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Spatial and Temporal Variations in Geochemistry of Cauvery River Sediments (Tamilnadu, India): Indicators of Provenance and Weathering

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Abstract

South-West, North-East and Post-monsoon Cauvery River sediment geochemistry characterizes the intensity of chemical weathering ascribing to the relative mobility of elements during weathering. The negative correlation between Al_2O_3% and SiO_2% signifies that the sediments are enriched with quartz. The Al_2O_3% vs. TiO_2% relationship deduces the granite and granodiorite as the major source rocks of Cauvery River sediments. The weathering trend of sediments is accounted by the incidence of illite clay minerals. The weathering intensity of SW monsoon sediments (57.73%), NE monsoon sediments (64.17%) and post-monsoon sediments (64.79%) specifies the weak to intermediate intensity of weathering, which is controlled by precipitation. The higher concentration of Ba (459.45-856.95ppm) reflects presence of K-feldspar in the source rocks.

Keywords: Geochemistry, Cauvery River, Weathering, South India.

Introduction

Studies on weathering of rocks deduce the continental erosion and consumption of CO_2. The processes of weathering of rocks modify the earth surface and factors in the geochemical cycle. The bedrock is transformed into sediments and to the soil by the combined effects of physical, chemical, and biological weathering. Hence the unique signature of the source rock remains in the sediments (Singh, 2010). The study attributes of the chemical composition of clastic sediments which is controlled by the composition of source rocks, atmospheric chemistry, temperature, precipitation and topography, duration weathering, transportation mechanism, depositional environment and post-depositional processes (Hayashi et al., 1997). The trace elements; Sc, Th, Zr, Cr, Ni, Co and REEs in the sediments are immobile during the weathering processes and are indicators of source rock composition and environment. This paper appraises the spatio-temporal variations of geochemical elements of Cauvery River sediments in middle and lower regions (Tamilnadu region) and their provenance, paleo-weathering, intensity of weathering and maturity.

Geological Setting

The Cauvery River is an easterly flowing river of the Peninsular India which flows across three states of southern India. The river originates at Tala Kaveri, Western Ghats, and traverses through the Mysore plateau, forming a delta on the eastern coastline of southern India, before it debouches into the Bay of Bengal (Fig.1). The upper part of the river basin comprises of granitoid-gneisses, granulite, charnockites, meta-igneous, meta-sedimentary and carbonates rocks (Ramakrishna and Swaminath, 1981; Narasimha et al., 2009; Radhakrishna, 1992; Mahabaleswar et al., 1995; Valdiya, 1998). The middle part of the river basin comprises of granulites, migmatite gneissic, granite, small patches of carbonate rocks (John et al., 2005), calcareous sandstone, limestone, marl, fossiliferous limestone, and shale. The river flows through the alluvium sediments in its lower region. The tributaries of the Cauvery River are Bhavani and Amaravathy which receive water during the NE monsoon and join the river in the middle region (Fig. 1).

Materials and Methods

The middle and lower regions of the Cauvery River flows 400km in Tamilnadu. The sediment sampled at 25km interval from the middle region (Pannavadi (L-1) to Mutharasanur (L-9)) to lower region (Appakudathaan kovil (L-10) to Pommbugar (L-15)) of the river basin. The conning and quarter method was followed for surface sediment sampling during South-West (SW), North-East (NE) and Post monsoon. The powdered samples were treated for removal of moisture, organic matter and $CaCO_3$. The dried (50°C) sediment powdered in agate mortar and sieved to 230 ASTM mesh. The powder samples dried at 110°C for removing the moisture content. After LOI pressed pellets were prepared using aluminium cups (Govil, 1985) which are filled with boric acid as binder. 1gm of the fine powdered sample placed on the top of the boric acid and pressed with a hydraulic press at 20 tons pressure to obtain a 40mm diameter pellet. Bruker model S4 Pioneer sequential wavelength dispersive X-ray spectrometer equipped with a goniometer with 4kW Rh X-ray tube with 60 samples loading system was used at NCESS, Thiruvananthapuram. Calibrated the major and trace elements were completed by taking care of dead time correction, background, line overlap correction and matrix effects. The results are in weight % and in ppm.

Results and Discussion

Major oxides and trace element concentration of SW monsoon sediments

The distribution of major and trace elements of the sediments reflects the composition of the source rocks and sorting of sediments (He et al., 2015). The concentration of SiO_2 in analysed sediments ranges from 65.51% to 85.1% (avg. of 75.81%), whereas the TiO_2 ranges from 0.21% to 3.08% with an average of 0.90% (Table. 1). The Al_2O_3 varies from 6.71% to 15.14% with an average of 10.2% and the MnO varies from 0.03%-0.17% (avg. of 0.07%). Besides, Fe_2O_3 concentration varies from 1.62% to 8.49%. These variations of major oxides indicate the presence of garnet, ilmenite, and rutile heavy minerals in the Cauvery River sediments. Similarly, the CaO content is ranging from 1.52% to 4.72% with an average of 2.89%, MgO varies from 0.54%–2.66% with an average of 1.33%. The Ca and Mg characterizes for the higher mobility of the geochemical elements during the chemical weathering of rocks. Successively, the concentration of Na_2O concentration of 1.6 to 3.43%, and K_2O from 1.43 to 3.63% (Fig. 2) and P_2O_5 of 0.06% to 0.26% (avg. of 1.33%; Table. 2). These variations in major oxides in the downstream of the river appraise the nature of sorting processes (He et al., 2015). The increasing trend of major oxides is SiO_2>Al_2O_3>Fe_2O_3>CaO> Na_2O>MgO >K_2O>TiO_2> P_2O_5 (Fig.2) in the studied samples of middle and lower regions of the river basin. The chemical alteration index (CIA) of SW monsoon sediments varies from 55.59% to 61.61% with an average of 57.73% reflecting weak to moderate rate of weathering. The plagioclase index alteration varies from 57.42% to 64.8% indicating weak to moderate maturity of sediments. The concentration of Ba ranges from 236.84ppm to 1269.74ppm with an average of 630.09ppm. This comparatively higher concentration of Ba in the sediments represents the presence of K-feldspar (Nemee, 1975). The Cr and Ni are enriched in sediments due to the adsorption of clay minerals (Table.3) (Young et al., 2013). The concentration of Cu (56 ppm to 96ppm) and Sr (190.01 ppm to 603.16ppm) indicates that the source of these elements is weathering of plagioclase feldspar in the Cauvery River sediments (Rahman & Suzuki, 2007). The concentration of Zn (90.30ppm to 162.72ppm) is relatively higher in the sample no.15 (162.72ppm) (Table.3) which is attributed to the influence of seawater with river water and local fishing harbour interface (Shilpa et al., 2015).

Table. 1 Sediment sample locations

L.No	Sample locations	Stage wise	Latitude	Longitude	Elevation. (m)
1	Pannavadi	Middle regions of the river	11°54’28.7” N	77°46’19.2” E	236.2
2	Kudakal		11°40’14.1” N	77°46’08.7” E	190.5
3	Konavaikal		11°25’22.0” N	77°40’48.1” E	159.1
4	Sitharkovil		11°18’44.7” N	77°46’34.9” E	155.1
5	Karuvelampalayam		11°09’10.1” N	77°53’07.3” E	135.3
6	Killakkuthavitupalayam		11°03’48.0” N	78°07’28.2” E	123.7
7	Sriramasamuthiram		10°57’46.1” N	78°12’41.8” E	110.6
8	Kulithalai		10°56’21.0” N	78°25’51.7” E	88.4
9	Mutharasanur		10°51’59.1” N	78°39’05.6” E	72.8
10	Appakudathaan kovil	Lower regions of the river	10°50’07.5” N	78°51’45.0” E	56.9
11	Kandiur bridge		10°51’54.2” N	79°05’22.7” E	44.2
12	Thiruvalanchuli		10°56’56.1” N	79°19’38.8” E	33.2
13	Suriyanarkovil		11°01’34.9” N	79°28’59.2” E	21.64
14	Paniur		11°08’12.9” N	79°35’29.4” E	13.4
15	Poombughar		11°08’12.2” N	79°51’24.1” E	2

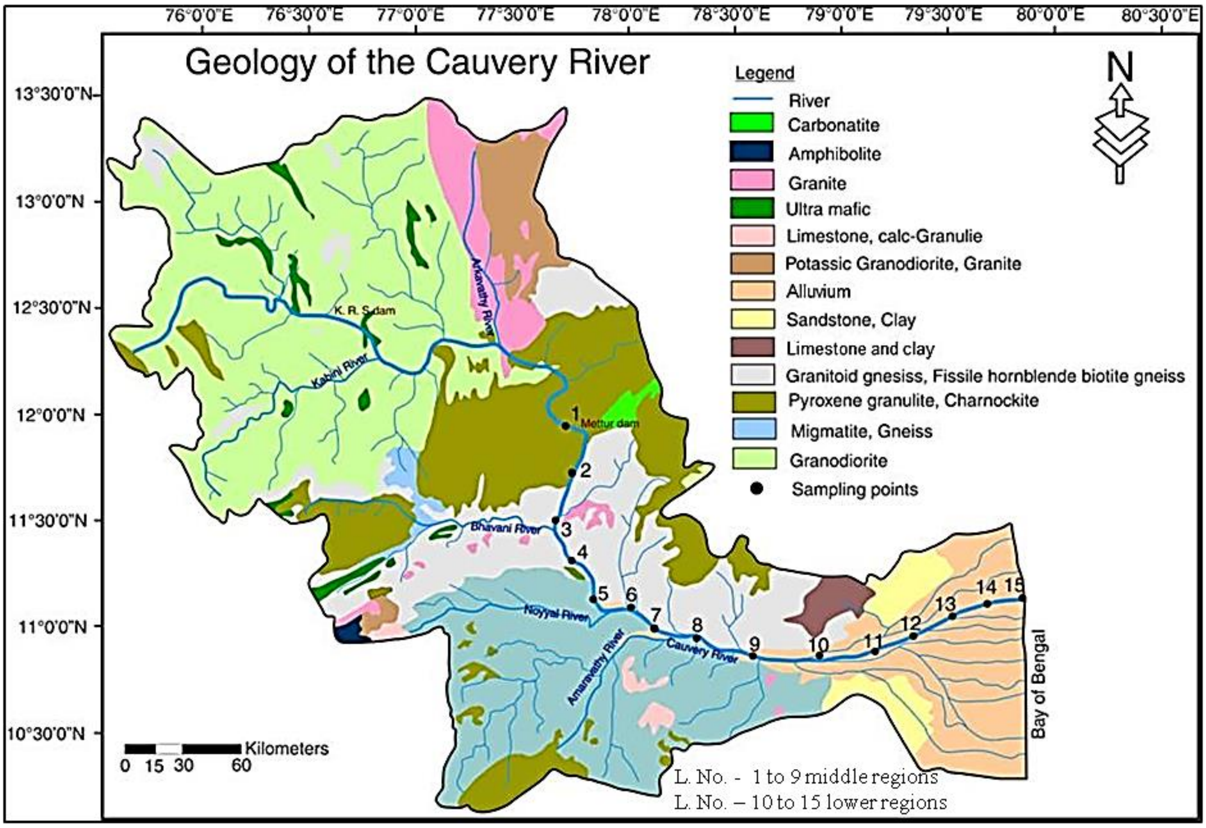

Fig. 1 Cauvery River Basin with sediment sample locations (1-15)

Table. 2 Distribution of major oxides in the sediments of SW monsoon

Loc. Nos.		SiO_2	TiO_2	Al_2O_3	MnO	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	CIA	PIA
		Concentration (%)											
1	Middle regions	67.68	1.04	15.14	0.08	4.52	3.75	1.43	3.6	2.2	0.16	61.32	63.78
2		65.51	0.94	14.43	0.08	4.39	4.72	2.13	3.18	3.63	0.23	55.59	57.75
3		67.93	1.48	12.61	0.09	6.41	4.14	2.14	3.01	1.43	0.21	59.51	60.99
4		66.32	0.79	14.64	0.07	4.8	4.67	2.31	3.43	2.15	0.26	58.82	60.66
5		83.35	0.28	7.33	0.03	2.22	1.96	0.87	2.04	1.56	0.07	56.87	59.06
6		84.47	0.22	7.04	0.04	1.9	1.82	0.7	1.98	1.57	0.07	56.73	59.01
7		76.47	0.56	10.2	0.06	3.31	2.81	1.45	2.77	1.92	0.11	57.63	59.74
8		81.49	0.41	8.27	0.04	2.28	2.11	0.89	2.23	1.88	0.12	57.07	59.55
9		81.58	0.21	8.75	0.04	1.71	2.04	0.7	2.44	2.2	0.07	56.71	59.38
10	Lower regions	77.24	1.47	8.38	0.07	4.7	2.34	1.09	2.31	1.86	0.1	56.28	58.37
11		85.1	0.22	6.88	0.03	1.62	1.52	0.54	1.89	1.89	0.06	56.49	59.4
12		78.84	0.39	9.87	0.05	2.53	2.44	0.94	2.5	2.18	0.08	58.09	60.89
13		75.31	0.67	11.97	0.05	3.08	2.76	1.06	2.59	2.11	0.14	61.61	64.83
14		65.57	3.08	10.78	0.17	8.49	4.43	2.66	2.46	1.49	0.23	56.26	57.42
15		80.37	1.69	6.71	0.09	4.82	1.84	0.97	1.6	1.63	0.08	56.96	59.62

Major and trace element concentration of NE monsoon sediments

The concentration of major and trace elements in the NE monsoon sediments is presented in Tables 4 & 5. The SiO_2 concentration varies from 60.87% to 84.65% in the studied sediments. The other dominant major oxides include Al_2O_3 (8.3% to 15.63%), Fe_2O_3 (1.78% to 7.69%) and CaO (1.27 to 6.42%) representing the variation in the degree of weathering of the source rocks. The MgO is relatively uniform (0.44% to 3.03%), the lesser concentration of Ca and Mg signify higher mobility of elements during chemical weathering. Similarly, the concentration of TiO_2 (0.25% to 2.38%), K_2O (0.3% to 2.18 %), and MnO (0.02% to 0.15%) content is relatively uniform. The CIA of NE monsoon sediments ranges from 54.71% to 72.59% (average of 64.17%) which indicates weak to intermediate weathering intensity, whereas the PIA varies from 54.69% to 73.5% with an average 66.94%. The relative abundance of major oxides is $SiO_2>Al_2O_3>Fe_2O_3>CaO>MgO>Na_2O>K_2O>TiO_2>MnO>P_2O_5$ (Fig. 3).

Table 3. Distribution of trace elements in the sediments of SW monsoon

Loc. No.		V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Zr	Nb	Cs	Ba
		Concentration (ppm)												
1	Middle	54.79	94.19	10.06	33.54	42.99	95.37	12.24	31.91	338.16	66.46	7.38	0.26	669.28
2		42.84	65.26	10.71	38.17	54.58	125.25	11.01	34.52	281.46	53.73	2.75	0.37	630.53
3		50.81	67.28	7.87	28.02	47.46	117.04	7.61	28.13	190.01	77.59	2.37	0.28	511.93
5		39.06	62.26	7.82	32.46	55.05	92.04	8.61	29.15	234.20	57.28	2.94	0.28	560.60
7		39.88	72.19	8.58	28.44	39.61	90.30	8.16	25.63	220.53	70.74	2.44	0.21	531.67
14	Lower	116.95	76.66	15.66	36.31	48.13	112.80	15.00	22.99	603.16	146.20	5.26	0.28	1269.74
15		471.20	258.28	27.49	51.54	46.80	162.72	17.02	5.09	238.32	87.35	12.23	0.17	236.84

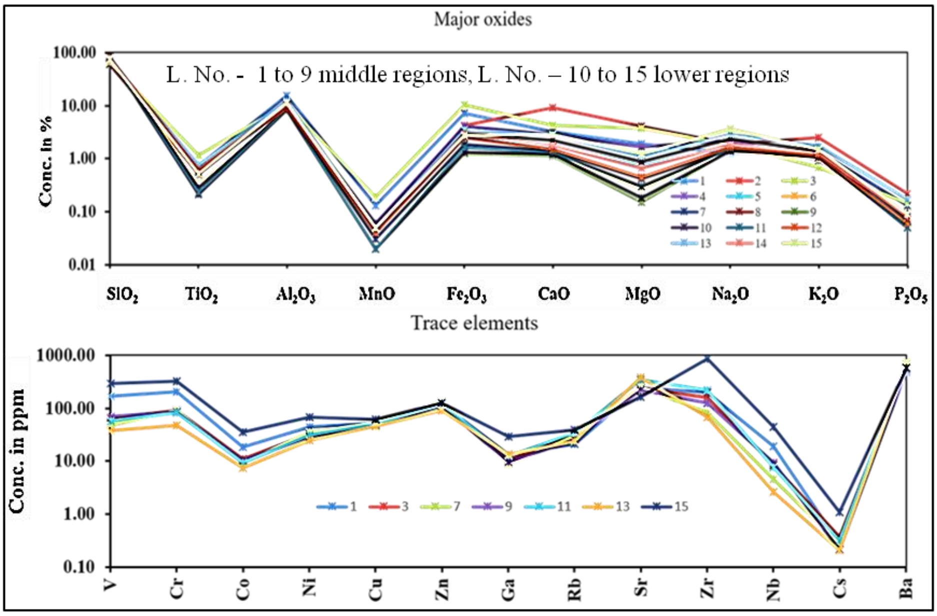

Fig. 2 Distribution of major oxides and trace elements in sediments of SW monsoon

The Ba is the principal element in the Cauvery River sediments whose concentration varies from 459.45 ppm to 856.95ppm. This variation is influenced by the K-feldspar (Nemee, 1975). The other trace elements are Zn (74.81ppm-155.58ppm), V(25.25ppm-121.61ppm),Cr (33.72ppm-153.36ppm), Co (5.71ppm-16.06ppm), Ni (26.01ppm-38.18ppm), Cu (41.88 ppm-55.12ppm), Ga (6.78 ppm-14.22ppm), Rb (24.08 ppm-31.67ppm), Sr (197.51 ppm-376.13ppm), Zr (36.80 ppm-194.03ppm), Nb (1.74 ppm-11.98ppm) and Cs (0.18 ppm-0.32ppm) (Fig.3). The variation of Zn concentration 155.58ppm in the sediments at Poombughar (L-15) is attributed for the river water, and sea water and local fishing harbor interface.

The distribution of major oxides in the post-monsoon sediments is presented in Tables 6 & 7. The SiO_2 (58.09% to 85.35%) concentration is higher as compared to the other oxides. The Al_2O_3 (8.28% to 15.63%), Fe_2O_3 (1.22% to 10.32%), and CaO (1.22% to 9.02%) are relatively uniform. The K_2O (0.68%-2.52 wt. %), MgO (0.26%- 4.04 wt. %), Na_2O (1.4-3.57 wt. %), TiO_2 (0.21-1.16 wt. %), P_2O_5 (0.05-0.22 wt. %) and MnO (0.02-0.19 wt. %) are of low concentration in these sediments. The relative abundance of major oxides is in the order of $SiO_2>Al_2O_3>Fe_2O_3>CaO>Na_2O>K_2O>MgO>TiO_2>P_2O_5>MnO$ (Fig. 4). The concentration of trace elements in the post-monsoon sediments reflects the directive pathway to understand the provenance and its environments (Table. 7). The trace elements Co, Sc, and Cr having low concentrations specify the felsic source (Bhuiyan et al., 2011). The trace element concentrations tend to decrease towards the downstream due to the variation of sorting of sediments.

Table 4 Distribution of major oxides in the NE monsoon sediments

Loc. Nos.		SiO_2	TiO_2	Al_2O_3	MnO	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	CIA	PIA
		Concentration in %											
1	Middle regions	75.13	0.89	11.2	0.08	6.08	2.48	1.4	1.45	0.3	0.07	72.59	73.5
2		62.44	0.81	13.13	0.07	4.36	5.99	2.79	2.7	2.18	0.27	54.71	55.75
3		60.87	1.08	11.86	0.13	7.41	6.42	3.03	2.32	1.31	0.19	54.13	54.69
4		74.32	0.5	10.65	0.07	4.45	3.15	1.76	2.4	1.13	0.11	61.45	63.17
5		82.29	0.42	8.72	0.04	2.77	1.56	0.68	1.6	1.15	0.06	66.92	70.55
6		83.7	0.23	8.54	0.02	1.92	1.39	0.56	1.57	1.15	0.06	67.51	71.4
7		82.65	0.25	9.02	0.03	2.18	1.62	0.69	1.79	1.21	0.05	66.13	69.61
8		84.65	0.25	8.45	0.02	1.78	1.27	0.44	1.49	1.25	0.05	67.82	72.29
9		83.98	0.34	8.22	0.03	2.15	1.27	0.48	1.38	1.22	0.05	67.99	72.54
10	Lower regions	70.03	0.77	12.98	0.06	4.29	3.08	1.38	2.78	1.8	0.13	62.89	65.61
11		78.64	0.72	10.13	0.05	3.28	2.05	0.83	2.17	1.46	0.07	64.07	67.26
12		71.31	0.77	13.21	0.06	3.74	3.05	1.22	3.21	1.9	0.13	61.82	64.37
13		71.82	0.54	13	0.06	3.81	2.47	1.13	2.36	1.71	0.14	66.53	70.04
14		67.1	0.7	14.8	0.09	4.96	2.82	1.51	2.48	1.83	0.12	67.49	70.99
15		69.84	2.38	10.25	0.15	7.69	3.42	2.13	2.05	1.21	0.16	60.54	62.3

Table 5. Distribution of trace elements in NE monsoon sediments

Loc. Nos.		V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Zr	Nb	Cs	Ba
		Concentration in ppm												
1	Middle	71.56	113.29	11.30	36.50	55.12	81.41	13.00	30.54	344.05	136.18	11.00	0.28	662.34
3		82.39	105.09	11.78	32.36	43.00	79.25	12.74	31.67	283.26	194.03	11.98	0.32	636.52
5		42.04	71.92	7.71	26.89	42.28	74.81	9.31	30.12	259.91	64.00	3.83	0.24	606.21
7		25.25	33.72	5.86	26.01	45.60	87.33	6.78	28.80	197.51	45.12	1.74	0.20	459.45
9		121.61	153.36	16.06	38.18	42.47	114.01	14.22	37.13	310.84	127.76	11.88	0.30	611.64
11	Lower	70.89	96.33	10.78	30.96	41.88	82.59	9.93	24.08	264.63	93.95	6.84	0.19	573.36
15		26.86	36.68	5.71	23.30	45.14	155.58	11.80	29.06	376.13	36.80	2.21	0.18	856.95

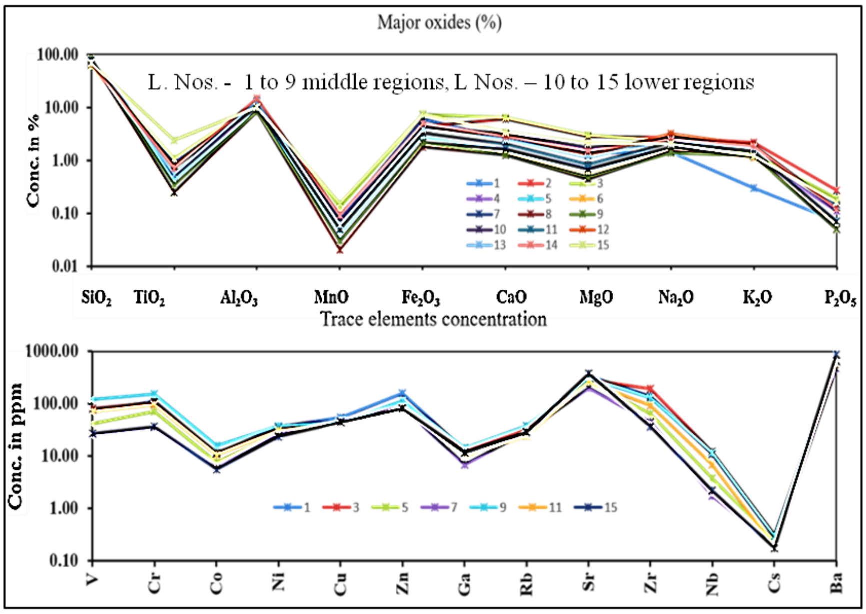

Fig. 3. Distribution of major oxides in NE monsoon sediments

Major and trace elements concentration of Post-monsoon sediments

The sample (L-15) at Poombugar shows higher concentration of trace elements linking to the influence of Bay of Bengal. Concentration of Ba ranges from 477.61ppm to 731.39ppm pointing towards the presence of K-feldspar, similarly, the concentration of Zn (90.43 ppm to 140.05ppm) is representing intermixing of river and sea waters and local fishing harbor interface. The Sr (165.32 ppm to 374.85ppm) variation is due to the weathering of plagioclase feldspar. The other trace element concentration in the sediments are V (37.15 ppm - 297.88ppm), Cr (47.09 ppm -328.22ppm), Co (7.31 ppm -35.20ppm), Ni (24.79 ppm -66.76pm), Cu (45.85 ppm -61.94ppm), Ga (8.82-29.20ppm), Rb (20.82 ppm-39.12ppm), Zr (66.73 ppm-847.75ppm), Nb (2.58 ppm -43.83ppm) and Cs (0.20 ppm-1.09ppm) (Fig. 4).

Table 6. Distribution of major oxides in Post-monsoon sediments

Loc. Nos.		SiO_2	TiO_2	Al_2O_3	MnO	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	CIA	PIA
		Concentration in %											
1	Middle regions	58.09	0.73	15.63	0.13	7.04	3.2	1.9	1.26	1.4	0.13	72.73	76.14
2		61.53	0.51	10.75	0.05	4.17	9.02	4.04	1.88	2.52	0.22	44.48	43.02
3		66.19	1.16	10.6	0.19	10.32	4.24	3.71	1.82	0.68	0.14	61.13	62.08
4		76.55	0.53	10.23	0.06	4.14	2.81	1.69	2.22	0.94	0.09	63.15	64.87
5		81.79	0.34	9.1	0.04	2.59	1.79	0.76	1.75	0.98	0.06	66.81	69.64
6		84.43	0.34	8.28	0.02	1.85	1.22	0.26	1.4	1	0.05	69.58	73.54
7		84.33	0.28	8.5	0.03	1.85	1.38	0.42	1.49	1.05	0.05	68.44	72.19
8		78.39	0.58	10.32	0.04	3.04	2.22	0.89	2.37	1.41	0.07	63.24	66
9		84.62	0.21	8.45	0.02	1.22	1.13	0.15	1.45	1.19	0.05	69.15	73.78
10	Lower regions	85.35	0.21	8.3	0.02	1.31	1.23	0.18	1.4	1.15	0.05	68.71	73.11
11		84.7	0.23	8.49	0.02	1.61	1.31	0.3	1.53	1.14	0.05	68.08	72.13
12		82.27	0.59	8.75	0.04	2.49	1.48	0.45	1.63	1.13	0.06	67.36	71.02
13		72.78	0.75	12.28	0.05	3.56	2.87	1.1	2.84	1.71	0.17	62.34	64.93
14		78.46	0.62	10.22	0.05	2.96	1.76	0.66	1.83	1.25	0.08	67.86	71.42
15		73.73	0.52	11.22	0.05	2.78	2.8	1.23	3.57	1.48	0.09	58.84	60.46

Table. 7 Distribution of trace elements in post-monsoon sediments

Loc. Nos.		V	Cr	Co	Ni	Cu	Zn	Ga	Rb	Sr	Zr	Nb	Cs	Ba
		Concentration in ppm												
1	Middle	169.0	202.1	18.2	43.9	52.3	123.1	13.2	20.8	244.9	195.8	9.21	0.2	477.6
3		66.28	90.38	10.8	33.0	52.5	111.3	10.4	30.9	242.2	157.0	8.50	0.3	556.6
7		46.65	89.96	9.43	35.0	52.1	127.0	8.82	29.8	246.7	81.66	4.57	0.2	611.6
9		70.60	84.21	10.4	28.9	46.6	110.8	9.50	25.2	220.1	125.9	9.33	0.2	519.8
11	Lower	58.44	81.41	9.30	31.2	50.2	118.0	12.5	33.6	341.5	218.4	7.61	0.3	714.3
13		37.15	47.09	7.31	24.7	45.5	90.43	13.1	24.3	374.8	66.73	2.58	0.2	731.3
15		297.8	328.2	35.2	66.7	61.9	140.0	29.2	39.1	165.3	847.7	43.8	1.0	581.9

Mineral Composition

The major and trace element concentration in sediments reflects the mineralogy of Cauvery River sediments. The average concentration of SiO_2 is 75.82% (SW monsoon), 74.58% (NE monsoon), and 76.88% (Post-monsoon). The Al measures 10.2%, 10.9% and 10.1% for SW, NE and Post-monsoon samples with the average concentration of alkalis; CaO is 2.89% (SW monsoon), 2.80% (NE monsoon) and 2.56% (Post-monsoon), followed by Fe_2O_3 average concentration is 3.79% (SW monsoon), 4.06% (NE monsoon) and 3.39% (Post-monsoon). Comparatively, the higher concentration of Fe_2O_3 (Avg.3.9%), denotes that the source rocks were involved in oxidation, leaching, and hydration processes during weathering (Mikkel and Henderson, 1983).

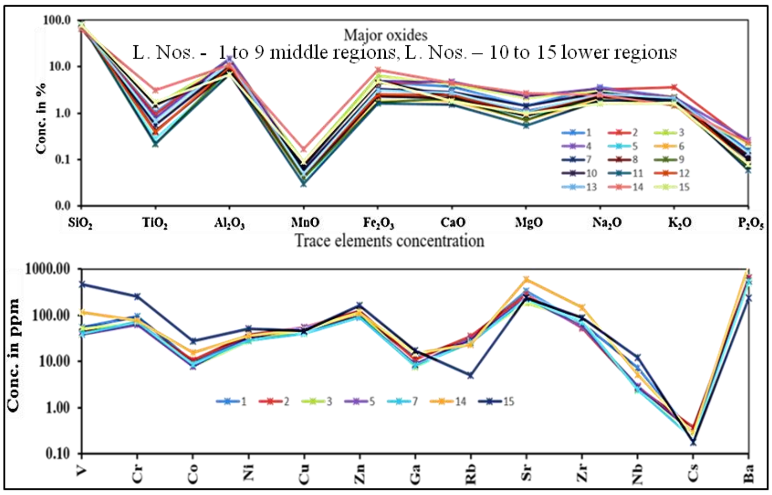

Fig. 4 Distribution of major oxides in Post-monsoon

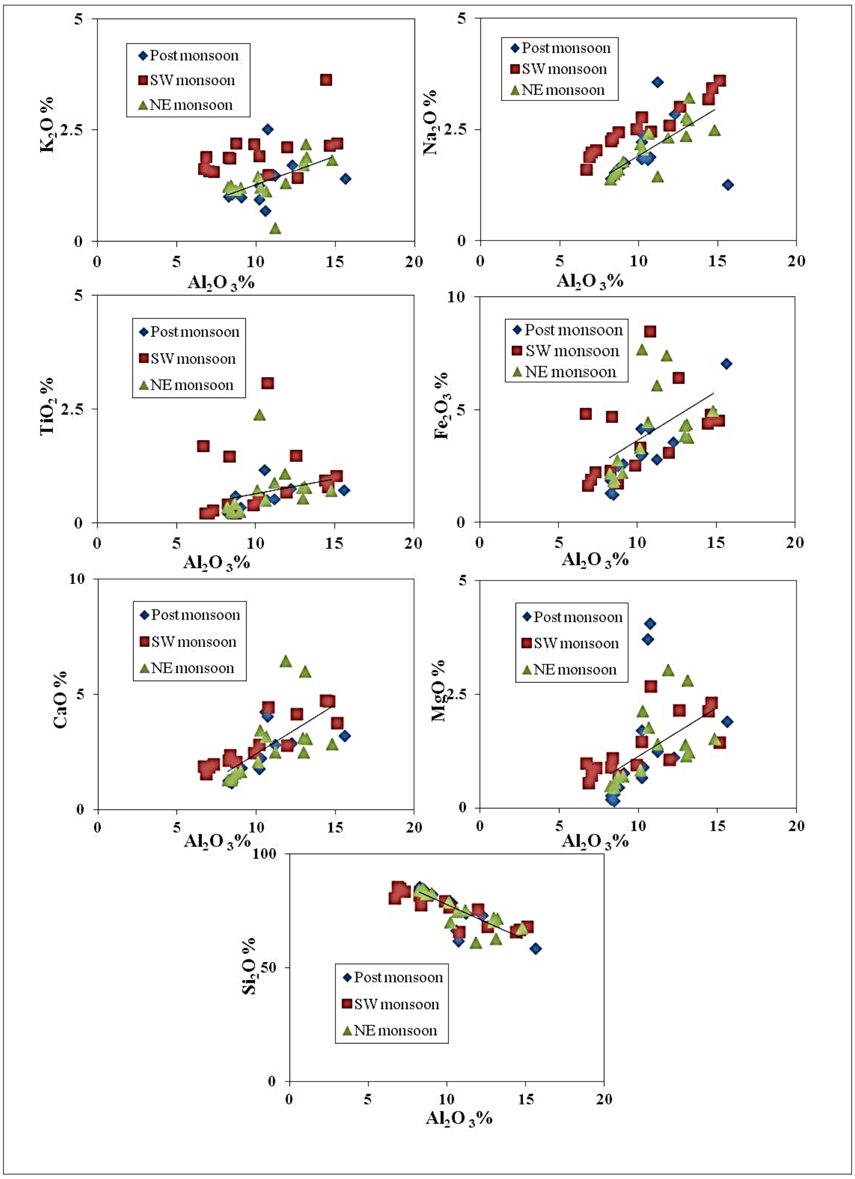

Fig. 5 Al_2O_3 v/s Major oxides

The relationship between Al_2O_3% and major oxides supports the occurrence of clay minerals in the sediments. The Al_2O_3% is positively correlated with Na_2O, K_2O, TiO_2, Fe_2O_3 and MgO, except SiO_2. These relationships between the oxides characterize the sediments encompass clay minerals (Fig. 5). The negative correlation between Al_2O_3% with SiO_2% reflects that the sediments are higher in quartz (Adel et. al., 2011). The positive correlation between K_2O (%) and Rb (ppm) in the sediments of all the seasons (Fig. 6), construes to the occurrence of illite mineral in the Cauvery River sediments (Cox and Lowe, 1995). The bivariate diagram of Al_2O_3 vs. TiO_2 deduced that the sediments are derived from granite and granodiorite rocks (Fig. 8 & 9).

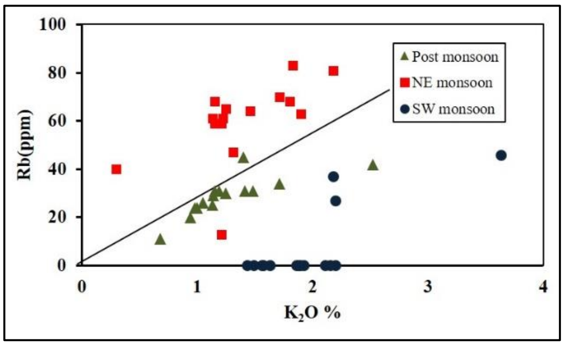

Fig. 6. Bivariate plots of Rb (ppm) vs. K_2O%.

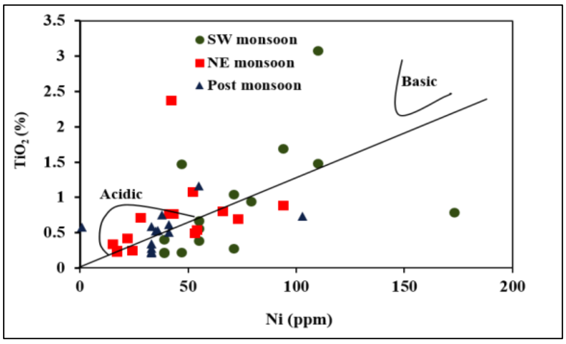

Fig.7. Classification of acidic and basic sources; Ni (ppm) vs. TiO_2 (%)

Sediment Geochemistry: implication to provenance

The relationship between TiO_2 vs. Ni signifies that the Cauvery River sediments are derived from the acidic rocks (Floyd et al., 1989) (Figure 4.9). Further, the bivariate variation between K_2O vs. Rb entails acid-intermediate composition of the source rocks (Fig.7) (Bhuiyan et al., 2011).

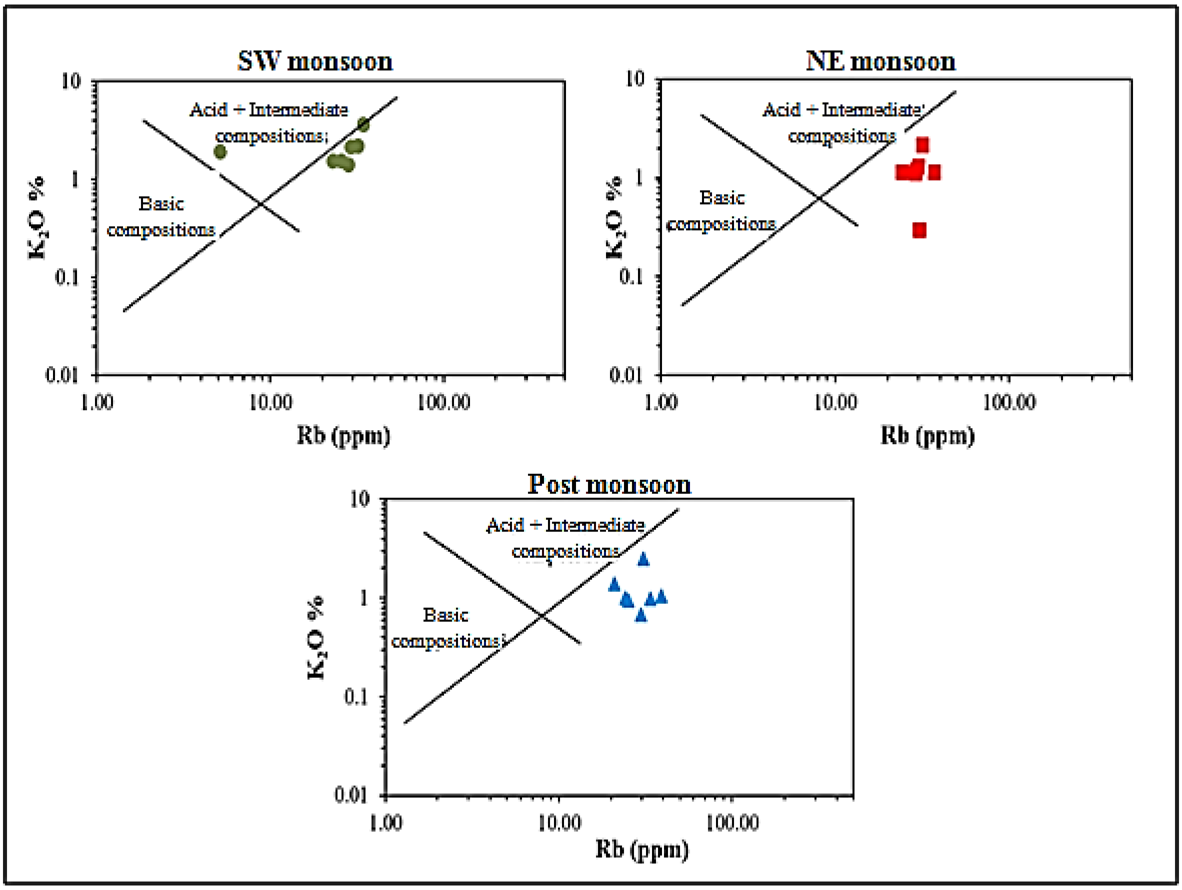

Fig. 8 Plot of K_2O vs. Rb in Cauvery River sediments

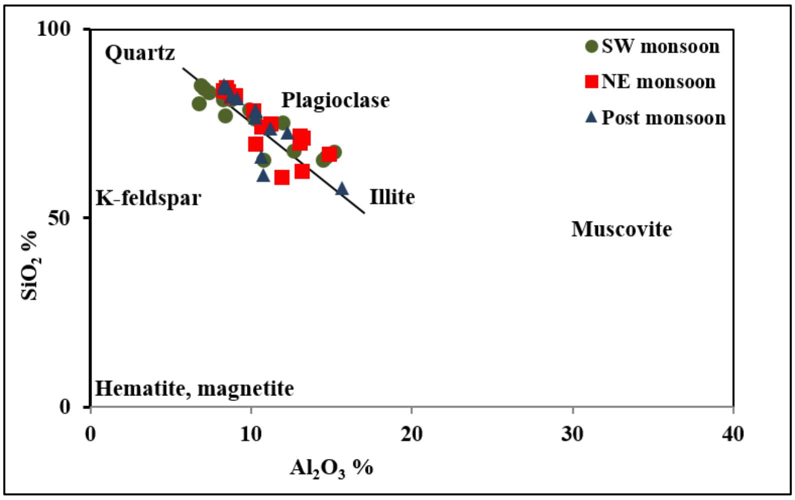

Fig. 9 Provenance of Cauvery River sediments (Floyd et al., 1989).

Source rock Weathering

The degree of weathering is controlled by the mineral composition of the source rocks, climatic conditions, and duration of weathering (Wronkiewicz and Condie, 1989). During the weathering, Ca, K, and Na was impassive from the source rocks, and tracing these elements in the sediments is a sensitive index of the intensity of weathering (Nesbit et al., 1997). The bivariate plots of SiO_2 vs. Al_2O_3 have been useful in discriminating the weathering of rocks and sediments. The Cauvery River sediments of SW, NE and Post-monsoon seasons follow the trend from quartz, plagioclase, K-feldspar to illite mineral (Fig. 10), which demonstrates that the sediments were weathered from quartz, feldspar, illite and other minerals in the rocks (Cullers and Podkovyrov, 2000).

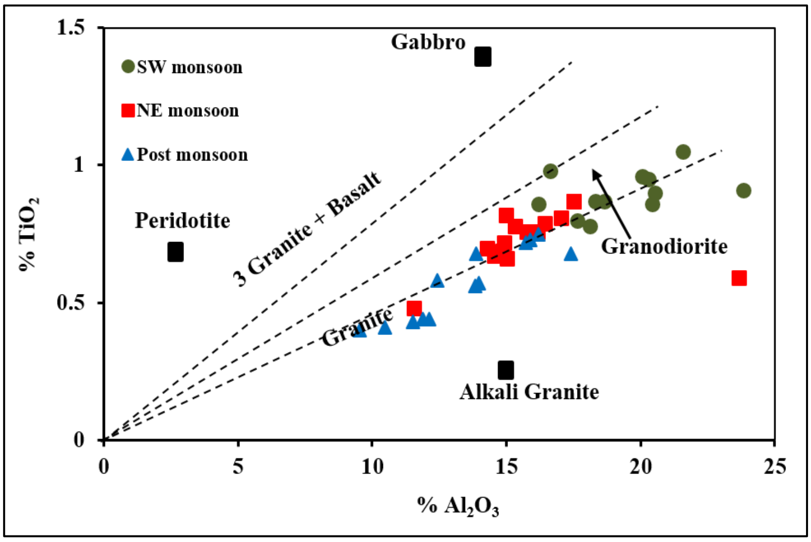

Fig. 10. Weathering trend: Al_2O_3 v/s. SiO_2 in Cauvery River sediments

The weathering of Cauvery River sediments follows the trend towards the illite mineral formation (Fig. 10). Further, the ternary plot displays the degree of weathering quantified by chemical index alteration (CIA) (Nesbitt & Young 1982) by using alumina and alkali minerals, which reflect the change in the proportions of feldspar and clay minerals during the weathering. The CIA is calculated by the following equation:

$$CIA = (Al_2O_3/ (Al_2O_3+CaO+Na_2O+K_2O)) *100$$

The CIA is used for evaluation of chemical weathering within the specific drainage basin (McLennan, 1993). The results of the Cauvery River sediment CIA is 55.58%-61.32% (SW monsoon), 60.54%-72.58% (NE monsoon) and 44.47%-72.73% (post-monsoon) indicate weak to intermediate weathering intensity (Fig.11). The CIA results of the sediments of different seasons are attributed to the chemical weathering controlled by the monsoon. The average CIA values of 57.73% (SW), 64.79% (NE) and 64.17% (post-monsoon) represent the rapid weathering intensity during the NE monsoon and post-monsoon (McLennan, 1993).

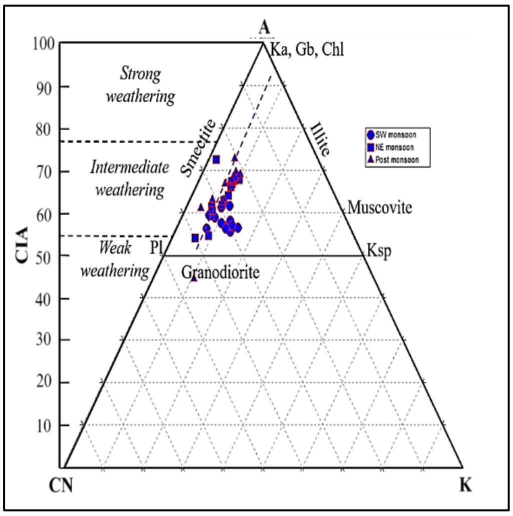

Fig. 11 A-CN-K relationship and weathering trend

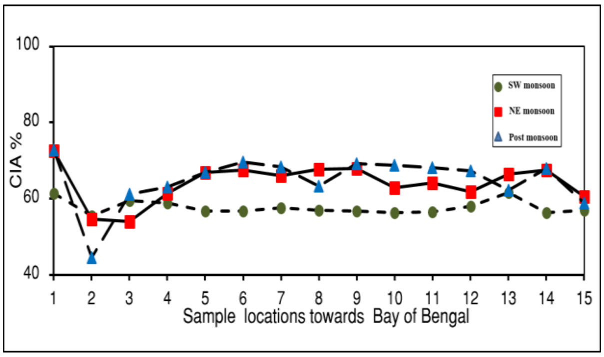

Fig. 12 Comparisons of CIA of Cauvery River sediments.

For understanding the controlling factor of weathering processes on rocks and sediments, the CIA values of sediments are spatially compared among the SW, NE, and post-monsoon samples (Fig. 12). The CIA of NE monsoon is rather higher (64.79%) than the other two seasons. The NE monsoon receives the advanced rainfall than SW and post-monsoon which suggests the weathering of rocks along the Cauvery River is controlled by the expanse of precipitation.

The average CIA value of World Rivers is 72.1%. The CIA values of African rivers are 83.4% (higher than the other continents), 71.7% for Asian rivers (closer to the average World Rivers) and 66.0% for North American (McLennan, 1993; Savenko, 2006; Viers et al., 2008; Chao li & Shouye yang, 2010). The average CIA value of Cauvery River is (60.95%) which is below the world average CIA of river sediments and very close to the Indus River sediments (Table 8, Fig. 13).

Table. 8 The average CIA values of global rivers sediment

World Rivers	Al_2O_3%	Na_2O%	CaO%	K_2O%	CIA%
Mississippi	15.49	0.75	1.47	1.92	77.2
Columbia	16.9	2.9	3.3	2.9	57.1
Amazon	14.6	1.1	1.1	2.2	70.9
Parana	16.76	1.21	1.04	2.9	70.4
Danube	12.1	2.38	6.39	2.51	53.4
Seine	11.58	0.26	13.18	1.47	82.5
Congo	25.1	0.32	1.34	1.64	89.9
Nile	18.8	1.0	5.68	2.32	76.4
Kala	55.65	13.75	25.76	13.38	48.2
Irtysh	11.6	0.49	1.8	1.51	78.1
Ganges	16.0	1.58	4.07	2.77	66.7
Indus	17.63	2.04	2.37	4.07	61.3
Brahmaputra	19.08	1.48	1.06	3.31	70.5
Cauvery	10.4	2.13	2.75	1.55	60.95

Conclusions

The high concentration of Si, Al, and K in the sediments infers that the sediments are derived from the source rock by the chemical weathering processes. The high concentration in Fe_2O_3 signifies that the sediments are affected by oxidation, leaching and hydration processes during their weathering. The negative correlation between the Al_2O_3% and SiO_2% of the sediments is attributed to the Cauvery River sediments enrichment with quartz. The relationship between Al_2O_3 vs. TiO_2 infers that the provenance of Cauvery River sediments is represented by granite and granodiorite rocks. The trend of weathering of sediments is eminent by the occurrence of illite clay minerals.

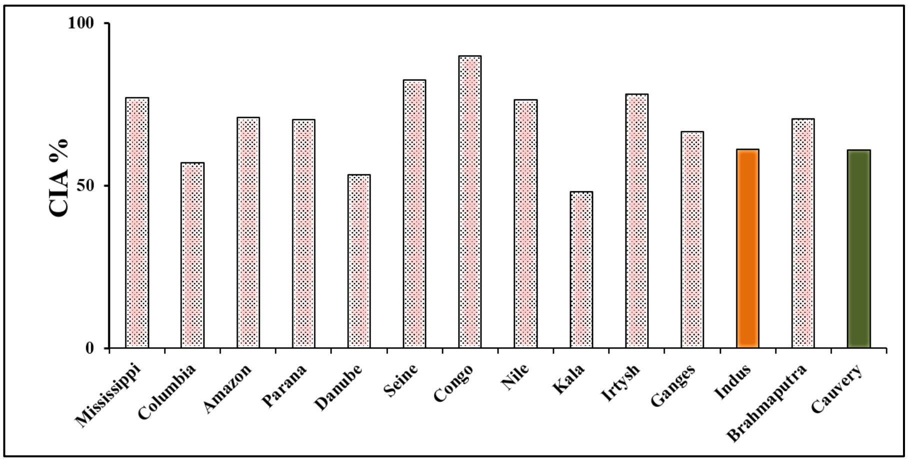

Fig.13. CIA values of Cauvery River sediments with global rivers

The CIA of Cauvery River sediments of SW (57.73%), NE (64.17%) and post-monsoon (64.79%) indicates week to intermediate weathering intensity. These low CIA values are attributed to the impact of weathering on the Cauvery River rocks controlled by precipitation. The average CIA value of Cauvery River sediments (60.95%) is below the average CIA values of world Rivers (72.1%) and it's near to the Indus River (61.3%). The concentration of Ba in the Cauvery River sediments varies from 459.45 ppm to 856.95ppm reflecting the presence of K-feldspar in the source rocks. The decreasing trend of trace elements in the downstream is influenced by the variation of sorting, whereas the sediments at Poombugar (L-15) show higher concentration influenced by the Bay of Bengal.

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