Shell chemistry of Loxoconchidae family, Recent benthic Ostracoda, off Rameswaram, Tamil Nadu, Palk Bay, Southeast coast of India

[*]Baskar, K., [*]Sridhar, S.G.D., [*]Maniyarasan, S., [#]Hussain, S.M. and [$]Balakumar, S.
[*]Department of Applied Geology and Centre for Environmental Sciences, [#]Department of Geology and Centre for Natural Hazards and Disaster Studies, [$]Centre for Nano-Sciences and Nano-Technology, University of Madras, Guindy Campus, Chennai 600 025, India.
Corresponding author: sgd_sri@yahoo.co.in

Abstract-**The area under investigation is off Rameswaram in northeastern transect of the shallow inner shelf region. From the bottom sediment samples that were collected from October 2010 to September 2011, during four different seasons that exist in the study area, benthic Ostracoda from its family Loxoconchidae, namely, *Loxoconcha gruendeli, Loxoconcha sp., Loxoconcha mandviensis, Loxoconchella anomala,* and *Loxocorniculum lilljeborgii* were identified and their shell chemistry were determined using SEM-EDAX. The following elements were found to be present in the above mentioned five species in different percent: C, O, Mg, Al, Si, Cl, K and Ca. The element C ranges from 18.26 to 21.83%, its lowest and highest were found in *Loxoconcha gruendeli* and *Loxoconchella anomala*, respectively; O ranges from 48.95 to 60.50% and it is found in *Loxoconcha sp.*, and *Loxoconcha mandviensis*; Mg ranges from 1.35 to 2.29%, its lowest and highest were found in *Loxoconchella anomala* and *Loxoconcha mandviensis*; Al is found as 0.83% in *Loxoconcha gruendeli* only; Si ranges from 0.75 to 1.79% and were found in *Loxoconcha mandviensis* and *Loxoconchella anomala*, respectively as lowest and highest; Cl ranges from 0.52 to 0.58% and were found in two species only as the lowest and highest namely, *Loxoconcha gruendeli* and *Loxoconchella anomala*, respectively; K ranges from 0.56 to 1.02% and it is found as lowest and highest in *Loxoconcha mandviensis* and *Loxoconcha sp.*, respectively; and Ca ranges from 13.03 to 28.97% and found in *Loxoconcha mandviensis* and *Loxoconcha sp.*. The percentages of these elements present in each species are discussed and their sources were arrived at.**

Keywords: Shell chemistry, Recent benthic Ostracoda, Family Loxoconchidae, off Rameswaram.

I INTRODUCTION

Past and current ecological conditions of aquatic habitats can be characterized by using Ostracoda as indicator [1-3]. Trace element geochemistry of Ostracod shells is a recently developed method, increasingly used to infer past environmental conditions in diverse water bodies [4-7]. In the case of dead Ostracod valves deposited in areas of high sedimentation rate usually display fewer micro-boring holes and the degree of dissolution of the calcareous wall is less for Ostracod valves deposited in environments with low rate of sedimentation as reported by [8]. [9] Discussed the result that reveals that the Ostracod shells contain 9 kinds of elements, Calcium (Ca), Aluminium (Al), Iron (Fe), Magnesium (Mg), Potassium (K), Chlorine (Cl), Sulphur (S), Sodium (Na) and Barium (Ba). The Ostracod mineralized portion is carbonatic and mainly composed of low Mg calcite. In some cases the presence of amorphous calcium carbonate is reported [7]. The calcitic Ostracod shell contains a number of elements of which Mg and Sr are generally the most abundant. The trace-element chemistry of the shell provides a reliable indication of the composition of the host water at the time of shell secretion. The remainder of the carapaces is represented by organic material; an estimation of 2 to 15% content is chitin and proteins for living specimens [10].

Conducted experiments with endemic Australian Ostracoda, (*Australocypris/Mytilocypris*) examining the relationship between Ostracod shell chemistry and water chemistry [3], [11-13]. Their results showed that Mg uptake by Ostracod is dependent on both water temperature and the Mg/Ca ratio of the host water; whereas, Sr uptake is only dependent on the Sr/Ca ratio of the water. Similarly, [14] recognized a relationship between Ostracod shell chemistry and the host water using a ubiquitous North American species, *Candona rawsoni*. Their study indicates, however, that the Mg/Ca ratio in Ostracod has a direct function of salinity to Mg/Ca of the water. [15] reported the anisotropic fixing of elements in the carapace before or during molting of *Leptocythere psammophila* and the distribution of elements, namely, Si-Al-Fe-Ca-Mg-Na-Mn-Ba-Sr-P-S-Cl is controlled by metabolism and passive trapping in a marine environment of Baltic Sea, North Sea and English Sea.

II STUDY AREA

The area under present investigation is a tropical region situated off Rameswaram, in the Palk Bay, Southeast coast of India. The study area is represented in the Survey of India toposheet Nos. 57 O/7 and 57 O/8. It lies between coordinates: latitude 9°20' N and 9°24'40" N; longitude 79°20' E and 79°24'40" E, which is the Northeastern, transect off Rameswaram island. The region is a shallow inner shelf, with a topography having a gentle slope towards the sea. Plenty of coral reefs are seen. The location map of the study area is shown in **Fig. 1**.

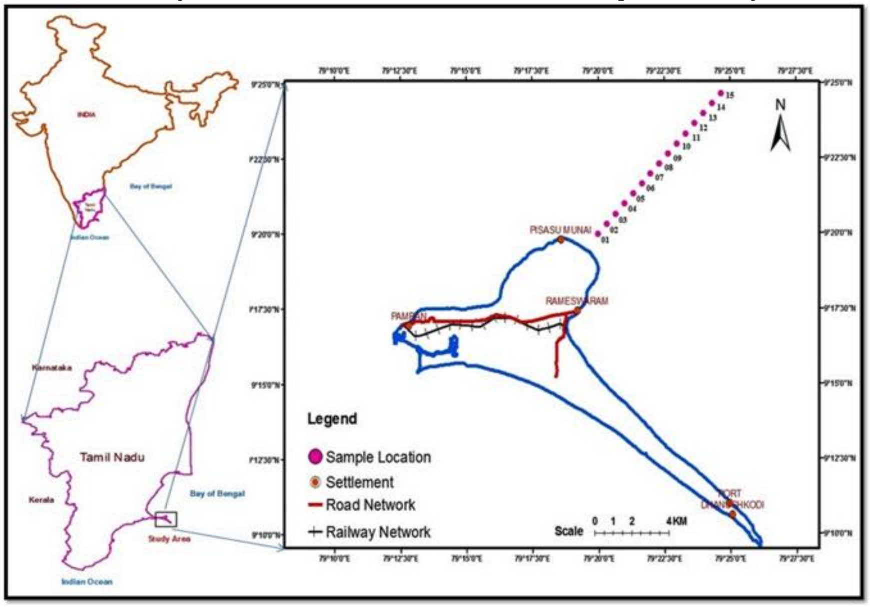


Figure1. Location map of the study area

III MATERIALS AND METHODS

The sample collections were done by adopting standard scientific methods established by [16]. 25 ml (dry weight) samples were slowly passed through a 63 µm sieve, and the samples were stained rose Bengal in order to recognize the living individuals. Ostracods were hand-picked using a .00 soft-bristled brush under a stereo zoom binocular microscope (NOVEX-Holland) from a representative (25 ml) preserved sample. The use of total assemblage (live and dead specimens) was preferred as an indicator of average environmental conditions for documenting of the Ostracodal response to anthropogenic inputs [17].

The species selected for EDAX were dead species. As the species for the present study are from recent benthic Ostracoda, there is no coating over the shells. They rarely contain the external organic layer, which may alter the results of EDAX; therefore, most of the potential contamination comes from adhering particles. The adhering foreign particles can be composed of organic material and/or clay particles. However, in practice, for fossil populations without a chitin sheath, most authors [18-21] found that the use of a chemical reagent to remove the organic fraction (sodium hypochlorite, hydrogen peroxide) alters either the isotopic or the elemental composition of carbonates and is therefore, not recommended. Consequently, foreign organic matter be removed only physically from the valve.

All other water parameters were analyzed in the Tamil Nadu Water Supply and Drainage (TWAD) Board's Hydrological Laboratory. Sediment samples have been digested for the present study following the procedure elaborated by [22]. Trace element concentration were determined using Atomic Absorption Spectrophotometry (AAS - Perkin Elmer AA700 AAS equipped with a deuterium background corrector) involving direct aspiration of the aqueous solution into an air-acetylene flame.

IV RESULT AND DISCUSSION

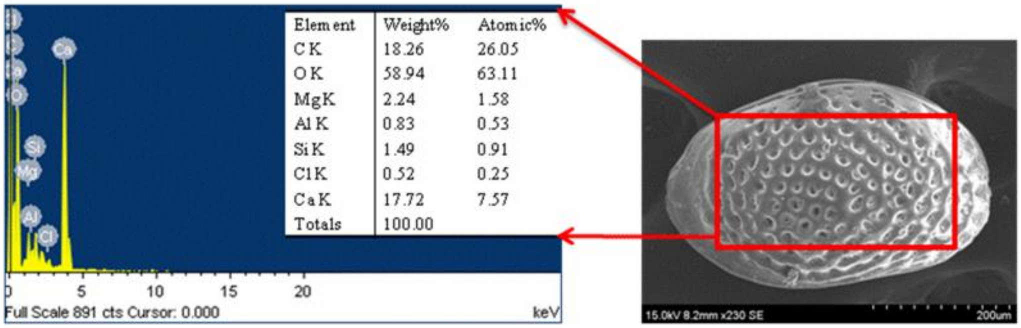
After the cleaning procedures, the hypo-types of identified species from the Family Loxoconchidae were made use. The following five species were identified from this family in the study area: *Loxoconcha gruendeli*, *Loxoconcha sp.*, *Loxoconcha mandviensis*, *Loxoconchella anomala*, and *Loxocorniculum lilljeborgii*. Their shell chemistry using EDAX were determined, and the concentration of elements found are shown in **Table. 1**. The SEM photomicrographs with its EDAX results are shown from **Fig. 2** to **Fig. 6**. The following elements were determined: C, O, Mg, Al, Si, Cl, K and Ca. The average concentration of elements/compounds that are found in water and sediments for four different seasons are shown in **Table 2**. The instrument model number is S3000n whose brand name is Hitachi, attached with a Scanning Electron Microscope (SEM) instrument. Shell-chemistry offers a mean of testing Ostracod environmental interpretation and in many cases a means of refining those interpretations [23] since Ostracod shells commonly consist of ~ 90% $CaCO_3$ [11].

Table 1 Elemental composition of Loxoconchidae family

Sl. No.	Species/Elements	C	O	Mg	Al	Si	Cl	K	Ca
01	*Loxoconcha gruendeli*	18.26	58.94	2.24	0.83	1.49	0.52	---	17.72
02	*Loxoconcha sp.*	21.05	48.95	---	---	---	---	1.02	28.97
03	*Loxoconcha mandviensis*	21.83	60.50	2.29	---	1.79	---	0.56	13.03
04	*Loxoconchella anomala*	21.82	57.66	1.35	---	0.75	0.58	---	17.85
05	*Loxocorniculum lillgeborgii*	20.23	60.48	2.22	---	1.09	---	---	15.98
Minimum		18.26	48.95	1.35	---	0.75	0.52	0.56	13.03
Maximum		21.83	60.50	2.29	---	1.79	0.58	1.02	28.97
Average		20.64	57.31	2.03	---	1.28	0.55	0.79	18.71

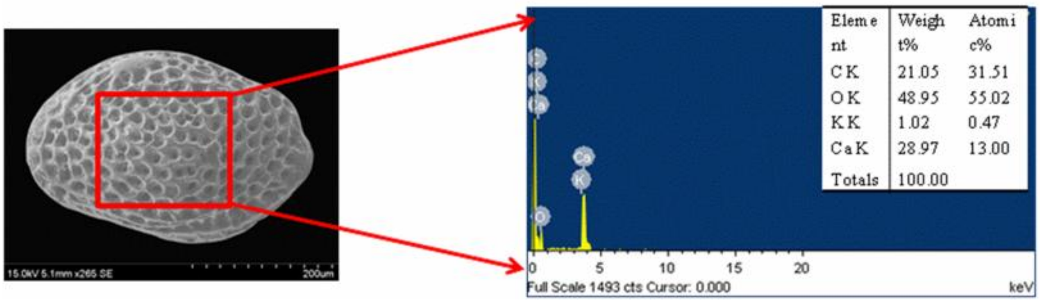
Table 2 Average concentration of Elements/compounds during different seasons

Elements in mg/l/Season	NE-Monsoon	Winter	Summer	SW-Monsoon	Average
From water					
Ca	1720.00	1460.00	1400.00	1620.00	1550.00
Mg	860.00	578.00	564.00	816.00	704.50
Na	5950.00	5650.00	6750.00	7250.00	6400.00
K	1150.00	1000.00	950.00	750.00	962.50
Fe	0.59	0.19	0.06	0.06	0.22
NH_3	0.03	0.04	0.03	0.04	0.03
NO_2	0.01	0.01	0.01	0.01	0.01
NO_3	2.50	2.00	2.50	3.00	2.50
Cl_2	14704.00	13115.00	13613.00	15717.00	14287.30
F	0.54	0.62	0.47	0.12	0.43
SO_4	8261.50	1350.00	2300.00	1630.00	3385.50
PO_4	0.11	0.01	0.02	0.02	0.04
O	0.25	0.85	0.80	0.70	0.65
SiO_2	2.19	1.14	1.08	3.50	1.98
From sediment					
Al	76380.20	75109.60	73102.70	74206.40	74699.70
$CaCO_3$ (%)	26.64	24.80	23.80	23.60	24.71
Org. mat. (%)	0.70	1.84	0.61	0.68	0.96



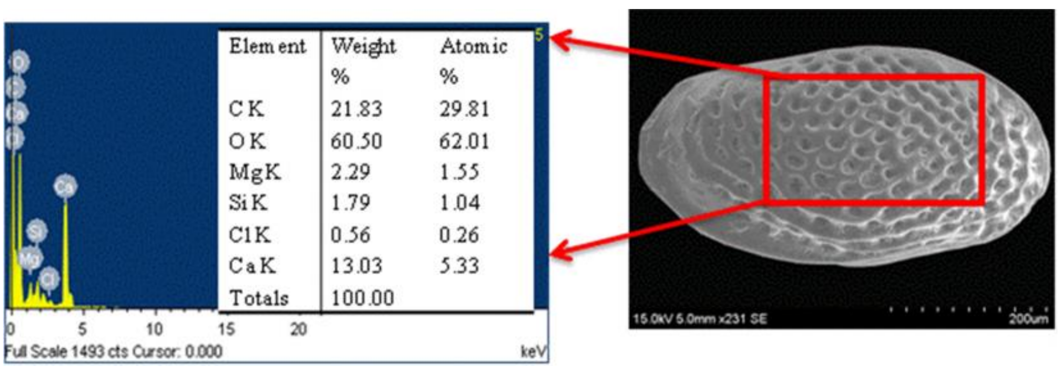
Element	Weight%	Atomic%
C K	18.26	26.05
O K	58.94	63.11
MgK	2.24	1.58
Al K	0.83	0.53
Si K	1.49	0.91
C1K	0.52	0.25
CaK	17.72	7.57
Totals	100.00	

Figure 2. *Loxoconcha gruendeli*



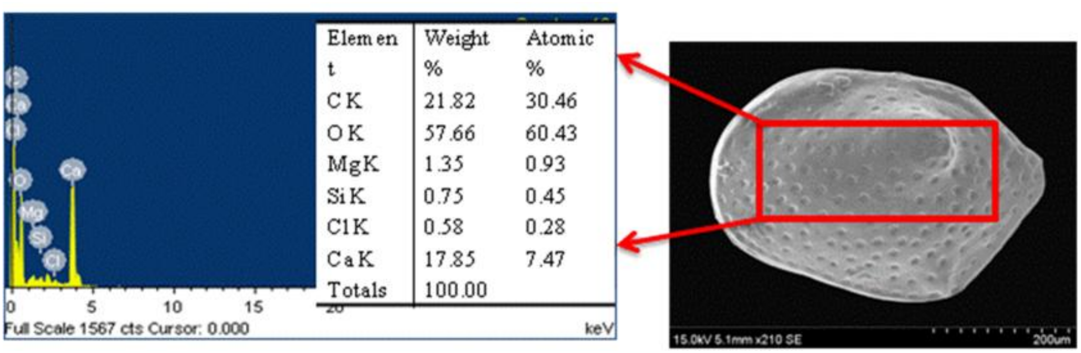
Element	Weight%	Atomic%
C K	21.05	31.51
O K	48.95	55.02
K K	1.02	0.47
CaK	28.97	13.00
Totals	100.00	

Figure 3. *Loxoconcha sp.*



Element	Weight %	Atomic %
C K	21.83	29.81
O K	60.50	62.01
MgK	2.29	1.55
Si K	1.79	1.04
C1K	0.56	0.26
CaK	13.03	5.33
Totals	100.00	

Figure 4. *Loxoconcha mandviensis*



Element	Weight %	Atomic %
C K	21.82	30.46
O K	57.66	60.43
MgK	1.35	0.93
Si K	0.75	0.45
C1K	0.58	0.28
CaK	17.85	7.47
Totals	100.00	

Figure 5. *Loxoconchella anomala*

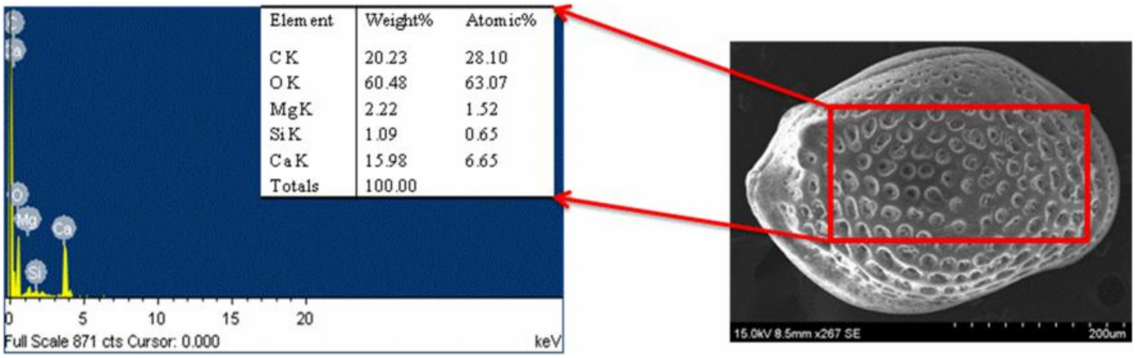


Figure 6. *Loxocorniculum lillgeborgii*

A. Carbon (C)

The element C ranges from 18.26 to 21.83%, its lowest and highest were found in *Loxoconcha gruendeli* and *Loxoconchella anomala,* respectively; The carbon content in Ostracoda valves, except some rare species, are in equilibrium with the DIC (Dissolved Inorganic Carbon) of water [24]. Organic carbon or organic matter enters the marine environment from allochthonous (external) and autochthonous (internal) sources [25]. [26] Attempted to provide a general framework for evaluating the risks of reduced benthic species richness from organic loading and associated stressors in sediments within different ranges of total organic carbon. [27] Reported sediments deposited during the highest pollution period (1940–1980) to contain high levels of heavy metals (As, Pb), the maximum occurrence in Foraminifers, *Ammonia tepida* morph (C) and an absence of Ostracod from southern Bay of Biscay. In the present investigation, the element C is being recorded in all the five species and it might have come from both water and sediments.

B. Oxygen (O)

O ranges from 48.95 to 60.50% and it is found as lowest in *Loxoconcha sp.,* and highest in *Loxoconcha mandviensis*. The results from lake Geneva validate the findings of that the O-isotope fractionation is similar for juveniles and adults, males and females, as well as for taxonomically close species (with in the same genus, subfamily and possibly family), but varies between more taxonomically distant taxa (super family and suborder) [28]. The only exception is *Herpetocypris repentance* for which juveniles show a higher O-isotope fractionation factor than adults, which was also observed in small spring-fed pond in England [29]. The present study shows that the element O is being recorded in all the five species and it is inferred that the element might have come both from water and sediment. Oxygen being available readily as Dissolved Oxygen (DO) in water, it is attributed that the DO might have played a conspicuous role in the composition of shells. As reported by [28], the concentration of Oxygen is around 58% in four species out of the five that were being identified from the Family Loxoconchidae of the study area.

C. Magnesium (Mg)

Mg ranges from 1.35 to 2.29%, its lowest and highest were found in *Loxoconchella anomala* and *Loxoconcha mandviensis*. Magnesium plays an important role in Ostracod bio-mineralization processes, as the magnesium content in the initial stage of valve calcification is high compared to the final calcified valve [9]. It acts as a calcification inhibitor [30-31]. The present study shows that the element Mg is being recorded in all the species, except *Loxoconcha sp.*, even though very less in content, and is being inferred that it might have come from water.

D. Aluminum (Al)

Al is found as 0.83% in only one species, namely, *Loxoconcha gruendeli* only. [9] Reported the element Al in the shell that varies between 1.10 and 1.30% of the composition. Only a few specimens showed higher values and there is a little difference in the average content of marine and non-marine shells, which is 1.317% and 1.29%, respectively. He (op. cit.) also reported from various areas, like, South China Sea, Bohai Sea, East Lake in Wuhan of Hubei, Caohai lake in Guizhou and a pond near Daqing of Heilongjiang. In the present study, *Loxoconcha gruendeli* have recorded this element and is being inferred that it might have come from the sediment alone because the water parameters does not have this element.

E. Silicon (Si)

Si ranges from 0.75 to 1.79% and were found in *Loxoconcha mandviensis* and *Loxoconchella anomala*, respectively, as lowest and highest. The most important factor controlling the dissolution rate is the specific surface area of the constituent parts (silicon spheres and nanometer-scale structures) and also the morphology of the whole diatom, which can lead to differential preservation of certain species [32-35]. The present study shows that the element Si is being recorded in all the species except *Loxoconcha sp.* and it is being inferred that it might have come from both water and sediment.

F. Chlorine (Cl)

Cl ranges from 0.52 to 0.58% and were found in two species only, namely, *Loxoconcha gruendeli* and *Loxoconchella anomala*, as the lowest and highest, respectively. [9] Reported the element Cl to be present in less than half of the specimens examined and only in a smaller amount. 45 trace elements have been determined, from various areas, like, South China Sea, Bohai Sea, East Lake in Wuhan of Hubei, Caohai Lake in Guizhou and a pond near Daqing of Heilongjiang. In the present investigation, the element Cl might have come from water. As salinity plays an important role for the element Cl, the concentration of Cl in the shell depends on salinity.

G. Potassium (K)

The element K is being found in two species only as 0.56% and 1.02%, namely, *Loxoconcha mandviensis* and *Loxoconcha sp.*, respectively. Living specimens show much higher potassium content than fossil specimens as reported by [9]. In the present study, it is being inferred that this element might have come from water.

H. Calcium (Ca)

Ca ranges from 13.03 to 28.97% and found as lowest in *Loxoconcha mandviensis* and highest in *Loxoconcha sp.* Ca is being reported by [9] as main constituent and makes up about 32% of the shell composition. The percentage of Ca seems not to be related to the thickness of calcitic shell, but the Ca content seems inversely proportional to the amount of all the trace elements in the Ostracoda shell. All the five species taken into consideration recorded the element Ca and it is being the chief element that occurs in the coral areas, it is being inferred that the element is from corals apart from the sediment.

V CONCLUSION

Shell chemistry of the species of benthic Ostracoda belonging to the Family Loxoconchidae were identified. Totally, eight elements, C, O, Mg, Al, Si, Cl, K and Ca have been determined from the shell by EDAX. The highest percentage is being recorded by Oxygen (60.50%) followed by C and Ca. Other elements are either minor or trace. *Loxoconcha gruendeli* has all the reported elements except K. *Loxoconcha mandviensis* does not have Al, Cl. *Loxoconchella anomala* does not have Al and K. *Loxocorniculum lillgeborgii* does not have Al, Cl and K. *Loxoconcha sp.* have only C, O, K and Ca. The elements that constitute these shells might have come either from water or sediment or from both. But, most of the elements are from water. The only species that has “Al” is *Loxoconcha gruendeli* and this element might have come from sediment, as it is not found in water. From the average, it is found that the order of preference of elements for the species of this family is O > C > Ca > Mg > Si > Al > K > Cl.

ACKNOWLEDGEMENT

The authors are thankful to the Department of Forestry, Coastal Police and Indian Navy for according permission to carry out the field work off Rameswaram. They acknowledge the help rendered by the Department of Applied Geology, University of Madras, especially to Prof. K.K. Sharma. Authors are grateful to DST (Department of Science and Technology), as the research work was carried out under DST PURSE program. Thanks to National Centre for Nanosciences and Nano-Technology (NCNSNT) of University of Madras for providing SEM-EDAX. Authors are thankful to the authorities of University of Madras.

REFERENCES

[1] Delorme, L.D. (1969). Ostracodes as quaternary paeoecological indicator. *Can. Joul. Earth Sci.* Vol. 6. pp. 1471-1476.
[2] Chivas, A.R., De Deckker, P. and Shelley, J.M.G. (1983). Magnesium, strontium and barium partitioning in nonmarine astrict shells and their use in paleoenvironmental reconstructions: A [1]preliminary study. In Maddocks, R. F. (ed.), Applications of Ostracoda. *Geosciences*, University of Houston, Houston, pp.238–249.
[3] Mezquita, F., Griffiths, H.I., Dominguez, M.I. and Lozana-Quilis, M.A. (2001). Ostracod (Crustacea) as ecological indicators: a case study from Iberian Mediter-renean brooks. *Arch. Hydrobiol*. Vol 6. pp. 545-560.
[4] Holmes, J.A. (1996). Ostracoda faunal and microchemical evidence for middle Pleistocene sea-level change at Clacton-on sea (Essex, UK).- In: Keen, M.C. (ed): proceeding of the second European Ostracodologist meeting. *British. Micro. Pal. Soci*, pp.135-140.
[5] Correge, T. and De Deckker. (1997). Faunal and geochemical evidence for changes of intermediate water temperature and salinity in the coral sea (N.E. Austalia) During the late Quaternary. *Palaeogeogr. Palaeoclimatol. Palaeoecol*.131. pp.183-205.
[6] Xia, J., Ito, E. and Engstrom, D.R. (1997). Geochemistry of ostracode calcite: Part 1. The experimental determination of oxygen isotope fractionation. *Geochemica et Cosmochemica Acta*, Vol.61(2), pp.377-382, New York.
[7] Hu, F.S., E. Ito, L.D. Brubaker and Anderson, P.M. (1998). Ostracode geochemical record of Holocene climatic change and implications for vegetational response in the Northwestern Alaska range. *Quat. Res*. Vol 49, pp.86-95.
[8] Danielopol, D.L., Ito, E., Wansard, G., Kamiya, T., Cronin, T.M., and Baltanas, A. (2002). Techniques for collection and study of Ostracoda. In the Ostracoda: Application in Quarternary Research. (J.A. Holmes, and A.R. Chivas, Eds). *American Geophical Union*, Washington D.C. pp. 65-97.
[9] Zhao Yuhong. (1990). Trace elements of Ostracoda shell used as an indicator for Paleoenvironmental reconstruction. *Paleontologia cathayana*, Iss.5, pp.269-276.
[10] Sohn, I.G. (1958). Chemical constituents of ostracodes; Some application to paleontology and paleoecology, *Jl Paleont*, Vol.32(4), pp.730-736.
[11] Chivas, A.R., De Deckker, P. and Shelley, J.M.G. (1986a). Magnesium and strontium in nonmarine ostracode shells: A new paleosalinometer and paleothermometer. *Palaeogeog. Palaeocli. Palaeoecol*. Vol.54, pp.43–61.
[12] Chivas, A.R., De Deckker, P. and Shelley, J.M.G. (1986b). Magnesium and strontium in nonmarine astrict shells as indicators of paleosalinity and paleotemperature. *Hydrobiologia* Vol.143, pp.135–142.
[13] Chivas, A.R., De Deckker, P. Cali, J.A., Kiss, E. and Shelley, J.M.G. (1993). Coupled stable-isotope and trace-element measurements of lacustrine carbonates as paleoclimatic indicators. In Swart, P.K., Lohman, K. C., McKenzie, J. and Savin, S. (eds), Climate Change in Continental Isotopic Records. *Geophysical Monograph* 78. Washinton, D.C.: American Geophysical Union, pp.113–121.
[14] Engstrom, D. and Nelson, S. (1991). Paleosalinity from trace metals in fossil ostracodes compared with observational records at Devils Lake, North Dakota, USA. *Palaeogeog. Palaeocli. Palaeoecol*. Vol.83, pp.295–312.
[15] Rio, M., Bodergat, A.M., Carbonel, G. and Keyser, D. (1997). Anisotropie chimique de la carapace des ostracodes. Exemple de Leptocythere psammophila. C. R. *Acad. Sci.*, Paris, Vol.324. pp.827-834.
[16] Murray, J.W. 2006. Ecology and applications of benthic foraminifera. *Cambridge University Press*, New York, 426 p.
[17] Armynot du Châtelet, E., Debenay, J.P., Soulard, R. (2004) Foraminiferal proxies for pollution monitoring in moderately polluted harbours: *Environmental Pollution*, Vol.127, pp.27-40.
[18] Barker, P.A. (1992). Differential diatom dissolution in Late Quaternary sediments from Lake Manyara, Tanzania: an experimental approach. *Journal of Paleolimnology* Vol.7, pp.235–251.
[19] Barker, S., Lamy, F., Arz, H.W., Major, C., Kwiecien, O. and Wefer, G. (2003). Abrupt changes of temperature and water chemistry in the late Pleistocene and early Holocene Black Sea. *Geochem. Geophys. Geosyst*. Vol.9, Q01004, DOI: 10.1029/2007GC001683.
[20] Jin, Z., Bickle, M., Chapman, H., Yu, J., Greaves, M., Wang, S. and Chen, S. (2006). An experimental evaluation of cleaning methods for fossil ostracod Mg/Ca and Sr/Ca determination. *Journal of Paleolimnology*, Vol.36, pp.211-218.
[21] Keatings, K.W., Holmes, J.A., and Heaton, T.H.E. (2006). Effects of pre-treatment on ostracod valve chemistry. *Chemical Geology*, 235, pp. 250-261.
[22] Tessier, A., Campbell, P.G.C. and Bisson, M. (1979). Sequence Extraction procedure for the speciation of particulate trace elements. *Analy. Chem*. Vol.51(7), pp.844-851.
[23] Nevio Pugliese, Marie Eugenia Motenegro, Francesco Sciuto and Niram Chaimanee. (2006). Environmental monitoring through the shallow marine ostracods of Phetchaburi area (NW Gulf of Thailand). *Grazybowski found. Sp. Publication*, Vol.11, pp.85-90.
[24] Decrouy, L., Vennemann, T.W. and Ariztegui, D. (2011). Controls on ostracod shell geochemistry: Part 2. Carbon and oxygen istotope composition. *Geochemica et Cosmochemica Acta*,Vol.75, pp.7380–7399.
[25] Pearce, F. (1998). Washed up. *New Scientist*, 25 July 1998, pp.32-35.
[26] Hyland, J., Balthis, L., Karakassis, I., Magni, P., Petrov, A., Shine, J., Vestergaard, O. and Warwick, R. (2005). Organic carbon content of sediments as an indicator of stress in the marine benthos. *Mar. Ecol. Prog. Ser*. Vol..295, pp.91-103.
[27] Pascual, A., Rodrıguez Lazaro, J., Weber, O. and Jouanneau, J.M. (2002). Late Holocene pollution in the Gernika estuary (southern Bay of Biscay) evidenced by the study of Foraminifera and Ostracoda. *Hydrobiologia*, Vol.475/476, pp.477–491.

[28] Grafenstein, U., Erlemakeuser, H. and Trimborn, P. (1996). Oxygen and carbon isotopes in modern fresh-water ostracod valves; assessing vital offsets and autecological effects of interest for paleoclimate stuudies. *Paleogeog, paleocli, paleoeco*, Vol.14, pp.133-152.

[29] Keatings, K.W., Heaton, T.H.E. and Holmes, J.A. (2002). Carbon and oxygen isotope fractionation in non-marine ostracods; results from a nature culture environment. *Geochemica Cosmochemica Acta*, Vol.66, pp.1701-1711.

[30] Davis, K.J., Dove, P.M., De Yoreo, J.J. (2000). The role of Mg^{2+} as an impurity in calcite growth. *Science,* Vol.290, pp.1134–1137.

[31] Ziegler, A. (2008). The cationic composition and pH in the moulting fluid of Porcellio scaber (Crustacea, Isopoda) during calcium carbonate deposit formation and resorption. *Journal of Comparative Physiology. B, Biochemical, Systemic, and Environmental Physiology*. Vol.178, pp.67–76.

[32] Hurd, D.C., Pankratz, H.S., Asper, V., Fugate, J. and Morrow, H. (1981). Changes in the physical and chemical properties of biogenic silica from the Central Equatorial Pacific: Part III. Specific pore volume, mean pore size and skeletal ultrastructure of acid-cleaned samples. *American Journal of Science*, Vol.281, pp.833–895.

[33] Ryves, D.B., Juggins, S., Fritz, S.C. and Battarbee, R.W. (2001). Experimental diatom dissolution and the quantification of microfossil preservation in sediments. *Palaeogeog Palaeocli Palaeoeco*, Vol.172, pp.99–113.

[34] Ryves, D.B., Jewson, D.H., Sturm, M., Battarbee, R.W., Flower, R.J., Mackay, A.W. and Granin, N. (2003). Quantitative and qualitative relationships between planktonic diatom communities and diatom assemblages in sedimenting material and surface sediments in Lake Baikal, Siberia. *Limnol. Oceanogr*, Vol.48, pp.1643–1661.

[35] Battarbee, R.W., Mackay, A.W., Jewson, D.H., Ryves, D.B. and Sturm, M. (2005). Differential dissolution of Lake Baikal diatoms: correction factors and implications for palaeoclimatic reconstruction. *Global and Planetary Change*, Vol.46, pp.75–86.