Chapter 1

INTRODUCTION
Pollution of marine ecosystems by heavy metals is of environmental concern worldwide. Domestic sewage, industrial effluents, combustion emissions, mining operations and metallurgical activities are among the sources of anthropogenic metal inputs. Although heavy metals in trace concentrations are normal constituents of marine organisms, at high levels they are potentially toxic and may disrupt the biological activities of aquatic ecosystems. The ability of heavy metals to be concentrated in the organs of marine organisms accounts for their toxicity and also poses a direct threat to both aquatic biota and man (Watling, 1983).

The term ‘trace metal’ is used to designate the elements, which occur in small concentrations (<100 ppm) in natural biological systems. There are both essential and non-essential trace metals. It is well known that Cu, Ni, Zn, Cr, Co, Fe and Mn are essential to life (Mertz, 1981) and known as essential trace metals. The elements Al, Sb, Hg, Cd, Ge, V, Si, Rb, Ag, Au, Pb, Br, Ti etc are believed to be acquired by animal body from environmental contaminants, due to interaction of organism with the environment. These elements are usually unevenly concentrated in different organs and are called non – essential elements. Essential metals function either as an electron donor system or as ligands in complex enzymatic compounds in animals. Since essential elements are used by the organisms only in trace amounts, their enrichment in the organisms does not exceed the level which allows the enzyme system to function without
interference (Presley, 1997). However, if the heavy metal concentration at
the source of supply is too high, the homeostatic mechanism ceases to
function and the essential heavy metals act in either acutely or chronically
toxic manner. Thus, in the event of extended bioaccumulation of heavy
metals, the organism may be affected.

Bivalve molluscs are notorious for concentrating trace metals both
from the environmental water as well through food web. These species
reflect the concentration of heavy metals in the surrounding medium.
Based on this property Goldberg (1978) had adopted 'mussel watch'
programme to monitor the levels of heavy metals in the environment as
reflected in the animal body. Of late metallothionines have been monitored
in fish and shellfish to gather an early information about metal pollution.

1.1. Trace metals in the aquatic environment and its effect
on aquatic life.

Trace metals are introduced in the environment from both natural
sources and as a result of human activity (Penrose et al., 1975; Phillips
et al., 1982; Martin and Scanes, 1996; Presley, 1997). A large number of
heavy metals may be contributed by corrosion of metal pipes, smelting,
refining, etc. Weathering is a natural source of dissolved and particulate
trace metals. Geological weathering of rocks produces the clays and other
minerals that make up the bulk of detrital sediments as well as the bulk of
dissolved metals in seawater. Volcanic activity, either on land or in the sea,
is another natural source of metals. Data from several experiments during the 1990's (Radach and Heyer, 1997) showed that large pools of cadmium were contained in the sediments and were ingested by the benthos (Hall et al., 1996). Phytoplankton may absorb metals and as a result, significant concentration of cadmium and mercury are found in kidney and livers of top predators. Pollution from metals, which are persistent and are bioaccumulated by marine organisms with serious public health implications (Phillips and Rainbow, 1993).

The environmental impact of a metal depends less on its source than on its behaviour. Its behaviour, including mobility, transport, transfer and biological uptake, depends strongly on the chemical and physical form of the metal. The toxicity of a metal is mainly determined by its ionic size, electron affinity, electro negativity, stability, solubility and its inherent capacity to adversely affect any biological activity (Wittmann, 1974). The heavy metals have high affinities for ligands containing sulphur and nitrogen, and hence are bound easily to organic molecules such as proteins, enzymes etc (Richardson, 1980).

Toxic metals change the biological structures and systems into inflexible and irreversible conformation leading to deformity in the body and finally death (Kudesia, 1980). Cd, Hg, Ni, Pb, Zn and As are known to produce a broad spectrum of lethal effects which includes histomorphological changes, deformities and biochemical alterations in the
cells. Diarrhea, nervous disorder, loss of memory, tissue damage, respiratory failure, liver necrosis, anaemia and hypertension are some of the symptoms of heavy metal poisoning.

Contamination of marine organisms with toxic metals such as mercury is of ecological and health concern worldwide (Goldberg, 1995). The presence and behaviour of mercury in aquatic systems is of great interest and importance since it is the only heavy metal which bioaccumulates and biomagnifies through all levels of the aquatic food chain (Lindqvist et al., 1991). Mercury has many industrial uses such as in the manufacture of plastics, caustic soda, paints, certain fungicides and pesticides. The effluents coming from such factories pollute the aquatic environment. The first reported human poisoning by Hg in seafoods occurred in Japan, between 1953 and 1964, which is known as 'Minamata disease' (Nitta, 1972). Investigations revealed that the victims had eaten shellfish contaminated with mercury containing effluents from a nearby plastic industry. The methyl mercury compounds present in the effluent wastes discharged into the Minamata bay were gradually bioconcentrated by fish and shellfish in the bay. A similar incident of Minamata disease was reported from Niigata, where seafish and shellfish were eaten regularly from the inflowing Agano River carrying effluents from the electrical industrial plant. The discharge of wastes containing mercury from chlor – alkali plants, Rayon factory and paper industry causes mercury poisoning, which is evident in Chaliyar River in Kerala, Rushikulya River in Orissa and Thane
creek near Bombay. Mercury poisoning results in chromosomal damages resulting from the combination of mercurials with -SH groups of enzymes and –NH₂ groups of amino acids.

Cadmium is regarded as one of the most toxic metals. The poisoning implicated by cadmium containing food is known as ‘itai-itai’ disease in accordance with the patient’s shrieks resulting from painful skeletal deformities. ‘Itai-itai’ disease was first reported in Jintsu River, Toyama Prefecturor, Japan (Friberg et al., 1974). The disease was characterized by kidney malfunction, drop in the phosphate level of the blood serum and loss of minerals from the bones. Anthropogenic sources of Cd include the mining and minerals processing industries, Zn smelting, paint and plastic industry, effluent from Ni/Cd batteries, urban runoff due to the elevated Cd concentrations in phosphate fertilizers etc.

Copper is an essential trace element for the fixation of Fe in haemoglobin and is not a potent liver toxin except in certain cases of genetic defects resulting in the inability to excrete copper, the primary homeostatic mechanism, for instance Wilson’s disease. Copper in ionic form is found to be toxic and inhibits photosynthesis and affect the growth of unicellular algae (Nielson and Anderson, 1970). Cu in excessive amounts causes haemolysis, hepatotoxic and nephrotoxic effects. The phenomenon of green – sick oysters is caused by high content of copper in the environmental water. The effluents from copper refineries, pesticide
and fungicide manufacturing industries bring copper to the aquatic systems. In Taiwan, copper pollution due to the discharges from the local copper recycling operation has been reported (Hung, 1988) and this has caused serious toxicity in green oysters (Hung et al., 1989). The highest level of Cu in the oysters collected from the polluted area was 4400 ppm (Hung and Han, 1991). Thus, higher level of Cu in the environment or marine organisms adversely affects quality and fishery and can cause great economic loss.

Zinc is another metal that is also toxic to fish and other aquatic organisms at higher concentrations (Pringle et al., 1968). It has adverse effects on fish growth rate and cause mortality at higher concentrations. The main sources of Zn in the aquatic systems are the effluents from factories manufacturing zinc compounds, zinc plating wastes, galvanizing wastes, storage battery, rayon wastes, etc.

Lead is considered as a protoplasmic poison, which is a cumulative, slow-acting and subtle. The Greek poet-physician Nicander described the disease known as plumbism, which is caused by acute lead poisoning. The widespread and general use of lead due especially to its exceptional properties such as high degree of ductility and low corrosiveness has resulted in lead being concentrated in the environment. Lead is introduced into the environment by various industries such as storage batteries, production of chemicals including paints, gasoline additives and various
metal products (eg sheet, pipes). Lead is emitted in large amounts from municipalities, by incineration of waste products. High levels of Pb have been found in urban runoff. Because Pb is used as an antiknocking agent in gasoline in many countries, elevated levels of Pb was found in urban air and by precipitation it will be carried to the near by water bodies.

Manganese is another element, which is quite significant in the marine environment because of its reactivity. It is present in appreciable amounts in marine sediments. Mn affects trace metal distribution in the marine environment as a result of adsorption on manganese nodules (Morgan and Stumm, 1964; Murray, 1975; Cronan, 1980; Manheim, 1986). The geochemical distribution of Mn in seawater is quite erratic and is influenced mostly by its redox potential. Mn toxicity in humans is characterized by a severe psychiatric disorder resembling Schizophrenia, followed by a permanently crippling neurological disorder clinically similar to Parkinson’s disease (Hurley and Keen, 1987).

Arsenic is another cumulative poison. Large quantities of arsenical compounds are released into the environment through mining operations and from industries producing biocidal formulations like herbicides, pesticides, war chemicals etc. Arsenic is also emitted during the burning of fossil fuels (Lederer and Fensterheim, 1982). Arsenic intoxication in humans has also been reported (WHO, 1981; Nriagu, 1988). Regulatory agencies of many countries have introduced permissible limits for As in Fish
and Fish products (Bebbington et al., 1977; Phillips et al., 1982) and in drinking water (Zielhuis and Wibowo, 1984; Farmer and Johnson, 1985). Fish and shellfish have a tendency to accumulate many folds of Arsenic in their body. Bioaccumulation and toxicity of As has been well documented (Moore and Ramamoorthy, 1984; Phillips, 1990). Recently in Bangladesh, high level of Arsenic content has been observed in ground water and implicated Black foot diseases in people residing in around 41 districts (Biswas et al., 1998). It was also found that water from 96% of tube wells of many districts of Bangladesh were not suitable for drinking. The symptoms of As poisoning were diffused melanosis, spotted melanosis and spotted keratoses. The ‘black foot disease’ is caused by the chronic ingestion of inorganic arsenic.

Many other diseases like Bush Sickness, Black foot diseases, Gena velgum diseases, Wilson’s diseases, White muscle disease are reported as manifestations of heavy metal poisoning. It is in light of the above, monitoring of heavy metals in marine fishes and shellfishes assumes importance from the view point of consumer safety.

Safety of seafoods are of paramount importance in the present global scenario. Seafood should be free from all kinds of hazards affecting human health. When considering heavy metal content in organisms suitable for human consumption, the most important aspects are its toxicity
towards humans and affinity for other ligands in the enzyme or protein matrix.

Higher levels of Cd and other toxic metals were observed in cephalopods, especially in many squid products imported to Italy (Cantoni, 1986) and in the cuttlefish products exported from India. Some of the frozen cephalopod products (mainly squid and cuttlefish) were detained or rejected in the late 80’s, owing to higher levels of Cd. Recently, in 2001 some cuttlefish products exported from Veraval, India, also had high Cd concentration. Presence of high levels of cadmium in the economically important class of cephalopods has caused serious concern in the processing and export industry. In the light of these observations, investigations were carried out by Lakshmanan (1988a, 1989) and Lakshmanan and Stephen (1993) in seafood products particularly in cephalopods from the west coast of India. The survey indicated that finfishes in general, had only lower levels of Cd and other trace metals compared to squid and cuttlefish. The cephalopods showed an unique phenomenon of bioaccumulation of Cd and other trace metals in different organs of the body. Cephalopods being voracious fish eaters depend on a wide range of marine animals particularly crustaceans, molluscs and fishes and hence there exist the possibility of bioaccumulation of pollutants through food chain. The presence of these toxic chemicals/metals in cephalopods has to be monitored and sources ascertained.
To meet the global challenges in seafood trade, we need to ensure that our fish products are both safe and comply with international quality requirements and standards. Safety of seafood and consumer health are of paramount importance. In order to ensure seafood safety, the European Union and the US have introduced regulations and standards for various fish and fishery products. EU directive of 91/493/EEC and the regulations of US-FDA of July 1997, have made HACCP based (Hazard Analysis Critical Control Point) seafood quality assurance system mandatory for the industry as well as for all countries that want to export to EU and US, in order to ensure safety.

Cephalopods being an important marine export item from India, a detailed study on trace metal levels and uptake by cuttlefish are warranted. The world experience calls for sound environmental knowledge and high standards of environmental ethics. Monitoring of marine environment for Cd and other toxic metals, their probable source and implications of toxicity on the consumers form part of the study. These informations are of great significance for producing safe products and boosting the export potential of this seafood delicacy in the global market. Wholesome and safe cephalopod products would certainly enhance the market potential in the overseas market.
1.2. Cephalopod fishery and resources of India.

Cephalopods are fished from the seas around India from very early times and constitute one of the important exploited marine fishery resources of our country at present. Cuttlefish, squid and octopus are the three major groups of cephalopods which belong to the highly evolved class of the phylum Mollusca, namely Cephalopoda, animals with feet around head. The squid and octopus species are not dealt with in this thesis.

Cuttlefish is characterized by a large calcified internal shell, the cuttlebone, and an ovoid body somewhat flattened dorsoventrally. Cuttlefish are strong swimmers and voracious fish eaters. They live mostly in water column and are either neretic (200m depth zone) or oceanic (beyond 200m depth zone). They are generally bottom dwellers.

There are about 80 species of cuttlefish of commercial and scientific interest distributed in the Indian seas (Silas, 1968; Sarvesan, 1974; Oommen, 1977a). Silas (1968) has given an exhaustive account of the cephalopod species distributed in the Indian Ocean. The important species of cuttlefish available in Indian Waters are Sepia pharaonis, Sepia prashadi, Sepia aculeata and Sepia elliptica. Of these, Sepia pharaonis and S.aculeata dominated along the west coast of India. Sepia pharaonis showed differential growth and the rate of growth of females was higher than that of males. Higher catch rates were observed from the west coast centers.
Hornell (1917, 1951) has given an account of the fishing gear and fishery for cuttlefish. Sarvesan (1974) has briefly reviewed the fishing methods by which cephalopods are caught in India. These include fishing with shore seines, boat seines, hooks and lines, hand lines and trawl nets. The fishery is limited to 50m depth line in the traditional trawling grounds as it is the case in most of the marine fisheries of the country. Prawns and fishes form the chief item of food of this species (Guerra, 1985; Boucher-Rodoni et al., 1987; Castro et al., 1990). Other crustacean items like crabs, stomatopods and polychaetes also form the diet to a smaller extent. Cannibalism was often noticed in cuttlefish.

As a major fish-producing nation, Fisheries play an important role in the national economy. With the advent of the Law of the sea and the declaration of Exclusive Economic Zone (EEZ) by many nations, the cephalopod resource is gaining considerable importance from mere subsistence fisheries to directed fisheries in many developing countries.

Overall export of cephalopods have registered a growth of 5% by volume and 9.92% by value during 1999-2000 compared to 1998-99. Cephalopods are the third largest product group with a share of 21.21% in volume and 11.91% in value in export basket. During 1999-2000, cuttlefish constituted 45.08% in volume and 46.97% in value followed by squid and octopuses. The average unit value realization of cuttlefish has also increased to Rs. 286.22 crores during 1999-2000 from Rs. 273.31 crores.
European Union continued to be the largest market for Indian cephalopods.

1.3. Utilization of cuttlefish

Cuttlefish were of economic importance both as food and an item of export. The high protein and low fat content of cuttlefish make them suitable for human consumption (Roper et al., 1984). Padmanabhan (1970) has discussed the prospects of developing cephalopods into fishery products for internal and export trade and has given the methods of processing and preservation. Cuttlefish exported are processed in several styles such as cuttlefish whole, whole cleaned, cuttlefish fillet, tentacles, rings, wings, cuttlefish roes, IQF tubes, tray packed, ink and cuttlebone.

Apart from being a good source of human food and an effective bait in long line fisheries, cephalopods have many other uses. Cuttlefish are used as manure. The cuttlebone are commercially used in preparing fine abrasives and dentifrices (Dees, 1961). Certain medicinal properties are also attributed to the bones and ink of cuttlefish (via Boycott, 1957). The powdered cuttlebone is a good source of food for poultry and cage birds. Pulverized cuttlebone are used for cleaning the surface of woodwork and motor vehicles before they are painted (Sarvesen, 1974). They are also used in jewellery, making for moulding purposes.
1.4. Nutritional significance of cuttlefish

The nutritive value of cuttlefish and cuttlefish products are widely recognized. Cuttlefish meat has a very high nutritive value. The edible part of cuttlefish contains all essential minerals and the content of Zn, Mn and Cu were higher in cephalopods than fish meat. Consumption of marine invertebrates is of particular value in every stage of malnutrition, especially when there is a lack of animal protein. The cuttlefish contain 20% protein and very little fat and ash. Edible muscle of cuttlefish had around twenty essential amino acids. Cuttlefish has three times as much as collagen as fish and was found to contain 77-85% Myofibrillar protein, 12-20% Sarcoplasmic protein and 2-3% Connective tissue (Sugiyama, 1989).

Though the fat content is negligible, the muscle of head and arms of cuttlefish are known to contain high level of cholesterol. The lipid is found mainly in liver and also in the skin.

Cuttlefish are highly perishable at ambient temperature and the rate of quality degradation and spoilage are much faster compared to finfish. So, handling of cuttlefish requires special attention, the earliest, keeping the temperature very low. Hard rubbery texture, flabby and soft meat, high drip loss during thawing and pink or yellow discolouration of meat are some of the quality problems encountered in cuttlefish products. Furthermore, the presence of high levels of toxic metals adds to some of the important safety problems met in the cuttlefish export industry. Therefore, to increase
consumer acceptability, the quality of cephalopod raw materials and safety of finished products should be ensured.

1.5. Objectives of the study.

The main objectives of the present investigation are the following:

i. To monitor the levels of heavy metals, viz., Hg, Cd, Pb, Cu, Zn, Fe, Mn, Cr, and Ni in whole soft tissues as well as the edible (muscle) and the non-edible body components of the cuttlefish (Sepia pharaonis), found along the west coast of India and to provide base line data of trace metals in cephalopods.

ii. To determine the levels of toxic metals in cuttlefish caught from different geographic locations, viz., Cochin, Quilon, Mangalore and Mumbai region, so as to understand regional variation, if any, in metal distribution.

iii. To study seasonal variations of Cd and other toxic metals in cuttlefish caught off west coast of India.

iv. To study the levels of metals in food fishes, habitat water and their relation to metal levels in cuttlefish.

v. To evaluate Cd toxicity in experimental albino rats by feed trials using liver incorporated diets and observing the haematological and histopathological changes in the cells, and there by its toxicity to cephalopod consumer.
1.6. **Review of literature.**

Trace metals play an important role in the aquatic ecosystem. In marine organisms, uptake of heavy metals was reported by many researchers (Saiki *et al.*, 1955; Mullin and Riley, 1956; Martin and Goldberg, 1962). Brooks and Rumsby (1965) studied the biogeochemistry of trace metal uptake of Ag, Cd, Cr, Cu, Fe, Mn, Mo, Ni, Pb, V and Zn in three species of New Zealand bivalves. All the elements analysed showed more enrichment in molluscs than in the environment.

Since molluscs in general, concentrate in their bodies certain trace metals from the hydrosphere it becomes necessary to monitor the levels of these metals in seafoods. Trace metals in molluscs have been reported from various parts of the world (Decleir *et al.*, 1970; Bryan, 1973; Topping, 1973; Eustace, 1974; Ratkowsky *et al.*, 1974; Martin *et al.*, 1975; Bryan *et al.* 1977; Nambisan *et al.*, 1977; Ishii *et al.*, 1978; Schipp *et al.*, 1978; Lakshmanan and Nambisan, 1983; Eisenburg and Topping, 1984; Ray, 1986; Sadiq and Alam, 1989; Skulsky *et al.*, 1989; Chen, 1998; Frias *et al.*, 1999; Lakshmanan *et al.*, 2001).

The pioneer work on the levels of trace metals in cephalopods was carried out by Martin and Flegal (1975) and stated that cuttlefish are very good cadmium integrators from the environment. These authors had reported the levels of a range of metals. Decleir *et al.* (1978) determined the protein bound copper and zinc in some organs of the cuttlefish *Sepia*
Schipp et al. (1978) reported on the distribution of copper and iron in central organs of the cuttlefish Sepia officinalis. Cantoni et al. (1986) determined the Zn/Cd ratio in cuttlefish imported into Italy from four different countries and reported that about 50% of the samples had Cd content in excess of the tolerance limit. Falandysz (1988, 1989, 1990, 1991) had made an exhaustive investigation on the levels of metals in fresh and processed squid, Loligo patagonica and Loligo opalescens. Lozano Soldevilla (1989) found concentration of Cu, Cd, and Fe in whole bodies of Todarodes Sagittatus to be high when compared with those in mantles and tentacles. Furthermore, the maximum values for Cu and Cd permitted by Spanish law exceeded in a few individual whole body samples. A survey conducted by Sapunar (1990) in cephalopods from industrially polluted Kastela and Kijelka bays and a control area in the Adriatic sea revealed significant difference in Cd and Hg levels between polluted and non polluted areas. Heavy metal content in the mantle (edible part) and the intestines of cuttlefish (Todarodes sagittatus) from North east Atlantic was reported by Oehlenschlaeger (1990) and found cadmium and lead content were low in the mantle but very high in the intestines. Ikebe et al. (1991) determined the content of 16 metals in fish and shellfish of Japan. Miramand and Bentley (1992) measured the concentration of eleven heavy metals in the tissues of cephalopods collected from the French coast of the English Channel and found that the digestive gland contained greater than 80% of the total body burden of Ag, Cd and Co. Trace metal concentration in
cuttlefish from processing factories of Thailand were extensively studied by Attaya et al. (1993) and concluded that Cd content in cuttlefish meat are generally at safe level. Martoja and Marcaillou (1993) reported in liver of cuttlefish, *Sepia officinalis* L., the greater part of accumulated Cu is concentrated in spherulae, which are elaborated by the basal cells. Cisneros et al., (1995) reported the Cd contents of 77 fresh and frozen samples of cuttlefish, and the cadmium concentration ranged from 0.98 to 3.30 mg/kg (wet wt) in the muscle of cuttlefish from Argentina. Lu chavhua (1995) determined the levels of Cu, Pb, Zn, Cd, Cr and Ni in cephalopods collected from the Northern area of South China Sea and reported that there were no significant levels in the edible muscle. In another study by Galarini et al., (1996) the highest concentration of Cd was observed in cephalopods when 724 samples of marine and fresh water fish and shellfish from Umbria and Marche regions of Italy were analysed. Chen et al. (1998) assessed the contents of heavy metals in cephalopods from Zanijiang harbour waters and found the edible parts to be effected by Pb, Cd, Ni and Zn. Bustamante et al. (1998 a) analysed 350 individuals of 12 species of cephalopods from the French Atlantic coast to the sub-Arctic region and found high cadmium level in the cephalopods from the Sub-Arctic area than those from the lower latitudes. Jones et al. (2000) observed Zn concentration in the muscle of two species of cuttlefish from Cleveland Bay, in the range of 13-16 μg/g wet wt.
However, similar study in cephalopods from Indian waters is very scanty (Dious and Kasinathan, 1992). Ramamurthy (1979) and Patel and Chandy (1988) studied the base line levels of Hg in cephalopods. A comprehensive account of trace metals in cephalopods (squid and cuttlefish) was provided by Lakshmanan (1988a,b; 1989) and Lakshmanan and Stephen (1993) for the first time in India. This study has generated the idea of unique phenomenon of selective bioaccumulation of Cd in cephalopods.

Concentration of a metal in an organism mainly depends on the bioavailability of the metal, environmental conditions like salinity, dissolved oxygen, temperature and concentration of metals in their locality and the quality of food (Presley, 1997). Seasons do play a major role in the accumulation of trace metals from the habitat water. Seasonal distribution of heavy metals in molluscs have been reported worldwide. Brooks and Rumsby (1965) made a quantitative study of some trace metals in some bivalve molluscs of Newzealand. Segar et al (1971) gave the distribution of six major and thirteen minor elements in the shells and entire soft parts of 11 species of molluscs from Irish Sea. Another important piece of work is by Bryan (1973) on the occurrence and seasonal variations of Cu, Fe, Zn, Mn, Pb, Ni, Co, Cr, Cd and Al in the scallops Pectin maximus (L) and Chalmys opercularis (L). Hall et al (1974) had estimated the Hg content in certain clams and oysters. Eustace (1974) estimated the concentration of Cd, Cu, Zn, and Mn in certain species of finfish and shellfish caught from

However, not much attention is given to study the distribution of metals in cephalopods during different seasons. Dious and Kasinathan (1992) studied the concentration of Fe, Mn, Zn and Cu in different body tissues of *Sepiella inermis* during different seasons.

Studies on the trace metal levels in coastal and marine waters of India have been studied in detail by Sengupta *et al.*, 1978 and Qasim and Sengupta, 1981. Other important works included are those of Braganca
and Sanzgiri, 1980; Fowler et al., 1984; Kureishy et al., 1993; Krishnakumar et al., 1998; Senthilnathan et al., 1998.

Marine organisms take up heavy metals to varying degrees with concentration factor in the order of $10^2$-$10^3$. Trace metals can cause deleterious effects on density, diversity and productivity of aquatic organisms (Eisler, 1993; Moore and Ramamoorthy, 1984). Trace metals like Cd, Cu, Zn, Fe, Mn, As, Ba, Co, Mo, Ni, Sb, Sr, V and Zn can cause toxic effects to human beings with far reaching consequences (Mathew, 1991 a, b; Sharma, 1995).

Histomorphological alteration in the liver and kidney of albino rats have been reported by several workers (Cherian et al., 1976; Weigal et al., 1984; Dudley et al., 1985; Elinder 1986; Anderson et al., 1988; Sendelbach and Klaasen 1988 and Lin and Ho., 1992). Anderson et al., 1988 found histopathological alterations in the livers of mice ten days after oral exposure to a single dose of CdCl$_2$ (30 mg/kg body wt), and Elinder (1986) reported that for detecting the long term effects of Cd on the liver, liver morphology is a more sensitive parameter than the liver-enzyme activities in the blood. Groten et al., (1990) studied the toxicity of inorganic and liver incorporated cadmium in rats by feeding a test diet containing 30 mg Cd/kg. Chaterjee et al., (1996) reported degenerative changes of hepatocytes, widening of the bowman's space in the cortical region of kidney, necrosis
and degeneration of tubular epithelium in rats treated with CdCl₂ (1 mg/kg/day) for four weeks.

Cuttlefish have been identified as voracious fish eaters by many authors (Bidder, 1966 and Boyle, 1990). Cannibalism was also noticed in some species of cuttlefish (Oommen, 1977b). Feeding habits of cuttlefish play an important role in the accumulation of Cd and other metals (Bryan et al., 1983). The common food items are fish and prawns (Boucaud – Camou and Boucher – Rodoni, 1983; Guerra, 1985; Boucher – Rodoni et al., 1987, Blanc et al., 1998; Castro et al., 1990; Pinczon du sel and Daguzan, 1992). Further more cuttlefish are a prey to a great variety of seabirds, marine mammals, fishes and cephalopods themselves (Silas, 1963; Clarke, 1986; Rodhouse et al., 1992; Clarke, 1996; Croxall and Pierce, 1996; Smale, 1996). Oommen (1977) studied the structure of alimentary canal, digestive enzymes and food and feeding habits of this species from the South West coast of India.

Cephalopods, particularly cuttlefish are a significant source of Cd to their predators. This hypothesis was first proposed by Honda and Tatsukawa (1983) for striped dolphin from Japan. Muirhead and Furriness (1988) supported this hypothesis, by explaining very high Cd concentrations in the tissues of cuttlefish eating seabirds from Gough islands. Works has been carried out on the cuttlefish predator relationship by Paludan – Muller et al., 1993 and Caurant et al., 1994. Cadmium is transferred from water
and food to the cuttlefish, and from cuttlefish to their predators through the food chain. Therefore, cuttlefish play an important role in the bioaccumulation of Cd by their predators (Law et al., 1997; Sepulveda et al., 1997). Bustamante et al., 1998a observed that the bioaccumulation effect was found to be most evident at high latitudes. Food can be considered as the main source of metals in cephalopods (Bustamante et al., 2000). Jiro Koyoma et al., (2000) studied the relative contribution of Cd in water and food to bioaccumulation in oval squid and suggested that the main source of Cd in squid appear to be dietary.

The above literature review indicated a derth of information on the above topic from the Indian subcontinent. India, being a major exporter of seafood item including cephalopods, the safety of the marine products has to be ensured. Considering the importance in global trade, environmental contaminants particularly trace metals has to be monitored and safety has to be evaluated. The present study attempts to monitor Cd and other toxic metals in cephalopods, food fishes and habitat water from the west coast of India and to provide a base line information on the problem, which would greatly help the seafood industry.