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Seasonal Variation of Heavy Metals Accumulation in Water and Oyster (*Saccostrea cucullata*) Inhabiting Central and Western Sector of Indian Sundarbans

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Abstract: Most estuaries receive high heavy-metal input from industries. This is reflected in the relatively high levels found in estuarine organisms. Seafood containing heavy metals as a result of environmental contamination causes toxicity in human beings. To evaluate such kind of contamination, this study targeted the analysis of selected metals in estuarine water and oyster (*Saccostrea cucullata*) collected from Indian Sundarbans. The heavy metals in tissue samples were estimated using a Perkin-Elmer Sciex ELAN 5000 ICP mass spectrometer. Significant variation of heavy metals in water and oyster tissues collected from four different sampling stations (2 each in central and western sector) of Indian Sundarbans were observed. The distribution of heavy metals in ambient water and *Saccostrea cucullata* followed the order Fe>Mn>Zn>Cu>Pb>Ni>Co>Cd and Zn>Fe>Cu>Mn>Pb>Co>Ni>Cd, respectively. Heavy metal concentration in the water and oyster tissues tended to vary significantly among season and monsoon period showed particularly high metal concentration compared to pre-monsoon and post-monsoon. However, due to urbanization and unplanned tourism, a negative impact has been exerted on the positive health of the aquatic system. The contamination of water is also transmitted in the biological compartment, many of which are consumed as food by the local people. The low salinity and intense industrialization in the Hooghly estuarine stretch may be attributed to high concentration of heavy metals in the oyster muscle inhabiting the western sector than Central sector of Indian Sundarbans.

Key words: Trace metals, *Saccostrea cucullata*, Indian Sundarbans, Hooghly estuary, monsoon, industrialization, urbanization, low salinity

INTRODUCTION

Heavy metal concentration in aquatic environment is critical concern, due to toxicity of metal and their accumulation in aquatic habitats. A large part of the heavy metal input ultimately accumulates in the estuarine zone and continental shelf, since these areas are important sinks for suspended marine and associated land-derived contaminants. Heavy metals introduced into the aquatic environment by dumping domestic and municipal wastes, industrial effluents, urban run off, agricultural run-off, atmospheric deposition and mining activities (Srinivasa *et al*., 2007).

Marine organisms accumulate and concentrate heavy metals to high levels. Consequently, they are widely used as biomonitors indicating the extent of metal pollution in coastal waters (Lacerda *et al*., 1985; Raposo *et al*., 2009). Marine molluscan acts as indicators of contamination levels which are widely used in international and national Mussel Watch Program. Marine bivalves such as oysters have shown to have many advantages as bio-indicators for monitoring trace substances in coastal waters because of their wide geographical distribution, sessile life style, easy sampling and tolerance of a considerable range of salinity, resistance and high accumulation of a wide range of chemicals. Dense populations and communities of marine bivalves are commonly found in tidal environments where water flow provides an energy subsidy to these sessile animals by transporting in food and taking away wastes and inorganic materials. In these systems, bivalves are closely coupled to the water column and heavily dependent on the exchange of water

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(Takeoka *et al*., 1991; Goldberg *et al*., 1978). The ability of bivalve to accumulate heavy metals in their bodies to elevated levels reaching concentrations that are much higher than those of ambient water concentrations makes these organisms useful for assessment purposes (Turkmen *et al*., 2005). However, there is no consensus whether transplanted bivalves can accumulate trace elements up to the values found in resident populations and how much time is necessary for them to reach environmentally representative concentrations. Oysters have been identified as good bioindicators of pollution in aquatic environments in worldwide coastal areas (Jaffe *et al*., 1999).

The oyster is a scientifically the best known marine animal in the world. Oysters have proved highly amenable to aquaculture and exploitation of wild populations that contributes little to worldwide oyster production (FAO, 2002). Oysters have been introduced worldwide to almost 73 countries, considered as ecosystem engineers are influencing many ecological processes that preserves biodiversity, population and food web dynamics and nutrient cycling. The oyster-bed is an example of biocoenosis or a social community of living beings (Jacqueline *et al*., 2009).

The present study was conducted in the Indian Sundarbans which is a large mangrove ecosystem in the north-east coast of India located at the apex of the Bay of Bengal (between 21°40/N-22°40/N latitude and 88°03/E to 89°07/E longitude). The presence of 34 true mangrove species and some 62 mangrove associate species (Mitra, 2000) in the zone is the only mangrove based home ground of Royal Bengal tiger (*Panthera tigris*) in the planet. The deltaic complex sustains 102 islands, out of which 48 are inhabited and 54 are uninhabited. The flow of Ganges (Bhagirathi) river through Hooghly estuary in the western sector of Indian Sundarbans to end up at Bay of Bengal has made the geographical situation totally different from the central sector where five major rivers have lost their root with Ganga-Bhagirathi system due to heavy siltation. The main sources of heavy metals in the Indian Sundarbans are the industries, fishing harbour, agricultural activity, Haldia seaport, urbanized wastes on the western sector of Indian Sundarbans along the bank of Hooghly estuaries (Mitra, 1998) (Table 1).

The most widely distributed species of oyster in Indian Sundarbans is *Saccostrea cucullata* which is found throughout the Indian ocean and tropical western Pacific (Mitra and Choudhury, 1992). *Saccostrea cucullata* is the most abundant bivalve in the Hooghly estuary and normally found attached to rocks, boulders and several underwater structures, submerged branches and trunks of mangroves, concrete embankments and piles and even on lighthouse bases of Indian Sundarbans ecosystem (Mitra *et al*., 1995). Here we attempted to understand with the 1 year data set the real situation in terms of heavy metal accumulation in edible oyster tissue and ambient aquatic system of Indian Sundarbans. The present paper aims to highlight the level of selective heavy metals (Fe, Zn, Mn, Pb, Cd, Co, Cu and Ni) in the muscle of Saccostrea cucullata and water body collected from the aquatic subsystem of four stations distributed in two sectors (western and central Indian Sundarbans) of the lower Gangetic region.

Table 1: Different sources of heavy metals in Indian Sundarbans (Mitra, 1998)

Trace metals	Sources of trace metals in in Indian Sundarbans
Zn	Galvanization units, paint manufacturing units and pharmaceutical processes
Cu	Antifouling paints, particular type of algicides used in different aquaculture farms, paint manufacturing units pipe line corrosion and oil sludges (32-120 ppm)
Pb	Discharge of industrial waste waters,such as from painting, dyeing, battery manufacturing units and oil refineries
Mn	Wastes from painting industry, pharmaceutical nit and galvanizing industry and other industrial operations
Ni	Untreated wastes from electroplating units, land fill, bubble bursting and gas exchange in ocean, weathering of soils and geological materials, galvanizing and other metal industries
Cd	Waste water from electroplating, fossil fuel burning, chemical industries, application of phosphate fertilizers and mining wastes from Pb-Zn mines without adequate treatment
Fe	Corrosion of pipe lines and pumps, explosive manufacturing units, floating old stranding and rusty barges in the coastal harbours
Co	Industrial effluents from metal industry

MATERIALS AND METHODS

Study area: Two sampling sites were selected each in the western and central sectors of Indian Sundarbans, a Gangetic delta at the apex of the Bay of Bengal. The deltaic complex has an area of 9630 km^2 and houses 102 islands. The western sector of the deltaic lobe receives the snowmelt water of mighty Himalayan glaciers after being regulated through several barrages on the way. It also receives wastes and effluents of complex nature from multifarious industries concentrated mainly in the upstream zone. The central sector on the other hand is fully deprived from such supply due to heavy siltation and clogging of the Bidyadhari channel since the late 15th century (Chaudhuri and Choudhury, 1992). The present geographical locale thus offers a unique test bed to study the effect of pollution on biological species. On this background four sampling stations (two each in western and central sectors) were selected to analyze the concentrations of heavy metals in the water body and *Saccostrea cucullata* (Table 2 and Fig. 1).

Table 2: Brief description of experimental area in Indian Sundarbans

Station	Coordinates	Salient features
Satjelia island (Stn. 1)	88°50′43″E 22°11′52″N	Located in the central sector of Indian Sundarbans. Noted for its wilderness and mangrove diversity; selected as the control zone
Bali island (Stn. 2)	88°39′46″E 22°15′45″N	Located in the Matla Riverine stretch in the central sector of Indian Sundarbans
Chemaguri (Stn.3)	88°09′11″E 21°39′49″N	Located in the western part of Indian Sundarbans and faces river Muriganga on the eastern side
Sagar South (Stn.4)	88°01′47″E 21°39′04″N	Situated at the confluence of the River Hooghly and the Bay of Bengal on the western sector of Indian Sundarbans This is selected most affected place of different anthropogenic pollution

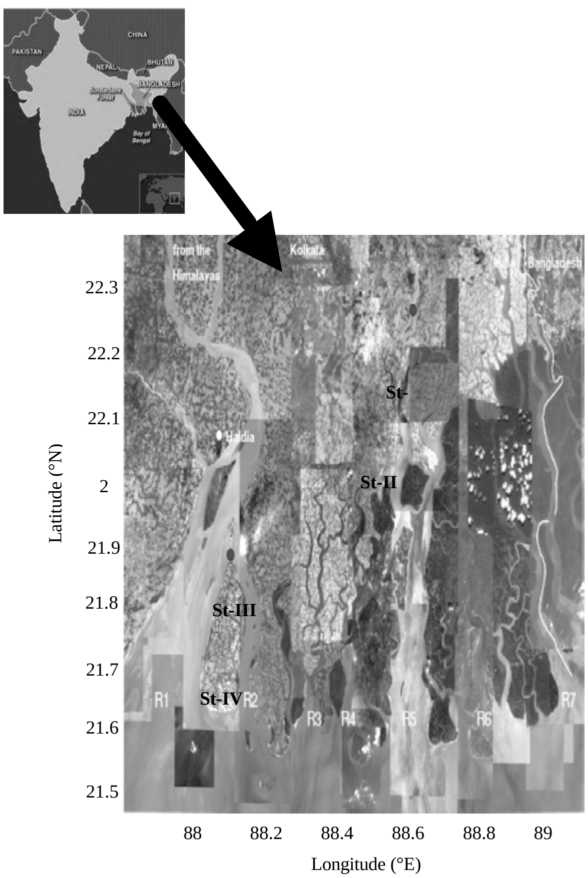

Fig. 1: Map of the study area

Analysis of trace metals in water: Surface water samples were collected using 10-1 Telfon-lined GO-FLO bottles, fitted with Teflon taps and employed on a rosette or on Kevlar line with additional surface sampling carried out by hand. Shortly after collection, samples were filtered through Nucleopre filters (0.4 μm pore diameter) and aliquots of the filters were acidified with sub-boiling distilled nitric acid to a pH of about 2 and stored in cleaned low density polyethylene bottles. Dissolved heavy metals were separated and pre-concentrated from the seawater using dithiocarbamate complexation and subsequent extraction into Freon TF, followed by back extraction into HNO_3. Extracts were analyzed for Zn, Fe, Cu, Mn, Co, Ni, Cd and Pb by A Perkin-Elmer Sciex ELAN 5000 ICP mass spectrometer. The accuracy of the dissolved trace metal determination is indicated by good agreement between the values and reported for certified reference seawater materials (CASS 3) (Table 3).

Table 3: Analysis of the reference materials of the near shore sea water (CASS-3)

Events	Zn	Fe	Pb	Cu	Mn	Ni	Co	Cd
Certified value (ppm)	1.24	1.26	0.012	0.517	2.51	0.386	0.05	0.030
Measured average (ppm)	1.20	1.25	0.010	0.510	2.50	0.370	0.04	0.025
Maximum (ppm)	1.30	1.50	0.020	0.525	2.70	0.390	0.08	0.035
Minimum (ppm)	1.15	1.20	0.005	0.508	2.45	0.365	0.02	0.020

Oyster collection and trace metal analysis: Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is now a day accepted as a fast, reliable means of multi-elemental analysis for a wide variety of sample types (Date and Gray, 1988). A Perkin-Elmer Sciex ELAN 5000 ICP mass spectrometer was used for the present analysis. A standard torch for this instrument was used with an outer argon gas flow rate of 15 L min^{-1} and an intermediate gas flow of 0.9 L min^{-1}. The applied power was 1.0 kW. The ion settings were standard settings recommended, when a conventional nebulizer/spray is used with a liquid sample uptake rate of 1.0 mL min^{-1}. A Moulinex Super Crousty microwave oven of 2450 MHz, frequency magnetron and 1100 W maximum power polytetrafluoro ethylene (PTFE) reactor of 115 mL volume, 1 cm wall thickness with hermetic screw caps were used for the digestion of the muscle samples of the *Saccostrea cucullata*. All reagents used were of high purity available and of analytical reagent grade. High purity water was obtained with a Barnstead Nanopure II water-purification system. All glasswares were soaked in 10% (v/v) nitric acid for 24 h and washed with deionised water prior to use.

The analyses were carried out on composite samples of 20 specimens of *Saccostrea cucullata* having uniform size. This is a measure to reduce possible variations in metal concentrations due to size and age. About 20 mg composite muscle samples were weighed and successively treated with 4 mL aqua regia, 1.5 mL HF and 3 mL H_2O_2 in a hermetically sealed PIFE reactor, inside a microwave oven, at power levels between 330-550 W, for 12 min to obtain a clear solution. The use of microwave-assisted digestion appears to be very relevant for sample dissolution, especially because it is very fast

Table 4: Concentrations of metals found in standard reference material DORM-2 from the National Research Council, Canada (all data as means±standard errors, in mg kg^{-1} dry weight)

Events	Zn	Fe	Pb	Cu	Co	Mn	Ni	Cd
Certified value (ppm)	830	539	0.37	66	2.25	18.50	1.04	4.15
Measured average (ppm)	820	530	0.36	64	2.20	18.45	1.02	4.10
Recovery (%)	99	98	97.00	97	98.00	99.00	98.00	98.00
Maximum	850	545	0.45	68	2.35	19.50	1.08	4.20
Minimum	810	525	0.30	58	2.15	18.30	1.01	4.05

(Nadkarni, 1984). After digestion, 4 mL H_2BO_3 was added and kept in a hot water bath for 10 min, diluted with distilled water to make up the volume to 50 mL. Taking distilled water in place of muscle samples and following all the treatment steps described above the blank process was prepared. The final volume was made up to 50 mL. Finally, the samples and process blank solutions were analyzed by ICP-MS. All analyses were done in triplicate and the results were expressed with standard deviation. The accuracy and precision of the results were checked by analyzing standard reference material (SRM, Dorm-2). The results indicated good agreement between the certified and the analytical values (Table 4).

Statistical analysis: A logarithmic transformation was done on the data to improve normality. Analysis of Variance (ANOVA) was performed to assess whether heavy metal concentrations varied significantly between sites, seasons and samples; possibilities <0.01 ($p<0.01$) were considered statistically significant. Statistical methods applied include correlation analysis ($p<0.01$) was done for find out the relationship between dissolved metals and trace metal accumulation of *Sacccostrea cucullata*.

RESULTS AND DISCUSSION

The accuracy of the analytical method was checked using two different certified reference materials, mussel tissues (SRM, Dorm-2) and water body (CASS-3) for heavy metal determination. These Certified Reference Materials (CRMs) were considered because no commercial oyster certified material was available at the monitoring study time and the similar matrix effects between water and oyster samples on the trace metal analysis could be assumed. The results (Table 3 and 4) are in good agreement with the certified values. The concentration of Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd in the water body and *Saccostrea cucullata* at the sampling stations exhibited a seasonal and station base oscillation. In the present study heavy metals accumulated in water body in the order Fe>Mn>Zn>Cu>Pb>Ni>Co>Cd and demonstrated a unique seasonal pattern with highest concentration during monsoon season and lowest during pre monsoon season (Fig. 2-5).

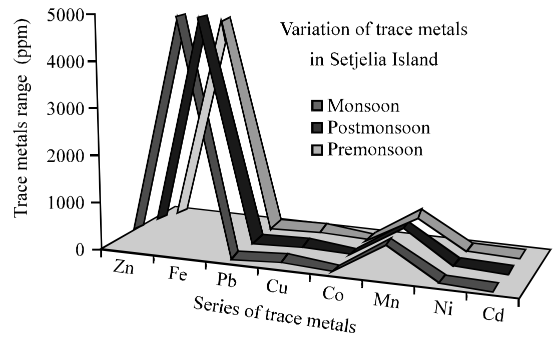

Fig. 2: Variation of dissolved trace metals in St-1

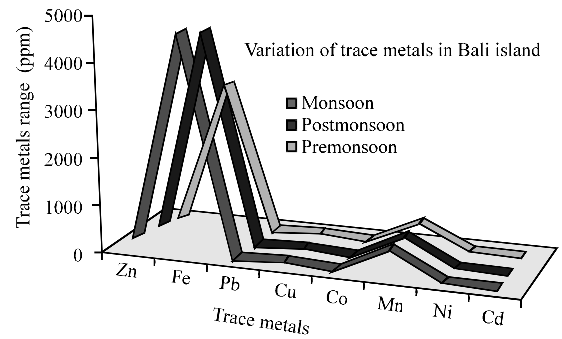

Fig. 3: Variation of dissolved trace metals in St-2

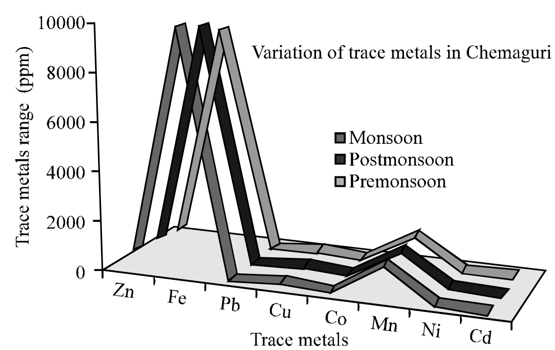

Fig. 4: Variation of dissolved trace metals in St-3

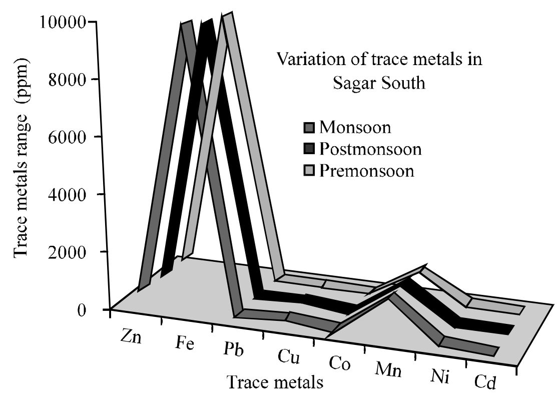

Fig. 5: Variation of dissolved trace metals in St-4

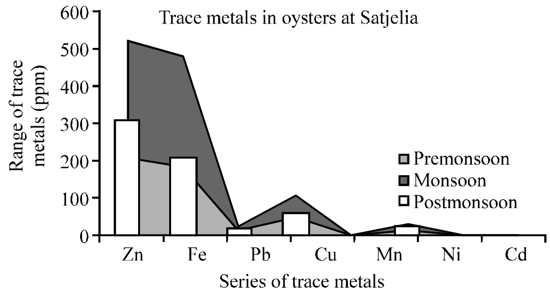

Fig. 6: Variation of trace metals in *Saccostrea cucullata* at St-1

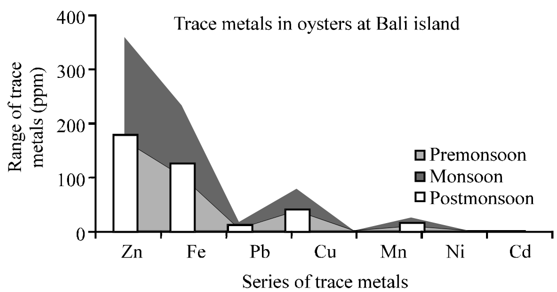

Fig. 7: Variation of trace metals in *Saccostrea cucullata* at St-2

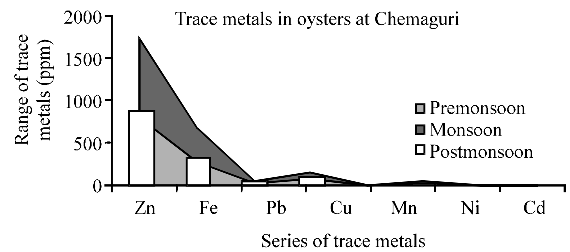

Fig. 8: Variation of trace metals in *Saccostrea cucullata* at St-3

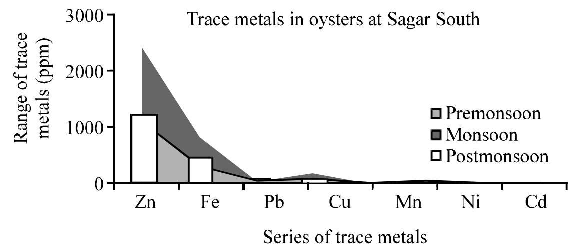

Fig. 9: Variation of trace metals in *Saccostrea cucullata* at St-4

Significant spatial variations of heavy metal concentrations in estuarine system of Indian Sundarban were observed between the selected stations which reflects the adverse impact of industrialization and urbanization on the coastal waters and found in the order, Sagar South>Chemaguri>Satjelia>Bali island. In the present study, trace metal concentration in *Saccostrea cucullata* followed the order Zn>Fe>Cu>Mn>Pb>Co>Ni>Cd.

Significant seasonal variation of trace metal accumulation (ppm) for *Saccostrea cucullata* observed that exhibited a unique seasonal pattern with highest values during the monsoon season. Moreover, the trace metal concentrations at four stations observed in the order Sagar South>Chemaguri>Satjelia>Bali island (Fig. 6-9).

Two-way Analysis of Variance (ANOVA) was used to assess the heavy metals concentration variation according to location and water and *Saccostrea cucullata*. Table 5 shows the Two-way ANOVA result of this study. In the present study, all the trace metal accumulation pattern between water and *Saccostrea cucullata* were completely differences ($p<0.05$) because all the cases it was found that $F_{obs>}F_{crit}$ The significant negative correlations ($p<0.05$) of trace metal accumulation between ambient water body and *Saccostrea cucullata* were observed in all the stations (Table 6-9).

The Hooghly estuary, situated on the western sector of the Indian Sundarban receives drainage from these adjacent cities which have sewage outlets into the estuarine system. The chain of factories and industries situated on the western bank of the Hooghly estuary is a major cause behind the gradual transformation of this beautiful ecotone into stinking cesspools of the megapolis (Mitra and Choudhury, 1992).

This estuarine complex is considered possibly the most polluted estuary in the world with almost a large number of main factories located close to the mouth discharging almost half a billion liters a day of untreated waste including the effluent from pulp and paper mills, pesticides manufacturing plants, distilleries, thermal power plants, yeast, rayon, cotton, vegetable oils, soap, fertilizers, leather manufacturing units and antibiotic plants.

About 1125 million liters of waste water is discharged per day through Hooghly estuary. A vital ingredient of the released wastes is the heavy metal (UNEP, 1992). In the present study all the trace metals concentration in water and *Saccostrea cucullata* were observed highest concentration at Sagar South and lowest recorded at Bali island. Continuous receiving industrial drainage of Kolkata, Howrah and Haldia port through Hooghly-Matla estuarine complex lead to such high level of trace metals in western sector of Indian Sundarban (Mitra *et al*., 2010).

The present study exhibited significant spatial variation in metal level in *Saccostrea cucullata* between the western and central sectors of Indian Sundarbans

Table 5: Two-way ANOVA analysis of heavy metals in water and *Saccostrea cucullata*

Metals	Variation	Sum of square	df	Mean square	F-ratio	p-value	F_{crit}
Fe	Seasonal difference	38885822	11	3535074.8	1.194189	0.386862	2.817930
	Events differences	248162129	1	248162129	83.832010	1.77	4.844336
Zn	Seasonal difference	1525127	11	138647.9	2.037728	0.126646	2.817930
	Events differences	509521.6	1	509521.6	7.488512	0.019252	4.844336
Cu	Seasonal difference	18847.96	11	1713.451	22.176400	6.33	2.817930
	Events differences	5323.175	1	5323.175	68.895380	4.59	4.844336
Pb	Seasonal variation	2808.024	11	255.2749	15.065340	0.000044	2.817930
	Events differences	316.6814	1	316.6814	18.689310	0.001208	4.844336
Mn	Seasonal variation	631176	11	57379.63	1.143295	0.4141	2.817930
	Events differences	4530514	1	4530514	90.270960	1.23	4.844336
Ni	Seasonal variation	1953.413	11	177.583	1.152854	0.4088	2.817930
	Events differences	6774.096	1	6774.096	43.976880	0.000037	4.844336
Cd	Seasonal difference	25.65565	11	2.332331	1.411113	0.288786	2.817930
	Events differences	27.4562	1	27.4562	16.611620	0.001833	4.844336
Co	Seasonal difference	231.3653	11	21.03321	2.839699	0.048802	2.817930
	Events differences	384	1	384	51.843930	0.0000175	4.844336

Table 6: Inter-relationship of heavy metals accumulation between water and *Saccostrea cucullata* in the Station-1

	Wzn	OZn	Wfe	Ofe	WPb	Opb	WCu	OCu	WCo	OCo	WMn	OMn	WNi	ONi	WCd	OCd
Wzn	1															
OZn	0.887744	1														
WFe	0.978006	0.772203	1													
OFe	0.305112	0.709249	0.099771	1												
WPb	0.740095	0.966593	0.58355	0.866247	1											
OPb	0.6734	0.938125	0.504394	0.909489	0.995546	1										
WCu	0.928239	0.6528	0.98541	-0.07103	0.436825	0.350077	1									
OCu	0.538707	0.866065	0.351135	0.966686	0.965273	0.985602	0.186654	1								
WCo	0.501175	0.843267	0.309662	0.976998	0.952864	0.977223	0.143316	0.999035	1							
OCo	0.776327	0.399015	0.890725	-0.36341	0.150658	0.05679	0.95509	-0.11284	-0.15638	1						
WMn	0.999349	0.903778	0.969842	0.33928	0.763882	0.699641	0.91421	0.568759	0.532077	0.753074	1					
OMn	0.98976	0.812943	0.997764	0.166052	0.636522	0.560978	0.971832	0.412931	0.372522	0.858352	0.983964	1				
WNi	0.456175	0.814617	0.260532	0.986641	0.936066	0.965065	0.092414	0.995471	0.998686	-0.20678	0.487992	0.324479	1			
ONi	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
WCd	0.77632	0.39901	0.89072	-0.3634	0.15065	0.05679	0.95509	-0.1128	-0.1563	1	0.75307	0.8583	-0.206	0	1	
OCd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

W = Water body, O = Oyster accumulation of trace metals

Table 7: Inter-relationship of heavy metals accumulation between water and oyster in the Station-2

	Wzn	OZn	WFe	OFe	WPb	OPb	WCu	OCu	WCo	OCo	WMn	OMn	WNi	ONi	WCd	OCd
Wzn	1															
OZn	0.25694	1														
WFe	0.57324	0.93916	1													
OFe	0.59279	0.93062	0.99971	1												
WPb	0.14860	0.99388	0.89547	0.88450	1											
OPb	0.66668	0.891617	0.99289	0.99547	0.83614	1										
WCu	0.31983	0.99784	0.95968	0.95264	0.98448	0.91941	1									
OCu	0.31086	0.99841	0.95698	0.94972	0.98609	0.91566	0.99995	1								
WCo	0.6779	0.88465	0.99097	0.99391	0.82773	0.99988	0.91335	0.90946	1							
OCo	-0.0541	0.95109	0.78713	0.77206	0.97939	0.70814	0.92876	0.93222	0.69735	1						
WMn	0.30056	0.99896	0.95379	0.94628	0.98783	0.91126	0.99979	0.99994	0.90491	0.93608	1					
OMn	0.25800	0.99999	0.93954	0.93103	0.99375	0.89211	0.99791	0.99848	0.88516	0.95075	0.99901	1				
WNi	0.60085	0.92690	0.99941	0.99995	0.87977	0.99637	0.94954	0.94653	0.99497	0.76563	0.94299	0.92731	1			
ONi	0	0	0	0	0	0	0	0	0	0	0	0	0	1		
WCd	-0.0541	0.95109	0.78713	0.77206	0.97939	0.70814	0.92876	0.93222	0.69735	1	0.93608	0.95075	0.76563	0	1	
OCd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

W = Water body, O = Oyster accumulation of trace metals

which may be due to different salinity profile as well as environmental conditions. The western part of the Gangetic delta is connected to Himalayan glacier through Bhagirathi river. Researchers pointed out that the glaciers in the Himalayan range are melting at the rate of 23 m year^{-1} (Hasnain, 2002). This along with Farraka discharge has resulted in gradual freshening of the system which has role in elevation of dissolved metal level in the system by way lowering of pH. The presence of chain of factories and industries along the bank of Hooghly estuary is another major cause of increased metal level in the aquatic phase of Hooghly estuary that have been reflected in the oyster muscles. The central sector on contrary is deprived from freshwater supply of Ganga-Bhagirathi system on account of siltation of Bidyadhari river in the 15th century. The Matla river, in the central sector is now tide fed with an increasing trend of salinity (Mitra *et al*., 2009). In the present study trace

Table 8: Inter-relationship of heavy metals accumulation between water and oyster in the Station-3

	Wzn	OZn	WFe	OFe	WPb	OPb	WCu	OCu	WCo	OCo	WMn	OMn	WNi	ONi	WCd	OCd
Wzn	1															
OZn	0.95541	1														
WFe	-0.9322	-0.7838	1													
OFe	0.86678	0.97538	-0.6276	1												
WPb	0.94262	0.99917	-0.7579	0.98353	1											
OPb	0.80071	0.94189	-0.5296	0.99278	0.95476	1										
WCu	0.91461	0.99322	-0.7063	0.99440	0.99712	0.97455										
OCu	0.91916	0.99448	-0.7143	0.99313	0.99792	0.97193	0.99993	1								
WCo	0.96892	0.99876	-0.8137	0.96319	0.99591	0.92401	0.98620	0.98802	1							
OCo	0.89859	0.98808	-0.6789	0.9977	0.99352	0.98236	0.99927	0.99878	0.97920	1						
WMn	0.88224	0.98191	-0.6521	0.99949	0.98879	0.98845	0.99726	0.99636	0.97128	0.99935	1					
OMn	0.99143	0.98579	-0.8769	0.92449	0.97815	0.87210	0.95959	0.96273	0.99293	0.94820	0.93617	1				
WNi	0.95152	0.99991	-0.7757	0.97814	0.99961	0.94615	0.99463	0.99575	0.99803	0.98999	0.98428	0.98354	1			
ONi	0.69553	0.87667	-0.3884	0.96118	0.89549	0.98733	0.92665	0.92230	0.85164	0.94026	0.95189	0.78342	0.88281	1		
WCd	0.95975	0.99988	-0.7931	0.97194	0.99844	0.93672	0.99135	0.99278	0.99939	0.98565	0.97895	0.98821	0.99960	0.86932	1	
OCd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

W = Water body, O = Oyster accumulation of trace metals

Table 9: Inter-relationship of heavy metals accumulation between water and oyster in the Station-4

	WZn	OZn	WFe	OFe	WPb	OPb	WCu	OCu	WCo	OCo	WMn	OMn	WNi	ONi	WCd	OCd
WZn	1															
OZn	0.95389	1														
WFe	0.99540	0.97824	1													
OFe	0.90845	0.99202	0.94429	1												
WPb	0.86615	0.97622	0.91002	0.99576	1											
OPb	0.99067	0.98589	0.99916	0.95693	0.92617	1										
WCu	0.90700	0.99158	0.94315	0.99999	0.99607	0.95592	1									
OCu	0.95560	0.99998	0.97942	0.99128	0.97496	0.98684	0.99082	1								
WCo	0.79305	0.93932	0.84772	0.97506	0.99134	0.86865	0.97582	0.93733	1							
OCo	0.29566	0.56876	0.38576	0.66789	0.73352	0.42307	0.67046	0.56402	0.81639	1						
WMn	0.92775	0.99699	0.95922	0.99881	0.99009	0.96995	0.99863	0.99652	0.96308	0.63080	1					
OMn	0.98207	0.99337	0.99560	0.97095	0.94483	0.99859	0.97012	0.99401	0.89365	0.47043	0.98146	1				
WNi	0.0208	0.31996	0.11645	0.43682	0.51771	0.15687	0.43992	0.31450	0.62554	0.96124	0.39244	0.20891	1			
ONi	0.99895	0.93919	0.98999	0.88842	0.84243	0.98342	0.88683	0.94115	0.76441	0.25174	0.90975	0.97244	-0.0248	1		
WCd	0.73398	0.90399	0.79563	0.95067	0.97517	0.81968	0.95173	0.90151	0.99580	0.86581	0.93441	0.84884	0.69431	0.70221	1	
OCd	0.99894	0.93919	0.98999	0.88842	0.84243	0.98342	0.88683	0.94115	0.76441	0.25174	0.90975	0.97244	-0.024	1	0.70221	1

W = Water body, O = Oyster accumulation of trace metals

metal accumulation in *Saccostrea cucullata* exhibited a unique seasonal pattern with highest values during the monsoon season and lowest during pre-monsoon season. This variation may be attributed to huge run-off from the adjacent land masses during the monsoon. During monsoon, the dilution factor (df) of all the sampling stations in the coastal and estuarine zone of West Bengal increase manifold which results in the decrease of salinity and pH. The lowering of pH might facilitate the dissolution of the precipitated form of metals and increase the amount of metallic ions in solutions (Mitra, 1998; Bansal, 1998).

In the present study, Pb concentration level (17 ppm) in *Saccostrea cucullata* was significantly different with respect to the other trace metals. Present study indicated the concentration of Pb found higher range (5.10-30.60 ppm) than recommended value for FAO/WHO (1992) as 0.05 ppm, US-FDA (2003) as 1.7 ppm for sea food. Mtanga and Machiwa (2007) stated that high level of Pb in *Saccostrea cucullata* found indicative of the contributions of heavy metal pollution from several anthropogenic sources such as industrial and agricultural activities. Central Sundarbans exposed to all these activities being proximal to the highly urbanized city of Kolkata, Howrah and the newly emerging Haldia port-cum-industrial complex. On the other hand, western Sundarbans fall in the navigational route of the ships and tankers for Haldia port. This Hooghly channel is also the recipient for the wastes of the upstream region that finds its way to the Bay of Bengal. Oysters normally accumulate high concentrations of Cu and Zn (Engel and Brouwer, 1982) and considered strong net accumulators of both metals (Rainbow *et al*., 1990). Present study showed that the average range of Zn level in *Saccostrea cucullata* was 626 ppm which is higher range 100 ppm by World Health Organization (WHO, 1989) but lower than Food and Agricultural Organization (FAO/WHO, 1992) level as 1000 ppm for Zn in sea food. Present study showed that *Saccostrea cucullata* at Sagar South accumulated high range of Zn level (1096.45-1321.50 ppm) for all the year round. Largest delta of Indian Sundarbans and large number of fishing vessels and trawlers in adjacent island to the fishing harbours may be one possible source of contamination of this metal through antifouling paints.

Present study indicated that *Saccostrea cucullata* is at high risk of Cu pollution in the western Sundarbans. WHO (1989) and FAO/WHO (1992) proposed the standardization of Cu range of marine sea food 30 and 10 ppm, respectively but the range of this metal in *Saccostrae cucullata* (34.80-116 ppm) indicated far away from certified value. Genrally, Ship bottom paints has been found to produce very high concentration of Cu in seawater and sediments in harbours of Great Britain and southern California (Bellinger and Benham, 1978). From the different investigation, it was found that western sundarbans exhibited maximum Cu concentrations in the surface water and aquatic living organisms which can't only be attributed to the conditioning of huge number of authorized and unauthorized fishing vessels, trawlers, traveler boat and cargo ships in the creeks and bay regions but also to the leaching from several aquacultural farms in the area that use Cu compounds as algicide (Mitra, 1998).

From the ANOVA analysis, significant seasonal differences ($p<0.05$) have been found between water and *Saccostrea cucullata* for the accumulation of Cu and Pb because of run off process the load of heavy metal changes with season. According to Hashmi *et al.* (2002) continental sources (river runoff and atmospheric transport), oceanic sources (upwelling) and digenetic exchanges at water-sediment interface have been identified as the factors that influence the heavy metals in coastal aquaculture organisms. Moreover, anthropogenic atmospheric inputs, sewage sludge and fertilizers are often inferred to be significant because of important these metals input. The relationships evaluated between metal concentration and season and location sites suggest an influence of age and physiological patterns of oysters in metal uptake. This fact may condition the interpretation of the experimental data and multivariate analysis was found as an important tool to interpret the analytical data obtained. In that sense, ANOVA and correlation analysis confirmed that trace metals patterns vary throughout the sampling area and reflect contaminant source locations.

Regarding the economic significance of this bivalve mollusk, favourable natural farming conditions and planned production increase, more detailed knowledge of the spatiotemporal distribution of this element would allow the appropriate planning of production locations and sale of the final product in the market. In addition, increased metal concentrations can be expected owing to the global warming effect (Sokolova, 2004) and the planning of prevention measures, e.g. use of triploids for their faster growth (Amiard *et al.*, 2005), demands more detailed knowledge and awareness of the current state.

CONCLUSION

The knowledge of heavy metal concentrations in native species is very important with respect to nature management, human consumption of these species and to determine the most useful biomonitor species and the most polluted area. The River Ganga in the Indian sub-continent is the lifeline of millions in terms of livelihood and natural resources.

However, due to rapid industrialization, urbanization and unplanned tourism, a negative impact has been exerted on the positive health of the aquatic system. The contamination of water is also transmitted in the biological compartment, many of which are consumed as food by the local people. The present study is important not only from the human health point of view but it also presents a comparative account of heavy metals in water and oyster *Saccostrea cucullata* from western and central two sectors of Gangetic delta that are physico-chemically different.

The present zone of investigation situated in and around Indian Sundarbans, a world Heritage site, demands regular monitoring of metal status for effective management and conservation of this famous mangrove gene pool. Industrial discharge and heavy use of agriculture contaminants such as fertilizers and pesticides should be controlled as a remedy to minimize coastal pollution in Indian Sundarbans. The high concentrations of heavy metals in *Saccostrea cucullata* from Western Sundarbans is a cause of concern and requires regular monitoring of water quality around the point sources present opposite to the western bank of the island.

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