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Assessment of Heavy Metal Concentration in River Sediments Along Vamanapuram River Basin, South Kerala, India

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ABSTRACT

The present study narrates the geo-environmental setting of the Vamanapuram River Basin (VRB) through the heavy metal assessment in river sediments. The granulometric distribution of trace metals in medium sand, fine sand, very fine sand, silt and clay fractions of the Vamanapuram river sediments has been determined for selected samples and the variation is compared with that of the respective bulk sediments. The order of abundance of trace elements in sand fractions is Fe> Mg> Zn> Mn> Pb> Cr> Ni> Cu> Co> Cd, and in mud fractions is Fe> Mg> Zn> Mn> Cr> Pb> Cu> Ni> Co> Cd. The sediment distribution characteristics have been brought out in a convincing manner.

INTRODUCTION

Environmental degradation is one of the largest threats that is being looked at in the world today. Geo-environmental studies help to predict geosystem response to various types of active interactions. It is an in-depth treatment of the relations between man and his geologic, geomorphic, physical and cultural environments. The study of sediments, their granulometric composition, geochemical characteristics, contaminant concentrations, etc. is a widely used method of environmental quality assessment (Forstner & Wittmann 1979) since sediments integrate contaminants concentration over time, rendering a long term picture of influence of different factors like natural weathering, agriculture and urbanization on aquatic systems. Sources of trace metals accumulated in sediments are a combination of both natural weathering as well as anthropogenic influence. Of the chemical pollutants, heavy metals being non-biodegradable, they can be concentrated along the food chain, producing their toxic effect at points after removal from the source of pollution (Tilzer & Khondker 1993). Exposure to heavy metals leads to several human ailments such as brain development retardation, kidney damage, cancer, foetus abortion, effect on intelligence and behaviour and even death in some cases of exposure to very high concentration.

STUDY AREA

Vamanapuram River Basin (VRB) with a catchment area of 582 sq.km is located mainly in Thiruvananthapuram district, and a small portion of it falls in Kollam district of Kerala State. The river basin is bounded by latitudes of 8°40'12.2"N and 8°49'13" N and longitudes of 76°45'35" E and 77°12'45" E. The river basin shows varied conditions from the upper to the lower reaches, in terms of natural as well as anthropogenic aspects. Upland portions of the basin are mostly occupied by rubber plantation, the midlands occupied by mixed vegetation whereas the lowlands are subjected to large scale urbanization.

MATERIALS AND METHODS

For the present study, representative river bed sediments were collected from Vamanapuram mainstream and its tributaries during the pre-monsoon season (Fig. 1) and granulometric distribution of trace elements in medium sand, fine sand, very fine sand, silt and clay fractions has been determined and the variation is compared with that of the respective bulk sediments. The samples were sun-dried and passed through 2.0, 1.0, 0.5, 0.25, 0.125, 0.062, and 0.031 mm sieves for getting separate sediment fractions of medium sand, fine sand, very fine sand, silt and clay fractions. For trace element analysis, different size fractions and the bulk sediments were first dried in an oven at 60°C for 24 hours. The dried sediment was ground to powder using an agate mortar and pestle to ensure homogenization. Powdered sample of about 0.25 g dry weight was digested using HF-$HClO_4$-HNO_3 acid mixture as described in APHA (1995). Trace elements Fe, Mn, Zn, Cu, Co, Pb, Cr and Cd in the samples were determined by using atomic absorption spectrophotometer (AAS).

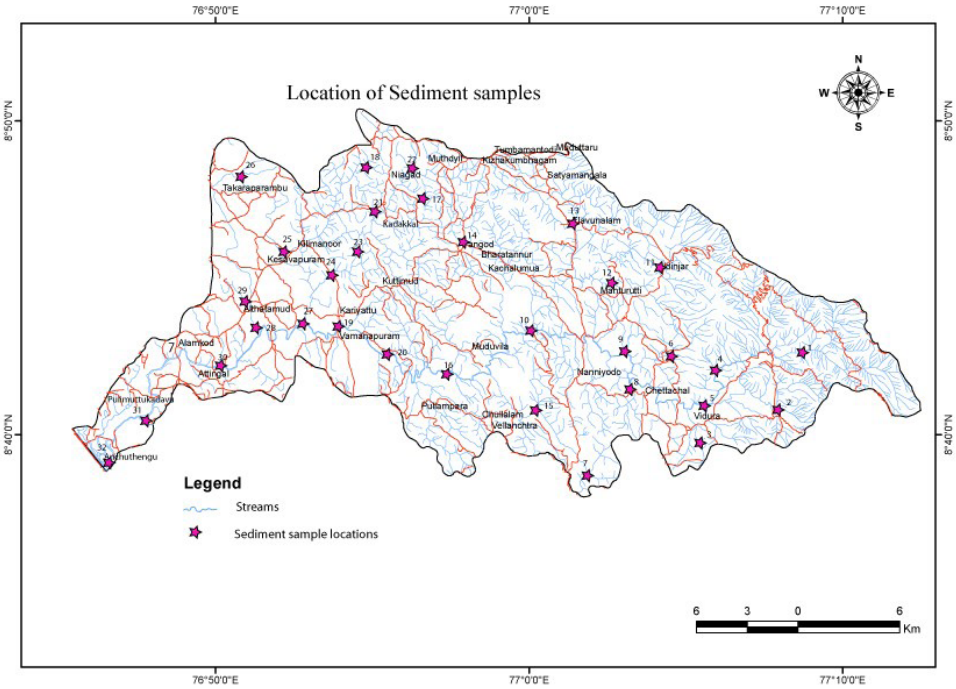

Fig 1: Location of sediment samples in VRB.

RESULTS AND DISCUSSION

Sediments are known to capture hydrophobic chemical pollutants entering waterbodies and slowly releasing the contaminants back into the water column (Mccready et al. 2006). Therefore, ensuring a good sediment quality is crucial to maintain a healthy aquatic ecosystem, which in turn ensures the protection of human health and aquatic life. In the present study, an attempt has been made to get an idea about the extent of heavy metal accumulation in Vamanapuram river sediments using tools like enrichment factor, contamination factor, pollution load index and geoaccummulation index.

The granulometric distribution of trace metals in medium sand, fine sand, very fine sand, silt and clay fractions of the Vamanapuram sediments has been determined for selected samples and the variation is compared with that of the respective bulk sediments (Table 1). In the bulk sediments, the concentration range of various trace elements in ppm are Pb 0.160-0.377, Zn 0.514-0.840, Co 0.01-0.06, Cu 0.021-0.053, Cd 0.001-0.011, Cr 0.075-0.392, Fe 7.96-80.3, Ni 0.025-0.103, Mg 0.051-1.326, and Mn 0.046-0.423. The concentration of Pb in various sand fraction ranges from 0.085-0.420 ppm, whereas in mud fraction it is 0.252- 0.412 ppm. Zn shows a value ranging from 0.427-1.356 ppm in sand fractions and 0.869-1.605 ppm in silt and clay fractions. The concentration range of Co, Cu, Cd, Cr and Ni in various sand fractions are 0.008-0.075 ppm, 0.006- 0.099 ppm, below detectable limit, 0.014 ppm, 0.04-0.4 ppm and 0.007-0.11 ppm respectively, and in mud fraction 0.029-0.081 ppm, 0.060-0.196 ppm, 0.001-0.014 ppm, 0.120- 0.480 ppm, 0.045-0.15 ppm respectively. Fe showed higher values ranging from 14.26 to 99.9 ppm in sand fractions and 28.7 to 96.85 ppm in mud fraction. For Mg, values range from 0.050-5 ppm in sand fraction and 1.137-3.92 ppm in mud fraction, and for Mn it is 0.069-1.1 ppm for sand fractions and 0.24-0.80 ppm for mud fraction.

The order of abundance of trace elements in sand fractions is Fe> Mg> Zn> Mn> Pb> Cr> Ni> Cu> Co>Cd, and in mud fractions is Fe> Mg> Zn> Mn> Cr> Pb> Cu> Ni> Co> Cd.

The concentrations of the selected trace elements in sediments samples were very high in all sampling points compared to the concentration of the trace elements in water samples from same sites (Table 2). In sedimentary environments, geochemical behaviour of Mn will always be coupled with Fe (Forstner & Wittman 1983). The study also reveals that the concentration of Fe and Mn in river sediments is many times higher in the mud fraction when compared with bulk sediment. The increase in the concentration of Fe and Mn in finer silt and clay is primarily related to the greater surface of these particulates (Gibbs 1977).

Table 1: Trace metal analysis of river sediments (ppm).

No.	Location name	Sediment Type	Pb	Zn	Co	Cu	Cd	Cr	Fe	Ni	Mg	Mn
1	Vitura	Bulk sediment	0.160	0.459	0.022	0.028	0.001	0.279	44.20	0.060	0.051	0.092
		Medium sand	0.179	0.590	0.029	0.033	0.003	0.325	48.20	0.062	0.067	0.122
		Fine sand	0.221	0.604	0.034	0.047	0.004	0.386	48.57	0.078	1.544	0.311
		Very fine sand	0.214	1.187	0.046	0.078	0.006	0.412	53.38	0.079	1.599	0.424
		Silt + Clay	0.252	1.315	0.049	0.083	0.007	0.480	54.00	0.087	1.63	0.45
2	Muduvila	Bulk sediment	0.170	0.570	0.021	0.027	0.003	0.284	44.60	0.058	0.058	0.083
		Medium sand	0.186	0.583	0.024	0.029	0.004	0.355	47.20	0.061	0.060	0.175
		Fine sand	0.201	0.694	0.029	0.033	0.006	0.373	48.63	0.067	0.847	0.201
		Very fine sand	0.244	1.081	0.033	0.058	0.007	0.402	51.88	0.072	1.048	0.294
		Silt + Clay	0.258	1.201	0.035	0.073	0.007	0.461	53.01	0.077	1.37	0.41
3	Vamanapuram	Bulk sediment	0.258	0.685	0.020	0.051	0.011	0.392	80.3	0.063	1.326	0.423
		Medium sand	0.271	0.692	0.028	0.055	0.013	0.411	90.8	0.082	1.618	0.633
		Fine sand	0.278	0.730	0.035	0.058	0.015	0.423	91.8	0.128	1.778	0.679
		Very fine sand	0.321	0.823	0.039	0.068	0.021	0.452	95.6	0.141	2.652	0.783
		Silt + Clay	0.365	0.936	0.04	0.196	0.024	0.476	98.5	0.150	2.878	0.800
4	Pullampara	Bulk sediment	0.202	0.691	0.018	0.046	0.013	0.303	87.5	0.103	1.634	0.621
		Medium sand	0.251	0.722	0.024	0.056	0.014	0.375	90.3	0.112	1.718	0.946
		Fine sand	0.283	0.820	0.028	0.064	0.019	0.468	92.8	0.144	1.785	1.009
		Very fine sand	0.328	0.897	0.035	0.082	0.023	0.485	95.6	0.181	1.957	1.607
		Silt + Clay	0.377	0.953	0.039	0.186	0.026	0.496	96.9	0.185	2.078	1.800
5	Kadakkal	Bulk sediment	0.167	0.840	0.030	0.021	0.005	0.035	49.62	0.025	0.768	0.189
		Medium sand	0.215	0.878	0.034	0.032	0.006	0.047	68.61	0.028	1.83	0.503
		Fine sand	0.289	1.336	0.039	0.047	0.010	0.142	83.51	0.051	2.04	0.557
		Very fine sand	0.399	1.356	0.064	0.181	0.017	0.149	91.82	0.056	2.07	0.635
		Silt + Clay	0.412	1.605	0.071	0.190	0.024	0.162	93.03	0.060	2.137	0.690
6	Kilimanur	Bulk sediment	0.142	0.808	0.050	0.023	0.004	0.077	79.25	0.026	0.803	0.253
		Medium sand	0.315	0.854	0.062	0.030	0.006	0.079	79.91	0.028	1.56	0.478
		Fine sand	0.309	1.146	0.074	0.038	0.012	0.152	83.61	0.041	2.04	0.647
		Very fine sand	0.358	1.367	0.078	0.081	0.017	0.179	90.83	0.057	2.139	0.695
		Silt + Clay	0.374	1.605	0.081	0.140	0.028	0.194	91.84	0.064	2.146	0.702
7	Alamkode	Bulk sediment	0.031	0.414	0.002	0.012	0.001	0.142	50.05	0.016	2.356	0.142
		Medium sand	0.075	0.455	0.005	0.016	0.002	0.165	57.28	0.022	3.064	0.265
		Fine sand	0.156	0.507	0.013	0.037	0.002	0.189	85.08	0.047	3.501	0.472
		Very fine sand	0.202	0.595	0.035	0.089	0.004	0.265	96.14	0.054	3.725	0.547
		Silt+clay	0.247	0.763	0.048	0.105	0.005	0.298	96.55	0.061	3.770	0.588
8	Attingal	Bulk sediment	0.085	0.504	0.008	0.005	0.001	0.137	40.55	0.027	2.597	0.198
		Medium sand	0.131	0.514	0.010	0.010	0.002	0.185	47.60	0.029	3.614	0.235
		Fine sand	0.148	0.527	0.015	0.017	0.002	0.199	83.48	0.043	3.821	0.438
		Very fine sand	0.252	0.605	0.040	0.099	0.003	0.252	99.9	0.058	3.928	0.567
		Silt+clay	0.257	0.869	0.045	0.125	0.004	0.297	96.85	0.062	3.975	0.592
9	Pulimutukadavu	Bulk sediment	0.277	0.618	0.051	0.021	0.004	0.138	7.96	0.002	0.970	0.046
		Medium sand	0.281	0.728	0.058	0.039	0.005	0.142	14.26	0.017	1.810	0.069
		Fine sand	0.389	0.770	0.067	0.057	0.007	0.163	30.70	0.049	4.578	0.132
		Very fine sand	0.420	1.064	0.075	0.081	0.007	0.184	35.59	0.061	4.90	0.160
		Silt+clay	0.453	1.209	0.081	0.090	0.008	0.190	36.70	0.075	4.972	0.245
10	Anchuthengu	Bulk sediment	0.347	0.318	0.063	0.028	0.005	0.145	6.06	0.008	0.860	0.045
		Medium sand	0.381	0.362	0.061	0.035	0.006	0.152	12.24	0.019	1.733	0.058
		Fine sand	0.469	0.576	0.077	0.047	0.007	0.163	28.10	0.046	3.848	0.272
		Very fine sand	0.480	0.704	0.075	0.078	0.007	0.197	33.54	0.061	5.00	0.306
		Silt+clay	0.493	0.949	0.080	0.091	0.008	0.202	37.40	0.076	5.802	0.335

Correlation coefficient: Pearson correlation (PC) matrix for analysed trace elements in sediments was calculated to find the interrelations of elements with each other in the bulk sediments and mud fraction and the results are presented in Tables 3a and 3b.

Zinc shows a positive correlation with Cr in the bulk sediments and mud fraction of Vamanapuram River. In the bulk sediment, it exhibits significant positive correlation with Fe, Cr and Mn, and shows a marginal positive correlation with Ni. Average concentration of Zn in mud fraction shows four times enrichment compared to the bulk sediment. The marked enrichment of Zn in the mud fraction can

Table 2: Trace metal analysis of river water (ppm).

Location number	Location name	Pb	Zn	Co	Cu	Cd	Cr	Fe	Ni	Mg	Mn
1	Vitura	ND	ND	ND	ND	ND	ND	0.234	ND	0.675	ND
2	Muduvila	ND	ND	ND	ND	ND	ND	0.247	ND	0.681	ND
3	Vamanapuram	ND	ND	ND	ND	ND	ND	0.289	ND	0.726	ND
4	Pullampara	ND	ND	ND	ND	ND	ND	0.292	ND	0.783	ND
5	Kadakkal	ND	0.256	ND	ND	ND	ND	0.294	ND	0.793	0.008
6	Kilimanur	ND	0.269	ND	ND	ND	ND	0.292	ND	0.790	0.008
7	Alamcode	ND	ND	ND	ND	ND	ND	0.423	ND	0.972	ND
8	Puvampara	ND	ND	ND	ND	ND	ND	0.438	ND	0.987	ND
9	Pulimutukadavu	ND	0.018	ND	ND	ND	ND	0.501	ND	1.208	ND
10	Anchuthengu	ND	0.021	ND	ND	ND	ND	0.524	ND	1.211	ND

Table 3a: Correlation among heavy metals in bulk sediments.

	Pb	Zn	Co	Cu	Cd	Cr	Fe	Ni	Mg	Mn
Pb	1									
Zn	-.044	1								
Co	.740*	.122	1							
Cu	.542	.203	.057	1						
Cd	.554	.222	.200	.637*	1					
Cr	.229	-.125	-.347	.803**	.201	1				
Fe	-.369	.594	-.409	.461	.213	.369	1			
Ni	.115	.058	-.356	.789**	.167	.915**	.467	1		
Mg	-.423	-.164	-.466	-.284	.005	-.145	.152	-.377	1	
Mn	-.029	.483	-.271	.658*	.522	.444	.831**	.440	.338	1

Table 3b: Correlation of mud fraction of sediments.

	Pb	Zn	Co	Cu	Cd	Cr	Fe	Ni	Mg	Mn
Pb	1									
Zn	.197	1								
Co	.677*	.487	1							
Cu	.248	.055	-.196	1						
Cd	.354	.415	.065	.638*	1					
Cr	-.518	-.365	-.898**	.083	.073	1				
Fe	-.310	.501	-.401	.777**	.406	.142	1			
Ni	.170	.328	-.530	.517	.506	.692*	.211	1		
Mg	.510	-.471	.514	-.246	-.451	-.538	-.366	-.224	1	
Mn	.030	.459	-.445	.706*	.680*	.442	.613	.777**	-.386	1

be explained by the increased surface area of the fine particles, which in turn favour its adsorptive capacity (Williams et al. 1978). Likewise, Fe, Mn and Zn concentration also shows a marginal increase in the downstream areas compared to the upstream side. The significant positive correlation of Zn with Fe and Mn also suggest a common source for these elements. Fe-Mn oxides are usually considered as an efficient scavenger for Zn (Singh & Subramanian 1984). These Fe-Mn oxides, which are products of weathering, can carry Zn and transport them to the river mouth.

In the bulk sediments, Ni exhibits better correlation with Zn, Cr and Fe. The comparatively high content of Ni in mud fraction can be explained by the fact that a significant part of Ni might have been held up in clay minerals either by adsorption or cation exchange mechanism. In the mud fraction, Pb shows significant correlation with Cd and Cr; Pb in bulk sediments show significant correlation only with Mg. Cr shows highly significant positive correlation with Fe, Mn and Zn in the bulk sediments. It also shows slightly positive correlation with Ni and Cu. In the mud fraction Cr exhibits positive correlation with Fe, Pb and Zn.

SUMMARY

Granulometric distribution of trace elements in medium sand, fine sand, very fine sand, silt and clay fractions has been determined and the variation is compared with that of the respective bulk sediments. The order of abundance of trace elements in sand fractions is Fe> Mg> Zn> Mn> Pb> Cr> Ni> Cu> Co>Cd, and in mud fractions is Fe> Mg> Zn> Mn> Cr> Pb> Cu> Ni> Co> Cd. The study reveals that the concentration of Fe and Mn in river sediments is many times higher in the mud fraction than the bulk sediment. The increase in the concentration of Fe and Mn in finer silts and clays is primarily related to the greater surface area. The study also reveals that the concentrations of the selected trace elements in sediment samples were very high in all sites compared to the concentration of the trace elements in water samples from the same site.

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