Trace Element Geochemistry of the Ponnaiyar River Sediments, Tamil Nadu, India: Inferrences on Provenance.

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Abstract

The Ponnaiyar river sediments from nine sampling station between Thirukovilur and Cuddalore were subjected to geochemical studies to understand the trace elemental characteristics and their interrelation and to determine the source of trace elements present in the sediments. Chemical analysis was carried out on samples for P, Li, B, V, Cr, Co, Ni, Zn, Sr, Y, Nb, Mo, Sb, Ba, La, Ce, Pb and Zr. The granites, granitic-gneiss, charnockites, alkaline syenite-carbonatite, pyroxenites, garnetiferous-sillimanite gneiss, granite-pegmatites, mafic and ultra mafic litho-component and other granulitic rocks of the Ponnaiyar river basin form the source for all the trace elements studied. The migration of trace elements from source to river sediments could have taken place through particulate minerogenic phase as detrital heavy minerals and clay minerals. The average trace elemental content of the Ponnaiyar sediment exhibits an enhancement of P, V, Cr, Ni, Ba, La, Pb, Zr and a strong depletion of Zn relative to the upper continental crust (UCC) values. The study indicates that the Felsic rocks of the drainage basin contribute predominantly trace elements to the river sediments. The higher value of Cr, V, Ni, Pb, and P might have been derived from anthropogenic input to the river from industrial effluents and chemical contamination from agricultural lands, besides natural geochemical background contribution.

Key words: Sediment, trace elements, provenance, Ponnaiyar river.

1.0.0 Introduction:

The topography, climate, lithology, weathering processes of the source rock area determine the nature and composition of the river sediment. Trace element or trace metal are lithosphere component that are released into the environment during volcanism and rock weathering (Fergusson, 1990). The minerals present in the sediments exert control on the chemical composition of the sediments. The sandy and silty sediments are product of physical weathering whereas fine grained sediments are derived from chemical weathering process of the source rocks. Rivers play an important role in transporting the eroded sediment detritus from the continents to oceans. The eroded material would have been derived from various source rocks. The study of sediment geochemistry could give information about influence of provenance, weathering, tectonic and fluvial processes involved in making up the composition of sediments (Nesbitt and Young,1982; Taylor and McLennan,1985; Armstrong-Altrin et al. 2013; Nagarajan et al. 2017; Madhavaraju et al. 2020).

Sediment geochemistry of a few peninsular rivers of India have been studied by earlier workers; Singh and Rajamani, 2001; Rajamani et al, 2009; Sharma et al.2013; Silva, J. D. et al (2014): Madhavaraju et al. 2015; Saibabu et al. 2021; Shaik Saibabu et al. 2021. Though many studies have been carried out in the peninsular river, there still exists a gap in knowledge to understand the source and mode of transportation and dispersion of trace elements in the riverbed sediments. This present study attempts to investigate the source, correlation, and interrelationship among the trace elements of the lower Ponnaiyar river sediments.

2.0.0 Study Area:

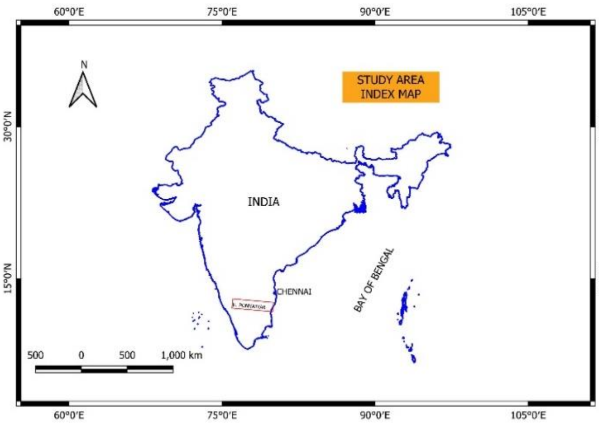
The Ponnaiyar river rises from Nandi hills in Karnataka and drains through Archaean rocks with Cretaceous formations (calcareous sandstone, claystone), Cuddalore sandstone and recent alluvium in the coastal region Tamil Nadu (Krishnan,1982 and Subramanian et.al, 2001), The riverbed comprises of medium and fine sand predominantly with occasional coarse sand occurrences. The constituent minerals are quartz, feldspars, amphiboles, ortho & clino-pyroxenes, zircon, monazite, kyanite, epidote, tourmaline, ilmenite, magnetite, sphene, micas etc.

3.0.0 Materials and methods:

The Nine riverbed surface sediments were collected from channel bar, point bar along the course of the Ponnaiyar River 8 to10 km interval from Thirukoilur to Cuddalore (Fig-1). After proper cone and quartering representative samples from each location were taken for various laboratory analysis. Chemical analysis for trace elements was carried out on air dried samples for P, Li, B, V, Cr, Co, Ni, Zn, Sr, Y, Nb, Mo, Sb, Ba, La, Ce, Pb and Zr by ICP-AES techniques.

4.0.0 Bulk analytical data handling:

Chemical analysis carried out on nine bulk sediments for eighteen trace elements to understand their characteristic and relationship among various elements of the samples and to determine the source and mode of transportation, dispersion, and migration of elements in the river sediments. The abundance of trace elements in the Ponnaiyar river bed sediment is given in Table-1. The minimum, maximum and average elemental values obtained from the results of the analysis and the elements crustal value (UCC) are tabulated (Table-2). Pearson correlation coefficient for several trace elemental combination has been determined (Table-3). The correlation coefficient higher than 0.40 is considered significant at 98% confidence limit.



Study area Index map

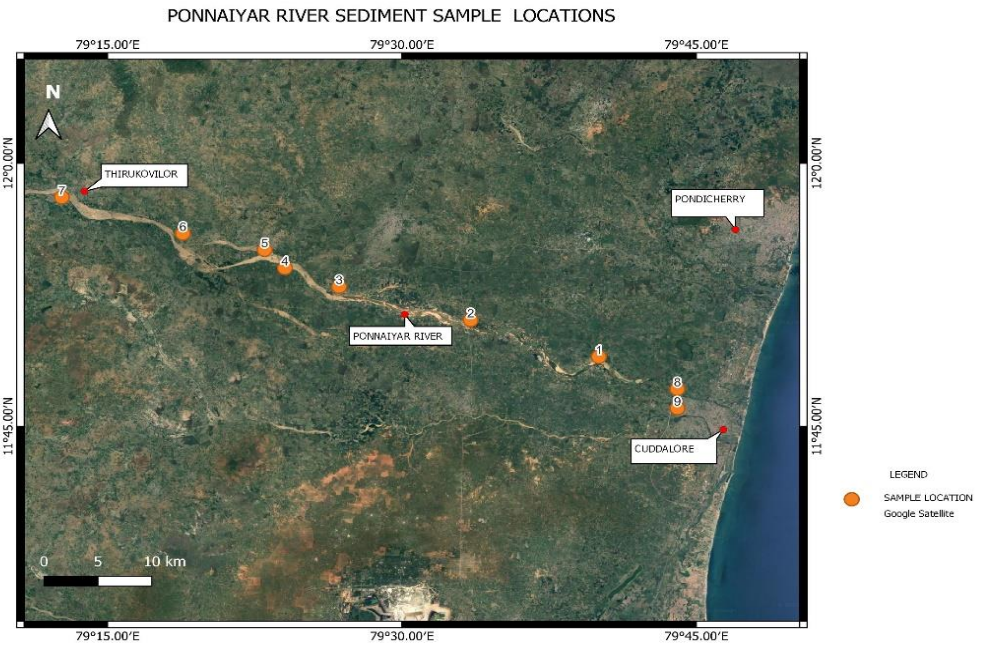


Fig. 2. Map showing Sediment sample locations in the Ponnaiyar River.

TABLE-1. ABUNDANCE OF TRACE ELEMENT CONTENT IN THE SEDIMENTS.

(Values in ppm)

Samp	P	Li	B	V	Cr	Co	Ni	Zn	Sr	Y	Nb	Mo	Sb	Ba	La	Ce	Pb	Zr
1	598	10	87	122	175	6	91	54	387	20	20	38	25	794	51	106	152	548
2	637	10	84	124	162	7	82	45	388	20	20	36	17	805	45	93	149	301
3	767	10	86	87	198	6	111	44	373	20	20	40	42	853	35	94	160	213
4	1312	11	89	276	241	19	108	64	368	27	41	34	15	733	189	389	175	826
5	1252	10	89	285	241	18	106	69	416	27	41	34	11	785	205	416	177	1017
6	830	11	87	135	219	11	116	44	386	20	20	39	39	860	67	164	168	277
7	903	10	87	212	215	14	101	52	362	21	26	34	14	747	100	218	161	579
8	778	10	86	129	188	8	98	45	389	20	20	38	41	850	57	138	166	450
9	363	13	89	0	261	9	137	49	103	20	28	55	91	567	42	137	173	962
MIN	363	10	84	0	162	6	82	44	103	20	20	34	11	567	35	93	149	213
MAX	1312	13	89	285	261	19	137	69	416	27	41	55	91	860	205	416	177	1017
Avg.	**827**	**11**	**87**	**152**	**211**	**11**	**106**	**52**	**352**	**22**	**26**	**39**	**33**	**777**	**88**	**195**	**165**	**575**

Table -2 TRACE ELEMENT CONTENT MINIIMUM, MAXIMUM, AVERAGE VALUES AND UPPER CRUSTAL VALUES (UCC).

Elements	MIN	MAX	AVG	UCC * Values
P	363	1312	**827**	610.00
Li	10	13	11	20.00
B	84	89	87	0.00
V	0	285	**152**	97.00
Cr	162	261	**211**	71.00
Co	6	19	11	17.30
Ni	82	137	**106**	44.00
Zn	44	69	52	71.00
Sr	103	416	352	350.00
Y	20	27	22	22.00
Nb	20	41	26	25.00
Mo	34	55	39	0.00
Sb	11	91	33	0.00
Ba	567	860	**777**	550.00
La	35	205	**88**	30.00
Ce	93	416	**195**	64.00
Pb	149	177	**165**	20.00
Zr	213	1017	**575**	190.00

UCC* from Taylor S R and McLennan, S. M. (1985).

TABLE -3 CORRELATION COEFFICIENT MATRIX OF TRACE ELEMENTS

Variabl	P	Li	B	V	Cr	Co	Ni	Zn	Sr	Y	Nb	Mo	Sb	Ba	La	Ce	Pb	Zr
P	**1.00**	-0.37	0.38	**0.95**	0.30	0.85	-0.15	**0.73**	**0.58**	**0.88**	**0.74**	-0.73	**-0.70**	0.27	**0.91**	**0.88**	**0.51**	0.29
Li		**1.00**	**0.54**	-0.47	**0.70**	**0.06**	**0.84**	-0.05	**-0.91**	-0.05	0.19	0.84	**0.80**	**-0.80**	-0.11	-0.01	0.49	0.46
B			**1.00**	0.31	**0.90**	**0.68**	**0.66**	**0.71**	-0.39	**0.64**	**0.78**	0.24	0.20	**-0.59**	**0.64**	**0.70**	**0.84**	**0.85**
V				**1.00**	0.17	0.84	-0.34	**0.77**	**0.64**	**0.84**	**0.70**	**-0.83**	**-0.84**	0.25	**0.90**	**0.86**	0.34	0.33
Cr					**1.00**	0.66	**0.84**	**0.49**	**-0.55**	**0.52**	**0.71**	0.39	0.37	**-0.65**	**0.52**	**0.62**	**0.90**	**0.75**
Co						**1.00**	**0.17**	**0.82**	**0.15**	**0.89**	**0.91**	-0.41	-0.43	**-0.21**	**0.95**	**0.97**	**0.72**	**0.65**
Ni							**1.00**	**0.00**	**-0.75**	0.04	0.25	**0.74**	**0.76**	**-0.59**	0.01	0.12	**0.69**	0.42
Zn								**1.00**	0.17	**0.93**	**0.92**	-0.37	-0.46	-0.26	**0.92**	**0.91**	**0.54**	**0.79**
Sr									1.00	0.24	-0.04	**-0.93**	-0.87	**0.88**	0.30	0.21	-0.28	-0.43
Y										1.00	**0.95**	-0.44	-0.48	-0.13	**0.98**	**0.97**	**0.65**	**0.67**
Nb											1.00	-0.20	-0.27	-0.41	**0.93**	**0.95**	**0.75**	**0.83**
Mo												1.00	**0.98**	**-0.66**	**-0.51**	-0.43	0.18	0.21
Sb													1.00	**-0.54**	**-0.55**	-0.46	0.22	0.11
Ba														1.00	-0.09	-0.16	-0.37	**-0.73**
La															1.00	**0.99**	**0.65**	**0.65**
Ce																1.00	**0.73**	**0.70**
Pb																	1.00	**0.69**
Zr																		1.00

TABLE-4 TRACE ELEMENTAL RATIOS of Cr/Ni, Cr/v, Y/Ni and Zr/Co.

SAMPLE	**Cr/Ni**	**Cr/V**	**Y/Ni**	**Zr/ Co**
1	1.92	1.43	0.22	91.33
2	1.98	1.31	0.24	43.00
3	1.78	2.28	0.18	35.50
4	2.23	0.87	0.25	43.47
5	2.27	0.85	0.25	56.50
6	1.89	1.62	0.17	25.18
7	2.13	1.01	0.21	41.36
8	1.92	1.46	0.2	56.25
9	1.91	2.61	0.15	106.89
Min	*1.78*	*0.85*	*0.15*	*25.18*
Max	*2.27*	*2.61*	*0.25*	*106.89*
avg	***2.00***	***1.49***	***0.21***	***55.50***

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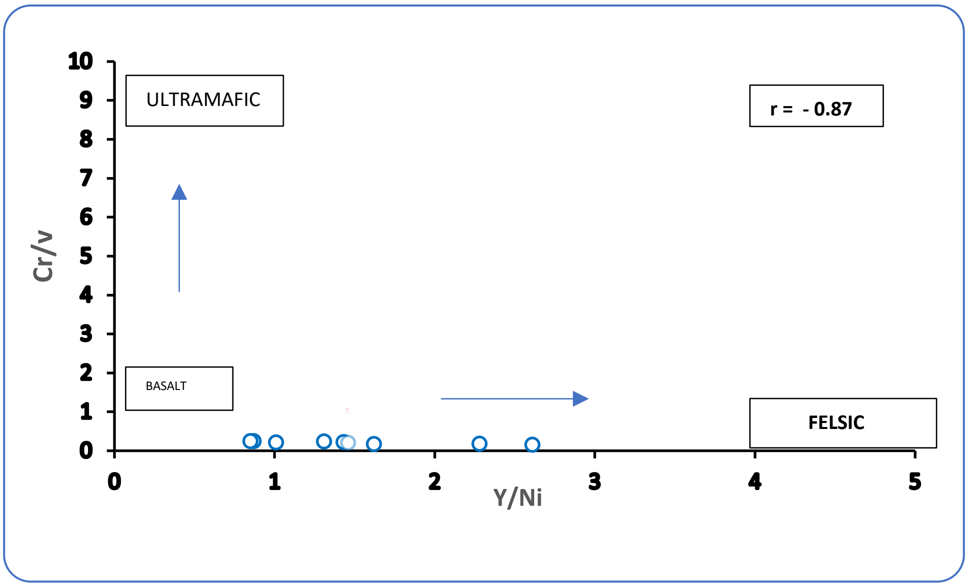

FIG. 3. Showing the ratio-ratio plot of Cr/V and Y/Ni of the Ponnaiyar River sediments.

(adopted from Mclennan et al. 1993 and Mongelli et al. 2006).

5.00 Results and discussion:

The Ponnaiyar river drainage basin experiences physical and chemical weathering due to dominant humid, tropical climate. The seasonal rainfall and temperature play important role in the weathering of rocks and in the liberation of the weathered mineral grains which later form the sediments of the riverbed, Chemical weathering influences the alkali and alkaline earth metal elements concentration of the sediments (Nesbitt and Young,1982).

The trace elemental content in the sediments (Table-1) of the study area varies from 98 to 7440.27 ppm with an average of 1869.22 ppm. The Pearson correlation coefficient among the elemental variables was calculated and presented in Table-3. The average trace element content (TE) of the Ponnaiyar river is 1869.22 ppm, which is higher than UCC and PAAS values of 1633.50 ppm (Rudnick et al.2003) and 1807.20 ppm (Pourmand et al.2012) respectively. The average elemental content of the Ponnaiyar sediment exhibits an enhancement of P, V Cr, Ni, Ba, La, Pb, Zr and a strong depletion of Co and Zn relative to the upper continental crust (UCC) values (Table-2). The correlation matrix (Table-3) indicates positive correlations among a group of elements such as P, V, Co, Zn, Sr & Y, Nb, La, Ce, Pb, which could have been derived from the heavy mineral content of the source rocks. The Ba and Sr have negative correlation with other elements is inferred to be derived from the Cretaceous limestone occurring in the Ponnaiyar basin. The element Mo has strong positive correlation with Sb, Li and Ni. The element Sb has positive correlation with Li. Ni and Mo. Both Mo and Sb show strong negative correlation with P, V, and Sr. The Sb and Mo could have been derived from the gold bearing quartz veins and schitose rocks of the Ponnaiyar river basin. Positive correlation of P with Zn (+0.73) and Pb (+0.51) suggests that these elements are associated with phosphate mineral. High field strength elements such as Zr, Nb, Y reflect the provenance composition due to their immobile nature. The occurrence of the elements Zr, Nb and Y in the sediments indicates their derivation from heavy minerals such as zircon, rutile, and tourmaline. Tourmaline mineral can also contribute to La, Li and B. The heavy minerals, such as monazite and zircon, can contribute Ce, La, Nd, Y and P to the sediments.

The trace elemental ratios of Cr/V, Cr/Ni, Y/Ni and Zr/Co are presented in Table-4. The ratio of Cr/V shows 1.49 which is also higher than in UCC (0.95). Bhattacharya et al. (2012) reported Cr/V value 1.28 for granitic rock source. The ratio of Cr/Ni exhibits 2.00 which is higher than in UCC (1.95). If the Cr/Ni ratio value falls between 2 to 7, indicating the elements derivation from heavy minerals and cr minerals from the source (Garver et al.1996). The Y/Ni ratio is 0.21 which is lower than in UCC (0.44). Low Y/Ni <0.50 suggests a mixture of felsic and mafic source rocks.The plot of Y/Ni vs Cr/ V (Fig.3) shows that the samples analysed fall under felsic field indicating a granitic source for the trace elements (Mc Lennan et al. 1993; Mongelli et al. 2006). The ratio of Zr/Co is 55.50, which is much higher than in UCC (11.20). Borges et al. (2008) reported that Zr/Co ratio values on an average of 12 for mafic character for Lena river sediments; Zr/Co ratio value on an average 29, indicates felsic character in Salween river sediments. Accordingly, Zr/Co ratio value of 55.50 in the study area, suggests a felsic source rock for the Ponnaiyar river sediments.

The correlation coefficient value (Table-3) and elemental ratios (Table-4) discussed above suggest that the source for the trace elements are from felsic source rocks of the Ponnaiyar river drainage basin. The felsic rocks such as gold bearing quatz vein associated schists, granites, gneisse, alkaline syenite, carbonatites and Cretaceous limestones of the area played major role in the supply of trace elements to the sediments of the Ponnaiyar river. The higher value of Cr, Ni, Pb and P might have been derived from anthropogenic input from industrial effluents and chemical contamination from agricultural lands along the river course, besides natural geochemical background contribution. Overall, the study suggests that the mineral content of felsic rocks of the Ponnaiyar river basin form the major source for the trace elements present in the sediments. However, the mafic rocks might have played a subdued role in the supply of certain elements to the sediments in the study area.

6.0.0 Conclusions:

The mineralogy and trace element geochemistry of the sandy sediments of the lower reaches between Thirukoilur and Cuddalore part of the Ponnaiyar river indicate the following::

1. The chemical analysis of eighteen trace element content in the Ponnaiyar river sediments varies from 98 to 7440 ppm with an average value of 1869.22 ppm.

2. The correlation coefficient and elemental ratios of the trace elements suggest that felsic rocks of the Ponnaiyar river drainage basin form the source for these elements.

3. The felsic rocks such as gold bearing quatz vein associated schists, granites, gneisse, Pegmatites, alkaline syenite, carbonatites and Cretaceous limestones of the area played major role in the supply of trace elements to the sediments of the Ponnaiyar river.

4. The trace elements have been transported to the riverbed in particulate minerogenic phase as detrital minerals.

5. High ΣTE in the river sediments of the study area is due to the enrichment of trace elements through anthropogenic input from industrial effluents and chemical contamination from agricultural lands along the river course, besides natural geochemical background contribution.

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