SUMMARY

The crux of the present day environmental problem concerning water is further concentrated due to every day pouring in the filth from the communities and untreated wastes from industries and even increasing run off of excess and unutilized fertilizers and pesticides from agricultural fields. The problem of water pollution is getting from bad to worst with the advancement of technology pertaining to more agricultural and industrial production to meet the increasing requirement of swelling population. The unmanaged environment is incapable of assimilating societal wastes without being seriously degraded at certain times. Therefore it is the primary and urgent task to save the environment from the dangers of pollution.

Among the various kinds of water pollution, great concern is about the heavy metal pollution because it has serious damage not only on the organism which live in the water but also on the human beings who consume the organisms. In the present study, two essential heavy metals Copper and Zinc and two non-essential metals Lead and Cadmium were analysed. The impact of heavy metals on L. marginalis from Chediyan pond and M. casta from Agniar estuary possessed most of the characteristic features of an ideal bio-monitor have been studied.
Environmental parameters such as rainfall, water discharge, salinity, pH, dissolved oxygen, temperature were collected and studied. The physio-chemical parameters of freshwater and estuarine water were influenced by water discharge and monsoonal rainfall. Based on the monsoonal cycle four seasons could be recognized in a year, post monsoon, summer, pre monsoon and monsoon. North east monsoon (October - December) brought maximum rain to this region. South east monsoon effect was feeble and brought moderate rain during pre monsoon period (July - September). Rainfall was scanty during post monsoon (January - March) and summer months (April - June).

More amount of water discharged into Agniar river from the month of September to December. Though there was rain in other seasons, there was no discharge or it would be very low level. Analysis of variance showed significant difference in temperature with respect to seasons. So far radiation played a major role in the increasing of water temperature. The lower temperature recorded during monsoon months could be due to monsoonsal rain cloudy sky and cold water.

Data on salinity of the present study showed two different situations in the estuary ie. marine dominance during March-May and freshwater dominance during October-November. Fresh water showed very low salinity. High
salinity values noticed during nonmonsoon months in the estuary was coinciding with high solar radiations, neritic water dominance and lack of freshwater during monsoonal rainfall. Salinity showed a positive correlation with temperature and pH and negative correlation with dissolved oxygen. Analysis of variance showed significant variation in salinity between seasons. Dissolved oxygen was found to be maximum during monsoon and minimum during summer and also maintained a significant inverse relationship with salinity. It also showed a significant variations between the seasons, both in freshwater and estuarine water. The seasonal variations of hydrogen ion concentrations were narrow except during monsoon period.

Heavy metal concentrations in freshwater and estuarine water showed higher values during monsoon and lower values during summer. The variations in metal concentrations between different seasons were statistically significant. The higher concentration of metals observed could be attributed to the heavy rainfall and subsequent river run off. Among the four metals studied zinc concentrations were found to be maximum in Chediyan pond as well as Agniar estuary. The decreasing order of metal present in both waters was zinc > copper > lead > cadmium. These were due to the discharge of industrial effluents, agricultural wastes,
municipal wastes, coconut coir rutting works and sewage sludges into the Agniar River.

The heavy metal concentration in water was influenced by physico-chemical parameters. The metal concentration was inversely proportional to pH and temperature of the medium and maintained a negative correlation. The dissolved oxygen content of the medium was positively correlated with metal concentration. The metal concentration was high when temperature, salinity and pH were low.

The dissolved metal concentration showed a significant negative relationship between salinity, and an inverse relationship between salinity and metal concentration was observed. This might be due to dilution of metal rich freshwater by metal impoverished sea water and the physico-chemical processes such as precipitation, coagulation of colloidal particles, co-precipitation etc.

The concentration of heavy metals in the soft body of *L. marginalis* and *M. casta* matched well with that of the medium. The order of levels of metals in the soft body of both bivalve species was Zn > Cu > Pb > Cd and Zn > Pb > Cu > Cd in shell. There was greater concentration of lead in shell than in soft body of the bivalves tested. This accumulation pattern was common for both species tested. Therefore the shell of bivalves could be used as a good indicator of exposure to zinc and lead whereas the soft body would
indicate the level of zinc and copper.

Measurement of metal concentrations in digestive gland, gill, viscera, mantle and foot-adductor muscles of two bivalves species revealed that the tissues possessed a differential bioaccumulation ability. The order of metal accumulative ability of these organs had been digestive gland > gill > viscera > mantle > foot-adductor muscle. The general pattern of metal accumulation in different organs remain the same in *L. marginalis* and *M. casta*. Among the organs, digestive glands showed a greater ability to concentrate metals. This higher concentration of metal might be due to higher metabolic activity of the organ. Next to digestive gland, gill and mantle accumulated higher concentration of metals. This was mainly due to intimate contact between these organs and circulating water in the mantle cavity and the mucous layer covering these organs. The adductor muscles did not have absorptive or secretory function and therefore less metal concentration was observed.

Seasonal changes had a decisive influence on the rate of metal uptake in both freshwater mussel and estuarine clam. The rate of uptake was maximum during monsoon and minimum during summer months. The differences in metal uptake in different seasons were statistically significant. The obvious reason was the variation in bio-availability of these metals in the medium. The higher metal content during monsoon might
be due to low salinity that facilitated the dissolution of precipitated metal and the increase in the amount of ionic species in solution thereby increasing bio-availability.

The bioconcentration of copper, zinc, lead and cadmium in the whole body tissue and different tissues viz. digestive glands, gill, viscera, mantle, foot-adductor muscle and shell showed a linear significant relationship with dissolved metal concentrations in the medium. The relative abundance of the metals in the medium coincided with the concentration of metals accumulated by the organism. The linear relationship was due to absorption by organisms from the ambient medium and intimacy between the bivalves and ambient water.

The concentration of metals in different body components showed a negative correlation with salinity. Higher metal content was observed during lower saline period and vice versa. The phenomenon of higher accumulation could be explained by the fact that the freshwater influx into estuarine ecosystem lead to metal enrichment and increased bio availability.

The concentration factors of copper, zinc, lead and cadmium were higher in the digestive gland of both bivalves than that in other tissues. Higher concentration factors for zinc were observed in all tissues while it was low in shell. Among the bivalves, higher concentration factors of metals
were calculated in freshwater mussel *L. marginalis*. This was indicative of low metal level in Chediyan pond than in Agniar estuary.

Bivalves which are exposed under laboratory conditions to different sublethal concentrations of heavy metals showed differential ability of metal uptake. Accumulation of metals increased in different body components of *L. marginalis* and *M. casta* with increasing concentration of test medium as well as duration of exposure. The order of metal accumulative ability in the tissues exposed to different sublethal concentration was found to be digestive gland > gill > viscera > mantle > foot-adductor muscle > shell in both bivalve species. The order of preference of metal uptake in tissues was Zn > Cu > Pb > Cd and in shell Zn > Pb > Cu > Cd.

Accumulative ability of tissues was also widely variable under laboratory condition. Among the body component digestive glands accumulated higher metal levels. It might be due to high metabolic activity of the glands and greater involvement in feeding process. Next to digestive glands gill accumulated more metals. It could be due to capacity of binding large quantities of heavy metals on a low molecular protein and also due to filter feeding across the gill. Higher metal levels in the mantle was attributed to the siphoning and adsorptive process on the mantle surface.
Bio-accumulation of copper and zinc was more in all tissues exposed for 30 days in sublethal concentrations. Since, these metals were essential they were accumulated more and stored in soft parts of the bivalves. Lead was accumulated at a higher rate in shell and cadmium was present in very less amount in tissues and shell. Since lead and cadmium were non essential trace metals their uptake was very less when compared to copper and zinc which are essential metals. These findings from laboratory experiments confirm the trends observed in field study.

From the observation made in the field and in laboratory it was proved that the ability of the bivalve to accumulate the metal was depending on the bioavailability of the metals. The higher accumulative capability as evidenced in the field and laboratory studies ascribed to the tolerance mechanisms evolved in the bivalves to meet out the adverse environmental conditions. The differential ability of the body components could be used to trace specific metal content in the medium.

The physiological processes such as respiration, heart beat, dissolution and reformation of crystalline style and growth condition index were adversely affected when the bivalves were exposed to different sublethal concentrations of copper, zinc, lead and cadmium. An initial increase in the rate of oxygen consumption was observed in all sublethal
concentrations of copper, zinc, lead and cadmium exposed to 10 day period in *L. marginalis*. *M. casta* showed a similar trend when exposed to sublethal concentrations except in the concentration of lead. But a decline in the rate of oxygen consumption was recorded when the duration of exposure extended. The decreased rate of oxygen consumption was noticed in higher concentrations in the test medium. Thus these metals acted as respiratory depressors during long term exposure. The accelerated respiration during the continuous and prolonged exposure to heavy metals was attributed to the toxic effect of heavy metals on gill surface, closure of valves and state of inactivity.

The bivalves subjected to chronic exposure to heavy metals showed an increase in the rate of heart beat in 10 days of exposure, whereas decrease in the heart rate was recorded only in higher concentrations of 20 and 30 days of exposures. Among the metals copper and cadmium depressed the heart rate more sharply than zinc did. Lead caused only a slight decrease in the rate of heart beat in *L. marginalis* and *M. casta*. Among the two bivalves heart of, *M. casta* was more sensitive to metals. Analysis of variance showed that the variation between duration of exposure and concentrations of metals was significant at 0.01 level. The metal stress caused an initial elevation of heart beat rate associated with inactivity.
Analysis of variance showed that the variation between the dissolution and reformation and the sublethal concentrations of the metal were significant. The rate of dissolution was proportional to the higher concentrations of metal in the medium. Dissolution of crystalline style of both bivalves varied for each metal. The decreasing order of toxic effect of metals on the dissolution was observed to be copper > cadmium > zinc > lead in both bivalve species. Dissolution of crystalline style *M. casta* took more time than in *I. marginalis*. The variation in the time required for complete dissolution of crystalline style could be explained on the basis of nature of the stress and sensitivity of bivalves to the stress in the medium. Reformation of crystalline style was quicker in the bivalve exposed to low sublethal concentrations of heavy metals. But reformation in bivalves exposed to 20% and 30% sublethal concentrations was greatly delayed. The rate of style reformation was quicker in *L. marginalis* than in *M. casta*. The rate of style reformation reflected the amount of stress load already received by the bivalves during chronic bioassay. The style reformation was relatively faster than dissolution and this was considered to be built in adaptive feature which enabled the bivalves to initiate feeding and digestion when opportune time arrived.

There was a decline in the growth condition index of heavy metal exposed fresh water mussels and estuarine clams.
The decrease in growth condition index was well pronounced in the bivalves exposed to sublethal concentrations of heavy metals for 20 days. These bivalves after 30 days of exposure managed to get over the physiological impairments to certain extent with the progression of time. Among the metals copper caused a maximum decrease in growth condition index in the bivalves. Among the two bivalves, *M. casta* was more sensitive. Analysis of variance showed that the variations in growth condition index between the sublethal concentration of Cu, Zn, Pb and Cd were significant at 0.01 level. Since the physiological processes such as respiration, heart beat, dissolution and reformation of crystalline style were very much affected due to the heavy metal exposure, the growth condition index study reflected the overall decline in the metabolic processes of test bivalves.

Although fresh water mussel *L. marginalis* and the estuarine clam *M. casta* belong to totally different habitats namely Chediyan pond and Agniar estuary respectively, the pattern of metal accumulation in soft body and shell and physiological responses to the toxic effect of the metals did not vary. This has been evidenced by the present investigation in field as well as laboratory. Hence the bivalve species commonly available in any habitat could profitably be utilized for the purpose of biomonitoring of aquatic metal pollution and evaluation of toxic effect of metals at sublethal concentrations.