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Research Article

A STUDY ON HEAVY METALS IN MARINE GASTROPOD (NERITA ORYZARUM: RECLUZ, 1841) AT NUCLEAR POWER PLANT SITE, TARAPUR, MAHARASHTRA, INDIA

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ABSTRACT

A study on heavy metals (Cu, Zn, Pb, Cd, Mn, Cr, Ni, Hg, Co and Fe) was conducted which got accumulated in soft tissue and shell of gastropod, *Nerita oryzarum* around Tarapur Atomic Power Station (TAPS), Tarapur, Maharashtra. The degree of accumulation of these elements in soft tissue and shell was Cd<Cr<Ni<Mn<Cu<Zn<Fe and Pb<Cr<Ni<Cu<Mn<Fe respectively. The Hg and Co were not detectable, while Zn and Cd were absent in shell and Pb in tissue. The high concentration of metals was recorded in tissue and shell at Nandgaon, expressing industrial wastewater impact. The range of accumulation of different metals in the tissue was, Cu (0.43-1.37 ppm), Zn (1.03-1.42 ppm), Cd (0.02-0.05 ppm), Mn (0.36-0.78 ppm), Cr (0.03-0.13 ppm), Ni (0.06-0.09 ppm), Fe (3.14-4.57 ppm) and in the shell it ranged Cu (0.11-0.32 ppm), Pb (0.04-0.11 pmm), Mn (0.12-0.47 ppm), Cr (0.07-0.08 ppm), Ni (0.1-0.11 ppm) and Fe (0.94 -1.03 ppm). Among all heavy metals, Fe showed the maximum values in tissue as well as in shell. The objective of the present study is to evaluate the bioaccumulation of heavy metals in gastropods, which are used as cheap and easy source of food by local communities around TAPS.

INTRODUCTION

The industrialisation in coastal areas of developing countries, where the environmental quality standards are not so well developed, make it necessary to monitor the aquatic environment of coastal zones. The point and non-point sources of pollution by anthropogenic activities are significantly responsible for increase of toxic contaminants in aquatic environment. The concentration of heavy metals in aquatic environment and their potential ecological effects are of great concern due to their highly bioaccumulative nature, persistent behaviour and higher toxicity (Gupta and Singh, 2011). In biological system, some metals play important role such as copper, iron, zinc and manganese which are essential but can produce toxic effect at higher concentration (Sivaperumal *et al.*, 2007). The metal like mercury, cadmium and lead are toxic even in trace amounts and these three heavy metals are included in the list of hazardous metals in the regulation of European Union (EC, 2001), while chromium, arsenic and nickel are included in USFDA (USFDA, 1993). The detection of various pollutants in aquatic ecosystem can be probed by employing bioindicator organisms (Kennish, 1992; Phillips and Rainbow, 1993). Molluscs are common, highly visible, ecologically and commercially important on global scale as food and as non-food resources. The seafood have high demand in the human population especially for coastal inhabitants; therefore, it is necessary to check the chemical contaminants in the food from aquatic environment to know the hazardous levels.

In marine biota, the gastropods can be used as potential biomonitor of heavy metals pollution (Yap *et al.*, 2006; Praveen and Devi, 2008; Yap and Cheng, 2013). Gastropods are filter feeders and thus uptake of heavy metals in these organisms is not only from food and water but also from ingestion of inorganic particulate material too (Fang *et al.*, 2003; Sidoumou *et al.*, 2006). In tropical and subtropical regions, the *Neretidae* species are abundant at rocky intertidal locations. They are spatially distributed, relatively large in size and easy to collect (Turkmen and Turkmen, 2004) with average life span of 3-4 years. The shell also serves as a geological record of man induced changes for metal level in environment (Bertine and Goldberg, 1972) and the biological half-life of metal in shell is much longer than the tissue (Carrikar *et al.*, 1980).

Although, Tarapur Atomic Power Station (TAPS) has been running successfully since 1969, the study related to release of radionuclides in marine environment was conducted by (Kamat *et al.*, 1966, 1970; BARC, 1995; Baburajan *et al.*, 2005 and Rao *et al.*, 2010), yet the chemicals released from nuclear site

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and there accumulation in marine environment has not been studied. In the present study, an attempt was made to record the accumulation of heavy metals in soft tissue and shell of *Nerita oryzarum,* which is used as cheap source of food by surrounding fishermen community.

MATERIAL AND METHODS

Study area

The Tarapur Atomic Power Station (TAPS) is located around 100 km north of Mumbai, on west coast of India ($19^0$50' N, $72^0$41' E). It is a multi-facility nuclear site comprising TAPS 1&2, a Boiling Water Reactor (BWRs) and TAPS 3&4, two Pressurised Heavy Water Reactors (PHWRs). Apart from these, the site also has the Power Reactor Fuel Reprocessing Plant (PREFRE), Waste Management Facility (WMF), Advanced Fuel Fabrication Facility (A3F) and Away From Reactor (AFR) which is a spent fuel storage facility located at about 0.5 km from reactor operating island. The TAPS 1&2 reactors have duel discharge system, where at the source released effluent flow is divided into south and north direction. The waste from AFR is also released into the discharge of TAPS 1&2. The discharge channel of TAPS 3&4 is away from the release of TAPS 1&2.

Table 1 GPS positioning of sampling locations and their salient features.

Sampling location	Latitude and Longitude	Salient features of locations
TAPS 1&2	N $19^0$50'02.00" E $72^0$39'06.82"	Intake channel (North side)
Light House	N $19^0$50'32.1" E $72^0$39'21.6"	Discharge channel of TAPS 1&2 (North side)
Varor	N $19^0$54'32.4" E$72^0$40'35.6"	8.00 km from the discharge channel of TAPS 1&2 (North side)
TAPS 3&4	N $19^0$49'19.53" E $72^0$39'30.99"	Intake channel (South side)
Popharan	N $19^0$49'09.73" E $72^0$39'46.49"	Discharge channel of TAPS 3&4 (South side)
Nandgaon	N $19^0$45'09.0" E $72^0$41'19.2"	8.4 km from the discharge channel of TAPS 3& 4 (South side)

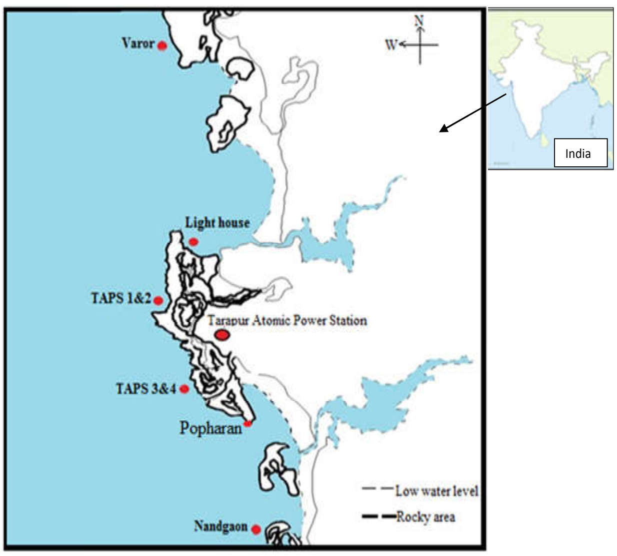


Figure 1 Study area map and sampling locations around Tarapur Atomic Power Station (TAPS)

The discharge effluent from TAPS 1&2 and TAPS 3&4, before it got mixed with open sea water, passes through the channel of ~1.5 km (north of TAPS 1&2 reactors) and a pond of ~1ha area (south of TAPS 3&4 reactors) for the purpose of adequate dilution and heat dissipation.

The samples for *Nerita oryzarum* were collected along the intertidal zone of six different locations within 10 km radius of TAPS as given in Table 1.

Sample collection and preparation

All glasswares, bottles and tools used in collection and analysis were washed with 10% HCl and then rinsed three times with double distilled water to avoid possible contamination. The 20 to 40 specimens of *Nerita oryzarum* were collected from each location by hand picking method. In laboratory, collected animals were allowed to depurate for 24 hrs. Having measured shell length and width, soft tissue was removed with the help of plastic spatula and dried in oven at 60^0C. The dried samples were ground in glass mortar and pestle to fine powder stage. The shells were also dried and converted to powder form. The tissue and shell powder were kept in desiccator till further analysis. For pre-treatment of samples, the acid digestion of tissue and shell was conducted in Advanced Microwave Digestion System (ETHOS EASY, Milestone Inc.). The instrument vessels were cleaned with 5% HNO_3. In the tissue and shell samples, 8 ml HNO_3+ 2 ml H_2O_2 were added and digestion of samples was carried out by using preloaded programme in Microwave Digestion System for environmental samples. The final volume of digested sample was made to 25 ml with double distilled water. The metal analysis was conducted in ICP-Atomic Emission Spectroscopy (ICP-AES), model-ARCOS, SPECTRO Analytical instruments GmbH, Germany with wavelength range of 130 nm to 770 nm and resolution of approximately 9 pico meter.

Statistical analysis

The Pearson correlation (IBM SPSS Statistics software Version 20) was employed to understand the significance of metals with respect to environmental parameters, tissue and shell and to get the correlation within metals. The One-way ANOVA was followed by a post-hoc Duncan's multiple range test on the concentration of metals to understand the variation in concentrations at different locations. For graphical presentation of concentration of metals, the frequency distribution graphs were plotted where height of each bar is the count of values of a metal concentration falling within the interval. A histogram shows the shape, centre and spread of distribution and a normal curve was superimposed on a histogram for normal distribution of the data.

RESULTS

The detailed results for mean metal concentration in tissue and shell of *N. oryzarum* around TAPS are presented in Table 2.

Physico-chemical analysis

The maximum water temperature (33.90^0C) was recorded at Popharan.

Table 2 Mean metal concentration in tissue and shell around TAPS, Maharashtra.

Location	n	Tissue weight (gm)	Shell weight (gm)		Metal concentration (ppm)									
					Cu	Zn	Pb	Cd	Mn	Cr	Ni	Co	Fe	Hg
TAPS 1&2	28	21.1	62.9	Shell	0.17	-	-	-	0.12	0.07	0.11	-	0.99	-
				Tissue	0.99	1.07	-	-	0.59	0.06	0.06	-	3.77	-
TAPS 3&4	27	18.9	45.9	Shell	0.18	-	0.06	-	0.24	0.08	0.11	-	0.94	-
				Tissue	1.03	1.03	-	0.02	0.36	0.07	0.08	-	3.26	-
Light house	32	20.9	52	Shell	0.16	-	0.04	-	0.26	0.07	0.11	-	0.96	-
				Tissue	1.29	1.07	-	0.02	0.38	0.03	0.06	-	3.14	-
Popharan	32	21.6	56.3	Shell	0.22	-	0.05	-	0.37	0.08	0.11	-	0.98	-
				Tissue	0.43	1.24	-	0.03	0.59	0.05	0.08	-	4.57	-
Varor	38	25.9	71	Shell	0.11	-	-	-	0.16	0.07	0.1	-	0.98	-
				Tissue	0.93	1.15	-	0.03	0.64	0.13	0.08	-	3.16	-
Nandgaon	26	19.2	45.3	Shell	0.32	-	0.11	-	0.47	0.07	0.11	-	1.03	-
				Tissue	1.37	1.42	-	0.05	0.78	0.05	0.09	-	3.15	-

*n=Number of organisms

The difference in water temperature between intake at TAPS 1&2 (30.5^{0}C) and discharge at Light house (32.4^{0}C) was 1.9^{0}C, while at TAPS 3&4 intake (28.6^{0}C) and discharge at Popharan it was 5.3^{0}C. The pH, salinity (ppt) and dissolved oxygen (mg/l) were in the range of 7.8 to 8.2; 32.1 ppt to 36 ppt and 5.8 mg/l to 6.9 mg/l respectively. Sediment texture was dominated by sand (73.2 % to 92.3 %), followed by clay (1.7 % to 20.7 %) and silt (6.02 % to 12.3 %). The organic carbon of sediment was maximum at Light house (1.32 %) and minimum at TAPS 1&2 (0.11 %) (Figure 2 and 3).

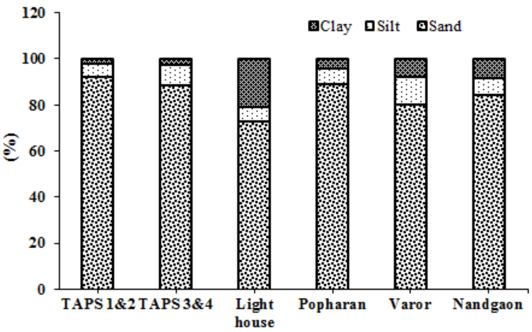
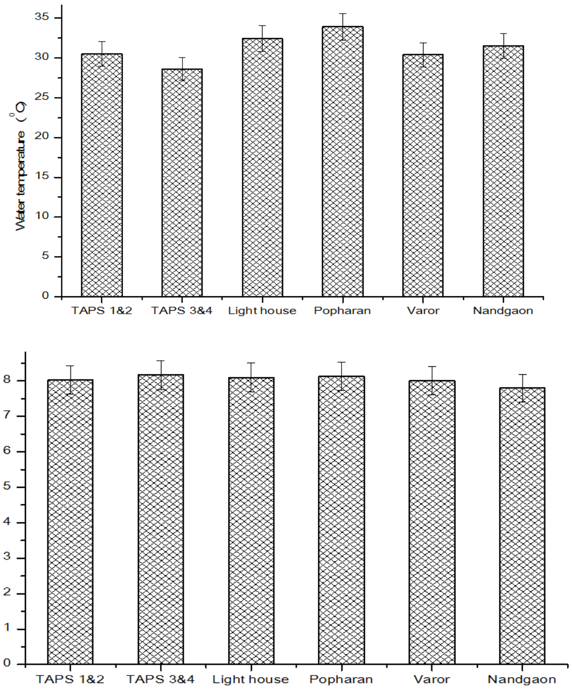


Figure 2 Percentage composition of different size fractions of sediment



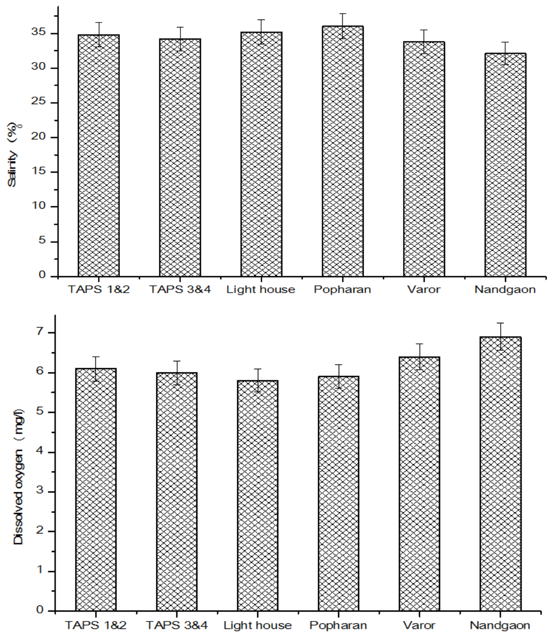


Figure 3 Analysis of various physico-chemical parameters around TAPS.

Analysis of heavy metals in tissue

The Cu (1.007±0.304 ppm) and Zn (1.164±0.136 ppm) were higher in tissue of *N. oryzarum*. The average level of concentration of Cd, Mn, Cr, Ni and Fe was; 0.029±0.011 ppm, 0.559±0.148 ppm, 0.066±0.031 ppm, 0.074±0.011 ppm and 3.505±0.523 ppm respectively. The minimum concentration of Cd (0.02 ppm), Cr (0.032 ppm), Ni (0.058 ppm) and Fe (3.135 ppm) was observed at Light house. TAPS 3&4 had minimum concentration of Zn (1.026 ppm) and Mn (0.357 ppm). The minimum level of Cu (0.431 ppm) was detected at Popharan area. In the present study, the maximum concentration of the elements *viz.*; Cu, Zn Cd, Mn and Ni were 1.372 ppm, 1.424 ppm, 0.051 ppm, 0.784 ppm and 0.087 ppm respectively which was observed at Nandgaon. The Cr (0.129 ppm) and Fe (4.566 ppm) had higher values at Varor and Popharan respectively. The concentration of Pb and Co was not detectable at all locations and Cd was absent at TAPS 1&2.

Analysis of heavy metals in shell

The concentration of Pb was (0.055 ppm), at TAPS 3&4, Light house (0.04 ppm), Popharan (0.052 ppm) and maximum at Nandgaon (0.112 ppm).

Table 3 Mean metals concentration (ppm) in gastropod tissue reported in previous studies.

Metal	Cu	Zn	Cd	Mn	Cr	Ni	Fe	Reference
Tissue								
Nerita crepidularia	15.16-38.56	15.26-2250	0.48-2.44	191.96-242.42	1.50-2.90	4.14-20.22	1121.2-2060.4	Palpandi and Kesawan, 2012
Nerita oryzarum	0.494	0.328	0.173	0.181	-	-	0.504	Kupekar *et al.,* 2012
Bursa spinosa	0.599	0.345	0.216	0.197	-	-	0.530	Kupekar *et al.,* 2012
Gastropods (Sunderban mangroves)	3.66	110	0.859	-	-	-	235	Kawser Ahmid *et al.,* 2011
Nerita oryzarum	0.43-1.37	1.03-1.42	0.02-0.05	0.35-0.78	0.03-0.13	0.06-0.09	3.14-4.57	Present study
Shell								
Nerita lineata	5.59	7.86	3.15	-	-	-	49.78	Palpandi *et al.,* 2010
Himisfuscus pugilinus	0.463	0.365	0.399	0.513	-	-	0.484	Kupekar and Kulkarni, 2014
Bursa spinosa	0.481	0.380	0.390	0.431	-	-	0.411	Kupekar and Kulkarni, 2014
Nerita oryzarum	0.04-0.11	0.1-0.32	-	0.12-0.47	0.06-0.08	0.1-0.11	0.94-1.03	Present study

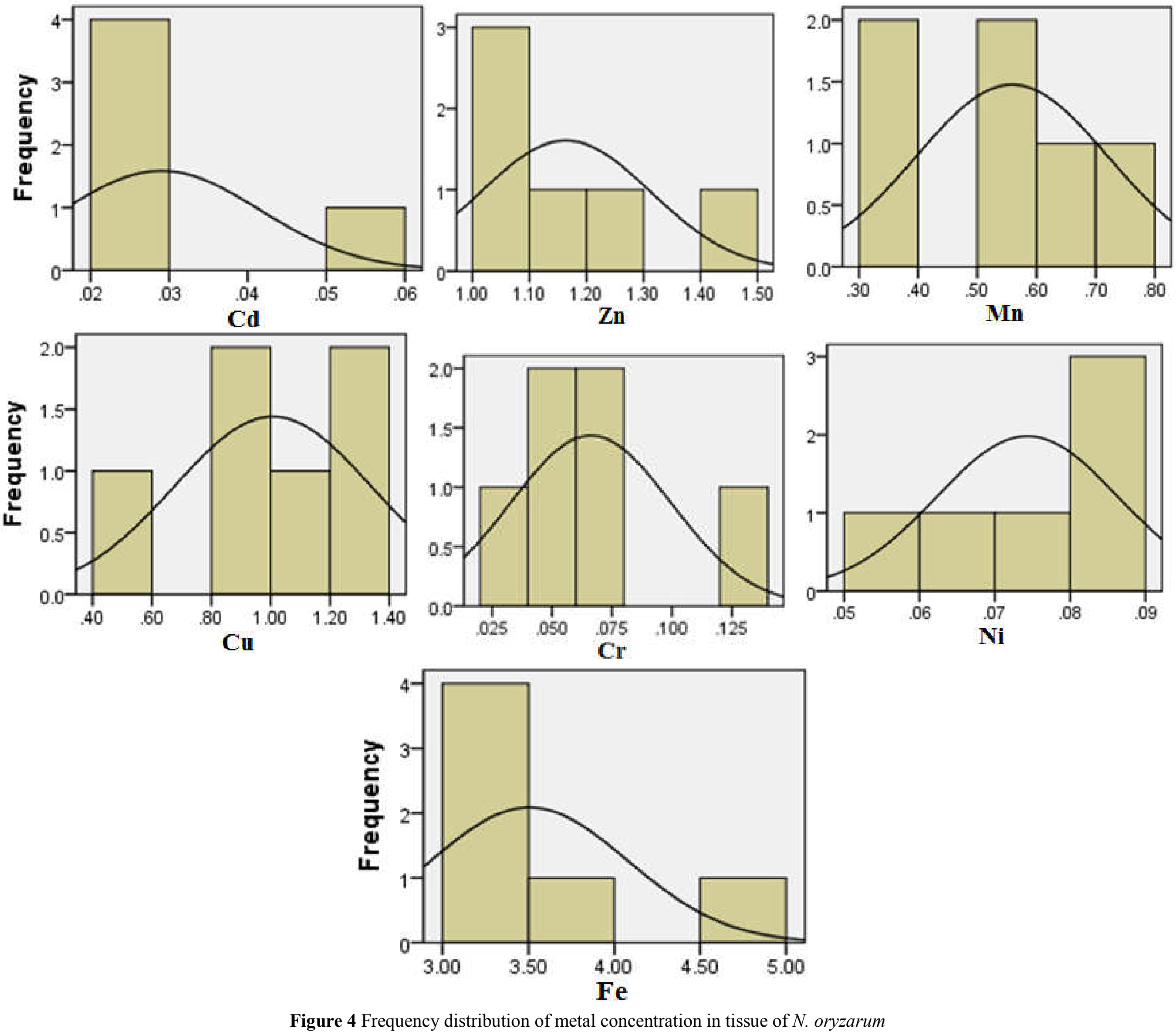


Figure 4 Frequency distribution of metal concentration in tissue of *N. oryzarum*

The concentration of other elements in the shell of *Nerita oryzarum* was Cu (0.190±0.071 ppm), Pb (0.065±0.32 ppm), Mn (0.270±0.130 ppm), Cr (0.073±0.006 ppm), Ni (0.107±0.003 ppm) and Fe (0.980±0.032 ppm). The maximum concentration of Cu (0.315 ppm), Pb (0.112 ppm), Mn (0.47 ppm) and Fe (1.028 ppm) was recorded at Nandgaon while, Cr (0.084 ppm) and Ni (0.112 ppm) was maximum at Popharan area.

The minimum concentration of Cu (0.107 ppm) and Ni (0.103 ppm) was observed at Varor and Light house had minimum concentration of Pb (0.04 ppm) and Cr (0.068 ppm). The lowest concentration of Mn (0.122 ppm) and Fe (0.935 ppm) was noticed at TAPS 1&2 and TAPS 3&4 respectively. The elements like Zn, Cd and Co were not detected in shell.

Table 4 Analysis of correlation between environmental parameters and concentration of heavy metals in tissue and shell of *N. oryzarum*.

	WT	ph	Salinity	DO	Sand	Silt	Clay	C_{org}	SH Cu	SH PB	SH Mn	SH Cr	SH Ni	SH Fe	TS Cu	TS Zn	TS Cd	TS Mn	TS Cr	TS Ni	TS Fe
WT	1																				
pH	-.046	1																			
Salinity	.433	.828*	1																		
DO	-.174	-.935**	-.927**	1																	
Sand	-.212	.095	.085	.033	1																
Silt	-.450	-.110	-.374	.352	-.186	1															
Clay	.366	-.058	.042	-.153	-.942**	-.154	1														
C_{org}	.115	-.283	-.282	.181	-.971**	.330	.864*	1													
SH Cu	.282	-.577	-.475	.558	.251	-.411	-.113	-.212	1												
SH Pb	.196	-.442	-.501	.473	-.025	-.265	.115	.037	.911*	1											
SH Mn	.493	-.438	-.339	.425	-.066	-.270	.158	.065	.892*	.939**	1										
SH Cr	.412	.348	.425	-.223	.559	-.108	-.526	-.632	.283	.206	.372	1									
SH Ni	.785	.157	.435	-.276	.166	-.693	.068	-.311	.565	.503	.668	.672	1								
SH Fe	.318	-.888*	-.524	.776	.167	-.070	-.144	-.011	.578	.298	.408	-.040	.097	1							
TS Cu	-.358	-.526	-.670	.437	-.492	-.067	.517	.562	.217	.340	.119	.845*	-.386	.148	1						
TS Zn	.451	-.783	-.546	.759	.034	-.016	-.029	.078	.813*	.706	.826*	.249	.383	.817*	.085	1					
TS Cd	.195	-.613	-.660	.696	-.270	.238	.189	.361	.693	.827*	.849*	.119	.208	.422	.286	.825*	1				
TS Mn	.251	-.854*	-.556	.826*	.199	.174	-.259	-.018	.507	.258	.387	.074	.011	.960**	.011	.836*	.496	1			
TS Cr	-.452	-.050	-.224	.267	.035	.937**	-.354	.113	-.531	-.509	-.485	-.056	-.724	-.005	-.241	-.122	-.031	.228	1		
TS Ni	-.112	-.279	-.488	.543	.328	.388	-.463	-.234	.573	.632	.614	.541	.153	.215	-.178	.602	.738	.392	.242	1	
TS Fe	.397	.539	.560	-.413	.432	-.098	-.402	-.546	.131	.131	.289	.970**	.660	-.264	-.852*	.070	.037	-.148	-.073	.443	1

WT-Water temperature (^{0}C), DO-Dissolved Oxygen (mg/l), C_{org}–Organic carbon in sediment (%), SH-Shell and TS-Tissue.

Correlation analysis

In correlation analysis, organic carbon is positively correlated with clay (r = 0.864, p<0.05) and negatively with sand (r = -0.971, p<0.01). The pH was negatively correlated with Fe in shell (r = -0.888, p<0.05) and Mn in tissue (r = -0.854, p<0.05). Dissolved oxygen was positively correlated with Mn (r = 0.826, p<0.05) and silt with Cr in tissue (r = 0.937, p<0.01). The metal concentration in shell and tissue showing positive correlation among them indicates the similar source of origin, except Cu and Fe in tissue (r = -0.852, p<0.05). Water temperature, Ni in shell and Cd, Mn, Cr, Ni in tissue did not show any correlation with any other metal concentration or environmental parameters studied.

ANOVA analysis

The One-way ANOVA results (Figure 5 to 8) indicate significant difference of each metal concentration at various locations in tissue and shell. However, there is no significant difference in Cd content in tissue at Popharan and Nandgaon, Cr content in the shell at TAPS 1&2, Varor, Nandgaon and Ni at TAPS 1&2, TAPS 3&4 respectively.

Frequency histogram

The frequency histogram for tissue and shell are presented in Figure 4 and 5. The Cu, Mn and Ni contents in tissue inclined towards higher concentration and Zn, Cd, Cr and Fe was on the lower concentration.

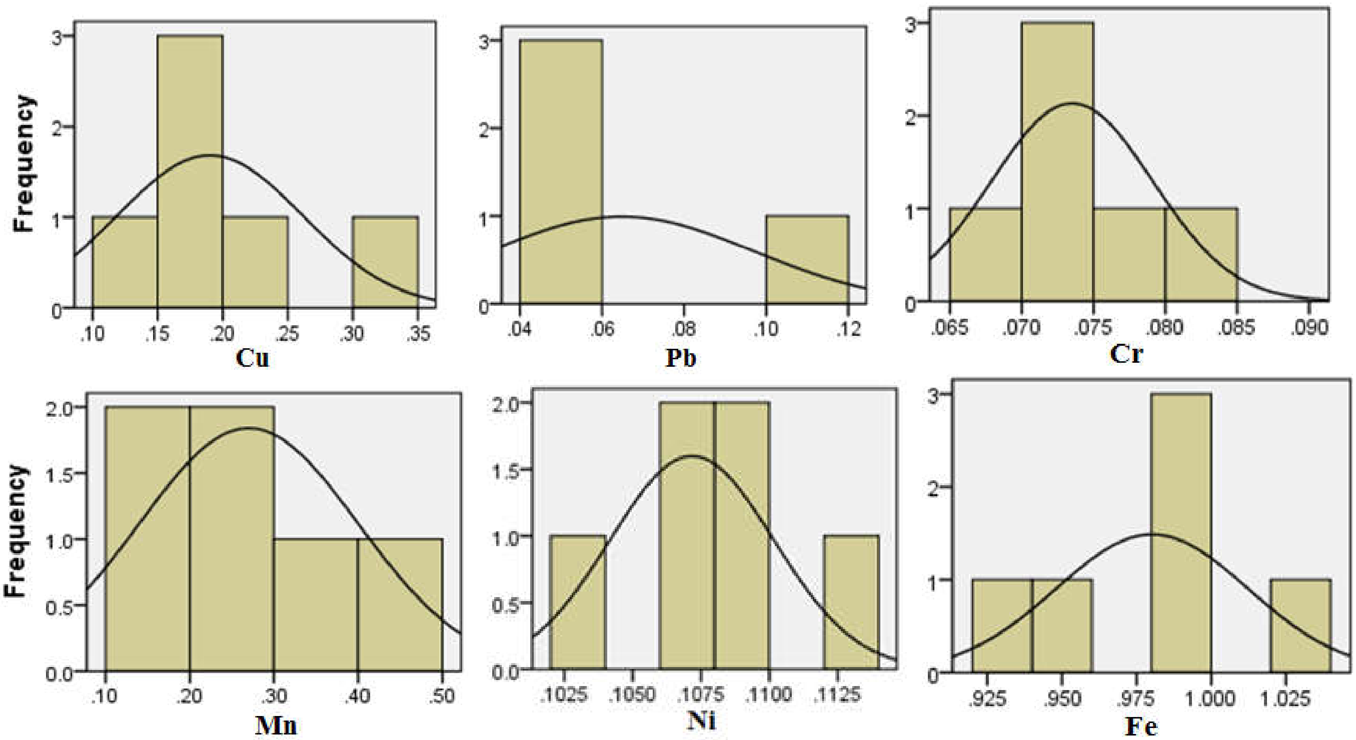


Figure 5 Frequency distribution of metal concentration in the shell of N. oryzarum

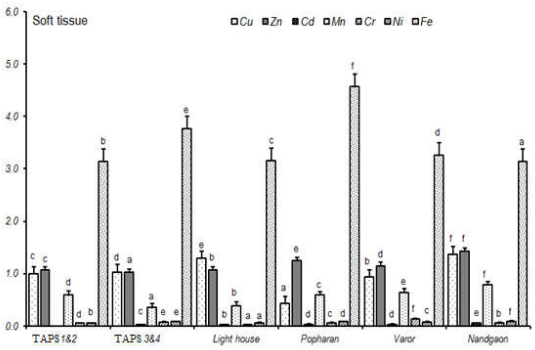


Figure 6 Mean metal concentration in tissue of *N. oryzarum* around TAPS, bars with different letters indicate the significant difference (p<0.05)

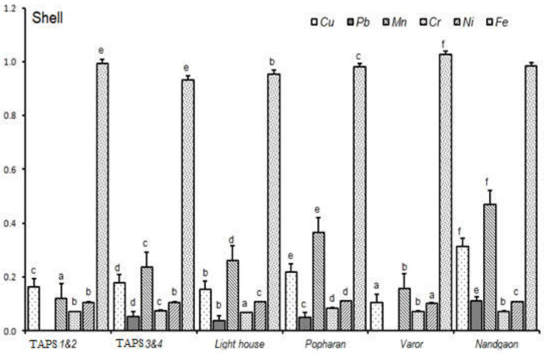


Figure 7 Mean metal concentration in shell of *N. oryzarum* around TAPS, bars with different letters indicate the significant difference (p<0.05)

The shell content of Cu, Pb, Mn and Cr showed more concentration towards the lower part of the chart, while Ni showed higher concentration in middle part and Fe towards the more concentration part of the histogram.

DISCUSSION

In the recent past, increased industrial activities such as effluent discharge, solid waste dumping, *etc*., have become the source of heavy metals into the environment (Mhatre, 1991). The nuclear power plants are among the industries which are situated near to large water bodies. The Cu and its alloys are extensively used as heat exchanger materials in power plant and other industries (Bott, 1995). At TAPS, the condenser and tube material are Aluminum –Brass (alloy of Cu and Zn) (Roy *et al.,* 2011). Tarapur Atomic Power station was commissioned on 1969, the studies on accumulation of residual radionuclides have been conducted by Kamat *et al*. (1970), BARC (1995), Baburajan *et al.* (2005), Rao *et al.* (2010), however, the accumulation of released or leaked chemicals in surrounding coastal environment are scarce. During the present study, the results of physico-chemical analysis revealed that the maximum difference (5.3^0C) in water temperature between intake and discharge channel at Popharan than at Light house (1.9^0C) was due to production capacity of TAPS 3&4 reactors (PHWR, 540 MWe) which is higher than TAPS 1&2 reactors (BWR, 160 MWe). It results in high heat energy generation. The increased temperature at Popharan coupled with increase in salinity (36 ‰) declined dissolved oxygen (5.9 mg/l). The minimum dissolved oxygen (5.8 mg/l) at light house might be due to high organic carbon (1.32%) than other locations.

The environmental assessment studies include the collection of sediment, water samples and also the species diversity and abundance. The use of organisms has more advantages. The concentration of pollutants found in the organisms expresses more about pollution load in that environment. Whatever pollution load received by coastal water, it is rapidly removed from water column and deposited at bottom sediment. This phenomenon provides the opportunity to bottom dwelling organisms to bio magnify this pollutant and remobilised them in food chain (Palpandi and Kesavan, 2012). In case of heavy metal pollution, the biota represents the direct bio-availability of metals and usually the metals are preconcentrated in some organisms which make the analysis practicable. At the same time it is not necessary that all organisms which accumulate metals are good bioindicator, as some organisms are capable of maintaining the fix body regulatory heavy metal level.

The benthic animals accumulate trace metals reflecting their concentration in surrounding environment. Tissue metal concentration can reflect contamination and molluscs in particular may therefore be sensitive biomonitors of anthropogenic metal inputs (Hendozko *et al*., 2010). In molluscs, gastropods and bivalves are most useful for biomonitoring as they are filter feeders, herbivores and/or carnivores and have potential to bioconcentrate contaminants present in water and sediment, even in trace amount (Gupta and Singh, 2011). In gastropods, the Neretidae species encompasses the considerable biomass at rocky intertidal area in tropical subtropical regions with average life span of about 3-4 years. In addition, they are sedentary, suitable size, weight, dimensions and easy to collect and identify. In the present study, tissue and shell of *Nerita oryzarum* were used for the analyses of ten elements, *viz.*, Cu, Zn, Pb, Cd, Mn, Cr, Ni, Hg, Co and Fe in close vicinity of nuclear power plant site at Tarapur. The concentration of Cu, Zn, Cd, Mn and Fe was higher in the tissue than shell that might be due to these metals being needed for metabolic activities; the similar result was reported in *Nerita lineate* by Amin *et al*. (2006). The greater metabolic rate of small organisms may partially account for the higher concentration of essential elements like Cu and Zn (Williamson, 1980). The ratio of shell /tissue for Cu, Mn, Cr, Ni and Fe is 0.19, 0.48, 1.11, 1.44 and 0.28 indicating higher values of Cr and Ni in shell than tissue. The Zn and Cd were not detected in shell while Pb in tissue. The tissue of marine molluscs is more efficient accumulator of metals than the shell (Rainbow, 1990). However, the composition of shell is strongly related to the chemical mineralogy which includes the metal accumulation from the environment (Carell *et al.,* 1987). The Pb found in the shell could probably be due to the fact that the crystalline structures of the shell matrix have a higher capacity for incorporation of these metals than the soft tissues (Al-Dabbas *et al.,* 1984; Koide *et al.,* 1982). The incorporation of Pb, Ni and Cr in the shell matrices may be faster than tissue. The contaminants accumulated in the shell which are not constantly exposed to metabolic processes ultimately have longer biological half life (Lee and Koide, 1987). The results of the current analysis for the tissue and shell of *N. Oryzarum* around TAPS showed less amount of accumulation of heavy metals than other gastropod species along west coast of India (Table 3).

Environmental variables have significant effect of the distribution of heavy metals in molluscs such as temperature, water current / flow, pH, salinity, sediment texture and organic carbon *etc*. In the present study, the organic carbon of sediment showed positive correlation with clay and negative with sand. The distribution of organic matter is closely associated with sediment texture and subsequently to clay content (Leticia *et al*., 2003), hence have strong positive correlation with clay content than sand. Typically, acidic pH is more favourable for metal dissolution and accumulation. In the present study, the Fe and Mn in shell and tissue respectively showed negative correlation at higher pH (7.8 to 8.2). The similar result of decreased concentration exponentially at pH greater than 4.8 was reported by Magda and Hutchinson (1982). Positive correlation between tissue Cr with silt content of sediment was possibly due to filter feeding activity of *N. Oryzarum* (Sidoumou *et al*., 2006). The heavy metal concentrations in tissue showed significant positive correlation with concentration in shell (Table 4), indicating the similar source of origin of the elements and *vice versa* for negative correlation. Cadmium and its compounds are considered carcinogenic and may cause damage to all types of body cells. The Cd concentration found in the tissue during present study was 0.03±0.01 ppm. The Cd concentration as 2.65 to 13.50 ppm at Uppanar, Kaduviar and 10.5 ppm in Vellar and 2.5 - 12.5 ppm at Kaduviar from *Crassostrea madrasensis* was reported by (Senthilnathan, 1990). The Cd was present in low level around TAPS compared to previous record (Table 3).

The Frequency histogram shows that the intertidal area around TAPS is unpolluted in regards to the heavy metals studied during present study. The ANOVA was followed by a post-hoc Duncan's multiple range test on the concentration of metals revealing the significant difference of metal concentration at various locations. The different environmental variables, topography and different levels of anthropogenic stress played significant role in difference of metal concentration at various locations such as, TAPS 1&2, where the sediment texture got constituted mainly of sand (92.3%), boulders and gravels which ultimately reduced the accumulation rate. TAPS 3&4 always engaged in dredging activity near intake channel, light house and Popharan which receive the effluent from TAPS 1&2 and TAPS 3&4 reactors respectively. Varor got impacted by local fishing activities and sewage discharge from surrounding villages. The coastal area of Nandgaon was ecologically stressed due to discharge of effluents (Sivaraj *et al*., 2014).

CONCLUSION

Although, the results of ecotoxicological studies are difficult to evaluate the impact of heavy metals in the field, due to the complexity of interrelationship between organisms and ecosystem, yet it enables the assessment of long term effects of heavy metals on organisms. In the present study, tissue and shell of *N. oryzarum* were analysed for metal contamination around TAPS, Tarapur which indicated minimum pollution load of heavy metals. The Nandgaon location is having comparatively higher side of metal concentration than other locations due to the presence of effluent discharge from the Tarapur MIDC area. The present work is prima facie around Tarapur Atomic Power Station and it also indicates that the tissue and shell of *N. oryzarum* can be used as potential bioindicator for further studies.

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