93	0.84	0.76
5	0.89	0.93	0.95
6	0.95	0.94	0.96
7	–	0.95	0.98
Range	0.89–0.97	0.76–0.95	0.13–1.23
Mean	0.93	0.89	0.85
Median	0.93	0.93	0.95

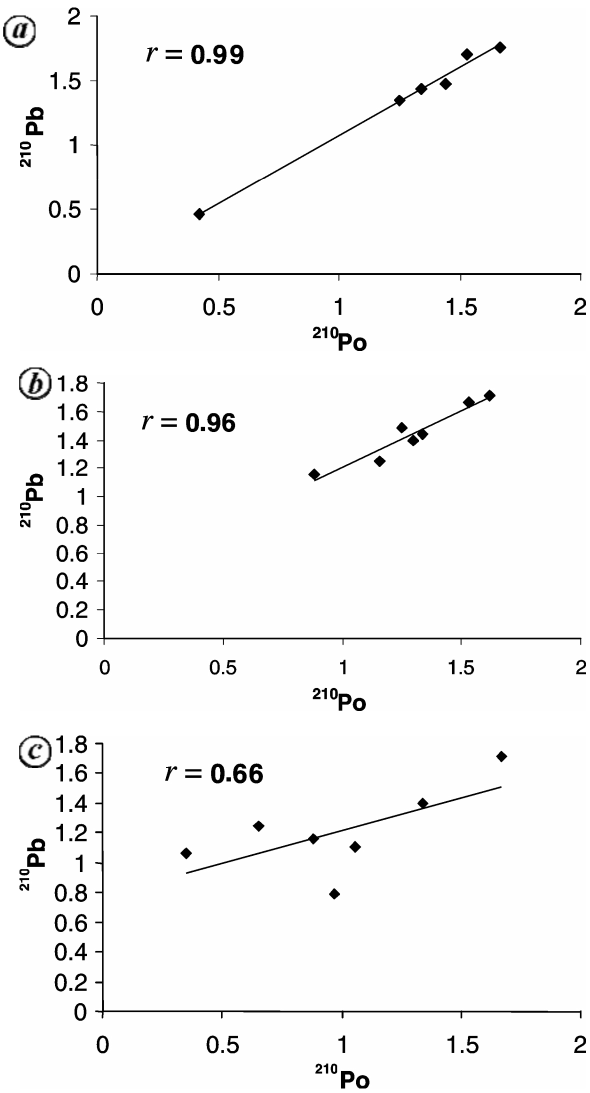

Figure 3. Correlation between ^{210}Po and ^{210}Pb activity in surface water samples of the Kali (***a***), Sharavathi (***b***) and Netravathi (***c***) rivers.

The ^{210}Po and ^{210}Pb contents in the water samples of near estuarine environments are found to be higher, when compared to the activity in the upper reaches of the riverine environment. The increase of ^{210}Po and ^{210}Pb in estuaries could suggest the presence of the marine organisms that have a preference for accumulating ^{210}Po, allowing this radionuclide to remain longer in the water column, whereas ^{210}Pb associates with sinking particles[7]. The presence of ^{210}Pb and ^{210}Po in surface water is due to the deposition from atmosphere and leaching from sediment, soil and rock. However, the main sources of ^{210}Po and ^{210}Pb are soil, dust and aerosols present in the atmosphere. The ^{210}Pb and ^{210}Po present in atmosphere will come back to the aquatic and terrestrial environments through wet and dry precipitation[8].

Table 1 presents $^{210}Po/^{210}Pb$ activity ratios, calculated from the measured concentration of these radionuclides. It can be seen from the table that the mean values of activity ratio are 0.93, 0.89 and 0.85 for the Kali, Sharavathi and Netravathi rivers respectively. This indicates the higher concentration of ^{210}Pb over ^{210}Po in river water. The reported activity ratios of the ^{210}Po and ^{210}Pb in fresh water and marine reservoirs are respectively 0.4–0.5 (ref. 8).

The correlation between the activity concentration of the two radionuclides, ^{210}Pb and ^{210}Po shows a good correlation with a correlation coefficient, $r = 0.99$ (Figure 3 *a*) for the Kali and $r = 0.96$ (Figure 3 *b*) for Sharavathi, with an appreciable correlation coefficient of $r = 0.66$ (Figure 3 *c*) for the Netravathi. The pH values were correlated with ^{210}Po and ^{210}Pb activities in water samples. A correlation coefficient of $r = –0.79$ was observed between pH and ^{210}Po activity and $r = –0.81$ between pH and ^{210}Pb activity in case of the Kali (Figure 4 *a*). The correlation between ^{210}Po and ^{210}Pb activity with pH shows an appreciable correlation with the correlation coefficient of $r = –0.57$ and $r = –0.48$ in case of the Sharavathi (Figure 4 *b*). No significant correlation has been found between pH and ^{210}Po ($r = –0.20$), pH and ^{210}Pb ($r = 0.47$) activity in case of the Netravathi (Figure 4 *c*).

The internal Committed Effective Dose (CED) to the population of the region due to ingestion of potable water is calculated from the measured activities of ^{210}Po and ^{210}Pb. The dose contribution was calculated using the

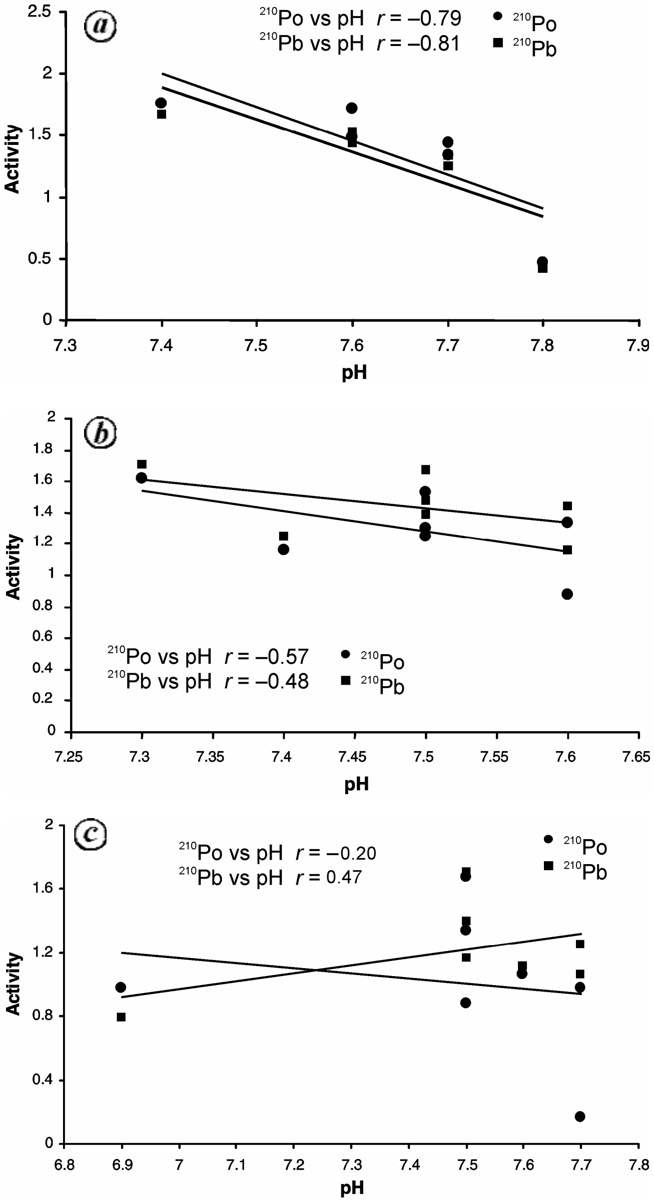

Figure 4. Correlation between ^{210}Po and ^{210}Pb activity and pH in surface water samples of the Kali (***a***), Sharavathi (***b***) and Netravathi (***c***) rivers.

concentration of radionuclides and the dose conversion factors from the International Commission on Radiological Protection[9] (ICRP) and International Atomic Energy Agency (IAEA)[10] for 1 l d^{-1} water consumption. The mean value of dose rate due to ingestion of ^{210}Po in river water was found to be 0.5, 0.6 and 0.4 mSv y^{-1} in the Kali, Sharavathi and Netravathi respectively. The mean value of dose rate due to ingestion of ^{210}Pb in river water was found to be 0.3, 0.4 and 0.3 mSv y^{-1} in Kali, Sharavathi and Netravathi respectively. A dose between 0.2 and 0.8 mSv y^{-1} is the typical worldwide range of ingestion radiation dose resulting from water as well as food (http://www.dwaf.gov.za/iwqs).

The activity of ^{210}Pb is high compared to that of ^{210}Po in most of the samples of the Kali, Sharavathi and Netravathi. Higher values of ^{210}Po and ^{210}Pb were observed in the Sharavathi, compared to the Kali and Netravathi. The ^{210}Po and ^{210}Pb contents in the water samples of near estuarine environments are higher than that in the upper reaches of these riverine environments. The biogeochemical processes and characteristics of particles in surface waters may play a significant role in the distribution of ^{210}Pb and ^{210}Po. The presence of ^{210}Pb and ^{210}Po in surface water is due to the deposition from atmosphere and leaching from sediment, soil and rock. The effective dose due to consumption of river water exceeds the limit recommended by the ICRP and IAEA (0.1 mSv y^{-1}).

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