ISSN 2321–340X

Journal of Aquatic Biology & Fisheries | Vol. 3 | 2015 | pp. 90-97

TRACE METAL DISTRIBUTION IN VELI LAKE, TRIVANDRUM, KERALA, SOUTHWEST COAST OF INDIA

Tresa Radhakrishnan, Nansimole, A.,* Sruthi, S., Gayathri Devi, T.V. and Sujatha, M.K.

Department of Aquatic Biology and Fisheries, University of Kerala, Trivandrum, Kerala, India
**Email: nansimolea@gmail.com*

Abstract: The distribution of trace metals such as Copper, Zinc and Lead in water, sediment and biota of Veli lake, a typical tropical bar built estuary in Kerala was estimated in three seasons namely monsoon (June-September), post-monsoon (October-January) and pre-monsoon (February-May). Among the trace metals studied, Copper was found to be the most abundant and Lead was the least in water, sediment and biota. In water, Zinc and Lead did not show significant seasonal variation. The study indicated that the concentration of all these three trace metals varied significantly between fishes. Copper concentration in water and sediment was recorded as very high in monsoon season, Zinc in post-monsoon and Lead in sediment showed high in monsoon season. It is a well-known fact that no organic life can develop and survive without the participation of metal ions and therefore some of these trace metals or micronutrients are essential to sustain biologic life. In this case, Copper and Zinc are essential elements, whereas Lead is nonessential as well as toxic to aquatic life. This study will through light on the extent and environmental ramification of heavy metal concentration in Veli Lake, which pose a serious threat to the living aquatic resources if these elements particularly the non-essential elements exceed the accepted permissible limit in aquatic systems.

Key words: Bar-built estuary, Trace metals, Biomonitoring, Bioaccumulation, Veli Lake.

INTRODUCTION

Ocean and coastal waters are one of the major resources for a variety of human activities like fisheries, agriculture, navigation, oil and mineral exploration and waste disposal (IMCO *et al.*, 1982). But in recent years man made sources have substantially increased the flux of many pollutants to the marine environment *via* atmosphere, surface runoff and direct discharge. The elevated concentration of such pollutants in the water body makes it unfit for biological consumption. The deterioration of water quality influences not only the aquatic biotic processes but the terrestrial life activities also. The impact of aquatic pollution may cause severe health hazards even to human life.

Heavy metals form a dangerous group of potentially hazardous pollutants, particularly in estuaries and nearshore waters (Bryan, 1984). High concentrations of heavy metals in the aquatic environment constitute serious threat to the aquatic life. Not only these substances involved are very toxic but they are also very persistent. The persistence of these substances leads to the concentration and bioaccumulation of them in living organism and can be transferred from one member to the other of the food chain. Bioaccumulation of these chemicals will reduce the quality of the commercial fishery products. The enrichment of trace metals within certain animals and their transfer through food chain to higher animals invite danger to man. High amounts of Zinc and Copper would cause symptoms of nausea and vomiting, the toxic effect of mercury is well known (Lakshmanan and Nambisan, 1977). Tragedies like 'Minamata' disease by mercury poisoning, 'itai-itai' disease by the intoxification of Cadmium, Zinc and Lead (Kobayashi, 1971) and occurrence of plumbism in man by lead poisoning were reported (Williams and Bobby, 1979).

Coastal marine ecosystems are vulnerable to adverse impacts from various urban and industrial developmental activities, which could facilitate the disposal of several chemical agents, with consequent degradation in the water quality causing serious health hazards to the aquatic organisms (Naqvi *et al.*, 2000; Jayakumar *et al.*, 2001; Balachandran *et*

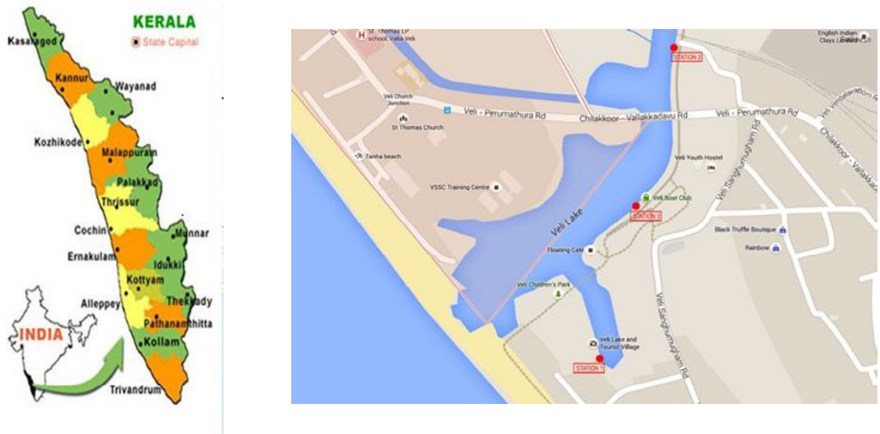

Fig. 1. Location map showing study sites

during the digestion process. While heating of samples, brown fumes of NO_2 started to evolve. The digestion process was continued until the brown fumes of NO_2 become colourless. When the solution become colourless and brought down to near dryness the digested samples were taken out of the hot plate and kept for a while for cooling down to room temperature. Aliquots of double-distilled water were added along the sides of the flask and rinsed the flask thoroughly with the contents. The digested samples with distilled water were filtered down through Whatmann No.40 filter paper into a 25 ml volumetric flask and the same was made up to 25 ml by adding aliquots of double distilled water. The made up samples (25 ml) were transferred into plastic vials and stored in the refrigerator for further analysis of metals by using the method, Atomic Absorption Spectrophotometer. Sample preparation was done as per the standard method (EPA, 1972; APHA, 1978). Standards of all the elements were prepared as per the preparation protocol of APHA (1978, 1985, 1998) and the calculation of the selected metals in selected tissues; water and sediment were calculated as per the following formula,

Concentration of the metal in the sample

$$= \frac{\text{AAS reading x Vol. of sample x dilution factor (if any)}}{\text{Dry weight of the material (g)}}$$

and the results were expressed as µg. l^{-1} for water and µg .g^{-1} air dry wt. for sediment and tissues

RESULTS AND DISCUSSION

The distribution of trace metals in water, sediment and biota of Veli Lake during three seasons were estimated and summarized in Table I and Figs. 2-4. The whole investigation period is divided in to three seasons premonsoon (February-May), monsoon (June-September) and postmonsoon (October-January). Analysis of variance of the different parameters was carried out and the data are included in Table 2. Studies showed that Copper was the most represented element among the three metals under investigation. In water and sediment high concentration of Copper were observed in all the stations during monsoon season and the seasonal mean range from 0.72 µg l^{-1} to 2.27 µg l^{-1} (Table 1). The maximum mean concentration in sediment (393.67 µg g^{-1}) was registered at station 1 and minimum (30.73 µg g^{-1}) at station 3. Results of ANOVA show that the Copper content in water, sediment and soft tissues did not show significant variation between the three stations. But significant variation is observed in the monthly and seasonal values. No positive correlation was observed between the copper content in water and sediment. High values of Copper were determined in the soft tissues than sediment and water. Among the animals the maximum concentration was determined in Scylla followed by Villorita and fishes. In Villorita the maximum seasonal mean values (271.75 µg g^{-1}) was observed during postmonsoon season at station 1.

Table 1. Trace metals (μg l-1) in water,sediment and animals (μg g-1 air dry wt.) fromVeli Lake(Mean± S.D).

		Stations						Animals			
		Water			Sediment						
		1	2	3	1	2	3	Villorita	Scylla	Gerrus	Caranx
Copper	Mon	2.27±0.55	2.17±0.39	1.78±0.23	393.67±112.11	305.83±61.36	352.55±104.42	111.4±29.31	258.33±143.88	66.34±9.44	71.28±19.12
	Pre	0.89±0.23	0.72±0.11	0.9±0.32	59.4±10.24	40.51±6.57	30.73±2.03	242.44±51.68	203±94.49	68.28±3.92	216±57.01
	Post	1.97±0.66	1.82±0.81	1.91±0.96	48±9.16	35.01±0.52	34.88±2.93	120.4±74.41	118.1±33.4	42.05±5.91	81.38±53.45
Zinc	Mon	0.39±0.22	0.43±0.08	0.66±0.08	119.56±8089	97.22±8.14	89.03±11.20	54.07±6.95	102.19±8.82	101.9±5.0	82.88±15.29
	Pre	0.68±0.16	1.06±0.37	1.05±0.47	93.01±18.9	53.63±14.63	43.87±4.74	138.83±29.07	118.73±9.16	108.46±11.6	80.94±4.81
	Post	0.99±0.25	0.38±0.06	0.94±0.47	83.97±8.09	43.38±3.21	46.37±8.67	109.94±9.79	165.18±9.01	64.13±19.56	130.53±14.81
Lead	Mon	1.23±0.87	2.24±2.14	0.57±0.19	125.05±12.0	138.83±18.84	202.15±30.5	143.29±48.83	40.89±16.74	7.4±4.17	13.4±13.2
	Pre	2.18±1.49	2.83±1.86	1.23±	72.63±24.79	55.5±51.42	29.3±11.59	103.44±36.93	69.2±7.35	86.65±20.32	92.74±9.82
	Post	0.86±0.33	0.56±0.31	1.1±0.66	80.7±22.09	35.88±7.40	51.5±4.08	71.14±23.19	43.88±4.91	25.43±13.6	34.1±10.91

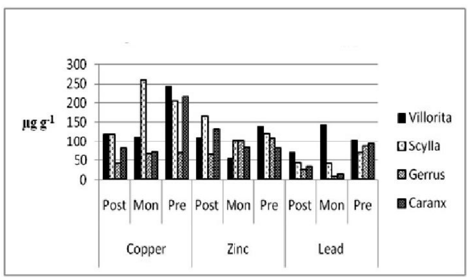

Fig. 4. Trace metals in animals (μg l^{-1})

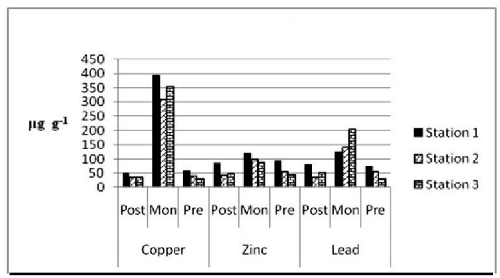

Fig. 3. Trace metals in sediments (μg g^{-1})

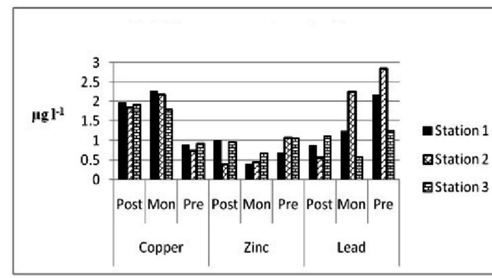

Fig. 2. Trace metals in water (μg $^{l-1}$)

The concentration in Villorita was well correlated with that of fishes. In Scylla the maximum values for seasonal mean was determined during monsoon (285.33 µg g^{-1}) and minimum during premonsoon season (118.10 µg g^{-1}). The tissue concentration in Scylla is positively correlated with that of Gerrus. Among fishes Caranx recorded high values of Copper. All three species of fishes maximum concentration was observed in the postmonsoon season. There is significant variation in Copper content during different seasons and different months.

In animal tissues high Zinc content was noticed during postmonsoon season. The distribution of Zinc shows no significant variation in concentration between the three stations. Eventhough the monthly values differ slightly, the seasonal mean show that the variation is not significant. Station 2 showed slightly high values of seasonal mean and station 1 had low values. In sediment the concentration of Zinc appeared to be seasonally dependent with high levels (119.56 µg g^{-1}) occurring in all stations during monsoon and low levels (43.87 µg g^{-1}) in premonsoon season (Fig 3). Zinc concentration in Villorita from the two sampling sites was apparently similar in magnitude and statistical analysis failed to resolve significant inter locational difference. The distribution of Zinc in the bivalve mollusc seems to be well influenced by season (Table 2). The highest and lowest values recorded were 160.08 µg g^{-1} and 90.43 µg g^{-1} observed at station 1and 3 respectively. The concentration of this metal was found to be more or less uniform during periods within seasons (Table 2). As in Copper, the Zinc content was comparatively high in Villorita from station 3 during all seasons. Seasonal and monthly variations in zinc concentration were not significant (Table 2). The maximum seasonal mean value is 165.18 µg g^{-1} and the minimum 102.19 µg g^{-1}. Seasonal and monthly variation in Zinc concentration was not significant (Table 2). The maximum seasonal value is 165.18 µg g^{-1} and the minimum 102.19 µg g^{-1} during premonsoon and monsoon respectively. Zinc content in Scylla showed positive correlation with Caranx and water concentration. In fishes considerable variation ($p< 0.05$) between the concentration of Zinc in the 2 species of fishes observed. Gerrus recorded high values followed by Caranx (Table 1). Tissues showed high values of Lead content than sediment and water. Lead content in Villorita was fond to be higher than in other organisms (Table 1). In water the concentration of Lead was below the detection limit during certain months (December, January, March and August) in all the three stations (Fig.2). Like Copper the concentration of Lead is also almost similar in all the stations and during all seasons, though monthly values differ slightly ($P<0.05$). There is not much variation of lead concentration in sediment between the three stations. Monthly variations are in significant. Mean values were different during different seasons ranging from 29.30 to 202.15 µng g^{-1} in station 3 during premonsoon and monsoon respectively. In Villorita the tissue concentration of Lead seems to be almost similar from staion1 and 3. Seasonal and monthly variations are found to be significant ($P< 0.05$, $P< 0.01$). The maximum seasonal mean concentration 188.50 and minimum 64.75 µg g^{-1} was obtained during monsoon and premonsoon seasons respectively in specimens collected from station 3. The maximum Lead concentration in Scylla was observed during postmonsoon (69.20 µg g^{-1}) and minimum during monsoon (40.89 µg g^{-1}). The concentration of Lead in Scylla is found to be positively correlated with that of water and Caranx. Among animals, Scylla recorded high values (0.2-3.84 µg g^{-1}) and very low values in Gerrus (Fig.4).

The present study clearly demonstrated that the different seasons greatly influenced the concentration of trace metals in water, sediment and tissues. The present results showed that Copper was the most dominant element among the three elements determined. The order of incidence of Copper, Zinc and Lead in the selected organisms, sediment and water were Scylla > Villorita > Fishes > Sediment > Water.

Among the trace metals studied, Copper was found to be the most abundant element and cadmium the least in water, sediment and biota. In water, Zinc and Lead did not show any marked seasonal variations. The study indicated that the concentration of all these three trace metals varied significantly between fishes. Copper concentration in water and sediment was the maximum during monsoon; however, Zinc concentration in water and sediment

Table 2. Analysis of Variance of Trace Metals in Water, Sediment and Tissues

		Copper			Zinc			Lead		
Source	df	ss	mss	F value	ss	mss	F value	ss	mss	F value
Water										
Total	35	76.388			11.47			179.2		
Stations	2	0.21	0.11	0.91	0.44	0.22	1.05	4.99	2.49	0.76*
Seasons	2	10.72	5.36	45.56**	1.19	0.59	2.82	9.35	4.67	1.43
Periods within Seasons	9	62.85	6.98	59.33**	5.2	0.58	2.74*	93.11	10.35	3.17*
Error	22	2.59	0.12		4.64	0.21		71.75	3.26	
Sediment										
Total	35	1112650			37474.64			167558.5		
Stations	2	10027.38	5013.69	1.91	10862.11	5431.06	10.27**	2276.78	1138.39	0.39
Seasons	2	765242.3		145.43**	13786.7	6893.35	13.03**	81833.94	40916.97	14.00**
Periods within Seasons	9	279500.5	31055.61	11.80**	1190.09	132.23	0.25	19150.22	2127.8	0.73
Error	22	57880.06	2630.91		11635.73	528.9		64297.59	2922.62	
Villorita										
Total	23	325548.8			38454.88			149118.8		
Stations	1	7169.75	7169.75	2.05	3170.72	3170.72	3.52	5077.41	5077.41	2.47
Seasons	2	85744.38	42872.19	12.24**	8079.66	4039.83	4.49**	20897.13	10448.56	5.08*
Periods within Seasons	9	194102	21566.89	6.15**	17304.59	1922.73	2.14	100536.3	11170.71	5.44**
Error	11	38532.63	3502.97		9899.91	899.99		22607.94	2055.27	
Scylla and Fishes										
Total	47	775349.1			56789.13			58500.92		
Stations	3	129191.8	43063.94	3.27*	21538.13	7119.38	8.34**	9806.91	3268.97	4.83**
Seasons	2	46073.25	23036.63	1.75	2941.31	1470.66	1.72	18297.31	9148.66	13.51**
Periods within Seasons	9	165861.3	18429.04	1.4	4319.5	479.94	0.56	8050.95	895.55	1.32
Error	33	434222.8	13158.27		28170.19	853.64		22345.75	677.14	
Fishes										
Total	35	247024.2			42425.94			49451.95		
Stations	2	25754.69	12877.34	3.47*	18442	9221	10.26**	6991.89	3495.95	4.39*
Seasons	2	43589.03	21794.52	5.87**	86.56	43.28	0.05	17190.48	8595.24	10.78**
Periods within Seasons	9	96040.13	10671.13	2.88*	4124.22	458.25	0.51	7731.47	857.05	1.08
Error	22	81640.81	3710.95		19773.16	898.78		17538.1	797.19	

* (P< .05) ** (P < .01)

had the maximum during postmonsoon and monsoon respectively. Among the animals, zinc concentration was the maximum in *Scylla serrata* and marked variation between the three fishes were noticed. In *Villorita cyprinoides*, seasonal fluctuation was well marked. High lead concentration was noticed in the sediment during monsoon. The tissue concentrations of lead differed markedly between different fishes and the seasonal changes were remarkably highlighted.

Among the trace metals studied, Copper was found to be the most abundant element, It was similar with the findings of Dipu and Anju (2012) that a very high concentration of Cu was noticed in all the samples compared with the standard value (30 mg/kg— USPHS 1997) in the sediments of Cochin estuary. Investigations by earlier workers like Wright (1978), Denton and Jones (1981), Lakshmanan and Nambisan (1983), Rajendran and Kurian (1986) and Nair *et al.* (1987) indicated seasonal variation in trace metal content in the different compartments namely, water, sediment and biota. Wright (1978) suggested that the natural metal levels in the aquatic systems are affected by temperature, salinity, suspended matter and industrial sources and these factors have an important bearing on the bioaccumulation of heavy metals, moreover the metal concentration decreased towards the bar mouth region where the salinity was high (Rajendran and Kurian, 1986; and Nair, 1990). The trace metal concentration in sediment revealed comparatively low values during premonsoon than in other two seasons. Nair *et al.* (1987) in the sediments of Ashtamudi estuary and Anju *et al.* (2011) in Cochin estuary and Periyar River also reported similar values. The present study results showed a positive correlation between the metal concentration in sediment and tissues. Cross *et al.* (1970) reported that it is difficult to correlate metal concentration in organisms with those in the sediment. Trace metal concentration in sediment indicated that the concentrations are hundred times greater than that of water. Carol *et al.* (1978) suggested that the higher concentration of trace metals in sediment than in water is due to the adsorption of metals by the sand causing a reduction of the concentration in the water immediately over the surface of the sand.

From the present study it was observed that, the concentration of all the three trace metals in the tissues was found to be several times more than that present in water. The observations by Brooks and Rumsby (1965), Pringle *et al.* (1968) and Fernandez and Jones (1989) indicated that aquatic invertebrates have the ability to concentrate copper and other metals several thousand fold above the ambient water levels. This view has been further supported by Lakshmanan and Nambisan (1986) in the case of tropical bivalve, *Perna viridis* of Cochin backwaters. Investigation by Sivadasan and Nambisan (1988) in Cochin backwaters showed a decrease of zinc concentration in water during monsoon and this view was attested by the present study results.

Lead concentration in *Villorita cyprinoides* was found to be high compared to the other animals and the result showed marked variation in different seasons and also at different stations. It is a well known fact that no organic life can develop and survive without the participation of metal ions, and therefore some of these trace metals or micronutrients are essential to sustain biologic life. The results of this study clearly revealed that Veli Lake is having detectable levels of trace metals and the animals, sediment and water from Veli Lake reflected a true replica of the same. The concentrations detected in the animals and sediment is more or less similar in their concentration, but water had considerably lower concentration than the other two compartments. Both the essential and non essential elements are exhibited in all the three compartments of Veli Lake in permissible limits and hence there is no reason for concern. It is also important that there should be a constant vigil on the discharge of wastes in to the water body as they will enhance the overall input of trace metals which will badly affect the health status of life in aquatic systems.

REFERENCES

Anju A. Kumar, S. Dipu, and V. Sobha, 2011. Seasonal Variation of Heavy Metals in Cochin Estuary and Adjoining Periyar and Muvattupuzha Rivers, Kerala, India, Global Journal of Environmental Research 5 (1): 15-20

APHA. 1978. *Standard Methods for Examination of Water and Waste Water*. American Public Health Association. New York.

APHA, 1985. *Standard Methods for Examination of Water and Wastewater*. American Public Health Association, Washington, D.C.

APHA, 1998. *Standard Methods for Examination of Water and Wastewater* (20th ed.), American Public Health Association, Washington, D.C.

Balachandran K.K, Thresiamma Joseph, Nair K.K.C., Maheswari Nair., and Joseph P.S., 2002. The complex estuarine formation of six rivers (Cochin backwater system on west coast of India) e sources and distribution of trace metals and nutrients, In: Proceedings of the Symposium on 'Assessment of Material Fluxes to the Coastal Zone in Southeast Asia and their Impacts', APN/SASCOM/LOICS Regional Workshop, Negombo, Sri Lanka, 8-11 December, 2002, pp.103-113

Breievora, E., Vajczikova, I., Sainkova, V., Stratilova, Fisera, M., Gregor, T., and Sajbidor, J. 2002. Biosorption of cadmium ion by different yeast species, Z. *Naturforsch*, 57c: 634-639.

Brooks, R.R and Rumsby, M.G.1965. The biogeochemistry of trace element uptake by some New Zealand bivalves. *Limnol. Oceanogr*., 10: 521-527

Bryan, G.W. 1984. Pollution due to heavy metals and their compounds. *In: Marine Ecology*, 5: Part III. Ed.O.Kinne. John Willey and Sons, New York, pp.1229-1431

Carol, E. Pesch and Morgan, D. 1978. Influence of sediment in copper toxicity tests with the polychaete, *Neanthes arenaceodentata*. *Water Research*, 12**:** 747-751.

Ciji, P.P. and Bijoy Nandan, 2014. Toxicity of Copper and Zinc to *Puntius parrah* (day, 1865), *Marine Environmental Research*, 93: 38-46

Cross, F.A., Duke, T.A and Willies, J.N. 1970. Biogeochemistry of trace metals in a coastal plain estuary. Distribution of manganese, iron and zinc in sediments, water and polychaete worms. *Chesapeake Sci*., 11: 221-234

Danielsson, L.G., Magnusson, B and Westerlund, S. 1978. An improved metal extraction procedure for the determination of trace metals in sea water by atomic absorption spectrometry with electro chemical atomization. *Anal. Chim. Acta*., 98: 47-57

Danielsson, L.G., Magnusson, B and Westerlund, S. 1982. Trace metal determination in estuarine waters by electrochemical atomic absorption spectrometry after extraction of dithio carbamate complexes into freon. *Anal. Chim. Acta*., 144: 183-188

Denton,G. R.W and Jones, B.C. 1981. Trace metals in fish from Great Barrier Reef. *Mar. Poll. Bull*., 17: 201-209

Dipu, S. and Anju. A. Kumar. 2012. Distribution of mercury and other trace metals in the sediments of Cochin estuary (a Ramsar site), Kerala, India. *Environ. Moni. Assess*. 184: No.12.

EPA, 1972. Methods for Chemical Analysis of Water and Wastes. United States Environmental Protection Agency, EPA-6004-79-020, USA. Methods: 110.1-430.2

Fernandez. T.V. and Jones, N.V. 1989. The distribution of zinc in the body of *Nereis diversicolor*. *Trop. Ecol.,* 30: 285-293

Gorbi, G. and Companini, G. 1983. Cadmium and chromium in the water, sediment and biota of the Valparma running water ecosystem. Schhweizervart Sche. Verlagsbuchhandlung, Stuttgert (FRG), 22: 198-199

Honjoh K., Sugawara A., Yoda K., and Yamasaki M., 1997.Isolation and characterization of nickel accumulating yeast. *Applied Microbiology and Biotechnology*, 48: 373-378

IMCO/ FAO/ UNESCO/WMO/WHO/IAEA/UN/UNEP. 1982. Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP). The Review of the Health of the Oceans. *Rep. Stud. GESAMP*., 15 : 108

James, R. O. 1978. Effects of heavy metals on aquatic life. Canberra, Commonwealth Scientific and Industrial Research Organization, Australia.

Jayakumar, D.A., Naqvi, S.W.A., Narvekar, P.V. and George, M.D., 2001. Methane in coastal and offshore waters of the Arabian Sea, *Marine Chemistry*, 74: 1-13

Kobayashi, J. 1971. Relation between the "itai-itai" disease and the pollution of river water by cadmium from a mine. *Proc. Ind. Water.Poll. Res. Conf*., 5.

Lakshmanan, P.T and Nambisan, P.N.K. 1977. Toxicity of copper on the bivalve, *Villorita cyprinoides var cochinensis*. *Ind. J. Mar. Sci*., 6: 83-85

Lakshmanan, P.T. and Nambisan, P. N. K. 1983. Seasonal variation in trace metal content in bivalve molluscs, *Villorita cyprinoides var. cochinensis* (Hanely), *Meretrix casta* (Chemnitz) and *Perna viridis* (L.). *Ind. J. Mar. Sci.*, 12: 100-103

Lakshmanan, P.T and Nambisan, P.N.K. 1986. Bioaccumulation and depuration of some trace metals by the mussel, *Perna viridis* (L.) *National Seminar on Mussel Watch*, 13-14: 35-42

Lithnor Goran. 1975. Pretreatment of samples (organic matter, water and sediment) for subsequent determination of heavy metals by atomic absorption spectroscopy. *Manual of Methods in Aquatic Environmental Research*. *Part II*. Methods for Detection, Measurement and Monitoring of Water Pollution FAO, Rome: 41-46

Nair, N. B., Abdul Azis, P.K., Suryanarayanan,H., Arunachalam, M., Krishnakumar, K. and Fernandez, T.V. 1987. Distribution of heavy metals in the sediment of the Ashtamudi estuary, south west coast of India. *Marine Sciences*, Felicitation Volume, 269-289

Nair, N.B. 1990. Ecobiology of Marine Fouling and Wood Boring Organisms along the Indian Coasts. Report to DOD, Govt. of India 311 pp.

Naqvi, S.W.A., Jayakumar D.A., Narvekar, P.V., Naik, H., Sarma, V.V.S., D'Souza, W., Joseph, S., and George, M.D., 2000. Increased marine production of N2O due to intensifying anoxia on the Indian continental shelf, *Nature*, 408: 346-349

Ouseph, P.P., P.K. Omana, Ramalingam Pillai and Ramadevi, 1994. Bio-accumulations of Cu, Cd, lead and zinc by economically important species of fishes along the South West Coast of India, In: Proceedings of sixth Kerala science Congress, pp: 96-97

Priju, C.P. and Narayana, A.C. 2007. Heavy and Trace Metals in Vembanadu Lake Sediments, *Int. J. Environ. Res.*, 1(4): 280-289

Pringle, B.H., Hissong, D.E., Katz, E.L and Mulawka, S.T. 1968. Trace metal accumulation by estuarine molluscs. *J. Sanit. Engg. Div. Am. Soc. Civ. Engns.*, 94: 445-475

Rajendran, N. and Kurian, C.V. 1986. *Crassostrea madrasensis* (Preston)- Indicator of metal pollution in Cochin backwaters. *National Seminar on Mussel. Watch*. 1: 120-127

Rainbow, P.S. and Luoma, S.N., 2011. Metal toxicity, uptake and bioaccumulation in aquatic invertebrates-modeling zinc in crustaceans. *Aquatic Toxicology*, 105: 455–465

Sivadasan, C.R and Nambisan, P.N.K. 1988. Seasonal variation of mercury, copper and zinc in the prawn, *Metapenaeus dobsoni* from Cochin backwaters. *Mar. Poll. Bull.*, 19: 579-580

William, R.B and Bobby, G.W. 1979. *Lead in the Environment*. Castle House Publication, Texas, 264 pp.

Wright, D.A. 1978. Heavy metal accumulation by aquatic invertebrates**.** In: *Applied Biology*, (Ed. Crocker), pp. 331-394.