STUDIES ON THE EFFECT OF SHIP SCRAPPING INDUSTRY WASTES ON MARINE PHYTOPLANKTON AT ALANG, GUJARAT.

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By

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CANDIDATE'S STATEMENT

I hereby declare that the work incorporated in the present thesis is original and has not been submitted to any University / Institution for the award of a Diploma or a Degree. I further declare that the results presented in the thesis and the considerations made therein, contribute in general to the advancement of knowledge in Marine Sciences and in particular to entitled "STUDIES ON THE EFFECT OF SHIP SCRAPPING INDUSTRY WASTES ON MARINE PHYTOPLANKTON AT ALANG, GUJARAT".

Signature of the Candidate

(Subir Kumar Mandal)

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To my

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Contents

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List of Tables

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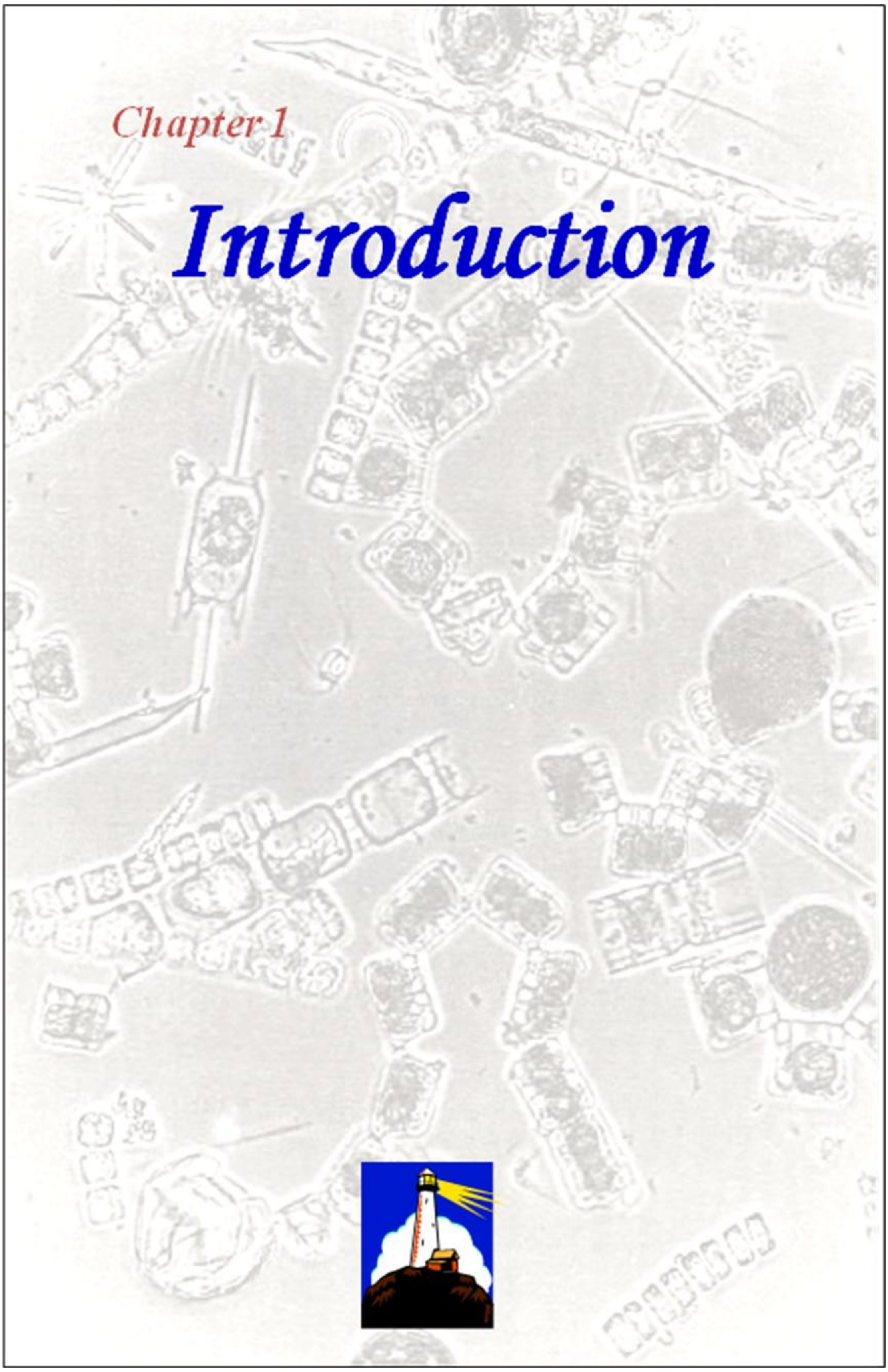
List of Figures

List of The Plates

Chapter 1

Introduction



Chapter 1

INTRODUCTION

Indiscriminate exploitation of nature by man has disturbed the delicate ecological equilibrium between living and non-living components of the environment as a whole. One of the most serious problems confronting the modern world today is the problem of water pollution, which has assumed global dimensions. Widespread water pollution has been regarded as the most probable contributing cause responsible for recent biodiversity related regional or global problems like the appearance of phytoplankton blooms, declining or alteration of other marine organisms etc. Now a days it becomes relevant and also important to understand the effect of pollution on marine biodiversity, on the basis of vigorous surveying of information obtained from the affected areas and from available research findings, in order to become alert before biodiversity loss (Mayers, 1995; Agarwal & Agarwal 2000).

1.1 An Overview of Marine Pollution:

All marine pollution must originate from one of two sources, either the land or the sea. Of course, marine pollution is defined as a human activity, and humans are land inhabitants and so it might be scientifically correct to assert a land-based origin for all marine pollution. The coastal areas are under pressure since they have become an ultimate dumping place for all the treated and untreated wastes from surrounding areas (Bhattacharya 1995). These kinds of human impacts generally alter the structure and function of marine aquatic ecosystems by changing the species composition of communities and also affecting nutrient cycle (Nemerow, 1985) and ultimately threaten the equilibrium of Planet's Biosphere. Moreover, an industry based lifestyle has inevitably lead to an increased anthropogenic impact on the Biosphere (McEldownney *et al*., 1993). It has already been predicted that perhaps a quarter of the Earth's total Biodiversity is at a serious risk of extinction during the next 20-30 years because of the severe impacts of pollution on marine environment (Ravan 1988).

For marine organisms and ecosystems, marine environmental quality could mean the difference between life and death. Population growth, coastal development, resource demand, climate, relative sea-level rise, and natural coastal processes affect marine environmental quality. Variations in environmental conditions affect the recruitment, distribution, abundances and availability of fishery resources. Yet, nearly all of the threats to habitat and marine environmental quality are human induced pressures i.e.` from physical alteration of the environment to pollution impacts leading to toxicity due to heavy metals and petroleum hydrocarbons from human activities conducted either directly or indirectly in/on marine waters.

Due to rapid increase of global population and industrialization in many developed and developing countries, the coastal areas are facing a serious threat of environmental degradation due to man made activities like waste disposal from land based sources and sea based activities. In order to sustain the productivity of coastal waters as well as to preserve the rich biodiversity, and restoration of ecological equilibrium, it is the need of the hour, as well as mandatory to take several remedial measures in appropriate direction. The activities causing pollution problems in developing countries are for more serious, as they have to face several priorities like employment, shelter, health etc. for alleviation of poverty and to promote industrial growth for better economy. The crucial role of ocean in the global life supporting system, and its major influence on the earth climate are no doubt quite appreciable for the development of communities, but at the same time, the government or the general public also should be properly aware of the need to protect the marine environment and to ensure that the seas / oceans remain healthy for the welfare of the mankind.

1.2 Pollution of the sea by Ships:

Shipping activity adds to the heavy metal pollution of coastal areas serving as harbors, because the ship bottom is painted with toxic paint to prevent algae and sessile marine animals from fouling the haul. Antifouling paints contain tin or copper as toxicants, the latter mostly as copper oxide, or more modern types of organo-metallic compounds, Chromium, lead and zinc are important constituents of primers, applied to bottom of ship. Cadmium is also used in some paints, and zinc is present in sacrificial anodes to prevent steel hulls from corrosion. Five to ten million tonnes of petroleum pollute the world's ocean per year. The estimated amounts were recalculated during 1970. But it was obviously not easy to get the exact amounts, and it was 6.1 million tones (1970), even though, there were still considerable gaps between the various estimates. In recent years the amount might be increased more than ten fold. (Sevestian,1981).

1.3 Status of Ship breaking Industry in the world:

A total of 10.75 million gross tonnages was demolished during 1993 in the ship-breaking industry in the world, and the major four countries, China (with a record output of 54%), India (18%), Bangladesh (13%) and Pakistan (8.6%) took major share (93%) of demolished tonnage. The following table shows the major share of ship scrapping activity, demanded by the different Asian countries during 1996 –1998.

All figures of LDT (Light Dismantling Tonnes) expressed in million tonnes.

Country	**Period**		
	1996	1997	1998
India	8.9	7.6	8.5
Bangladesh	4.4	2.9	5.2
Pakistan	2.0	0.8	2.7
China	0.2	0.2	1.4
Others	2.3	3.8	2.6
Total	17.9	14.5	20.4

Source: Iron & Steelscrap and Shipbreakers Association of India), c.f. *Lloyd's List* (*1999*)

Obviously, the only safe way to demolish a ship would be in a shipyard. The last ship was scrapped in the UK was over a quarter of a century ago. Usable facilities still exist in Spain and Turkey and Australia has undertaken a feasibility study to establish a facility. The

EU is also doing a study. China which until 1993 undertook half of the scrapping in the world, dropped out of the industry when stricter environmental laws were introduced.

According to Greenpeace the scrapping practices in Asia, where most ships end, have low safety and environment standards. They also maintain that most ships contain several poisonous chemicals and materials like PCBs and insulating material that can create severe health and environmental problems when removed and disposed in the surrounding environment (MPB News 1998).

Recycling of ships for scrap by the US has come under increasing pressure from the Basel Action Network (BAN) and Greenpeace. This may prevent the export of hazardous wastes from industrialized nations to developing countries. An international campaign by BAN and Greenpeace will attempt to amend the regulations of international and domestic laws so that hazardous exports for ship breaking will be banned (MPB News 2000).

1.4 Status of Ship breaking Industry in India:

Most of the ship scrapping work is carried out in India, Bangladesh and Pakistan where the high tides are especially conducive to landing the ships onto the beach. In India over 300 ships a year are now being processed at Alang, which has already demolished over 2,000 ships since its inception in the early 1980s. In this industry, 25,000 people or so work at Chittagong in Bangladesh and about 40,000 people are engaged at Alang in India for the tedious, laborious and dangerous work.

In India, the ship – breaking industry was started on a small scale during 1970’s at Bombay and Calcutta of Maharashtra and West Bengal respectively and subsequently shifted to Alang in Gujarat, because of its more accessibility for beaching facility.

The growth of ship-breaking activity in India is attributed to:

- The availability of ample semi-skilled manpower,
- Foreign exchange savings to the country as it has to spend less on importing ships for scraping.
- Energy saving to the main steel industry by using re-rollable scrap directly, and
- Ready local market for the recoveries, including electrical, non-ferrous items.

It can be seen from statistical data that growth of ship breaking industry is on a steady raise. In recent times, India has become a leader in world-ship breaking activity with a share record output of 60.4% in 1990 and 29.4% in 1991. Besides, the withdrawal of active participation of countries like Taiwan and Korea in the ship-breaking industry has indeed helped India to emerge as the leader in this industry during the past several years. Although, in India, there are over 130 ship-breaking sites, Alang area, is the main center of the ship-breaking activity and account for around 90% of the ship-breaking in the country. The following table shows the increasing trend of ship scrapping activities at Alang.

YEAR	**NO. OF SHIPS**	**LDT**
1982-83	5	24716
1983-84	51	259387
1984-85	42	228237
1985-86	84	516602
1986-87	61	395139
1987-88	38	244776
1988-89	48	253991
1989-90	82	451243
1990-91	86	577124
1991-92	104	563568
1992-93	137	942601
1993-94	175	1256077
1994-95	301	2173249
1995-96	183	1252809
1996-97	348	2635830
1997-98	347	2452019
1998-99	361	3037882
1999-00	296	2752414
2000-01	295	1934825
2001-02	333	2727223
TOTAL	3377	24679712

(*Source*: Report of Gujarat Maritime Board, Alang 2003, the unit LDT= Light Dead Tonnes)

The coastal town of Alang, around 55 km from Bhavnagar has achieved as main ship-breaking center in India, since its, inception in 1982 on a small and medium scale. Alang Sosiya Ship-breaking Yard is situated in the coast of Bhavnagar district of Gujarat. It is the largest ship-breaking yard in the world. Ships reaching the end of their lives contain a range of hazardous waste including PCBs, asbestos, lead based paints, glass wool and thermocol and heavy metals like cadmium, arsenic, lead, chromium, copper and zinc. More than 95% of the mass of an ocean going ship consists of high quality steel. Recovering the steel is main purpose of dismantling the ships. The remaining less than 5% made up of non-ferrous metal compounds, paints and coating, insulation and sealing material, electric cabling, cabin walls, decorative tiling, floor coverings etc, must be death with properly. The materials that are being generated while breaking the ships could further be classified as Hazardous and Non-hazardous type materials. The existing studies show that only 0.1% of the weight of ship contributes as Waste materials. Out of these, Hazardous materials like, asbestos in sheet form, thermocol in big pieces, unbroken insulation, and recovered oils are sold by the downstream Industries and therefore residual wastes belong to Hazardous categories which are the matter of concern to environment directly and to the human health indirectly.

The major ship breaking processes are accomplished along the shore zone. These include removal of super structure and cutting of ships hull, engine and propeller, and materials removed from the ship, consist of a variety of items like.

- pumping out of ballast water, fuel oil and lubricant.
- Dismantling and removing of furniture, life boat, loose cables, fire fighting equipment, ladder, window etc.
- Removing of electrical and navigational equipments, nylon and steel ropes, machinery spares.
- Dismantling and removing diesel generators, boiler, air compressor, pumps etc.

After removal of all these items, vessel is cut vertically into big blocks by oxygen-LPG torch. These dismantled pieces are pulled on to the shore with help of winches during low tide. As the size and weight of vessel is reduced, it is handled closer to shore line by winches during the high tide. Finally hull bottom is cut and pulled to shore.

Ships come for demolition usually carry different type of organic and inorganic materials, some of which pollute the marine environment. If not controlled during dismantling the material is released during ship breaking and it includes:

* Oil fuel and lubricants.
* Oil sludge in Oil tankers and Oil Carriers.
* Solid waste such as glass wool, thermocole, plywood, timber etc.
* Heavy metal and Other Chemical constituents of paints and coating.
* Remains of toxic chemical in Cargo compartments.

The oil and heavy metal pollution of water and sediments, change the composition and bio-mass of macro and micro organisms in the inter tidal region. In addition, the activities also result in discharge of solid waste. Due to high tidal current, such waste gets, diffused to a large extent. With the growth of a ship-breaking activity, several other activities like re-rolling of steel, transportation, oxygen and LPG bottling etc. also developped in the vicinity of ship breaking yard. Since, there is no specified zone for each activity of ship breaking, causes adverse effect to environment and considerably effects species diversity and habitat in surrounding marine environment. Damage starts when human activities modify the environment to such an extent that it can not be restored by the existing flora and fauna in the ecosystem. Diversity of the coastal environment is the result of many complex interactions, and the resultant development leading to disrupt this fine balance must be viewed seriously. The ship breaking industrial wastes, wash out oil from ships and boats cause much more damage to marine life in the ocean (Plate-I to Plate-VI).

1.5 Scope of Studies:

Ship breaking activities are considered as one of the hazardous activities classified world over. The present study is mainly aimed at the case study of some of the important impacts of the activities at Alang-Sosiya ship breaking yard, on marine environment. The study was carried out in the limited area, keeping time frame and limitations of data collection and acquisition. The study is mainly based on

a) Water quality parameters of coastal seawater.
b) Main contaminants present in the study area.
c) Effect of the pollutants on live organism, especially on Marine Phytoplankton.

The Monitoring and Assessment Research center (MARC) at Chelsea College, London broadly defines the term “heavy metals” as metals of atomic weight higher than that of sodium and having a specific gravity of more than 5.0 (i.e. densities above 5 g cm^{-3} (Passaw *et al*., 1961; Sorentino, 1979).

Heavy metals can be toxic pollutants if their concentration is high. They are used as components in many manufacturing processes and produced as wastes production in industrial effluent. These are also released into the surroundings during the dismantling processes at the Ship breaking Yard. Heavy metal can enter into the hydro-biological cycle, where they are concentrated upto the food chain, and ultimately reaching toxic levels.

Heavy metals such as lead, copper, zinc, cadmium, and nickel are responsible not only for degrading the quality of seawater but also for killing a number of marine organisms. Most heavy metals are practically not destructible in an aqueous environment. Many organisms can concentrate large amounts of heavy metals in their bodies and subsequently pass them on through the food chain from fish to man.

Metals are often associated with chlorinated hydrocarbons because hydrocarbons constitute a part of the metal, as napthenate in copper, as sulfate or oxide in zinc; as methyl, ethyl, alkoxyethyl, or mercuric chloride in mercury. Some heavy metals may come from the crude or heavy fuel oil leaks (or spill) from ships, pipelines, and offshore wells.Manganese, cobalt, and nickel are found in crude oils as nonvolatile porphyrins.

Recently oil has become the most frequently encountered water pollutant, and oil pollution incidents are becoming numerous. Unlike some pollutants, oil pollution is generally unpredictable as to location and time and usually exists as a surface phenomenon. A small quantity of oil may be important to produce a heavily polluted appearance having harmful effect on aquatic life.

The effect of a particular spill or leakage depends on many factors, including volume of oil spilled / leakage, seasonal effect, (air and water temperature, wind speed and direction), the presence of structure or resources in the path of spill, location of spill / leakage in relation to the nature and mixing of sediments, sea bottom topography, and geomorphology of the coast. The variability of these and other factors and their interactions could lead to a wide range of ecological, economic and physical effects.

1.5.1 Marine phytoplankton-As an indicator species of environmental contaminations:

The presence of chemical contaminants has become a pervasive threat to many natural aquatic ecosystems. Environmental contaminants could have toxic effects on different types of organisms and affect biological processes at the cellular, population, community and ecosystem levels of organization. Phytoplankton species vary widely in their response to toxic chemicals present in polluted environment.

Tests on single species of alga are therefore of limited applicability in assessing the effects of environmental contaminants on algal communities that are composed of an array of species with different sensitivities. Even at concentrations that are sub-lethal, toxicants can change the structure of Phytoplankton communities (Mosser *et al.,* 1972a,b).

The long-term problems of marine pollution biogeochemistry, include the general patterns of distribution and concentration of micro-impurities in marine ecosystems, the natural baseline levels of certain toxicants in seawater and marine organisms, physical factors in the behavior and migration of toxicants in marine environment, the role of food chains in the migration of pollutants, mechanisms of selective accumulation of toxicants in aquatic organisms, the use of biological indicators of persistent low level contamination, the influence of primary production on the distribution and migration of pollutants, auto-purification and auto-detoxification processes, the balance of pollution in individual regions, and the mathematical modeling of the processes of distribution of impurities in marine ecosystem.

The most urgent marine toxicological problems include the development of principles and methods of control and determination of permissible toxicant concentrations; studies of comparative resistance to toxicants, and identification of the most sensitive species and varieties of aquatic organisms and their developmental stages; evaluation of abnormalities caused by pollution in the primary and secondary productivity in the sea; providing a scientific basis for the permissible upper limits of pollutants in seawater; analysis of present day pollution in the marine environment and prediction of future biological and ecological consequences arising from toxicological problems and experimental modeling of the effect of toxicants on marine ecosystems.

Phytoplankton organisms may be used to identify 'natural regions' of the oceans and that regions may be characterized by typical species or species groups of marine phytoplankton. There are some indications in the literature, that phytoplankton organisms are also good indicators of natural regions as defined by latitude (e.g. boreal, subtropical, and tropical) and by oceanographic features like the oceanic gyres (Smayda, 1973). Phytoplankton may also be used to trace climatic changes in different geological periods. In paleontology, the environmental factors, e.g. temperature of recent species of skeleton –

bearing algae like diatoms or coccolithophores, are used to identify changes in prevailing the environment of past era.

Indicator values for pH, salinity, phosphorous, organic nitrogen enrichment, organic pollution, oxygen levels, etc. have been given to diatom taxa (Hustedt 1938-1939; Cholnoky 1968; Lange-Bertalot 1979; Stadecek 1986; van Dom *et. al*., 1994; Kelly and Whitton 1995; Kelly 1998). Such species specific indicator values of taxa have been included in autoecological indices currently used to evaluate water quality (eutrophication, organic pollution) (Whitton *et. al.,* 1991; Whitton and Rott 1996; Prygiel *et. al.,* 1999; Charles 1996; Stevenson and Bahls 1999). Similarly, classification and statistical correlation of diatom species according to their occurrence in waters differing in acidity and the use of corresponding analysis between diatom species and nutrients in standing and flowing waters (Ter Braak and van Dom 1989; Birks *et. al.,* 1990; Schreiner 1991; van Dom and Mertens 1995; Coring 1996; Lancaster *et. al*. 1996; Pan *et al.,*1996; Battarbee *et al.,* 1999) have been found to allow general conclusions on the trophic state of waters (Pan *et. al.,* 1996; Winter and Duthie 2000).

1.5.2 Objectives of the present study:

In recent years, applied aspects of phytoplankton research have become more and more important. Experiments on low-level perturbations are carried out in the laboratory or in *insitu* to obtain data on the effect of pollutants in the sea. There is clear evidence from experiments, that pollution stress is indicated mainly by the population structure and the succession of phytoplankton species rather than by changes of standing stocks in terms of chlorophyll or rate measurements of phytoplankton. Attempts are focused on specific phytoplankters, which might be useful as test organisms to identify the degree of pollution by harmful substances.

The main purpose of this study is aimed to understand the following parameters at ship breaking yard, at Alang:

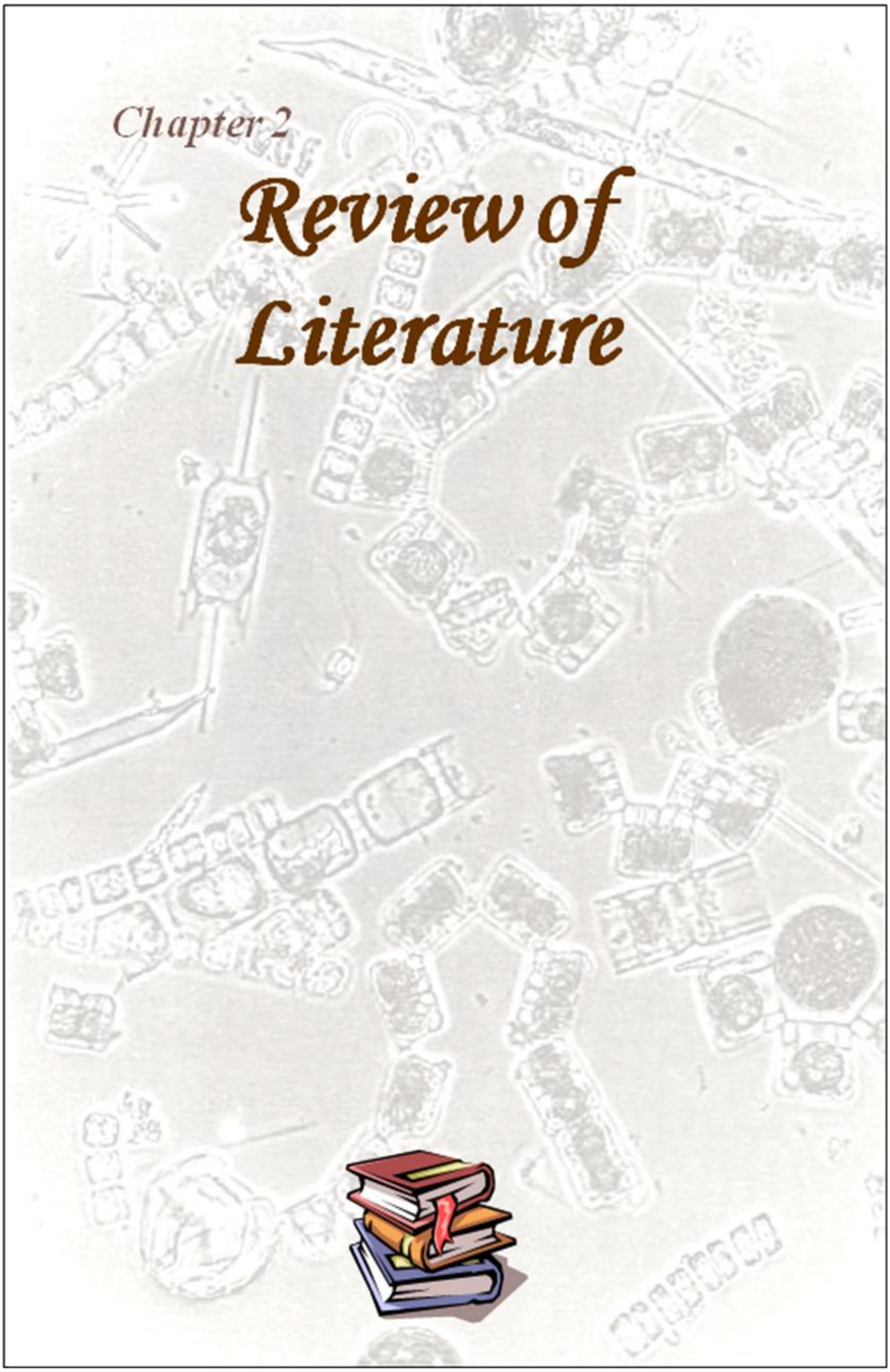
1) To find out physio-chemical status and nutrient dynamics which includes Air & Seawater Temperatures (°C), Total Suspended Solids (TSS), pH, Salinity (S‰), DO, BOD, NO_2^{-1}-N, NO_3^{-1}-N, NH_4^{+1}-N, PO_4^{-3}-P Chlorophyll-a, Pheophytin and Gross and Net primary productivity of the coastal area of Alang.

2) To assess the heavy metal (Fe, Mn, Cd, Co, Cu, Zn, Ni and Pb) and petroleum hydrocarbon contamination in seawater.
3) To study the bio-diversity and seasonal variations of Marine Phytoplankton.
4) To study the impact of heavy metals and petroleum hydrocarbon and their interrelationships as well as their role in succession and community composition of marine phytoplankton through biometry measurements.
5) To identify heavy metal and petroleum hydrocarbon tolerant species (Bio-indicator species) of Marine Phytoplankton at the coastal area in relation to ship breaking activity and to study the effects of pollutants on the isolated species in laboratory condition for future use of scaling out the degree of pollution caused by ship scrapping activities at Alang.

As a result of the above studies it may be arrived at presenting interpretive summaries on the impact of pollutants, which are causing physical and physiological effect on the marine phytoplankton at the coastal area of Alang to get a proper knowledge for taking conducive steps to maintain a healthy marine coastal environment.

Chapter 2

Review of Literature



Chapter-2

REVIEW OF LITERATURE

Ship breaking yards usually known as Dumping Docks. Stringent environmental and workers safety regulations in force in developed nations make it impossible for the ship breaking industry to set up there. The activity, therefore, finds its way into developing countries, where laws are lenient and labor is cheap in countries like India, Pakistan, Bangladesh and China. Ship breaking activity involves highly dangerous and hazardous in terms of worker safety and health.

An international seminar on Ship Breaking in Asia with the Liability Regime was held at Amsterdam, the Netherlands, on June 2, 2003. The seminar was organized by the International Institute for Asian Studies (IIAS) in cooperation with Greenpeace International. The IIAS is a post-doctoral research center in Leiden University, Amsterdam, concentrating on Asia. Greenpeace is an international environmentalist organization, based at Amsterdam, having offices in all countries including India. It focuses particularly on the extreme hazards of ship breaking in the Asian countries, most particularly at Alang, Gujarat, which is the largest ship-breaking yard in the world. The seminar was chaired by Paul Bailey from the ILO, Switzerland, and attended by about 30 people and stakeholders including ship owners, ship breakers, the personnel from Netherlands ministry of environment, and delegates from Greenpeace toxic campaigners from Belgium, Greece, Switzerland and Luxembourg. It emphasized that ship breaking had become a mega private industry in various parts of the world, giving large profits to the owners. The main purpose of ship breaking is to recover steel from the ships. After these ships have exhausted their average life of 25-30 years in the sea, they are sent by the developped countries to the ship breaking yards, mostly in India, Bangladesh, Pakistan, China, etc, for breaking. Here they recover the steel and other materials, and sell them in local markets, garnering huge profits. Alang ship-breaking yard near Bhavnagar, (Gujarat), being the largest ship breaking yard in the world, accounts for about 70 per cent of the ship breaking in the world. In India, ship breaking contributes to over 10 per cent of the country's annual steel production, recovering about 2.5 million tonnes. But the entire process is laborious with extreme hazards. In the name of international trade for ship breaking, ships laden with highly toxic and hazardous substances like asbestos in different forms, poly-chlorinated biphenyl's (PCBs), zinc, lead, inflammable oil products, explosives, etc, are sent to ship breaking yards for scrapping. The ship breaking operations cause enormous pollution to the surrounding environment and the sea, as a result of burning all unusable parts of the ship, which cannot be sold.

In 1999 at the first international conference on ship-breaking the following proposals were discussed to arrive at a possible solution, although no agreement has been reached:

- Design improvement of vessels that would not only make scrapping ships less labour intensive, but also environmentally friendly and profitable.
- Consideration of international duration limitations on vessel life cycles.
- The establishment of a "Global Scrapping Endowment Fund" in which Shipbuilders would include as part of the construction costs a cash payment to the fund in the amount of the expected costs for the ships eventual demolition.
- A 'Global Scrapping Tax `Fund' in which taxes would be levied on every ship (according to size and weight) in operation across in globe.

Require ship builders to reacquire control of a vessel when it is due to be demolished and to accept responsibility for the safe and environmentally sound scrapping of each ship. It could be better if working conditions at ship breaking yards are improved keeping in view the environmental protection as a whole.

A very preliminary works have been done by Islam *et al*. (1986) and Tewari *et al*. (2001) to study the effects of ship scrapping activities and its associated wastes on sediment and marine biota as a whole. A project, COMAPS (Coastal Ocean Monitoring and Prediction System) was launched by Central Salt and Marine Chemicals Research Institute (CSMCRI) to monitor the water quality parameters in that region. Metallurgical and Engineering Consultants (India) Limited (MECON) have reported that the study of the monitoring of the changes in the chemical and biological composition of coastal seawater at the coastal area of Alang Ship breaking yard.

The maximum values of Shanon Weaver Index of Phytoplankton for clean waters have been reported to be around 6 (six), though it may differ slightly in different locations. Decrease in the value of index may thus be taken as indicator of pollution. The index values of 3 and above are generally considered healthy condition of water bodies. The values between 1 and 3 and less than 1 are representative of semi and poor productivity respectively (NEERI EIA Report 2000 pp. 2.24).

2.1 Heavy metals in relation to Marine Phytoplankton:

The degree of toxicity of heavy metals is also influenced by the presence of competing cations or anions, whether they are toxic or non-toxic (Adiga et al., 1962; Bowen, 1966; Da Costa, 1972; Jones, 1973; Laborey and Lavollay, 1967; Sadler and Trudinger, 1967, Sastry et al., 1962). Un-dissociated salts and complexed ions usually tend to be less toxic than free ions (e.g. Temple, 1964; Temple and Le Roux, 1964). The effect of some of the complex industrial effluents containing heavy metals and other complex substances in relation to biota has been reported from different parts of the world including India (Mackie *et al*., 1978; Breder *et al*., 1980; Samain *et al*., 1980; Thomson and Ho, 1981; Modamio and Mallo, 1984; Hoshika and Shiozawa, 1986; Dale, 1987; Fabiano *et al*., 1994; Gajbhiye *et al*., 1995; Pan and Rao, 1997; Batten *et al*., 1998).

2.1.1 Iron (Fe):

The high Fe concentration in Phytoplankton probably contributes for normal growth of marine plants (Goldberg 1952). The main conclusions that Davies drew from measurements on the growth of *Dunaliella tertiolecta* under iron limiting conditions were ; that cells maintained in culture under iron deficient condition gradually adapt to that situation; that growth rate of cells may be expressed mathematically in terms of the metabolic iron content of the cells; and that chlorophyll production by phytoplankton may be governed by the supply of organo-iron complexes. Second, is the ability of most algal species to bio-magnify iron from the surrounding environment.

The ability of diatoms *Phaeodactylum tricornutum* to adsorb considerable iron from the medium at high ambient iron levels is demonstrated (Davies, 1967). Martin and Knauer (1973) observed that iron contamination associated with field collections of phytoplankton included metal particles in samples (196,000.0 mg/kg) rust from stainless hydrowire (142, 000 mg/kg), rust from non-stainless hydrowire (147,000 mg/kg), hull point (29 mg/kg. and open ocean tar-balls (8540 mg / kg).

Table : Iron reported in field collection of marine phytoplankton. Values are shown in mg Fe/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Phytoplankton (Whole)	624.0 mg/kg (280.0-1290.0) mg/kg (range)	Horowitz and presley, 1977
Phytoplankton (Organic fractions) * No Ti group * Ti group * Sr concentrated group	 224.0 mg/kg 1510.0 mg/kg 231.0 mg/kg	 Martin and Knauer 1973 Martin and Knauer 1973 Martin and Knauer 1973
Phytoplankton (Siliceous frustules) * No Ti group * Ti group * Sr concentrated group	 220.0 mg/kg 560.0 mg/kg 180.0-500.0 mg/kg	 Martin and Knauer 1973 Martin and Knauer 1973 Martin and Knauer 1973

Physical/chemical limits on uptake, oceanic species have been forced to decrease their cell size and/or to reduce their growth requirements for cellular iron by up to 8-fold. The biochemical mechanisms responsible for this reduction in metabolic requirements are unknown (Sunda,-W.G. *et al*., 1995).

Volker (1999) demonstrated the process of diffusion and chemical reactions in the microenvironment of a phytoplankton cell for influencing the efficiency of both strategies to increase the bioavailability of iron and to reduce iron stress. Low iron availability prevents diatom growth but is still adequate for nano-phytoplankton, the biomass of which is, however, kept to Chl a levels less than 1 mg m^{-3} due to the loss by the ubiquitous micrograzers (Lancelot, *et al*., 2000).

2.1.2 Manganese (Mn):

Early interest in manganese was simulated by the observation that radiomanganese-54, a common fallout product from nuclear weapons tests, was preferentially accumulated by marine micro-algae over other radioisotopes examined (Slowley *et al*, 1965). Stable manganese is also readily accumulated by algae over seawater levels. Manganese is an essential element for normal growth of *Dunaliella tertiolecta*, and probably for other species, with adverse effects documented when concentrations in the growth medium were <0.1 mg Mn / L (Noro, 1978).

Table : Manganese reported in field collection of marine phytoplankton. Values are shown in mg Mn /kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHORS
Phytoplankton (Whole) Texas Continental Self Monterey Bay, CA	21.7 mg/kg (4.4-41.5) mg/kg 35.0 mg/kg	Horowitz and Presley, 1977 Knauer and Martin, 1973
Phytoplankton (Organic fractions) * No Ti group * Ti group * Sr concentrated group	 6.1 mg/kg 13.3 mg/kg 7.7 mg/kg	 Martin and Knauer 1973 Martin and Knauer 1973 Martin and Knauer 1973
Phytoplankton (Siliceous frustules) * No Ti group * Ti group * Sr concentrated group	 Not Detected 4.3 mg/kg 1.2-22.0 mg/kg	 Martin and Knauer 1973 Martin and Knauer 1973 Martin and Knauer 1973

The field collections of algae world wide revealed Mn concentration between 3.8 and 3421.0 mg Mn/kg dry weight. The high variability of concentration of Mn among species may be due to a variety of biotic and extrinsic parameters. This parameters include seasonal collection (Pillai, 1956; Bryan and Hummerstone, 1973), tidal fluctuations (Saunders,1978), and abundance of lithogenic materials in the immediate environment (Lowman *et al*., 1967). Tidal fluctuations from 0.6 to 0.8 meters were found to be stimulatory to Mn-loaded phytoplankton, but the reverse was observed at higher tidal fluctuations of 1.0-1.2 meters (Saunders, 1978). Manganese uptake was almost exclusively oxidative and was inhibited by light even at low intensities (Moffett, *et al*.1996).

2.1.3 Cadmium (Cd):

The ability of micro-algae and macro-phytes to accumulate Cd from ambient seawater is well documented. Concentration factors (as denoted by the ratio between the accumulation of Cd in the cells of micro algae as compared to the ambient seawater) ranged from 4200 to 11,000 for field collections (Methuus *et al*, 1978) and from 11 to 36 in laboratory studies with radiocadmium (Hiyama and Shimizu, 1964). Diatoms present in seawater solution containing 1.0 mg Cd/L for 12 days yielded 8300.0 mg / kg fresh weight (Cossa, 1976); while concentrations of 0.010 – 0.025 mg Cd/L depressed the growth of *Skeletonema costatum* (Berland *et al*, 1976).

Table : Cadmium reported in field collection of marine phytoplankton. Values are shown in mg Cd/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Phytoplankton (Mixed)	7.0 mg / kg	Knauer and Martin, 1973
Phytoplankton (Mixed)	1.9 mg / kg (average) and ranged from(0.5 – 3.0) mg /kg	Horowitz and Presley, 1977
Skeletonema costatum (Whole , water content 0.010 mg Cd / L	4.0 mg /kg	Windom et al, 1976

Mixtures of Cd and Zn ions were more effective in the inhibition of growth of *Thalassiosira pseudonema* and *Skeletonema costatum* than either metal alone (Braek *et al*, 1976). However, Cd-Zn mixtures were less promising in producing growth inhibition of *S. costatum*. The relative resistance to heavy metals of the latter two species was attributed to competition for uptake sites by different chemical forms of Cd and Zn and thus it was concluded that high levels of non-toxic divalent cations such as ca, Mg, and Sr in sea water compete with the same uptake sites as toxic divalent cations such as Cd, Cu, and Zn and might, therefore, protect against metal poisoning in marine organisms (Braek *et al.*, 1976).

2.1.4 Cobalt (Co):

Cobalt is considered as an essential trace element for algae and it is a constituent of Vitamin B_{12}. Cobalt or cobalt combined organically in vitamin B_{12} (cobalamin) has been shown to be essential for large number of algae.

Table : Cobalt reported in field collection of marine phytoplankton. Values are shown in mg Co/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Diatoms (Whole)	15.0 mg /kg	Vinogradova and Koual'skiy, 1962

Cobalt uptake is non-oxidative and biologically mediated, and moreover enhanced by low to moderate levels of light. It is probably, due to uptake by phytoplankton (Moffett, *et al*.1996).

2.1.5 Copper (Cu):

Copper is essential, but at higher concentrations, it is an algal poison. In one study, using the diatom, *Thalassiosira aestivalis*, effects of a mixture of 10 heavy metals (Cu, Zn, Ni, Cr, Pb, Cd, Hg, As, Se,and Sb) was investigated at concentrations expected to occur in a moderately polluted estuary. Growth of the diatoms was not inhibited under under laboratory conditions. However, at 5 to 10 fold higher concentrations, however, growth of *Thalassiosira aestivalis* was inhibited, and it was solely due to Cu, with normal growth evident when Cu was deleted from the mixture (Thomas *et al* 1980). Copper concentration of 2.0 mg / L and higher inhibited regulation of cell volume in *Dunaliella marina* when transferred to hypotonic media (Riisgard, 1979). Cell membrane permeability is proposed as a suitable bio test for environmental contaminants, including heavy metals (Riisgard, 1979).

All copper residue data in photosynthetic organisms should be interpreted with the knowledge that numerous intrinsic and extrinsic factors can significantly affect Cu accumulation rates as well as growth and survival of this group. In *Duniliella tertiolecta*, and *Skeletonema* *costatum*, with increasing temperature a positive linear correlation was observed between the copper uptake and biomass with decreasing salinity of the media. (Mandelli, 1969). In regard of pH of medium, growth rate of *Thalassiosira pseudonema*, was altered independently of total copper concentration by varying pH (Sunda and Guillard, 1976). The reduction of copper toxicity might be happened due to the presence of decomposed natural plankton and detritus decreased toxicity of copper, probably by complexation or chelation of the copper to a biologically unavailable form (Erickson, 1972) or as experienced by Sunda and Guillard (1976) that the effects of potentially inhibitory levels of cupric ions in sea water on *T. pseudonana* could be reduced or eliminated, depending on degree of copper complexation by natural organic ligands.

The anionic constituents must also be considered in evaluation of algal copper kinetics, with different observations in chloride and sulphate salts (Nielsen and Wium-Anderson, 1970). Finally, high concentrations of iron or citrate in seawater reportedly reduced the biocidal properties of copper to algae (Nielsen and Kamp-Nielsen, 1970), probably by complexation.

Table : Copper reported in field collection of marine phytoplankton. Values are shown in mg Cu/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Asterionella japonica (Whole)	105.0 mg/kg	Riley and 1971
Diatoms (Whole)	100,000.0 mg/kg (AW)*	Vinogradova and Koul,sky, 1962
Dunaliella spp. (Whole)	52.0 – 57.0 mg/kg	Riely and Roth, 1971
Phytoplankton (Organic fraction)	1.7 – 45.4 mg/kg	Martin and Knauer, 1973
Phytoplankton (Siliceous frustules fraction)	1.3-80.0 mg/kg	Martin and Knauer, 1973
Phytoplankton (Whole)	50.0 mg/kg	Martin and Knauer, 1973
Phytoplankton (Whole)	8.1 mg/kg (Average) (5.2-9.5) mg/kg (Range)	Horowitz and presley, 1977
Phaeodactylum, trcornurum (Whole)	110.0 mg/kg	Riely and Roth, 1971

(AW)* = Ash Weight

Copper is a constituent of plastocyanins, which affect electron transport in photosystem I of photosynthesis (Sorentino, 1979). The electrochemical potential of Cu^{2+}/Cu^{+} is –268 mv, which is well with in the physiological range. Copper easily interacts with radicals, best with molecular oxygen. This radical character make copper very toxic (Nies, 1999).

2.1.6 Zinc (Zn):

Among all heavy metals except iron, zinc is especially abundant in marine flora, with many values recorded in excess of 1000.0 mg/kg dry weight These grossly elevated levels were usually associated with nearby industrial or domestic outfalls.

Increasing accumulation of zinc was observed in various species of marine algae with decreasing light intensity (Bachmann and Odum, 1960; Gutknecht, 1961); decreasing pH (Gutknecht, 1961; Parry and Hayward, 1973) and increasing temperature (Gutknecht,1961; Parry and Hayward, 1973; Styron *et al* , 1976; Baudin, 1977).

Skeletonema costatum, contained significant accumulation of Zn for development (Jensen et al, 1984). Growth stage of *Phaeodactylum tricornutum* was important in determining final zinc residue and may be linked to the number of Zn-binding sites at different growth cycles despite the availability of further Zn for uptake (Davies, 1978). In another study, *P. tricornutum*, the physiochemical status may account for differences observed in uptake rates of stable and radioactive Zn^{65} (Bernhard and Zattera, 1969). In general, increasing exposure to increasing ambient zinc concentration was associated with higher algal zinc residues, but this was not always the case (Mehran and Tremblay, 1965; Bryan, 1969; Bryan and Hummerstone , 1973; Baudin, 1977).

Table : Zinc reported in field collection of marine phytoplankton. Values are shown in mg Zn/kg dry weight.

NAME OF PHYTOPLANKTON	**AMOUNT RECORDED**	**AUTHOR**
Asterionella japonica (Whole)	115,0 mg/kg	Riely and Roth, 1971.
Diatoms Whole, Black Sea	5 000.0 mg/kg (Ag)	Vinogradova and Koul'skiy 1971
Dunaliella primolecta (Whole)	405. 0 mg/kg	Riely and Roth, 1971.
Dunaliella tertiolecta (Whole)	285.0 mg / kg	Riely and Roth, 1971.

Zinc is almost certainly required for normal growth and metabolism of all marine organisms, including the flora. *Thalassiosira weissfogii* grew best in the range 0.0007 – 0.0650 mg Zn / L and not at all at less than 0.0007 mg Zn / L (Anderson *et al*, 1978). The lead range for growth was found to be from 0.005 to 0.010 mg Zn/L for *Schroderella* and *Thalassiosira* (Kayser, 1977) and from 0.05 to 0.10 for *Amphinidium* and *Skeletonema* (Braek *et al*, 1976).

Besides, zinc is an extremely essential element for many enzymatic activities (Cheblowski and Coleman, 1976) in plants and animals. Zinc occurs exclusively as a divalent cation with its completely filled 'd' orbitals. The zinc cation is not able to undergo redox changes under biological conditions, and is used in the formation of complex polypeptide chains (Coleman 1998). Kennedy and Gonsalves, (1989) studied the effect of Zn ions on the ATPase activity of a plasma membrane function (Hussain *et al*.,1993).

2.1.7 Nickel (Ni):

Ni concentrations in algae and macrophytes reported on a dry weight basis ranged from 0.2 to 39.1 mg/kg, with most values less than 10.0 mg/kg. In general, micro algae reported to bio-magnify Ni over seawater levels by 146 to 1000 fold (Black and Mitchell, 1952; Sivalingam, 1978).

Table : Nickel reported in field collection of marine phytoplankton. Values are shown in mg Ni/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Diatoms	150.0 mg/kg	Vinogradova and Koul'skiy, 1962.
Phytoplankton Organic fractions	1.9 7.8 mg/kg	Martin and Knauer, 1973
Phytoplankton Whole Puget Sound, Wash., USA	5.5 mg/kg	Laevastu and Thompson, 1956.
Phytoplankton Whole South Texas Coast	4.4 mg/kg (2.2-7.5) mg/kg (Range)	Horowitz and Presley, 1977

2.1.8 Lead (Pb):

High bio-magnification of Pb from ambient seawater by marine plants are documented by several investigators. Differential sensitivity of species to Pb salts is also well-understood. Growth rate and biomass of *skeletonema costatum* were inhibited by dissolved Pb concentrations between 0.00005 and 0.010 mg/L, thus making this species as one of the most sensitive algal indicators of Pb insult (Rivkin, 1979).

Tetramethyl lead was 4 to 10 times more effective in producing deleterious effects in *Dunaliella* species than tetraethyl Pb salts (Marchetti 1978). *Dunaliella salina* was relatively unaffected at 0.3 mg Pb/L, but showed reduced growth and other adverse effects at 0.9 mg Pb/L and higher concentration (Pace *et al*, 1976). In the range 0.25 to 2.0 mg Pb/L, growth was inhibited in 18 species of unicellular algae (Berland *et al*. 1976) and in *Dunaliella tertiolecta* (Stewart, 1977).

Table : Lead reported field collection of marine phytoplankton reported. Values are shown in mg Pb/kg dry weight.

NAME OF PHYTOPLANKTON	AMOUNT RECORDED	AUTHOR
Duneliella primolecta (Whole)	16.5 mg/kg	Riely and Roth, 1971
Duneliella tertiolecta (Whole)	8.1 mg/kg	Riely and Roth, 1971
Diatoms (Whole)	3000.0 mg/kg	Vinogradova and Koul'skiy, 1962
Phytoplankton (Whole)	40.0 mg/kg	Kauner and Martin, 1973
Phytoplankton Organic fractions * No Ti group * Ti group * Sr concentrated group (Whole)	Not detected 7.2 mg/kg 9.2 mg/kg 12.1 mg/kg (1.6 -24.0) mg/kg	Kauner and Martin, 1973 Kauner and Martin, 1973 Kauner and Martin, 1973 Horowitz and Presley, 1977.

The kinetics of lead uptake and retention in *Phaeodactylum tricornutum* and *Platymonas subcordiformis* were studied by Schulz Baldes and Lewin (1976). Both species accumulated lead from the medium at ambient concentrations of 0.020 mg / L, and higher. In the first phase, the lead content of *Platymonas subcordiformis* continued to rise slowly whereas that of *Phaeodactylum tricornutum* declined after 2 or 3 days. In both species the content of bound lead increased with increasing exposure time, suggesting that during prolonged exposure to Pb solutions the metal ions are first adsorbed to the cell surface and then translocated into the cell wall, to the plasma membrane, and eventually to the cytoplasm.

2.2 Petroleum Hydrocarbons (PHC) in relation to Marine Phytoplankton:

Another kind of pollution that increasingly threatens the aquatic ecosystems of the world is oils spills and oil leakages. Oil spills could pronounce a serious impact on coastal ecosystems. Recovery can take many years and in some cases damage may not be repairable at all. It is true that the understanding of the effects of oil spills and leakages have been increased considerably over the last two decades, but the results of such research continue to be limited by lack of knowledge about the ocean ecosystem.

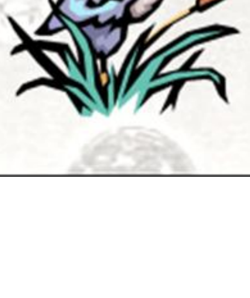
The residual fuel oils are complex mixtures of high molecular weight compounds having a typical boiling range from 350 to 650°C. They consist of aromatic aliphatic and napthenic hydrocarbons, typically having carbon numbers from C_{20} to C_{50}, together with asphaltenes and smaller amounts of heterocyclic compounds containing sulphur, nitrogen and oxygen. They have chemical characteristics asphalt with a very high molecular weight (2000 – 5000). Heavy fuel oils contain organo-mettalic compounds, of which the most important are trace elements nickel, iron, potassium, sodium etc.

All marine environments contain micro-organisms capable of degrading crude oil. Oil contains little nitrogen or phosphorus, and as a result, microbial degradation of oil tends to be nutrient limited. Bioremediation often depends upon on the controlled and gradual delivery of these nutrients, while taking care to limit the concurrent stimulation of phytoplankton activity.

The major spills of crude oil and petroleum products occur during their transport by oil tankers, loading and unloading operation, blowouts etc. It has been estimated by Hinrichsen D. (1990) that approximately 5 million tonnes of oil enters into the Arabian sea in each year. In the marine environment the spilled oil goes through a variety of transformations involving physical, chemical and biological processes. Surface oil and tar accumulations, and their distribution along the Indian beaches have been described by Gupta *et al.* (1989). Although there are a few reports (Gupta *et al*.,1989; Nair *et al.*, 1972; Dwivedi, *et al*., 1974a,b; 1975; Unnithan *et al*., 1981; Kadam *et al.*, 1985; Sen Gupta , *et al*.,1980; Sood *et al*., 1984; Qasim *et. al*., 1975; Rokade, *et al.*, 1986) in this regard, the actual damage caused to the flora, especially to micro-algal community has not been elucidated.

Chapter 3

Physio-chemical and Biological characteristics of Alang seawater.



Chapter-3

PHYSIO-CHEMICAL & BIOLOGICAL CHARACTERISTICS OF ALANG SEAWATER

The presence of chemical contaminants has become a pervasive threat to many natural aquatic ecosystems. Environmental contaminants lead to generate toxic effects on different types of organisms and also affect biological processes at different levels such as cellular, population, community, and ecosystem. In this chapter, different water quality parameters have been discussed to understand the physio-chemical interactions of the marine phytoplankton and to find out the regulatory factors, which may control over the succession of micro-algal population, community composition or productivity of the coastal seawater of Alang ship breaking yard area.

Study Area:

Gujarat, located at the northern frontier of India, occupies an area of 196,024 sq. km and has a coastline of 1663 km with a continental shelf of 165,000 sq. km. Depth of the Gulf of Khambhat ranges from 5 to 27 m with a deep channel of 50 m east of Piram island. Continental self of the West Coast of Saurashtra slopes very gently to a depth of 60 m, and up to a distance of 350 km. The bottom sediment is mainly made up of mud. Gulf of Khambhat can be expected to add around 74 MT sediments every year to the western continental shelf of India. The Gulf of Khambhat receives 38 km^3 runoff with a large quantity of sediment having over 151 Mm^3 industrial effluent being discharged every year from the rivers. Continental shelf stretches from the Indian West Coast including the Saurashtra peninsula. It is believed that the Indian continental shelf is the widest in this area and houses a rich fishery caused, mainly, by the large nutrient load coming out with the Gulf sediments. The Gulf of Khambhat has a positive water balance, mainly due to the high volume of river runoff. The rivers draining into the Gulf of Khambhat carry enormous amount of sediments in their discharges. Besides it is endowed with silty – muddy bottom, high suspended solids, large tidal amplitudes, and shallow depth range and, above all, with enormously strong tidal currents (Sengupta *et. al*.,2000).

The Alang ship breaking yard, situated about 50 km. from the district H.Q., Bhavnagar, on the western coast of Gulf of Cambay near Alang – Sosiyo village. The yard is about 9.3 km long, north-south, and covers a total area of 67 sq. km (Raman 1996). It covered under extended port limit of Talaja port, as per Govt. of Gujarat, Ports & Fisheries Dept. Notification dated 8/9/1995. Tidal amplitude is MHWS 7.8m. MLWS 1.6m and MHWN 6.3m. MLWN 3.0m MSL 4.7 m . There are altogether185 private plots varying in length (50-240 m) and breadth (30-120 m) placed parallel to the coast. Out of 185 plots 92 plots are situated in Alang Yard and 93 plots are in Sosiyo region, having an area of 1350 - 3600 Sq.m. 10 plots for VLCC having area of 6000 Sq.m (GMB Report). Sample collected from Alang and from Mahuva 40 km (approx) far from Alang. Mahuva is situated at the mouth of the Gulf of Cambay.

Materials and Methods:

To obtain data from seawater and sediment studies three principal factors were strictly followed: 1) The design and performance of a representative sampling program; 2) The adoption of analytical protocols, which enable measurements of appropriate accuracy and precision, and 3) If necessary, the selection and use of suitable storage procedures for samples to minimize changes in analyte concentrations and speciation prior to further treatment in the laboratory.

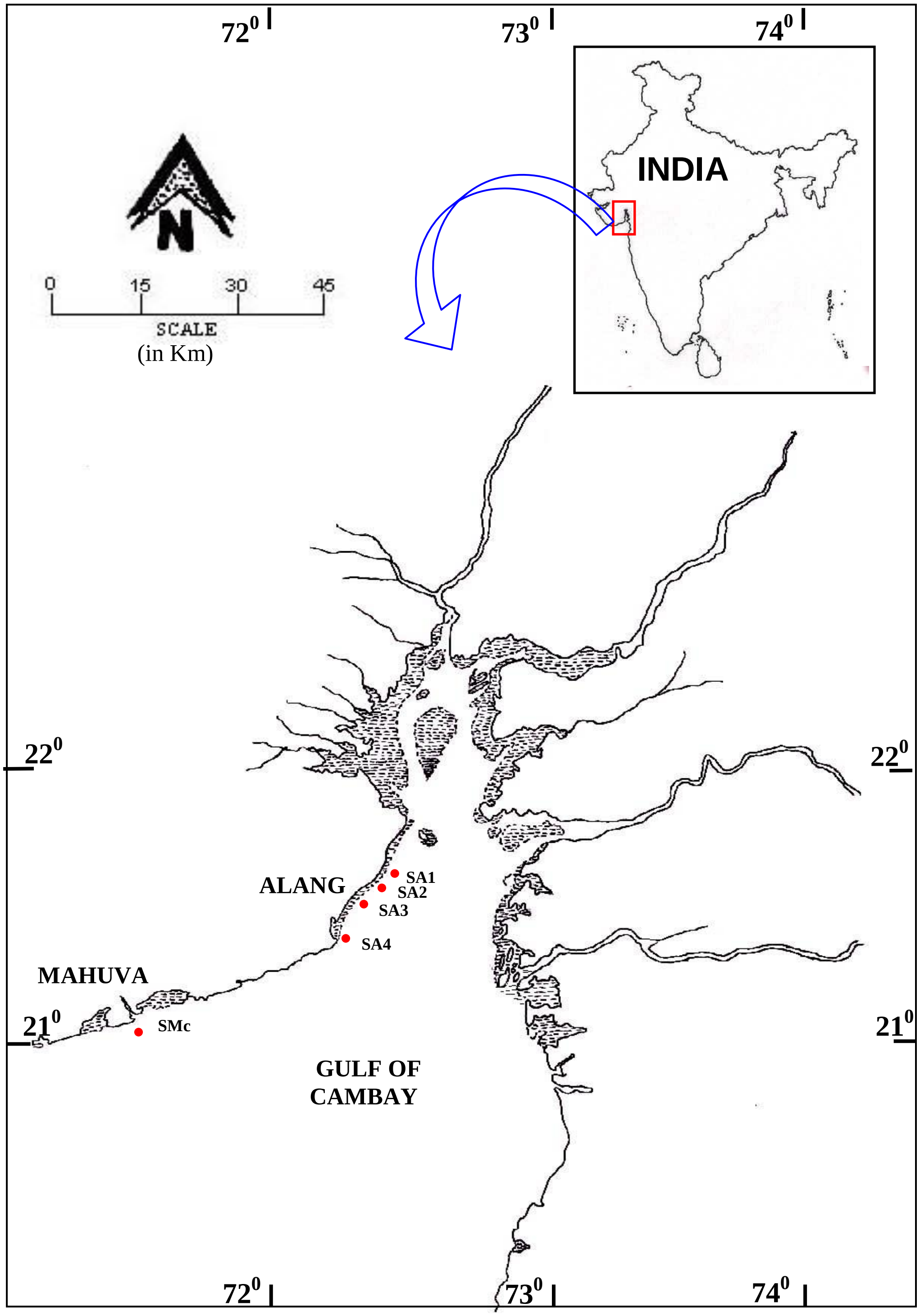


Fig. 1 . Location of the study area.

Sampling Strategies:

Samples were collected from four stations at Alang (SA1, SA2, SA3 and SA4) and one station from Mahuva (SMc). Latitude and Longitude for all the stations are as under SA1-21° 26.542' N and 72° 13.527' E, SA2-21° 26.163' N and 72° 13.240' E, SA3-21° 24.715' N and 72° 12.057' E and SA4-21° 22.569' N and 72° 10.065' E and from one station at Mahuva, SMc- 21° 03.356' N and 71° 47.554' E (Fig-1) (Plate-I to Plate VI). Different sampling strategies were designed based on the types of the samples and parameters to be studied to achieve the best performance of representative sampling. The analytical protocols were adopted to enable measurements of appropriate accuracy and precision. Cool packs with sufficient ice were used in each and every field collections for storage of the sample to minimize the changes in analyte concentrations for bringing to the laboratory of CSMCRI, Bhavnagar and subsequently, the samples were kept in refrigerator, prior to further treatment in the laboratory and the parameters were determined within few hours according to a given priority.

Sampling was done in every alternate month through out the study period for understanding of the biogeochemical processes really happening at the coastal area of Alang. Tide chart of Alang and Mahuva region during my study period are given in table 1 &2. Surface samples ($\geq$ 0.2 m) were taken with an at most care to avoid possible contamination risks during hand sampling or even with the use of arm-long gloves. Water samples were collected in acid-resistant polypropylene (1liter) bottles for estimation of nutrients, chlorophyll-a and heavy metal concentration. Only for determining of chemical parameters such as DO, BOD and productivity, transparent and dark glass bottle and for petroleum hydrocarbons brown colored glass bottles were used to avoid light interferences.

Utmost care had been taken for determining the depth, time and position of the sampling stations, cleanness of the sample bottles in all parameters and especially in the determination of trace constituents of seawater during collection of samples to avoid the systematic errors. Standardization and adaptation of the analytical methods, calibration of different types instruments before use and good practices of sample handling were adapted to avoid the random errors usually encountered by the errors inherent in the analytical methods itself, instrumental errors and personal errors.

The biological activity in seawater does not stop with sample collection, since bacteria and micro- and nano-plankton continue to digest and excrete material and low-density polythene, and tend to let water vapor and gases pass through slowly, the concentrations of nutrients and other bioactive elements in the sample are liable to change due to the activity of microorganisms naturally present in seawater. Furthermore, photolytic breakdown of organic compounds or changes in the speciation of inorganic constituents (due to changes of pH or redox potential) may also alter the composition of samples. Therefore the samples were collected in high-density polythene bottles and should not be exposed unnecessarily to light and analyzed within a few hours after collection.

Sample Storage & Refrigeration:

In many cases the walls of the sampler and sub-sampling bottle are excellent substrates for bacteria, often enhancing bacterial growth rates by several orders of magnitude. The concentrations of nutrients and other bioactive elements are liable to change due to the activity of microorganisms naturally present in seawater. Therefore, the samples were not exposed unnecessarily to light and were analyzed within a few hours after collection.

Different seasons samples from the same location may contain microorganisms of different species and concentrations, so that the given preservation regime was modified according to the variable season so that it could be effective in all seasons specially in rainy and spring season. With this in mind the following two approaches to preservation were outlined; refrigeration and poisoning.

When coastal seawater was collected and a delay of not more than 2 h is expected between sampling and analysis, the nutrient samples should be stored in the dark in a refrigerator at <8°C. Samples stored for detection of silicate was best preserved by acidifying the seawater sample with sulphuric acid to a pH of about 2.5. With respect to nitrate, the same amount of ammonium chloride buffer should be added immediately after sub-sampling, as required for the subsequent nitrate analysis, the solution was stored in the dark at <8°C. This buffer solution prevents further bacterial activities i.e., oxidation of ammonia and nitrite to nitrate. With respect to nitrite, in most cases, the storage of refrigerated samples upto 6 hours causes no significant changes in nitrite concentrations, provided the original ammonia level is < 1.0 μ mol / L. With regard to short term storage of dissolved phosphate samples, neither the addition of acid (causing hydrolysis of polyphosphates and release of phosphate from plankton and bacteria) nor the addition of analytical reagents were used for preserving the samples.

Methods of Analysis:

Air and Seawater Temperature:

Air and water temperatures were measured on the spot by precision mercury thermometer. Temperatures were recorded during the sampling time.

pH:

Seawater samples were collected with in cleaned PVC made plastic bottled. The pH of the water samples were measured within using a digital pH meter Horiba F-21 with the detectable range of 0 to 14 and accuracy ±0.01.

Total Suspended Solids:

The total suspended solids were determined by filtering 1000 ml of well shaken seawater through 0.45 µm pore size pre weighed filter paper. The solids were washed with distilled water and dried in oven (with filter) at 105°C till constant weighed was obtained. The difference in weighed was recorded.

Salinity:

Salinity was determined by Titrimetric method (with Silver nitrate solution) developed by Knudsen (1940) , reviewed thoroughly by Lewis (1980) and by Fofonoff (1985) and described in the standard seawater analysis book edited by Grasshoff K (1999). The relationship between chlorinity and salinity established by Knudsen was as follows: S ‰ = 1.805 Cl ‰ + 0.030

Dissolved Oxygen:

The determination of Dissolved Oxygen was done based on the Winkler method) first proposed by Winkler and modified by Carritt and Carpenter (1965) and as described by Strickland and Parsons, (1972). The samples were fixed immediately after collection in the field itself, with Winkler reagent A and Winkler reagent B. The physically dissolved oxygen in a measured volume of water was chemically bound by reacting with manganous hydroxide in a strongly alkaline medium. The dissolved oxygen present in water oxidizes this manganus hydroxide to manganese (III) hydroxide and precipitates from the samples. After that the samples were brought to the laboratory for further operation. The well settled precipitate was acidified to a pH<2.5 whereby it was dissolved and titrated against a standard solution of thiosulphate using starch as an indicator.

Biochemical Oxygen Demand:

The amount of oxygen utilized in the biodegradation of organic material over a given time period of 5 days was measured by determining the difference of dissolved concentration of the sample by titrimetric method (Strickland and Parsons, 1972) with thiosulphate solution, during collection time and after a period of 5 days of incubation. Oxygen becomes depleted as labile organic carbon is oxidized to carbon dioxide during respiration. Five-day BOD (BOD5) analysis addresses the organic matter, which is labile, or readily available for consumption.

Nitrite (NO_2-N):

The method of photometric determination of nitrite was based on the reaction of nitrite with an aromatic amine forming a diazonium compound and followed by the coupling of a second aromatic amino to form an azo dye as described in seawater analysis by Grasshoff, 1999). The method followed for seawater was proposed by Shinn (1941) and adopted by Bendschneider and Robinson (1952). In this method sulphanilamide hydrochloride is made to react with the nitrite followed by the coupling with n – (1 – naphthyl) ethylene diamine dihydrochloride. The absorbance of the resultant pink solution was measured at 543 nm with the help of SHIMADZU UV 160A Spectrophotometer.

Nitrate (NO_3-N):

The most sensitive and generally applied methods for the determination of nitrate in seawater are based on the reduction of nitrate to nitrite which is subsequently measured as above. The reduction of nitrate was done by a heterogeneous reaction where the sample was passed through the cadmium-mercury amalgam (in granules) column and quantitatively reduced to nitrite. Then the absorbance was measured after addition of 1 ml of sulphanilamide reagent, and

1 ml of n – (1 – naphthyl) ethylene diamine dihydrochloride, mixed thoroughly and then allowed to stand for 10 minutes. The absorbance was measured at 543 nm in a 1 cm cuvette against distilled water containing all reagents as a blank using SHIMADZU UV 160A Spectrophotometer.

Ammonia (NH_4-N):

In a moderately alkaline medium ammonia reacts with hypo-chlorite to form mono-chloroamine which in the presence of phenol, catalytic amounts of nitro-prusside ions and excess of hypo chlorite gives indo-phenol blue (Sagi, 1966). The absorbance was measured at 630 nm in a 1 cm cuvette against distilled water containing all reagents as a blank using SHIMADZU UV 160A Spectrophotometer.

Inorganic phosphate (PO_4-P):

The method for the determination of inorganic phosphate in sea water were based on the reaction of the phosphate ions with acidified molybdate reagent to give a phospho-molybdate complex which was then reduced to a highly coloured blue compound by ascorbic acid (Murphy and Riley 1962). The absorbance was measured at 880 nm in a 1 cm cuvette against distilled water containing all reagents as a blank using SHIMADZU UV 160A Spectrophotometer

Chlorophyll-a and Pheophytin :

Samples were collected from surface seawater in white colored clean PVC bottle (1 L capacity). Samples were kept within ice box immediately after collection and brought to the laboratory for pigment determination. The samples were filtered through a 0.45 µm Millipore membrane filter (Nitrocellulose made) with a vacuum pump. The filtrate was transferred to a homogenizer containing 25 ml of 90% acetone. The contents were ground thoroughly in shaded light. The test tube with the solution was then transferred to a dark colored cloth bag, which was placed in a refrigerator (4°C) for about 24 hours in order to facilitate the complete extraction of the pigment. After this span of time, the extract was transferred to a graduated centrifuge tube and the volume was made upto 25 ml by adding fresh 90% acetone. The solution was centrifuged for about 20 minutes under 5000 rpm and the supernatant solution was considered for the determination of the chlorophyll-a and pheopigments estimation by recording the optical density at 750, 664, 647, and 630 nm with the help of SHIMADZU UV 160A Spectrophotometer. All the extinction values were corrected for a small turbidity blank by substracting the 750 nm signal from all the optical densities and finally the phytoplankton pigments were estimated as per the following expressions; Chl-a = 11.85 OD_{664} – 1.54 OD_{647} – 0.08 OD_{630} (Jeffrey and Humphrey 1975).

For estimation of pheopigments 3 ml of clarified extract was transferred into a 1-cm curette and read optical density (OD) at 750 and 664 nm. Then extract in the curette was acidified with 0.1 ml of 0.1 N HCl and agitated gently. The optical density (OD) was measured after 90 s of acidification at 750 and at 665 nm. The volumes of extract and acid and the time after acidification were followed accurately as those were critical for consistent results. The 750 nm OD value was subtracted from the earlier readings (OD 664 nm, 647 nm, and 630 nm) and after acidification (OD 664_a nm) and (OD 665_a nm). Using the corrected values pheo-pigments were calculated.

Primary Productivity:

The procedure for determining the oxygen content of natural water is the classical 'Winkler Method'(Strickland and Parsons, 1972). The method is normally used in the 'Light – Dark bottle techniques' for studying production rates in standing and running waters. This method is based on the principle that photosynthesis of phytoplankton is accompanied by the release of oxygen apart from the production of starch. The amount of oxygen so liberated is considered as a measure of primary production.

A total of three ground stoppered leak-proof bottles (preferably BOD bottles) of about 300 ml capacity were taken. Of those, one is treated as light bottle, one as control (initial) and third one, which is black painted and waxed served as dark bottle. Water samples from the surface were collected using an ordinary white coloured good quality plastic bucket. Much care had been taken to ensure that the water was not agitated too much. All the three bottles were simultaneously filled with water samples in such a way so that no bubbles should form inside the sample bottles.

The initial bottle containing water sample is immediately fixed with 1 ml of manganese sulphate and 1 ml of alkaline iodide (fixatives normally used in the determination of oxygen by winkler's method). The dark bottles were further wrapped with aluminium foil and kept in a black cloth so as to be protected completely from sunlight.

The light and dark bottles were then suspended in the sea by a productivity measurement stand, designed and fabricated by CSMCRI. The stand was made with the facility for keeping 8 bottles at a time and with float, which helps to float all the bottles in the surface seawater only at all the tide levels. These bottles are normally incubated for a period of 4-6hours (between midday to before sunset) at the surface or in the respective depths, where water samples were taken for experiment. Owing to agitation of water column in the experimental site, the entrapped cells of the bottles were kept in motion, so that cells should not be accumulated at the bottom resulting in poor production. After the incubation period, the bottles were taken out and are fixed like initial bottles. The oxygen content of the different bottles were determined by the method of Winkler's chemical titration (Strickland and Parsons, 1972). The oxygen content of light bottle relates the amount of oxygen evolved during photosynthesis minus the amount of oxygen consumed in respiration by the entrapped phytoplankton. The amount of oxygen was utilized by the phytoplankton in the respiration were estimated by using measurements of oxygen changes concurrently in control and light bottles. Further, oxygen decreased in dark bottle (compared to that initial bottle) is due to respiration only as there could not be any photosynthesis owing to the absence of light. Hence, the total amount of photosynthesis (in term of gross primary production), was calculated by addition of negative change in oxygen content of the dark bottle and the positive change in the oxygen content of the light bottle.

Calculation:

1) Gross Primary Productivity (GPP) = $\frac{DL - DD}{Hr.}$

2) Net Primary Productivity (NPP) = $\frac{DL - DI}{Hr.}$

where, DI = Dissolved oxygen content in Initial Bottle,

DL= Dissolved oxygen content in Light Bottle, and

DD= Dissolved oxygen content in Dark (Black) Bottle,

Hr = Time of Incubation in seawater.

The results of the Primary productivity were expressed in terms organic carbon stored during photosynthesis by the following formulae:

Organic Carbons (mg C / m^3 / Hr.) = (mg O_2 / L / Hr) x 0.375 x 1000

Statistical Inferences:

Statistical calculations such as correlation coefficients within 15 water quality parameters, and one-way ANOVA calculations were done using the software packages like Origin, Statistica, Statview, SPSS 9.0 and Microsoft Excel 98. The minimum value of the calculated correlation coefficient (R) is 0.500, which showed a weak association within the related parameters and the significant value based on at least 95% confidence limit ($p<0.05$) for one-way ANOVA test is given importance for discussion.

Results and Discussion:

The results of the different parameters of seawater quality are depicted in the table number 3 to 17. The correlation coefficient was calculated within all 15 parameters and is tabulated in the table number 18 and 19. The results of the One-Way ANOVA calculation are presented in the table number 20 to show the level of significance.

Air Temperature:

Air temperature varied from 23.5°C at stations, SA3 and SA4 during February 2002 to 33.5°C at stations, SA2 and SA4 during October 2002 in Alang. Similarly the average air temperature within four stations in Alang ranged from 23.7°C during February 2002 to 33.1°C during October 2002, whereas, it varied from 26.0°C during February 2002 to 34.5°C during Jun 2002 in Mahuva. Air temperature showed a lower value during winter season but it showed higher value during post monsoon season might be due to direct sunlight reaches through the cloudless sky and makes the environment hot. There were no significant differences even at 95.0 % level of significance in air temperature between the stations at Alang and the station at Mahuva. Since geographically the two areas (Alang and Mahuva) are somewhat far the air temperature in different seasons showed a slight low in Alang as compared to Mahuva. However, the differences were not statistically significant. Air temperature showed a strong positive association with water temperature (R=0.760) and a strong negative association with pheophytin (R= 0.770) in Alang, while at Mahuva, it showed a strong positive association with water temperature (R = 0.825) and a weak negative association with dissolved oxygen (R= 0.513).

Water Temperature:

The seawater temperature also did not show any significant differences even at 95.0 % level of significance in water temperatures between Alang and Mahuva. Lowest seawater temperature (23.0°C) was observed at station SA4 during December 2002 and the highest temperature (34.5°C) was observed at station SA1 during Jun 2002 in Alang. The average water temperatures varied from 24.3°C during December 2002 to 33.8°C during April 2002. However, the lowest seawater temperature (25.0°C) noticed during February 2002 to the highest temperature (33.5°C) during Jun 2002 in Mahuva. The similar trend of seasonal variation in seawater temperature regime was noticed as seen in Air temperature regime. The difference in seawater temperature was also observed between Alang and Mahuva, which was also statistically proved insignificant. Water temperature also showed a moderate negative association with pheophytin (R=-0.625) at Alang, whereas, it showed a weak negative association with Chlorophyll-a content (R = -0.551) at Mahuva. As the increase of the temperature influence the rate of the temperature dependant chemical and metabolic reactions very fast, the negative correlations of seawater temperature with phaeophytin and chlorophyll-a were observed in the study area due to the effect of high temperature on the pigment degradation.

pH:

pH of the seawater was from 7.82 at station SA4 during August 2002 to 8.52 at station SA4 during February 2002 in Alang. However, the average pH ranged from 7.94 during October 2001 and August 2002 to 8.38 during December 2002 at Alang whereas, the same ranged from 7.94 to 8.34 in August 2002 and August 2001 at Mahuva. But, there were also no significant differences even at 95.0 % level of significance in pH between Alang and Mahuva seawater. Although there is a slight difference, in pH variation, in both the areas, which was totally seasonal effect due to rain. The pH differences between the areas were not statistically significant. pH showed a weak positive association with PO_4-P (R=0.514) at Alang and it did not show any remarkable association with any other parameters at Alang and Mahuva.

Total Suspended Solids (TSS):

Total suspended solids ranged from 170 mg L^{-1} at station Sa4 during October 2001 to 1923 mg L^{-1} at station SA4 during February 2003 in Alang. However the average total suspended solids within four stations in Alang varied from 229 mg L^{-1} during October 2001 to 1608 mg L^{-1} during April 2002; whereas, the total suspended solids varied from 293 mg L^{-1} during October 2001 to 854 mg L^{-1} during August 2002 in Mahuva. There were significant differences at 99 % level of significance in total suspended solid loads between Alang and Mahuva seawaters. The total suspended solids reduce the sunlight penetration into the water column and carry different types of pollutants with them. The differences in the amount of total suspended solids between Alang and Mahuva seawaters also may play an important role in bio-geo-chemical activities in that area. At Alang TSS showed a weak positive correlation with DO (R=0.518) whereas it showed a moderate positive correlation with NO_2-N (R=0.683) and a weak negative correlation with BOD (R=-0.530) at Mahuva. TSS-DO association was negative in Mahuva and positive in Alang, may be due to the agitation of seawater that increases the level of dissolved oxygen.

Salinity (S‰):

Salinity ranged from 25.56‰ at station SA3 during October 2002 to 35.00‰ at station SA3 during April 2002. The average value of salinity within four stations of Alang showed the similar trend, showing the lowest average salinity (26.448‰) during October 2002 and the highest salinity (33.515‰) during April 2003. But the salinity varied from 25.09‰ during Jun 2001 to 35.81‰ during August 2001 in Mahuva. There were no significant differences even at 95.0 % level of significance in salinity between Alang and Mahuva seawaters. No remarkable salinity differences were found between Alang and Mahuva that might be due to both the areas fall under arid region with a short period of rainy season and lack of perennial rivers. Although a slight change in salinity of seawater was recorded at both places due to rainfall during monsoon, the salinity differences between Alang and Mahuva were not statistically significant. Salinity showed a strong positive association with NO_3-N (R=-0.826) at Alang. But it did not show any remarkable association with any other parameter at Mahuva.

Dissolved Oxygen (DO):

Dissolved Oxygen content ranged from 2.998 ml L^{-1} at station SA2 and SA3 during Jun 2001 to 6.662 ml L^{-1} at station SA3 and SA4 during February 2003. The average concentration of Dissolved Oxygen within the four stations of Alang showed the similar trend showing the lowest concentration (3.159 ml L^{-1}) during Jun 2001 and the highest concentration (6.555 ml L^{-1}) during February 2003. But the dissolved oxygen concentration varied from 3.427 ml L^{-1} during August 2001 to 6.875 ml L^{-1} during February 2003 in Mahuva. There were no significant differences even at 95.0 % level of significance in dissolved oxygen values between Alang and Mahuva seawaters. Alang region is comparatively shallow with uneven bottom configuration as compared to Mahuva, so that in Alang there are different ways of dissolving oxygen into the water column like, advection of seawater during high and low tide, agitation of seawater and due to primary production etc., whereas in Mahuva, primary production is the main source for dissolve oxygen. However, the differences in DO values between Alang and Mahuva were not statistically significant. Dissolve oxygen showed a weak association with TSS at Alang and with air temperature at Mahuva (Value mentioned above).

Bio-chemical Oxygen Demand (BOD):

At Alang, bio-chemical Oxygen Demand (BOD) ranged from 0.002 mg L^{-1} at station SA2 during December 2002 to 2.258 mg L^{-1} at station SA1 during April 2003. However, the average value of Bio-chemical Oxygen Demand varied from 0.526 mg L^{-1} during August 2002 to1.542 mg L^{-1} during February 2002. But it varied from 0.15 mg L^{-1} during August 2002 to 2.105 mg L^{-1} during December 2001 in Mahuva. There were no significant differences even at 95.0 % level of significance between Alang and Mahuva seawaters. Due to high organic load in Alang. BOD showed a greater value as compared to Mahuva, even though the differences were not found statistically. The organic load in Alang was high, due to microbial contamination in that area, as it is used as open lavatory by 25,000 to 35, 000 laborer (Tewari, *et al*. 2001) whereas in Mahuva region, the BOD depends, to certain extent due to Phytoplankton, the primary producer and other consumer in that marine environment. Biochemical oxygen demand did not show any remarkable association with any parameters at Alang and showed a weak negative association with TSS (R=-0.530) at Mahuva.

NO_2-N:

NO_2-N concentration ranged from 0.263 µg at L^{-1} at station SA3 during August 2001 to 2.532 µg at L^{-1} at station SA4 during February 2003 in Alang, where as, the average concentration of NO_2-N within the four stations of Alang varied from 0.401 µg at L^{-1} during October 2001 to 1.625 µg at L^{-1} during Jun 2001. But the concentration of NO_2-N varied from 0.205 µg at L^{-1} during April 2003 to 1.756 µg at L^{-1} during Jun 2001 at Mahuva. There were no significant differences even at 95.0 % level of significance in NO_2-N concentration between Alang and Mahuva seawaters. As NO_2-N is an intermediate stage when N_2 gas gets dissolved in seawater and form NO_3-N after oxidation due to high dissolved oxygen content of seawater. However, the differences of NO_2-N concentration between Alang and Mahuva did not show statistically significance. NO_2-N showed a moderate negative correlation with GPP (R= -0.629) and a strong negative association with NPP (R= -0.719) at Alang, whereas, it showed only a moderate positive association with TSS at Mahuva.

NO_3-N:

Nitrate is usually considered the end product from a sequence of biologically mediated reactions in which organic nitrogen compounds are oxidized. NO_3-N concentration ranged from 2.96 µg at L^{-1} at station SA3 during Jun 2002 to 32.35 µg at L^{-1} at station SA3 during October 2002. Similarly the average concentration of NO_3-N within the four stations of Alang varied from 5.435 µg at L^{-1}during Jun 2002 to 29.213 µg at L^{-1} during October 2002. The NO_3-N concentrations varied from 2.81 µg at L^{-1} during Jun 2002 to 28.54 µg at L^{-1} during October 2002 in Mahuva. However, there were no significant differences even at 95.0 % level of significance in NO_3-N concentrations between Alang and Mahuva seawaters. As NO_3-N is more stable form than NO_2-N, it is more available than NO_2-N in seawater. The NO_3-N form may convert either NO_2-N or NH_4-N form depending upon the microbial activities and the dissolved oxygen content of the aquatic system. Even though there were a minute difference in NO_3-N concentration between Alang and Mahuva, the same was not statistically significant. NO_3-N showed a strong negative association with salinity at Alang, whereas, it did not show any remarkable association with any parameter at Mahuva.

NH_4-N:

NH_4-N concentration ranged from 0.13 µg at L^{-1} at station III during February 2003 to 14.847 µg at L^{-1} at station I during April 2003 in Alang. The average concentration of NH_4-N within the four stations of Alang showed the similar trend showing lowest concentration (0.778 µg at L^{-1}) during February 2003 and highest concentration (10.742 µg at L^{-1}) during April 2003. But the concentration of NH_4-N varied from 0.298 µg at L^{-1}during October 2002 to 17.114 µg at L^{-1} during October 2001 in Mahuva. Since the coastal area of Mahuva has a patchy distribution of mangrove vegetation, the organic litter of that area some time produces NH_4-N concentration somewhat more. In case of Alang the microbial contamination and degradable organic loads control the NH_4-N concentration. There were no significant differences even at 95.0 % level of significance in NH_4-N concentration between Alang and Mahuva seawaters. NH_4-N did not show any remarkable correlation with any other parameter at Alang, while, it showed a weak positive association with GPP at Mahuva.

PO_4-P:

PO_4-P concentration ranged from 1.251 µg at L^{-1} at station SA4 during February 2002 to 5.644 µg at L^{-1} at station SA2 during December 2002 in Alang. The average concentration of PO_4-P within the four stations of Alang showed the similar trend showing the lowest concentration (2.044 µg at L^{-1}) during February 2002 and highest concentration (4.339 µg at L^{-1}) during December 2002. But the concentration of PO_4-P varied from 1.02 µg at L^{-1} during April 2002 to 5.079 µg at L^{-1} during December 2002 at Mahuva. As the inorganic PO_4-P content is produced mostly through a recycled process from the degraded organic materials present in the water column, and get readily absorbed by primary producers it's presence in the coastal seawater is controlled by microbial activities, total suspended solids and primary producers of that region. There was no significant difference even at 95.0 % level of significance in PO_4-P concentration between Alang and Mahuva seawater. PO_4-P showed a weak positive association with pH and a weak negative correlation with GPP (R=-0.505) at Alang, whereas, it did not show any remarkable association with any parameter at Mahuva.

Chlorophyll-a:

Chlorophyll-a concentration ranged from 1.833 µg L^{-1} at station SA3 during August 2001 to 41.476 µg L^{-1} at station SA1 during October 2002, in Alang. The average concentration of chlorophyll-a concentration within the stations of Alang varied from 4.763 µg L^{-1} during August 2001 to 22.600 µg L^{-1} during December 2002. But, the concentration of chlorophyll-a varied from 0.759 µg L^{-1}during April 2003 to 15.797 µg L^{-1} during February 2003 in Mahuva. Chlorophyll-a concentration was high in Alang as compared to Mahuva region, and may be due to cyanobacterial growth on the sediment of the Alang region and this may be attributed to shallow, uneven bottom configuration, advection of seawater during high and low tide and mostly the ship scrapping activities, that may keep the micro organisms restless to settle down to the bottom. The difference between Alang and Mahuva seawaters was statistically proved as significant at 95.0 % level of significance. Chlorophyll-a content did not show any remarkable association with any parameter at Alang, while, it showed a weak negative association with water temperature at Mahuva.

Pheophytin:

Pheophytin ranged from 0.2 µg L^{-1} at station SA4 during April 2002 to 23.229 µg L^{-1} at station SA1 during 2001 in Alang, where as, the average concentration of Pheophytin within four stations of Alang varied from 4.946 µg L^{-1} during August 2002 to 13.000 µg L^{-1} during December 2001. But, the concentration of Pheophytin varied from 3.284 µg L^{-1} during August 2002 to 18.089 µg L^{-1} during October 2001, at Mahuva. There were no significant differences even at 95 % level of significance in Pheophytin concentration between Alang and Mahuva seawaters. Pheophytin showed a greater fluctuation at both the places due to different hydro-biological interactions, and no statistically significant differences were observed. Pheophytin showed a strong and moderate negative association with air (R= -0.770) and water temperatures (R=-0.625) at Alang, whereas, it showed a strong positive association with NH4-N and a weak positive association with GPP (R=0.539) and NPP (R=0.552) at Mahuva.

Primary Productivity:

The term ‘primary production’ refers to the rate of formation of organic matter by the phytoplankton and is distinguished from the ‘standing crop’, which refers to the amount of phytoplankton present at any one time in a unit volume of water. In other words, it is the rate at which new organic matter is added to the existing phytoplankton standing crop. It is expressed in terms of micrograms of carbon per liter per hour.

Gross Primary Productivity :

Gross Primary Productivity (GPP) ranged from 28.238 µg C L^{-1} hr^{-1} at station SA2 during Jun 2001 to 119.117 µg C L^{-1} hr^{-1} at station SA2 during April 2002 in Alang. The average value of Gross Primary Productivity showed the similar trend showing the lowest value (31.828 µg C L^{-1} hr^{-1}) during Jun 2001 and the highest value (96.564 µg C L^{-1} hr^{-1}) during April 2002. But the Gross Primary Productivity varied from 37.68 µg C L^{-1} hr^{-1} during August 2002 to 150.78 µg C L^{-1} hr^{-1} during February 2002 in Mahuva. There were significant differences at 99.0 % level of significance in the value of GPP between Alang and Mahuva seawaters. Gross primary productivity showed a less production at Alang as compared to Mahuva as a whole. The differences of gross primary productivity between Alang and Mahuva are also statistically established. Though the chlorophyll-a concentration in Alang seawater was higher than the seawater of Mahuva, the gross primary productivity was less as compared to Mahuva. This might be due to environmental stress condition at Alang as a result of ship scrapping activities increasing the heavy metal and petroleum hydrocarbon pollution in that region. GPP showed a weak negative association with NO_2-N and a strong positive association with NPP (R=0.841) at Alang, whereas, it showed a moderate positive association with NPP (R= 0.648) and a weak positive association with pheophytin (R=0.539) at Mahuva.

Net Primary Productivity:

At Alang, Net Primary Productivity (NPP) ranged from 12.446 µg C L^{-1} hr^{-1} at station SA3 during October 2002 to 67.839 µg C L^{-1} hr^{-1} at station SA1 during December 2001, whereas, the average value of Net Primary Productivity varied from 17.654 µg C L^{-1} hr^{-1} during Jun 2001 to 45.127 µg C L^{-1} hr^{-1} during December 2001. But Net Primary Productivity varied from 10.246 µg C L^{-1} hr^{-1} during August 2001 to 127.198 µg C L^{-1} hr^{-1} during October 2001, at Mahuva. There were significant differences at 95.0 % level of significance in the value of NPP between Alang and Mahuva seawaters. Net Primary Productivity also showed the similar trend as that of Gross Primary Productivity at both the places. High Net Primary Productivity with a high Gross Primary Productivity was noticed at Mahuva, as compared to the ones at Alang, indicating a more productive region at Mahuva. NPP showed a strong negative association with NO_2-N at Alang and a weak positive association with pheophytin at Mahuva.

The one-way ANOVA calculations showed the only independent variable that was statistically different between Alang and Mahuva was TSS. Turbidity is a measure of the amount of suspended organic and inorganic particulate matter in the water column. It is deleterious to water quality because it reduces the amount of light available to aquatic plants, and transports phosphorus downstream and it accelerates the great reduction of light and reduces the growth of phytoplankton, a primary producer. It was observed by Ebenhoeh, *et al*.,(1997) that a production-irradiance (p/I) relation with a high degree of photo inhibition leads to clear underestimates of primary production in turbid coastal waters. As Chlorophyll-a and GPP did not show any strong association with nutrients, such as NO_2-N, NO3-N, NH_4-N and PO_4-P at both the places, Alang and Mahuva, these nutrients may not be the limiting factors of the marine phytoplankton of that region in relation to productivity, chlorophyll-a production and community composition. The same type of observation with regard to Chlorophyll-*a* concentration and primary productivity was observed by Dzeha, *et al.* (1998), where as Smayda, (1973) observed that temperature, light, nutrients, grazing, possible species interactions, and hydrographic disturbances regulated the seasonal dynamics of *Skeletonema costatum*. Zhang,-Cheng (1997) also noticed from the nutrient uptake experiments that the nutrient limited growth of *P. pungens*, and showed a high ability to uptake inorganic nitrogen, and a relatively low ability to uptake inorganic phosphorous. Therefore, phosphorous might be the controlling nutrient of this species in the natural environment. In this study, chlorophyll-a content showed a negative correlation with seawater temperature at both the places. Seawater temperature has an effect on the rate of production and total population of phytoplankton. The biological factors influencing the productivity are the rate of multiplication of primary producer and the grazing relationship between primary and secondary producers. Productivity is mainly concerned with potential ability, and production with actual ability of the organisms or of the ecosystem as a whole. The rate of photosynthesis per unit of chlorophyll increases with increase in light intensity and at light saturation intensities the same differ greatly in the several groups of phytoplankton. Seawater temperature can also affect the dominance of phytoplankton groups and in shallow water it can change successions by inhibiting or killing of the more sensitive species (Burke, 1962). Therefore, the lower primary productivity at Alang with more chlorophyll content as compared to the one at Mahuva indicates the environmental stress due to ship scrapping activities at Alang.

Table 1: The Tide Chart of the Alang region during the collection period.

Samping date	Tide-Time	Seawater level (m)		Samping date	Tide-Time	Seawater level (m)
16/06/01	6:40 AM	3.30		7/6/02	2:06 AM	8.25
	1:00 PM	8.85			8:01 AM	3.10
	7:16 PM	4.25			2:12 PM	8.88
					8:37 PM	4.09
16/08/01	1:40 AM	8.50		6/8/02	2:30 AM	7.83
	8:14 AM	2.37			8:54 AM	2.52
	2:28 PM	10.10			3:09 PM	10.02
	9:25 PM	2.86			10:01 PM	3.10
13/10/01	1:17 AM	8.33		16/10/02	1:35 AM	7.91
	7:45 AM	2.81			7:58 AM	3.72
	1:45 PM	9.58			1:50 PM	8.83
	8:47 PM	1.56			8:47 PM	2.83
11/12/01	1:52 AM	9.59		1/12/02	1:53 AM	9.62
	8:21 AM	2.89			8:27 AM	2.75
	1:56 PM	8.81			1:57 PM	9.12
	8:41 PM	2.80			8:54 PM	1.40
8/2/02	2:11 AM	9.54		13/02/03	2:08 AM	8.99
	9:02 AM	3.37			8:53 AM	3.93
	2:32 PM	7.59			2:24 PM	7.16
	9:50 AM	2.80			8:54 PM	1.40
7/4/02	1:08 AM	8.75		12/4/03	12:34 AM	8.80
	8:17 AM	3.49			7:37 AM	3.74
	1:58 PM	7.56			1:18 PM	7.69
	8:17 PM	3.99			7:29 PM	3.60

Table 2: The Tide Chart of the Mahuva region during the collection period.

Samping date	Tide-Time	Seawater level (m)		Samping date	Tide-Time	Seawater level (m)
17/06/01	12:50 AM	8.30		8/6/02	2:52 AM	8.34
	7:35 AM	2.91			9:26 AM	3.11
	1:53 PM	9.10			2:55 PM	9.34
	20:18 PM	3.83			9:23 PM	3.68
17/06/01	2:43 AM	8.57		7/8/02	3:19 AM	8.29
	9:27 AM	1.81			9:56 AM	1.98
	3:23 PM	10.65			3:55 PM	10.48
	10:29 PM	2.25			10:55 PM	2.51
14/10/01	2:46 AM	10.16		17/10/02	2:36 AM	8.37
	9:24 AM	2.15			9:01 AM	3.35
	2:44 PM	10.04			2:44 PM	8.99
	9:47 PM	1.54			9:34 PM	2.45
12/12/01	2:46 AM	10.16		2/12/02	2:47 AM	10.34
	9:24 AM	2.57			9:31 AM	2.29
	2:52 PM	8.85			2:54 PM	9.31
	9:38 PM	1.31			9:53 PM	0.96
9/2/02	3:06 AM	9.77		14/02/03	3:01 AM	9.46
	10:04 AM	2.97			9:48 AM	3.30
	3:30 PM	7.82			2:24 PM	7.16
	9:53 PM	2.62			8:30 PM	3.18
8/4/02	2:13 AM	8.84		13/04/03	1:43 AM	9.18
	9:12 AM	3.11			8:41 AM	3.02
	2:54 PM	8.09			2:18 PM	8.44
	9:19 PM	3.61			8:45 PM	2.93

Table 3 : Air Temperature (°C) at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	27.0	26.0	26.0	26.0	26.3	31.5
Aug-2001	32.0	31.5	32.0	32.0	31.9	33.0
Oct-2001	33.0	32.0	32.0	31.0	32.0	34.0
Dec-2001	26.0	26.5	26.5	27.0	26.5	30.0
Feb-2002	24.0	23.8	23.5	23.5	23.7	26.0
Apr-2002	31.5	32.0	32.0	32.5	32.0	34.0
Jun-2002	33.0	32.5	32.5	31.5	32.4	34.5
Aug-2002	29.0	28.0	28.0	27.0	28.0	30.0
Oct-2002	32.5	33.5	33.0	33.5	33.1	33.5
Dec-2002	27.5	29.0	30.0	29.5	29.0	31.5
Feb-2003	27.0	28.5	29.0	28.0	28.1	26.0
Apr-2003	30.5	29.5	30.0	29.5	29.9	31.5

Table 4: Seawater Temperature (°C) at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	27.0	27.0	28.0	28.0	27.5	30.5
Aug-2001	30.5	30.0	30.5	30.5	30.4	31.0
Oct-2001	34.0	33.0	33.5	32.5	33.3	32.0
Dec-2001	27.0	27.0	26.5	26.5	26.8	27.0
Feb-2002	25.5	25.0	25.0	25.0	25.1	25.0
Apr-2002	33.5	34.0	34.0	33.5	33.8	31.5
Jun-2002	34.5	33.5	32.5	31.5	33.0	33.5
Aug-2002	31.0	30.0	32.0	30.0	30.8	31.0
Oct-2002	31.5	32.0	31.0	31.5	31.5	33.0
Dec-2002	24.5	25.0	24.5	23.0	24.3	27.5
Feb-2003	31.0	31.5	29.5	32.0	31.0	26.5
Apr-2003	31.0	31.5	31.0	30.5	30.5	33.5

Table 5: pH of seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	8.14	8.15	8.20	8.22	8.18	8.25
Aug-2001	8.21	8.24	8.25	8.27	8.24	8.34
Oct-2001	8.11	8.01	8.01	8.09	8.06	7.94
Dec-2001	8.07	8.07	8.14	8.19	8.12	8.10
Feb-2002	8.15	8.23	8.29	8.52	8.30	8.19
Apr-2002	8.11	8.00	8.31	8.10	8.13	8.10
Jun-2002	8.28	8.24	8.41	8.34	8.32	8.38
Aug-2002	7.94	8.01	8.00	7.82	7.94	7.94
Oct-2002	8.12	8.05	8.08	8.06	8.08	8.09
Dec-2002	8.49	8.44	8.30	8.28	8.38	8.33
Feb-2003	7.98	8.35	8.14	8.42	8.22	8.30
Apr-2003	8.17	8.22	8.16	8.11	8.17	8.08

Table 6: Total Suspended Solids (mg L^{-1}) in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	0.951	1.177	0.793	0.643	0.891	0.692
Aug-2001	0.505	0.737	0.956	0.406	0.651	0.813
Oct-2001	0.271	0.263	0.210	0.170	0.229	0.293
Dec-2001	0.547	0.431	1.643	0.910	0.883	0.561
Feb-2002	1.831	1.286	1.654	0.929	1.425	0.784
Apr-2002	1.816	1.879	1.633	1.105	1.608	0.479
Jun-2002	0.811	0.986	0.826	1.095	0.929	0.801
Aug-2002	0.264	0.149	0.811	0.907	0.5332	0.854
Oct-2002	0.852	1.261	1.582	1.321	1.254	0.296
Dec-2002	0.378	1.345	1.425	0.505	0.913	0.467
Feb-2003	0.328	1.656	1.217	1.923	1.281	0.648
Apr-2003	0.425	0.747	1.725	1.304	1.050	0.412

Table 7: Salinity (S‰) of seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	32.98	30.96	33.79	33.18	32.73	25.09
Aug-2001	29.74	28.33	29.94	29.94	29.49	35.81
Oct-2001	31.11	31.11	30.25	30.68	30.79	34.79
Dec-2001	31.54	31.54	32.19	32.41	31.92	34.57
Feb-2002	32.66	33.44	33.44	34.42	33.49	35.00
Apr-2002	33.52	33.30	35.00	32.24	33.52	34.15
Jun-2002	32.46	33.83	33.44	32.07	32.95	32.46
Aug-2002	31.16	31.16	30.75	30.75	30.96	32.17
Oct-2002	25.96	26.35	25.56	27.92	26.45	27.73
Dec-2002	29.20	29.40	29.00	31.4	29.75	30.20
Feb-2003	29.20	30.00	30.00	29.80	29.75	30.40
Apr-2003	28.12	28.71	29.69	30.87	29.35	31.66

Table 8: Dissolved Oxygen (ml L^{-1}) concentration of seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	3.213	2.998	2.998	3.427	3.159	3.439
Aug-2001	3.855	3.855	4.069	3.855	3.909	3.427
Oct-2001	4.085	4.085	3.439	3.866	3.869	3.654
Dec-2001	4.727	4.727	4.943	6.234	5.158	5.157
Feb-2002	5.157	4.942	4.943	5.587	5.157	4.942
Apr-2002	5.258	4.750	5.258	5.260	5.132	5.088
Jun-2002	3.868	3.654	3.223	3.653	3.600	4.083
Aug-2002	4.296	4.298	4.083	4.296	4.243	4.512
Oct-2002	5.375	5.374	4.941	5.587	5.319	5.156
Dec-2002	6.234	6.446	5.083	6.233	6.179	6.231
Feb-2003	6.234	6.661	6.662	6.662	6.555	6.875
Apr-2003	5.802	5.446	5.447	5.232	5.482	5.66

Table 9: Biochemical Oxygen Demand (mg L^{-1}) in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	0.600	1.049	0.600	0.900	0.787	0.900
Aug-2001	1.199	0.900	1.049	1.049	1.049	0.900
Oct-2001	0.754	0.754	0.301	1.805	0.904	1.204
Dec-2001	0.148	0.148	1.354	1.506	0.789	2.105
Feb-2002	1.202	0.902	2.106	1.957	1.542	0.450
Apr-2002	0.592	0.475	0.949	0.951	0.742	0.830
Jun-2002	0.450	1.053	0.601	0.302	0.602	0.751
Aug-2002	0.751	0.451	0.300	0.601	0.526	0.150
Oct-2002	1.656	0.45	0.752	1.353	1.053	0.902
Dec-2002	0.753	0.002	0.301	1.805	0.715	1.654
Feb-2003	0.904	1.205	0.902	1.654	1.166	0.601
Apr-2003	2.258	0.754	0.602	0.300	0.979	1.353

Table 10: NO_2-N (µg at L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	1.581	1.581	1.537	1.800	1.625	1.756
Aug-2001	0.571	0.395	0.263	0.834	0.516	0.659
Oct-2001	0.467	0.467	0.321	0.350	0.401	0.321
Dec-2001	0.739	0.739	0.674	0.652	0.701	0.696
Feb-2002	0.674	0.457	0.826	0.478	0.609	0.870
Apr-2002	0.702	0.774	0.508	0.847	0.708	0.484
Jun-2002	1.110	0.979	1.262	1.023	1.094	1.306
Aug-2002	1.315	1.781	1.484	1.442	1.506	1.527
Oct-2002	0.679	1.264	0.796	0.562	0.825	0.515
Dec-2002	0.771	1.095	0.791	0.892	0.887	1.034
Feb-2003	1.057	0.815	1.365	1.034	1.442	1.079
Apr-2003	0.548	0.502	0.434	1.079	0.457	0.205

Table 11: NO_3-N (µg at L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	**ALANG SHIP BREAKING YARD**					**MAHUVA**
	SA-1	**SA-2**	**SA-3**	**SA-4**	**(Average)**	**SMc**
Jun-2001	12.123	8.681	13.872	12.707	11.846	13.717
Aug-2001	25.463	20.581	28.119	30.534	26.174	26.270
Oct-2001	16.450	16.450	25.100	25.920	20.980	21.560
Dec-2001	21.670	21.670	18.380	23.920	21.305	22.290
Feb-2002	17.680	6.760	12.250	23.500	9.953	14.560
Apr-2002	10.110	18.980	5.510	3.120	12.720	19.910
Jun-2002	4.640	7.360	2.960	16.280	5.435	2.810
Aug-2002	15.910	22.850	23.200	6.780	22.258	20.550
Oct-2002	26.900	30.190	32.350	27.070	29.213	28.540
Dec-2002	29.110	30.700	29.350	27.410	29.065	23.500
Feb-2003	23.200	20.040	23.010	27.10	21.043	22.730
Apr-2003	18.460	12.830	18.090	17.920	17.815	21.200

Table 12: NH_4-N (µg at L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	**ALANG SHIP BREAKING YARD**					**MAHUVA**
	SA-1	**SA-2**	**SA-3**	**SA-4**	**(Average)**	**SMc**
Jun-2001	3.934	7.000	7.334	4.734	5.751	12.267
Aug-2001	1.467	0.933	0.533	1.200	1.033	4.267
Oct-2001	0.861	1.378	1.551	0.747	1.134	17.114
Dec-2001	1.999	1.840	2.499	3.090	2.357	2.340
Feb-2002	2.297	6.375	3.963	3.159	3.949	1.780
Apr-2002	5.140	5.711	3.712	0.857	3.855	2.855
Jun-2002	3.498	4.265	1.411	0.276	2.363	0.307
Aug-2002	1.481	2.393	1.652	0.513	1.510	0.399
Oct-2002	2.779	11.810	0.794	4.268	4.913	0.298
Dec-2002	3.061	2.643	1.982	1.982	2.417	2.400
Feb-2003	0.259	1.297	0.13	1.426	0.778	3.112
Apr-2003	14.847	4.049	10.348	13.722	10.742	8.773

Table 13: PO_4-P (µg at L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	2.859	2.770	3.127	3.082	2.960	3.708
Aug-2001	3.663	3.708	3.574	3.976	3.730	3.618
Oct-2001	2.948	2.948	2.904	3.127	2.982	3.261
Dec-2001	2.919	3.081	3.000	3.243	3.061	3.162
Feb-2002	1.697	1.343	3.886	1.251	2.044	2.368
Apr-2002	3.118	1.340	2.216	1.682	2.277	1.020
Jun-2002	2.626	2.093	3.390	2.578	2.793	2.196
Aug-2002	2.236	2.578	2.012	1.834	2.113	2.415
Oct-2002	2.282	2.370	2.636	2.231	2.345	3.701
Dec-2002	3.951	2.231	3.951	3.809	4.339	5.079
Feb-2003	3.600	5.644	3.549	4.107	3.777	4.614
Apr-2003	1.911	3.853	2.358	2.724	2.236	2.642

Table 14: Chlorophyll-a (µg L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	11.326	5.639	7.360	3.870	7.049	10.667
Aug-2001	10.244	5.005	1.833	1.969	4.763	5.863
Oct-2001	22.444	5.434	9.501	18.776	14.039	11.263
Dec-2001	12.600	4.759	12.231	21.598	12.797	5.914
Feb-2002	11.705	26.888	15.914	18.872	18.345	15.797
Apr-2002	10.315	5.266	10.025	3.073	7.170	4.674
Jun-2002	14.699	3.874	6.611	5.628	7.703	3.794
Aug-2002	22.964	7.688	2.762	12.947	11.590	12.396
Oct-2002	41.476	5.213	24.409	10.307	20.351	2.332
Dec-2002	15.219	24.409	11.566	38.637	22.600	10.422
Feb-2003	10.746	12.146	12.901	2.291	9.521	5.480
Apr-2003	25.157	14.893	6.66	4.661	12.843	0.759

Table 15: Pheophytin (μg L^{-1}) concentration in seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	**ALANG SHIP BREAKING YARD**					**MAHUVA**
	SA-1	**SA-2**	**SA-3**	**SA-4**	**(Average)**	**SMc**
Jun-2001	9.051	14.551	9.732	7.610	10.236	12.508
Aug-2001	8.411	8.411	4.406	0.534	5.441	5.273
Oct-2001	14.819	1.135	5.874	10.013	7.960	18.089
Dec-2001	23.229	5.674	8.811	14.285	13.000	10.747
Feb-2002	6.875	21.427	12.749	6.074	11.781	7.142
Apr-2002	4.940	9.278	7.676	0.200	5.524	14.898
Jun-2002	4.686	4.926	7.369	6.248	5.807	4.245
Aug-2002	3.419	3.212	6.477	6.674	4.946	3.284
Oct-2002	4.209	5.476	4.999	6.252	5.234	4.415
Dec-2002	5.496	7.003	7.390	8.063	6.988	6.422
Feb-2003	9.218	6.192	5.932	8.987	7.582	5.444
Apr-2003	6.601	10.864	8.590	6.288	8.086	6.058

Table 16: Gross Primary Productivity (μg C L^{-1} hr^{-1}) of seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	**ALANG SHIP BREAKING YARD**					**MAHUVA**
	SA-1	**SA-2**	**SA-3**	**SA-4**	**(Average)**	**SMc**
Jun-2001	28.370	28.238	42.337	28.366	31.828	146.052
Aug-2001	37.569	56.354	56.354	37.569	46.962	102.462
Oct-2001	48.614	64.573	64.530	80.890	62.652	141.447
Dec-2001	90.302	45.159	45.153	113.008	73.406	127.048
Feb-2002	84.500	90.378	82.269	75.461	83.152	150.777
Apr-2002	118.783	119.117	59.235	89.119	96.564	74.184
Jun-2002	56.358	75.377	93.930	75.236	75.225	92.301
Aug-2002	32.286	64.547	32.087	48.299	44.305	37.680
Oct-2002	112.892	37.71	37.511	62.761	62.719	64.424
Dec-2002	48.418	32.320	64.327	64.317	52.346	112.729
Feb-2003	32.302	32.322	32.074	48.16	36.222	64.379
Apr-2003	96.631	48.201	64.522	64.237	68.398	80.492

Table 17: Net Primary Productivity (µg C L^{-1} hr^{-1}) of seawater at Alang and Mahuva during the study Period.

TIME OF SAMPLING	ALANG SHIP BREAKING YARD					MAHUVA
	SA-1	SA-2	SA-3	SA-4	(Average)	SMc
Jun-2001	14.105	14.071	28.202	14.237	17.654	33.900
Aug-2001	18.785	37.569	18.785	18.785	23.481	10.246
Oct-2001	32.271	32.223	32.221	48.595	36.328	127.198
Dec-2001	67.839	22.613	22.533	67.524	45.127	98.879
Feb-2002	28.161	45.145	61.780	36.541	42.907	113.082
Apr-2002	29.754	59.66	29.615	29.320	37.087	44.631
Jun-2002	18.802	56.424	56.406	18.749	37.595	30.767
Aug-2002	16.269	16.064	16.066	32.33	20.182	25.77
Oct-2002	50.252	25.171	12.446	37.692	31.390	32.277
Dec-2002	32.08	16.279	48.278	48.273	36.228	64.454
Feb-2003	15.964	16.284	16.036	32.152	20.109	32.227
Apr-2003	64.464	16.116	32.074	48.268	40.109	64.454

Table 18: The value of correlation coefficient for the Seawater Quality parameters at the coastal area of Alang Ship breaking Yard

	A.T.	**W. T.**	**pH**	**TSS**	**Salinity**	**DO**	**BOD**	**NO2-N**
Air Temp. (°C)	1							
Water Temp. (°C)	***0.760	1						
pH	-0.137	-0.460	1					
TSS (mg L^{-1})	-0.155	-0.090	0.321	1				
Salinity (S ‰)	-0.430	-0.109	0.177	0.151	1			
DO (ml L^{-1})	-0.132	-0.224	0.205	*0.518	-0.391	1		
BOD (mg L^{-1})	-0.337	-0.266	0.281	0.403	-0.126	0.338	1	
NO_2-N (µg at L^{-1})	-0.305	-0.077	-0.111	0.020	0.133	-0.178	-0.355	1
NO_3-N (µg at L^{-1})	0.237	-0.145	-0.224	-0.292	***-0.826	0.369	-0.009	-0.154
NH_4-N (µg at L^{-1})	-0.059	-0.040	0.005	0.334	-0.104	0.232	0.126	-0.184
PO_4-P (µg at L^{-1})	0.065	-0.308	*0.514	-0.253	-0.242	0.164	-0.086	0.091
GPP (µg C $L^{-1}hr^{-1}$)	0.167	0.190	0.071	0.436	0.389	0.122	0.105	**-0.629
NPP (µg C $L^{-1}hr^{-1}$)	-0.012	-0.150	0.247	0.225	0.224	0.282	0.152	***-0.719
Chl-a (µg L^{-1})	-0.165	-0.494	0.125	0.097	-0.391	0.497	0.254	-0.245
Pheophytin (µg L^{-1})	***-0.770	**-0.625	0.167	0.083	0.408	0.064	0.379	-0.106

Table 18: (Contd..)	**NO3-N**	**NH4-N**	**PO4-P**	**GPP**	**NPP**	**Chl-a**	**Pheo**
Air Temp. (°C)							
Water Temp. (°C)							
pH							
TSS (mg L^{-1})							
Salinity (S ‰)							
DO (ml L^{-1})							
BOD (mg L^{-1})							
NO_2-N (µg at L^{-1})							
NO_3-N (µg at L^{-1})	1						
NH_4-N (µg at L^{-1})	-0.209	1					
PO_4-P (µg at L^{-1})	0.450	-0.470	1				
GPP (µg C $L^{-1}hr^{-1}$)	-0.401	0.197	*-0.505	1			
NPP (µg C $L^{-1}hr^{-1}$)	-0.202	0.248	-0.238	***0.841	1		
Chl-a (µg L^{-1})	0.433	0.123	0.006	0.137	0.423	1	
Pheophytin (µg L^{-1})	-0.272	0.166	-0.029	0.111	0.396	0.160	1

Note : A. T = Air Temperature, W. T. = Water Temperature, Chl-a = Chlorophyll-a concentration, Pheo = Pheophytin. And (***= $P<0.001$, **= $P<0.01$ and *= $P<0.1$)

Table 19: The value of correlation coefficient for the Seawater Quality parameters at the coastal area of Mahuva

	A.T.	**W. T.**	**pH**	**TSS**	**Salinity**	**DO**	**BOD**	**NO2-N**
Air Temp. (°C)	1							
Water Temp. (°C)	***__0.825__	1						
pH	-0.083	-0.236	1					
TSS (mg L^{-1})	-0.369	-0.272	0.413	1				
Salinity (S ‰)	-0.009	-0.151	-0.164	0.163	1			
DO (ml L^{-1})	***-0.513**	-0.438	0.103	-0.273	-0.133	1		
BOD (mg L^{-1})	0.223	-0.090	0.027	***-0.530**	0.064	0.175	1	
NO_2-N (µg at L^{-1})	-0.255	-0.211	0.351	****0.683**	-0.484	-0.171	-0.406	1
NO_3-N (µg at L^{-1})	-0.052	-0.097	-0.325	-0.484	0.024	0.310	0.262	-0.497
NH_4-N (µg at L^{-1})	0.227	0.233	-0.295	-0.390	-0.089	-0.407	0.221	-0.194
PO_4-P (µg at L^{-1})	-0.248	-0.350	0.379	-0.165	-0.436	0.316	0.312	0.173
GPP (µg C $L^{-1}hr^{-1}$)	-0.071	-0.369	0.167	-0.035	0.116	-0.376	0.390	-0.006
NPP (µg C $L^{-1}hr^{-1}$)	-0.202	-0.366	-0.412	-0.390	0.401	0.043	0.414	-0.417
Chl-*a* (µg L^{-1})	-0.421	***-0.551**	-0.144	0.351	0.115	-0.237	-0.286	0.430
Pheophytin (µg L^{-1})	0.280	0.021	-0.373	-0.451	0.156	-0.312	0.319	-0.281

Table 18: (Contd..)	**NO3-N**	**NH4-N**	**PO4-P**	**GPP**	**NPP**	**Chl-a**	**Pheo**
Air Temp. (°C)							
Water Temp. (°C)							
pH							
TSS (mg L^{-1})							
Salinity (S ‰)							
DO (ml L^{-1})							
BOD (mg L^{-1})							
NO_2-N (µg at L^{-1})							
NO_3-N (µg at L^{-1})	1						
NH_4-N (µg at L^{-1})	0.019	1					
PO_4-P (µg at L^{-1})	0.422	0.118	1				
GPP (µg C $L^{-1}hr^{-1}$)	-0.257	***0.514**	0.140	1			
NPP (µg C $L^{-1}hr^{-1}$)	-0.020	0.402	-0.077	***0.648**	1		
Chl-*a* (µg L^{-1})	-0.159	0.162	0.074	0.487	0.420	1	
Pheophytin (µg L^{-1})	-0.007	***0.709**	-0.213	***0.539**	***0.552**	0.206	1

Note : A. T = Air Temperature, W. T. = Water Temperature, Chl-a = Chlorophyll-a concentration, Pheo = Pheophytin and (***= P<0.001, **= P<0.01 and *= P<0.1).

Table 20: One way ANOVA Calculated value to find out statistically significant differences with Level of Significance of different water Quality parameters between Alang and Mahuva.

Water Quality Parameters		LEVEL OF SIGNIFICANCE	
		Significantly Different	Significantly Not Different
1	Air Temperature (°C)	-	95.0 %
2	Water Temperature (°C)	-	95.0 %
3	pH	-	95.0 %
4	TSS (mg L^{-1})	99.0%	99.9 %
5	Salinity (S ‰)	-	95.0 %
6	DO (ml L^{-1})	-	95.0 %
7	BOD (mg L^{-1})	-	95.0 %
8	NO_2-N (µg at L^{-1})	-	95.0 %
9	NO_3-N (µg at L^{-1})	-	95.0 %
10	NH_4-N (µg at L^{-1})	-	95.0 %
11	PO_4-P (µg at L^{-1})	-	95.0 %
12	Chl-*a* (µg L^{-1})	95.0%	99.0 %
13	Pheophytin (µg L^{-1})	-	95.0 %
14	GPP (µg C $L^{-1}hr^{-1}$)	99.0%	99.9 %
15	NPP (µg C $L^{-1}hr^{-1}$)	95.0%	99.0 %

Plate - I

Left : Alang Ship Breaking Yard Area.
Right:1 : Ships waiting for scrapping.
2 : Ship scrapping activity.
3 : Oil spillage due to ship scrapping

Plate - II

Left : Alang Ship Breaking Yard Area.
Right:1 : Beach affected by spilled oil.
2 : Finger prints of Dead Ship.
3 : Sediment contamination due to ship scrapping activities

Plate - III

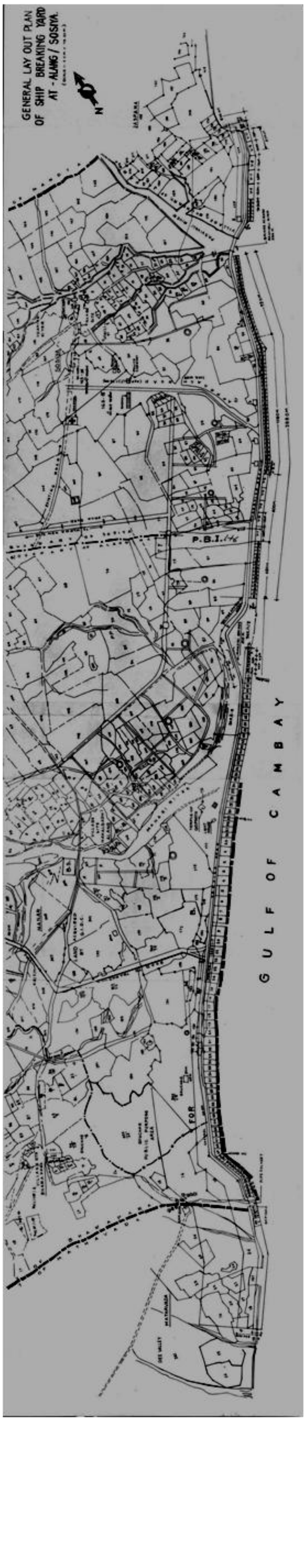
Left : Alang Ship Breaking Yard Area.

Right: 1 : Solid Wastes Disposal.

2 : Chemical wastes dumping zone.

3 : Paints spotted on beach.

Plate - IV

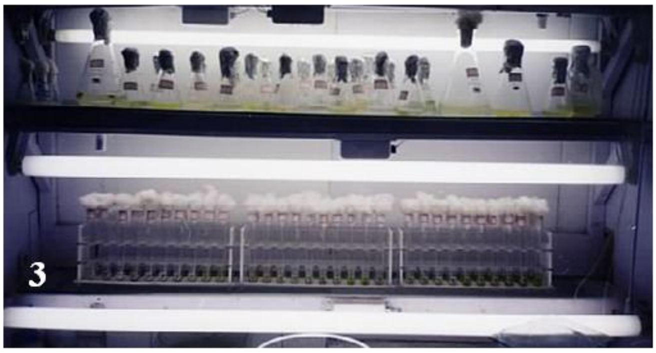


Left : Alang Ship Breaking Yard Area.
Right: 1 : Air pollution.
2 : Water pollution, and
3 : Land pollution at Alang.

Plate - V

Left : Alang Ship Breaking Yard Area.
Right: 1 : Burning of garbage.
2 : Productivity Stand placed in Field
3 : Mahuva, the station for comparison

Plate - IV

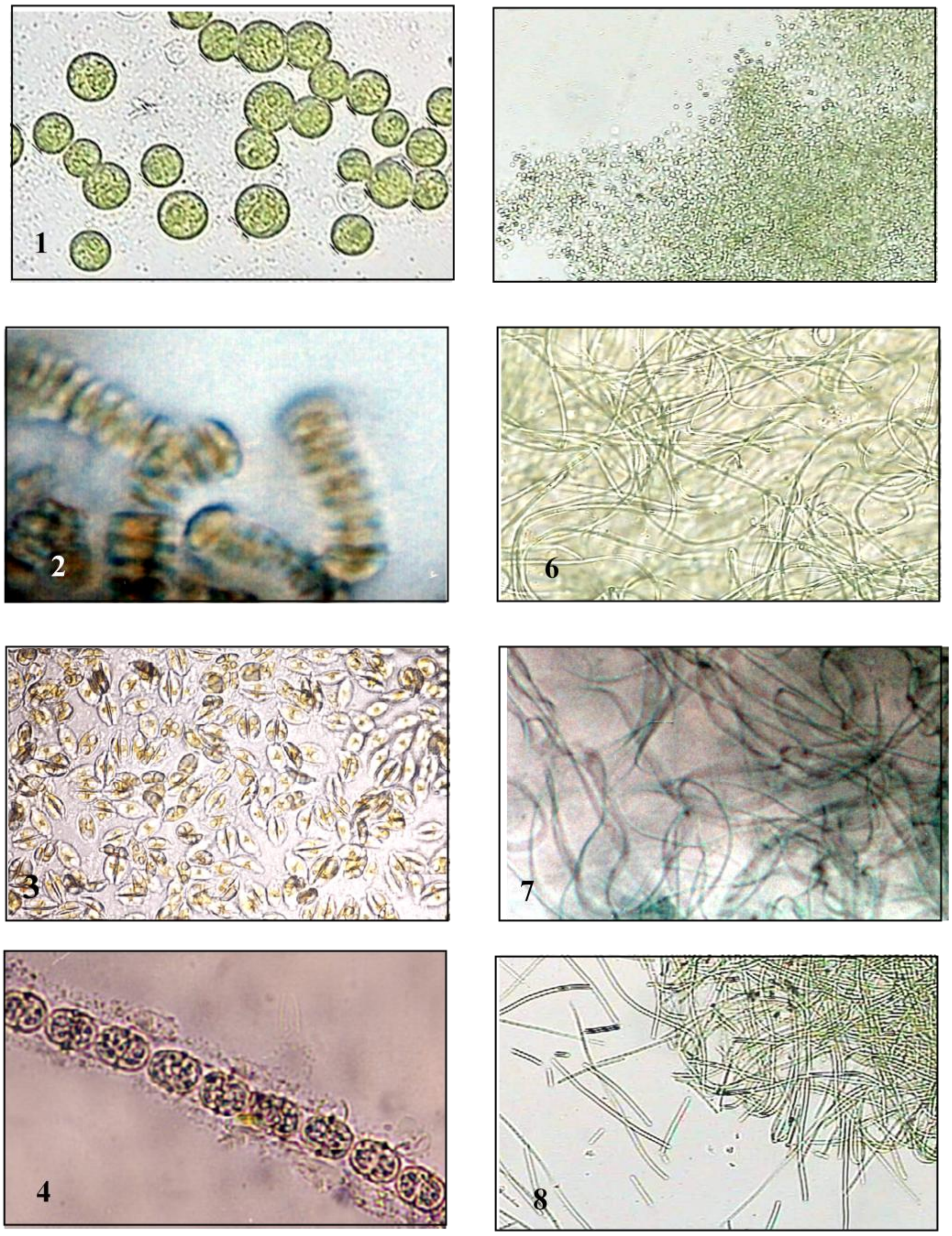


Left : Alang Ship Breaking Yard Area.

Right: 1 : Sampling 2 : Isolation

3 : Purification and 4: cultures of micro algae.

Plate - VII

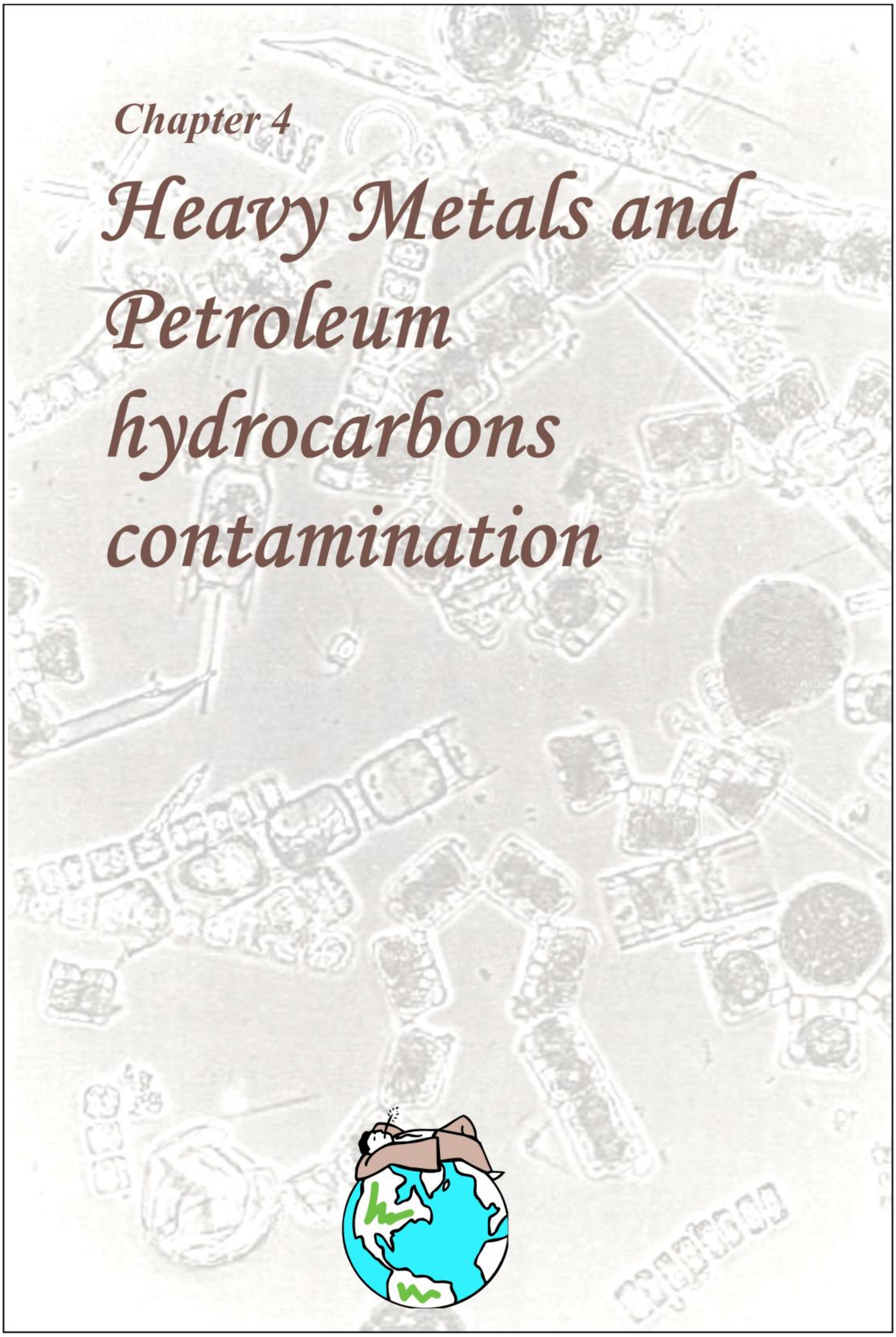


Different species were isolated from Alang and Mahuva as Heavy Metal and Petroleum Hydrocarbon Tolerant species.

1. Chroococcus macrococcus (Kutz) Rabenh. 2. Raphoneis Surirella (Ehrneb) Grun. 3. Amphora costata Wm. Sm. 4. Melosira moniliformes (Muller) Agardh. 5. Synechococcus species. 6. Lyngbya species 7. Phormidium species (metal tolerant) and 8. Phormidium species for Petroleum hydrocarbon tolerant species.

Chapter 4

Heavy Metals and Petroleum hydrocarbons contamination



Chapter 4

Heavy Metals and Petroleum Hydrocarbons Contamination

The earth's crust contains about 90 elements. Of these 9 elements viz. Al, Fe, Ca, Mg, O, Si, Na, K and Ti only account for over 99% by weight. The remaining 81 elements together account hardly 0.1% by weight and are are called as "trace elements" (Wittmann, 1979; Dara 1997). Out of about 40 naturally occurring elements, Mn, Fe, Co, Cu, and Zn seem to be highly "essential", and Cd and Pb may be non essential that are detected in living organisms (Dara, 1997). Iron is a widespread constituent of rocks and soils. It is the fourth most abundant, by weight, of the elements in the earth's crust. Almost all surface waters contain significant quantities of dissolved or suspended iron. In igneous rocks, iron may occur as fayalite ($FeSiO_4$), or as hematite (Fe_2O_4) and magnetite (Fe_3O_4), which are essential components of the pyroxenes, amphiboles, biotite and olivine. The ferrous oxidation state occurs as pyrite or marcasite (FeS_2), siderite ($FeCO_3$), hematite and magnetite.

In a natural undisturbed ecosystem, the primary source of most of heavy metals is the underline bedrock (Adriano, 1986 and Peterson, 1978) or surface material transported via the atmosphere from another location. Emissions of heavy metals as particulates and gases from volcanoes, forest fires, crustal materials and continental dust have always been a natural input into soils and ecosystems (Salomons and Frostener, 1984; Davidson et al., 1981). Heavy metals are found in the aquatic environment as inorganic cations or as complexed species originating in natural wheathering and leaching process or from anthropogenic process (Sorentino, 1979).

Although at natural concentrations, trace elements either constitute the prosthetic group of enzymes or function as enzyme activators, and at elevated concentration they act as inactivators of enzyme system and as protein precipitants (Nair,1984). The different oxidation states of metals determine certain degree of toxicity in aquatic organisms. The power of the elements to attract and accept electrons in compound formation is called "electro negativity", which has definitely some bearing on its ecological effects, with respect to toxicity to organisms. If the electro negativity is more, the toxicity will also be more (Waldichuk, 1974; Wittmann, 1979). The metals are classified into (i) Very toxic-effects seen at concentration bellow 1 ppm, (ii) moderately toxic-effects appear at concentrations between 1 and 100 ppm, and (iii) scarcely toxic-effects rarely appear (Nair, 1984).

Heavy metals have received much attention in eco-toxicological research because of their increasing input into the environment, prolonged persistence and widespread toxicity to the biota. To understand and detect these metals precisely newer and more accurate instrumentation, especially atomic absorption spectrophotometry became available to marine scientist during the past two decades. Increasing usage of these techniques by environmentalists, oceanographers, nutritionists, geochemists, toxicologists, radioecologists and others has provided much information with ambiguous data for same aliquote in the different techniques. In most cases, the relation between concentrations of selected metals in biological tissues has little direct relation to concentration of the same metals in the organism's immediate geophysical environment including sediments, sediment interstitial waters, and water column.

These elements are especially harmful because of the process called bioaccumulation where particular metals accumulate in tissue cells of organisms at the bottom of the food chain and get transferred in large dosages to higher organisms. Metals are susceptible to flocculation processes because of their charged nature and tend to accumulate in sediments. The potential toxicity of metals to marine organisms is not fully understood. However, it has been shown repeatedly that complexes of certain metals are extremely dangerous to particular marine. It is understood that the criteria for toxicity is not the same for each item in the table related to one specific test organisms, and that the toxic levels of any one element are different to different test organism. The degree of toxicity of any heavy metal depends on its presents in solution as free ion or a salt which is largely un-dissociated, or whether it is complexed organically or inorganically.

Ship-breaking activities add heavy metals to the coastal seawater as the bottom of ships are painted with toxic paints to prevent algae and sessile marine animals like barnacles and mussels from fouling the hull. Previously mercury, DDT and PCB's were extensively used in antifouling paint. Presently, most of the developed countries put restriction on the use of antifouling paints containing compounds of mercury, arsenic, DDT, HCH, and PCB's without any special permit granted by the authorities.

Antifouling paints, which use tin or copper as toxicants, the latter mostly as copper-oxide, or more modern types of organo-metallic compounds are legal. Chromium, lead, and zinc are important constituents of bottom primers, and cadmium are used in some paints, and zinc is sacrificial anodes to prevent steel hulls from corrosion.

4.1.1 Heavy Metals composition in natural seawater:

The concentration of various metals and antimony in the environment vary widely. The following table lists the average concentration of heavy metals in the seawater.

Table: Concentration of heavy Metals in natural Seawater.

Trace Element	**Goldberg (1965) (µg L^{-1})**	**Bowen (1966) (µg L^{-1})**	**Orr and Marshal, 1969 (µg L^{-1})**	**Brewer (1975) (µg L^{-1})**
Cd	1.0	0.10	0.04	0.10
Co	1.0	0.40	0.50	0.05
Cu	2.0	3.0	3.00	0.50
Fe	10.0	3.0	10.0	2.0
Mn	2.0	2.0	2.4	0.20
Ni	2.0	7.0	0.5	1.70
Pb	0.03	0.03	3.0	0.03
Zn	10.0	10.0	10.0	4.90

4.1.2 Heavy Metals in coastal seawaters of India:

Based on the published reports an attempt has been made here to review the level of heavy metals in coastal waters of India. The available standard values have also been tabulated for comparison and prediction of "safe" limits in the environment. The data presented in a table given in the next page:

Table: Heavy metals in coastal /marine waters of India (The unit is µg L^{-1})

LOCATION	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb	SOURCE
Base line for sea water	-	0.3	0.2	-	2.0	3.0	2.0	-	Goldberg, 1972
Probable safe concentration	5.0	-	-	-	15	50	53	30	Doudoroff and Katz, 1953; Meinick et al., 1956; Mc Kim and Benoit, 1971; EPA, 1973.
WHO's standard	-	-	2.0	-	3.0	5.0	-	1.0	Qusim and Sengupta, 1981
Arabian Sea	20	-	-	2.2	4.9	19.2	3.2	-	Sengupta et al., 1978
Bay of Bengal	-	-	0.3	-	6.8	15.3	30.3	-	Braganca and Sangiri, 1980; Qusim and Sengupta, 1981
Saurashtra Coast	-	10.4	-	8.3	8.0	11.9	3.1	-	Kesava Rao and Indusekar, 1996
Cuddalore marine water.	-	78.2	27	3.0	116.0	113.0	8.0	-	Ananthan et al., 1994
Mandapam seawater	-	-	-	-	24	52	-	19	Mohapatra, 1993
Parang Pettai	-	1.9	25	-	110.0	87	5.0	3.0	Ananthan et al., 1994

Source: Heavy Metal Toxicity in the Estuarine , Coastal and Marine Ecosystems of India.(Mohapatra and Rengarajan 2000).

4.1.3 Petroleum hydrocarbons:

In many areas oil has become the most frequently encountered water pollutant, as a result of numerous incidents. This reflects the expanding and widespread consumption of petroleum products. Oil pollution has harmful effect on aquatic life. Existing legislation concerning oil pollution cannot be effective unless there are adequate analytical means of detecting oil pollutants, identifying them with regard to their sources and determining their concentration.

Although marine oil pollution has received much attention in recent years, now there has been a need for an assessment of the analytical and related problems in this field.

Thousand different compounds are reported to be present in petroleum. 200 to 300 compounds are present in any particular grade of crude oil. More than half, 50% to 98%, of petroleum consists of hydrocarbons, such as Alkanes i.e. methane, ethane etc. (compounds with 5 to 7 carbon atoms and are liquids), Cycloalkanes i.e. naphthenes (with 5 to 6 carbon atoms arranged in a ring comprising 30% to 60% of petroleum. In addition to cyclo-pentane and cyclo-hexane, there are also bicyclic naphthenes and polycyclic naphthenes. These compounds are very resistant to microbial degradation. And the remaininga compose Aromatic compounds for 2% to 4% of petroleum. Volatile compounds in ring form (benzene, toluene and xylene), bicyclic aromatic hydrocarbons (principally naphthalene), tricyclic (like anthracene) and polycyclic ones with more than three rings (pyrene etc.) are present. There are some microorganisms, which are specialized in the biodegradation of these compounds.

The different components of crude petroleum are isolated in a refinery at above boiling point. Gasolene has a boiling point under 200°C and contains compounds with 5 to 12 carbon atoms. Medium distillates like kerosene, diesel oil, and light heating oil boil between 169°C to 375°C and contains compound with 9 to 22 carbon atoms (as water soluble, poisonous components, and contain principally naphthalene). Gas oil, heavy heating oil, lubricating oil and greases boil at higher temperatures and contain compounds with 29 to 36 carbon atoms. Residual oils with even higher boiling points have asphalt-like characteristics.

Unlike some pollutants, oil pollution is generally unpredictable to location and time, and usually exists as a surface phenomenon. Since oil can readily form a visible thin film of about $7.6X10^{-5}$ mm thickness, a small quantity of oil may be important and produce a heavily polluted appearance. It is often claimed that oil affects the transfer of oxygen into water; however, the effect in the case of thin films is not fully understood. Thick viscous layers do affect the transfer. Photosynthetic activity can be affected by increased reflection and possibly by the absorption of light by the oil. Most oil products are not considered particularly toxic. Heavy surface pollution and oil, which is emulsified, dissolved or associated with suspended solids in the body of the seawater may injure or kill aquatic animal life.

4.2 Materials and Methods:

4.2.1 Heavy metals detection in Ship scraps, soils, Sediment and Total Suspended Solids:

i) Sample Collection:

The metal dusts accumulated in ship scraps were collected from the plots during the ship scrapping activity in clean transparent polythene bag with zipper. The soils samples from the 12 plots of the Alang ship breaking yard were collected separately, in clean zippered transparent polythene bag and the samples were collected from extreme northern to southern side. The plots were approximately one-kilometer distance from each other. Both the samples, metal dust and Sediment were digested and estimated in a same procedure, following the analytical methods.

Sediment samples were collected in clean transparent polythene bag with zipper during low tide from each and every station. Then they were brought to the laboratory and dried in hot air oven at 110°C upto constant dry weight. After that 200 mg was taken in special vessel provided with the microwave digester (Milestone ETHOS 1600) and added HNO_3, HCl, H_2SO_4 or H_2O_2 or both, and $HClO_4$, in 5 : 3 : 1 : 1 ratio and total volume of the acid mixture was 10 ml. When H_2SO_4 and H_2O_2 were used, their composition was different such as 1+ 0 or ½ + ½ or 0+1 ml. Amount of other acids such as HNO_3, HCl, and $HClO_4$ varied ± 0.5 ml depending upon the Fe and organic matter content in the sediment soil. The acidified samples were then digested in 180°C for 35 minutes in the microwave digester (Milestone ETHOS 1600). After the complete digestion the samples were filtered and made upto volume of 25 ml by adding of MilliQ (an instrument can produce de-ionized and bacteria free distilled water) distilled water. The different heavy metals content within the extract were estimated by using Atomic Absorption Spectrophotometer, Shimadzu AA680 PR5. The digested sample was diluted or concentrated by addition of MilliQ distilled water or by evaporating on water bath. The metal in the ship dust or in sediment was calculated by using the following formula.

$$\mu g\ (\text{metal}) / g\ (\text{dry weight})\ \text{of sample} = \frac{C \times V}{W} \times df$$

Where,

C = Concentration of the element in digested sample in ppm ($\mu g\ mL^{-1}$)

V = Volume of the digested sample (cm^3)

W = Dry weight of the sample (g)

df = Dilution factor.

The dilution factor (df) was obtained from the equation

$$\text{Dilution factor (df)} = \frac{\text{Volume of the diluted sample}}{\text{Volume of the aliquot taken for dilution}}$$

4.2.2 Detection of dissolved Heavy Metals in Seawater:

i) Sample Collection:

White colored cleaned PVC made bottles (one liter capacity) were used for collecting seawater and at most care was taken to avoid any contamination during collection and handling the sample afterwards in field as well as in laboratory.

ii) Sample storage for the determination of trace elements:

In contrast to the major components and nutrients, trace elements in seawater are extremely dilute analytes. Even minor absolute losses or sample contamination in the ultra-trace range may significantly influence the results. In most cases, when long storage was necessary, storage methodology of Grasshoff. *et al*.(1999) was followed. According to Grasshoff's experience and are based on evaluation of published and unpublished data, the safest procedure to ensure minimum alteration of concentrations of the more often determined elements such as Cd, Co, Cu, Fe, Mn, Ni, Pb or Zn for a period up to 2 years (or possibly longer) is to filter the samples (except open ocean water), to acidify them to pH 1.5 –2.0 with ultra clean acid (approximately 1 µL of HNO_3 or HCl per ml of seawater sample)and to store them at about 4°C in properly cleaned containers made of Teflon or high-density polythene.

iii) Solvent Extraction:

The most frequently applied chelating agents are Sodium salt of diethyldithiocarbamate (NaDDTC) were used, mainly because of their non-selective complexing properties and a broad pH working range (optimum pH values for complexing of the elements under consideration: 4 to 11). The methods described here involves solvent, Carbon tetrachloride was used for dissolving the metal carbamate compound. Only part of the metal will be detected due to its colloidal fraction usually present in natural waters. It was also stressed that kinetically stable metal organic complexes that exist in seawaters (e.g. humic substances) might not be affected by the chelating agents, thus for metal release, such compounds were digested by chemical reaction or by UV irradiation before extraction. It was experienced that samples stored for several weeks at pH values between 1.0 and 2.0 release most of the metals combined with such components.

To bring the extracted metal concentration within the detectable range of Atomic Absorption Spectrophotometer two separating funnels (2000 ml) containing 1000 ml of sample seawater were used for extraction. Metals were extracted in four steps by altering the pH from 2-3, 3-5, 5-7 and 7-9 accordingly and the two sets were operated separately. One set from lower range to higher range and the other one higher to lower. Added 5 ml of 10% NaDDTC solution and 25 ml of CCl_4.Shaken for 5 minutes and kept for forming bi-layer. Then transfer the organic layer to the small separating funnel (250 ml) containing 20 ml of 4(N) HNO_3. And the aqueous portion was extracted again three times by changing the pH. Each and every time the organic layer was transferred to the same small funnel. After that the metal carbamate gets dissolved in the aqueous layer of 4 (N) of HNO_3. This extraction was repeatedly done for three times. Fist time only 20 ml of HNO_3 was added and all the other times only 10 ml of HNO_3 solution were added. The approximately collected 50 ml of HNO_3 solution containing the metal carbamate was filtered through the milipore filter paper (0.45 µm) and the metals were detected by Atomic Absorption Spectrophotometer, Shimadzu AA680 PR5.

iv) Preparation of standards:

Stock standard solutions (1000 µg/mL) were available from Merk Co., Germany, and working standards were prepared from the stock standard solutions depending upon the different metal and different detection limit of the Atomic Absorption Spectrophotometer, Shimadzu AA680 PR5 by dilution with the de-ionized water (MilliQ water) and kept in refrigerator (4°C).

Metal concentration was obtained by using the following formula.

$$\mu g\text{ (metal) / Seawater (L)} = \frac{C \times v}{V} \times cf$$

Where,

C = Concentration of the element of sample extract in ppm (μg mL^{-1})

v = Volume of the sample extract (cm^3)

V = Volume of the sample seawater extracted (L)

cf = Concentration factor.

The concentration factor (cf) was obtained from the equation

$$\text{Concentration factor (cf)} = \frac{\text{Volume of the sample extract}}{\text{Volume of the aliquot taken for extraction}}$$

4.2.3 Detection of Petroleum Hydrocarbons in Seawater:

UV fluorimetry (UVF) has found wide–spread applications for investigating and monitoring the degree of aquatic oil contamination because of its simplicity, sensitivity and easy of application. For oil spill monitoring, it is useful to calibrate the instrument against solutions of the spilled oil. However, even when the whole oil is available, it can be used as a standard (Grassoff, 1999).

Here aromatic hydrocarbons together with other lipophilic compounds are extracted from a known volume of seawater with n-hexane or cyclo-hexane, in which Gelbstoff and humic substances resulting from natural decay of recent biological material are insoluble. The different types of oil such as Lubricate oil, Diesel oil, Engine oil, Compressor oil and Farness oil used in different parts of ships for different purposes were collected and mixed in a known proportion for using as a standard to compare the sample.

Ambor colored glass bottles (2.5 liter capacity) were used for sampling. The bottoles were filled with detergent solution and kept at least for over night and then scrubbed with brushes. They were rinsed with copious amounts of tap water followed by de-ionized water and dried in hot oven. Samples were kept in refrigerator (4°C) for one or two days if required for determination of the samples. Experience showed that one extraction per sample removes >90% of dissolved form of moderately contaminated seawater. So it was not needed to extract the samples more than three times.

The extract is dried with anhydrous sodium sulphate. The dried extract is transferred into a 50 ml conical flask and reduced in volume to a few ml with a rotary evaporator and brought to the UV flurescent Spectrophotometer (Perkin Elmer Model No. LS 50 B). Detection of petroleum hydrocarbons were obtained by using the following formula.

$[FI_{(s)} – FI_{(b)}]$ x dilution factor x S x $V_{(s)} / V_{(w)}$

Where, $FI_{(s)}$ = FI readings (mV detector output) of samples,

$FI_{(b)}$ = FI readings (mV detector output) of Blank,

S = Slope of the regression line,

$V_{(s)}$ = Total volume of sample extract,

$V_{(w)}$ = Total volume of Sample Seawater extracted.

4.3 Result and Discussion:

4.3.1 Heavy Metals in Ship scraps (Metal dust):

Iron is the main constituent of the plate of the ship. Eight selected metals were detected from the ship cuttings of the Alang ship breaking yard and the data is depicted in the Table No-21. Fe, Mn, Cd, Co, Cu, Zn, Ni and Pb contained 90.76 to 93.98 % of the total metal content of the ship cuttings. The balance of 6.02 to 9.24% of the total metal content of the ship plate may be made by other impurities like, Al, Sn, Cr, etc. Within the detected eight metals, Fe contains from 98.681 to 99.626%. The other metals detected from the ship cuttings were 0.269 to 0.394% Mn, 0.002 to 0.003% Cd, 0.012 to 0.018% Co, 0.021 to 0.027% Cu, 0.03 to 0.046 % Zn, 0.020 to 0.023 % Ni and 0.02 to 0.027% Pb.

4.3.2 Heavy Metals in soil of the ship breaking Plots:

The details of data relating to metal contents are depicted in table no.22. Fe ranged from 131437.5 at plot no.XI to 476625.0 mg Kg^{-1} at plot no. VI with an average value 313552.1 mg Kg^{-1}. Average concentration of Fe found in soil sample was 34.10 % of the average concentration of the ship cuttings dust. The concentration of Mn in the soil sample of the 12 plots varied 943.3 at plot no.I to 4767.5 mg Kg^{-1} with an average concentration 2298.5 mg $Kg^{-}1$ in plot no. XI. Average concentration of Mn found in soil sample was 78.07 % of the average concentration of the ship cuttings dust. Cd concentrations were recorded from the above said 12 plots and varied from 10.75 at plot no.IX to 23.25 mg Kg^{-1} at plot no.VI with an average 16.46

mg Kg^{-1}. Average concentration of Cd found in soil sample was 82.99 % of the average concentration of the ship cuttings dust. Co observed from the 12 plots varied from 56.75 at plot no.III to 196.75 mg Kg^{-1} at plots IV with an average concentration 123.71 mg Kg^{-1}. Average concentration of Co found in soil sample was 88.00 % of the average concentration of the ship cuttings dust. Cu concentration ranged from 171.50 at plot no.I to 408.75 mg Kg^{-1} at plot no.IV with an average concentration 260.15 mg Kg^{-1}. Average concentration of Cu found in soil sample was 120.35 % of the average concentration of the ship cuttings dust. Zn concentration varied from 404.5 at plot no.XII to 1376.75 mg Kg^{-1} at plot no.V with an average concentration 850.25 mg Kg^{-1}. Average concentration of Zn found in soil sample was 252.05 % of the average concentration of the ship cuttings dust. Ni concentration recoded varied from 166.00 at plot no.XII to 549.75 mg Kg^{-1} at plot no.VI with an average concentration 257.94 mg Kg^{-1}. Average concentration of Ni found in soil sample were 129.83 % of the average concentration of the ship cuttings dust. Pb concentration was found to vary from 55.75 at plot no.X to 256.75 mg Kg^{-1} at plot no.III with an average concentration 153.63 mg Kg^{-1}. Average concentration of Pb present in soil sample was 68.94 % of the average concentration of the ship cuttings dust.

4.3.3 Heavy Metal Concentration in Sediment:

The details of data relating to heavy metal contents in sediment of Alang and Mahuva are depicted in table no 23 to 30.

In Alang Fe concentrations varied from 12687.5 mg Kg^{-1} at station, SA1 during December 2002 to 151062.5 mg Kg^{-1} at station, SA4 during August 2001. Average concentration of Fe as a whole varied from 27625.0 mg Kg^{-1} during April 2003 to 91250.0 mg Kg^{-1} during August 2001. In general, within the four stations, the average concentration of iron varied from 50166.67 mg Kg^{-1} at station, SA3 to 78661.46 mg Kg^{-1} at station, SA4 through out the study period. But, the concentration of Fe ranged from 7000.0 during Jun 2002 to 77000.0 mg Kg^{-1} during February 2002 in Mahuva. The variation in average concentration of Fe at Alang varied much as compared to Mahuva and it was found to be 10.63 % less during Jun 2001 and 663.39 % more during Jun 2002. The concentration of iron in sediment showed significant difference with 95% confidence limit between Alang and Mahuva.

Mn concentrations varied from 721.75 mg Kg^{-1} at station SA3 during October 2002 to 1753.25 mg Kg^{-1} at station SA4 during Jun 2002 in Alang. Average concentration of Mn in

Alang as a whole varied from 827.87 mg Kg^{-1} during April 2003 to 1146.81mg Kg^{-1} during Jun 2002. In general, within the four stations of Alang, the average concentrations of Mn were from 951.83 mg Kg^{-1} at station SA3, to 1146.90 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Mn ranged from 789.5 during December 2002 to 1163.0 mg Kg^{-1} during Jun 2001 in Mahuva. The average concentration of Mn at Alang varied much as compared to Mahuva and it was found to be 11.69 % less during October 2002 and 25.17% more during December 2002. The concentration of Mn in sediment also showed significant difference with 95% confidence limit between Alang and Mahuva.

Cd concentrations varied from non-detectable range at station SA3 during October 2002 to 15.25 mg Kg^{-1} at station SA4 during August 2001 in Alang. Average concentration of Cd in Alang as a whole varied from 1.94 mg Kg^{-1} during October 2002 to 12.63 mg Kg^{-1} during August 2001. In general, within the four stations of Alang, the average concentrations of Cd varied from 7.23 mg Kg^{-1} at station SA1, to 9.38 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Cd ranged from 0.75 during October 2002 to 11.75 mg Kg^{-1} during December 2001 in Mahuva. The average concentration of Cd at Alang varied much as compared to Mahuva and it was found to be 5.17 % less during April 2002 and 181.25% more during April 2003. The concentration of Cd in sediment also did not show any significant difference between Alang and Mahuva.

Co concentrations varied from 31.5 at station SA3 during Jun 2001 to 109.75 mg Kg^{-1} at station SA1 during December 2001 in Alang. Average concentration of Co in Alang as a whole varied from 41.31 mg Kg^{-1} during October 2002 to 99.00 mg Kg^{-1} during December 2001. In general, within the four stations of Alang, the average concentrations of Co varied from 63.71 mg Kg^{-1} at station SA3, to 70.67 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Co ranged from 49.5 mg Kg^{-1} during October 2002 to 91.75 mg Kg^{-1} during August 2002 in Mahuva. The average concentration of Co at Alang varied much as compared to Mahuva and it was found to be 23.56 % less during August 2002 and 49.62% more during April 2003. The concentration of Co in sediment also did not show any significant difference between Alang and Mahuva.

Cu concentrations varied from 75.75 mg Kg^{-1} at station SA3 during Jun 2001 to 184 mg Kg^{-1} at station SA4 during December 2002 in Alang. Average concentration of Cu in Alang as a whole varied from 86.81 mg Kg^{-1} during Jun 2001 to 114.56 mg Kg^{-1} during December 2002. In general, within the four stations of Alang, the average concentration of Cu varied from 95.17 mg Kg^{-1} at station SA2, to 125.65 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Cu ranged from 71.5 during August 2002 to 305.75 mg Kg^{-1} during Jun 2002 in Mahuva. The average concentration of Cu at Alang varied much as compared to Mahuva and it was found to be 68.64% less during Jun 2002 to 56.99% more during August 2002. The concentration of Cu in sediment also did not show any significant difference between Alang and Mahuva.

Zn concentrations varied from 91.00 mg Kg^{-1} at station SA3 during Jun 2001 to 458.00 mg Kg^{-1} at station SA4 during August 2001 in Alang. Average concentration of Zn in Alang as a whole varied from 128.75 mg Kg^{-1} during Jun 2001 to 217.06 mg Kg^{-1} during December 2002. In general, within the four stations of Alang, the average concentrations of Mn varied from 132.29 mg Kg^{-1} at station SA3, to 244.15 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Zn ranged from 88.50 during April 2003 to 247.25 mg Kg^{-1} during Jun 2002 in Mahuva. The average concentration of Zn at Alang varied much as compared to Mahuva and it was found to be 39.13 % less during Jun 2002 and 116.30 % more during August 2001. The concentration of Zn in sediment showed significant difference with 99.9% confidence limit between Alang and Mahuva.

Ni concentrations varied from 64.75 mg Kg^{-1} at station SA1 during Jun 2002 to 192.00 mg Kg^{-1} at station SA2 during February 2003 in Alang. Average concentration of Ni in Alang as a whole varied from 83.81 mg Kg^{-1} during Jun 2001 to 134.6875 mg Kg^{-1} during February 2003. In general, within the four stations of Alang, the average concentrations of Ni varied from 91.77 mg Kg^{-1} at station SA3, to 114.46 mg Kg^{-1} at station SA2 through out the study period. But, the concentration of Ni ranged from 38.75 during Jun 2002 to 120.25 mg Kg^{-1} during February 2003 in Mahuva. The average concentration of Ni at Alang varied much as compared to Mahuva and it was found to be 6.54% less during December 2001 and 126.94% more during April 2003. The concentration of Ni in sediment showed significant difference with 99.0% confidence limit between Alang and Mahuva.

Pb concentrations varied from 2.50 mg Kg^{-1} at station SA1 during Jun 2002 to 255.25 mg Kg^{-1} at station SA4 during August 2001 in Alang. Average concentration of Pb in Alang as a whole varied from 35.44 mg Kg^{-1} during Jun 2002 to 205.50 mg Kg^{-1} during August 2001. In general, within the four stations of Alang, the average concentrations of Pb varied from 110.29 mg Kg^{-1} at station SA2, to 137.75 mg Kg^{-1} at station SA4 through out the study period. But, the concentration of Pb ranged from 1.00 during October 2002 to 218.00 mg Kg^{-1} during October 2001 in Mahuva. The average concentration of Pb at Alang varied much as compared to Mahuva and it was found to be 14.25 % less during April 2002 and 3631.25% more during October 2002. The concentration of Pb in sediment did not show any significant difference between Alang and Mahuva.

4.3.4 Heavy Metal Concentration in Particulate Matter of Seawater:

The details of data relating to heavy metal contents in particulate matters in seawater of Alang and Mahuva are depicted in table no 31 to 38.

Fe concentrations varied from 7766.63 µg L^{-1} at station SA2 during August 2002 to 125667.19 µg L^{-1} at station SA4 during October 2002 in Alang. Average concentration of Fe in Alang as a whole varied from 13526.20 µg L^{-1} during October 2001 to 92650.77 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of iron varied from 46083.54 µg L^{-1} at station SA1, to 63000.17 µg L^{-1} at station SA3 through out the study period. But, the concentration of Fe ranged from 11948.00 during April 2003 to 58949.75 µg L^{-1} during Jun 2001 in Mahuva. The average concentration of Fe at Alang varied much as compared to Mahuva and it was found to be 20.61 % less during August 2001 and 201.52 % more during October 2002. The Fe transport from sediment to particulate matter in seawater was observed 0.105% at Alang, whereas, it was noticed for the same 0.121% at Mahuva, which may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 48 & 49). However, the concentration of iron in particulate matter did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Mn concentrations varied from 162.26 µg L^{-1} at station SA2 during August 2002 to 2701.09 µg L^{-1} at station SA3 during December 2002 in Alang. Average concentration of Mn in Alang as a whole varied from 268.51 µg L^{-1} during October 2001 to 1775.04 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Mn ranged from 849.77 µg L^{-1} at station SA1, to 1354.66 µg L^{-1} at station SA3 through out the study period. But, the concentration of Mn ranged from 191.58 during April 2003 to 1013.00 µg L^{-1}

during August 2001 in Mahuva. The average concentration of Mn at Alang varied much as compared to Mahuva and it was found to be 44.94 % less during August 2002 and 335.28% more during April 2003. The Mn transport from sediment to particulate matter in seawater was observed 0.108% at Alang, whereas, it was noticed for the same 0.064% at Mahuva, which may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 50 & 51). The concentration of Mn in particulate matter also showed significant difference between Alang and Mahuva with 95% confidence limit.

Cd concentrations varied from 0.29 µg L^{-1} at station SA2 during Jun 2002 to 24.23 µg L^{-1} at station SA3 during December 2001 in Alang. Average concentration of Cd in Alang as a whole varied from 2.56 µg L^{-1} during October 2001 to 18.19 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Cd varied from 6.83 µg L^{-1} at station SA1, to 11.25 µg L^{-1} at station SA3 through out the study period. But, the concentration of Cd ranged from 1.52 µg L^{-1} during December 2002 to 10.03 µg L^{-1} during Jun 2001 in Mahuva. The average concentration of Cd at Alang varied much as compared to Mahuva and it was found to be 66.12 % less during Jun 2001 and 450.02 % more during October 2002. The Cd transport from sediment to particulate matter in seawater was observed 0.142% at Alang, whereas, it was noticed for the same 0.102% at Mahuva, which may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area(Table 52 & 53). The concentration of Cd in sediment also did not showed any significant difference between Alang and Mahuva.

Co concentrations varied from 11.81 µg L^{-1} at station SA2 during August 2002 to 178.68 µg L^{-1} at station SA3 during December 2001 in Alang. Average concentration of Co in Alang as a whole varied from 22.26 µg L^{-1} during October 2001 to 111.18 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Co varied from 52.43 µg L^{-1} at station SA1, to 84.94 µg L^{-1} at station SA3 through out the study period. But, the concentration of Co ranged from 21.94 µg L^{-1} during April 2003 to 67.23 µg L^{-1} during February 2002 in Mahuva. The average concentration of Co at Alang varied much as compared to Mahuva and it was found to be 30.46 % less during August 2002 and 321.00% more during October 2002. The Co transport from sediment to particulate matter in seawater was observed 0.104% at Alang, whereas, it was noticed for the same 0.060% at Mahuva, which also may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 54 &

55). However, the concentration of Co in particulate matter also did not showed any significant difference between Alang and Mahuva.

Cu concentrations varied from 19.74 µg L^{-1} at station SA2 during August 2002 to 240.86 µg L^{-1} at station SA4 during February 2003 in Alang. Average concentration of Cu in Alang as a whole varied from 30.35 µg L^{-1} during October 2001 to 183.25 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Cu varied from 84.33 µg L^{-1} at station SA1, to 145.95 µg L^{-1} at station SA3 through out the study period. But, the concentration of Cu ranged from 28.79 µg L^{-1} during October 2001 to 106.91 µg L^{-1} during August 2001 in Mahuva. The average concentration of Cu at Alang varied much as compared to Mahuva and it was found to be 29.87% less during August 2002 and 338.10% more during October 2002. The Cu transport from sediment to particulate matter in seawater was observed 0.111% at Alang, whereas, it was noticed for the same 0.073% at Mahuva, which also may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 56 & 57). The concentration of Cu in particulate matter also showed significant difference between Alang and Mahuva with 95% confidence limit.

Zn concentrations were varied from 72.79 µg L^{-1} at station SA2 during October 2001 to 635.50 µg L^{-1} at station SA1 during February 2003 in Alang. Average concentration of Zn in Alang as a whole varied from 103.96 µg L^{-1} during October 2001 to 329.32 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Mn varied from 205.84 µg L^{-1} at station SA4, to 267.11 µg L^{-1} at station SA3 through out the study period. But, the concentration of Zn ranged from 69.83 µg L^{-1} during April 2003 to 577.30 µg L^{-1} during Jun 2001 in Mahuva. The average concentration of Zn at Alang varied much as compared to Mahuva and it was found to be 57.64 % less during Jun 2001 and 309.28 % more during February 2003. The Zn transport from sediment to particulate matter in seawater was observed 0.149% at Alang, whereas, it was noticed for the same 0.152% at Mahuva, which obviously play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 58 & 59). The concentration of Zn in particulate matter did not show any significant difference between Alang and Mahuva.

Ni concentrations varied from 12.57 µg L^{-1} at station SA1 during October 2002 to 212.36 µg L^{-1} at station SA3 during December 2001 in Alang. Average concentration of Ni in Alang as a whole varied from 19.65 µg L^{-1} during October 2001 to 131.09 µg L^{-1} during April 2002. In general, within the four stations of Alang, the average concentrations of Ni varied from 59.17 µg L^{-1} at station SA1, to 104.35 µg L^{-1} at station SA3 through out the study period. But, the concentration of Ni ranged from 14.80 µg L^{-1} during October 2002 to 76.99 µg L^{-1} during Jun 2001 in Mahuva. The average concentration of at Alang varied much as compared to Mahuva and it was found to be 33.91% less during August 2002 and 571.58% more during April 2002. The Ni transport from sediment to particulate matter in seawater was observed 0.084% at Alang, whereas, it was noticed for the same 0.057% at Mahuva, which may be an important factor in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 60 & 61). The concentration of Ni in particulate matter showed significant difference with 95.0% confidence limit between Alang and Mahuva.

Pb concentrations varied from 4.78 µg L^{-1} at station SA1 during April 2003 to 428.43 µg L^{-1} at station SA2 during Jun 2001 in Alang. Average concentration of Pb in Alang as a whole varied from 48.46 µg L^{-1} during October 2001 to 318.63 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Pb varied from 134.16 µg L^{-1} at station SA2, to 242.28 µg L^{-1} at station SA3 through out the study period. But, the concentration of Pb ranged from 8.14 during April 2003 to 194.28 µg L^{-1} during Jun 2001 in Mahuva. The average concentration of Pb at Alang varied much as compared to Mahuva and it was found to be 25.39 % less during August 2002 and 1079.75% more during April 2003. The Pb transport from sediment to particulate matter in seawater was observed 0.201% at Alang, whereas, it was noticed for the same 0.769% at Mahuva, which obviously play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 62 & 63). The concentration of Pb in Particulate matter did not show any significant difference between Alang and Mahuva.

4.3.5 Heavy Metals Concentration in Seawater as dissolved:

The details of data relating to heavy metal contents dissolved in seawater of Alang and Mahuva are depicted in table no 39 to 46.

Fe concentrations varied from 3.8 µg L^{-1} at station SA2 during Jun 2001 to 2344.00 µg L^{-1} at station SA1 during October 2001 in Alang. Average concentration of Fe in Alang as a whole varied from 6.88 µg L^{-1} during Jun 2001 to 1586.63 µg L^{-1} during October 2001. In general, within the four stations of Alang, the average concentrations of iron varied from 280.37 µg L^{-1} at station SA4, to 483.89 µg L^{-1} at station SA1 through out the study period. But, the concentration of Fe ranged from non-detectable range during Jun 2001 to 4622.5 µg L^{-1} during October 2001 in Mahuva. The average concentration of Fe at Alang varied much as compared to Mahuva and it was found to be 69.18 % less during April 2003 and 468.70 % more during February 2002 (value calculated within detectable range). Fe showed considerable strong positive association with Mn (R=0.778) and Co (R=0.726), and a moderate positive association with Zn (R=0.639) in Alang. But, Fe showed more strong positive correlation with Mn (R=0.950) and Cu (R=0.820) at Mahuva than Alang. The Fe transport from particulate matter in seawater to it's dissolved form was observed 0.001% at Alang, whereas, it was noticed for the same 0.003% at Mahuva, which may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 48 & 49). However, the concentration of iron as dissolved in seawater did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Mn concentrations varied from non-detectable range at station SA2 during April 2002 to 94.15 µg L^{-1} at station SA3 during April 2002 in Alang. Average concentration of Mn in Alang as a whole varied from 1.14µg L^{-1} during August 2002 to 56.43 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Mn ranged from 9.37 µg L^{-1} at station SA2, to 27.59 µg L^{-1} at station SA3 through out the study period. But, the concentration of Mn ranged from 0.25 during October 2002 to 58.85 µg L^{-1} during October 2001 in Mahuva. The average concentration of Mn at Alang varied much as compared to Mahuva and it was found to be 77.31 % less during April 2003 and 4602.5% more during April 2003. Mn showed a strong positive correlation with Fe (R=0.726) and Zn (R=0.728), and a moderate association with Cu (R=0.633) in Alang. But it showed a negative correlation with Cd (R= -0.541), a more strong positive association with Cu (R= 0.821) at Mahuva than Alang. The Mn transport from particulate matter in seawater to it's dissolved form was observed 0.002% at Alang, whereas, it was noticed for the same 0.003% at Mahuva, which may be an important factor in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 50 & 51). However, the concentration of Mn as dissolved in seawater did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Cd concentrations varied from non-detectable range at station SA4 during December 2001 to 8.05 µg L^{-1} at station SA1 during Jun 2001 in Alang. Average concentration of Cd in Alang as a whole varied from 0.54 µg L^{-1} during August 2002 to 5.89 µg L^{-1} during Jun 2001. In general, within the four stations of Alang, the average concentrations of Cd varied from 1.25 µg L^{-1} at station SA4, to 1.98 µg L^{-1} at station SA1 through out the study period. But, the concentration of Cd ranged from non-detectable range during October 2001 to 2.55 µg L^{-1} during April 2002 in Mahuva. The average concentration of Cd at Alang varied much as compared to Mahuva and it was found to be 49.72 % less during October 2002 and 1863.33% more during Jun 2001 (value calculated within detectable range). Cd concentration did not show any other considerable association with any metals except a weak negative association with Mn (R= -0.541) in Mahuva. The Cd transport from particulate matter in seawater to it's dissolved form was observed 0.029% at Alang, whereas, it was noticed for the same 0.027% at Mahuva, which also may play role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 52 & 53). The concentration of Cd as dissolved in seawater did not show any significant difference between Alang and Mahuva.

Co concentrations varied from non-detectable range at most of the stations at Alang such as SA1 during October, December of 2001, April, Jun, and December of 2002, at SA2 during August, 2001 and August and October 2002, at SA3 during August and October of 2001, August and October of 2002 and February and April of 2003, and at SA4 during August and December 2001, and February and April 2002 to 26.00 µg L^{-1} at station SA1 during August 2002 in Alang. Average concentration of Co in Alang as a whole varied from 1.4 µg L^{-1} during August 2001 to 13.4 µg L^{-1} during Jun 2002. In general, within the four stations of Alang, the average concentrations of Co varied from 3.44 µg L^{-1} at station SA3, to 6.14 µg L^{-1} at station SA1 through out the study period. But, the concentration of Co ranged from non-detectable range during October and December 2001, February, October and December of 2002 to 16.35 µg L^{-1} during August 2001 in Mahuva. The average concentration of Co at Alang varied much as compared to Mahuva and it was found to be 91.44 % less during August 2001 and 894.44% more during Jun 2002. Co did not show any other remarkable association with any metal except Fe (R=0.726) in Alang. But it showed a strong negative correlation with Zn (R= -0.807) and a weak positive correlation with petroleum hydrocarbons (R=0.584) at Mahuva. The Co transport from particulate matter in seawater to it's dissolved form was observed 0.005% at Alang, whereas, it was noticed for the same 0.009% at Mahuva, which obviously play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 54 & 55). However, the concentration of Co as dissolved in seawater did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Cu concentrations varied from non-detectable range at station SA4 during August 2001 to 35.60 µg L^{-1} at station SA4 during April 2002 in Alang. Average concentration of Cu in Alang as a whole varied from 0.91 µg L^{-1} during August 2001 to 14.75 µg L^{-1} during April 2002. In general, within the four stations of Alang, the average concentrations of Cu varied from 5.45 µg L^{-1} at station SA3, to 7.49 µg L^{-1} at station SA4 through out the study period. But, the concentration of Cu ranged from 1.90 during December 2002 to 11.85 µg L^{-1} during October 2001 in Mahuva. The average concentration of Cu at Alang varied much as compared to Mahuva and it was found to be 62.5% less during August 2001 and 249.47% more during December 2002. Copper showed a weak positive correlation with Mn (R=0.633), Zn (R=0.663) and Pb (R=0.500) in Alang. But it showed a strong positive correlation with Mn (R=0.821), a weak correlation with Zn (R=0.631) in Mahuva. The Cu transport from particulate matter in seawater to it's dissolved form was observed 0.007% at Alang, whereas, it was noticed for the same 0.010% at Mahuva, which also may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 56 & 57). However, the concentration of Cu as dissolved in seawater did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Zn concentrations varied from 5.5 µg L^{-1} at station SA1 during August 2001 to 124.50 µg L^{-1} at station SA4 during February 2002 in Alang. Average concentration of Zn in Alang as a whole varied from 3.59 µg L^{-1} during August 2001 to 57.40 µg L^{-1} during February 2002. In general, within the four stations of Alang, the average concentrations of Mn varied from 30.12 µg L^{-1} at station SA3, to 38.13 µg L^{-1} at station SA4 through out the study period. But, the concentration of Zn ranged from 4.90 µg L^{-1} during August 2001 to 54.40 µg L^{-1} during October 2002 in Mahuva. The average concentration of Zn at Alang varied much as compared to Mahuva and it was found to be 52.00 % less during October 2002 and 122.05% more during February 2002. Zn showed a positive correlation with Fe (R=0.639), Mn (R=0.728) and Cu (R=0.663) in Alang. But, it showed a strong negative correlation with Co (R= -0.807) and a weak positive correlation with Cu (R=0.631) in Mahuva. The Zn transport from particulate matter in seawater to it's dissolved form was observed 0.016% at Alang, whereas, it was noticed for the same

0.031% at Mahuva, which obviously play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 58 & 59). However, the concentration of Zn as dissolved in seawater did not show any significant difference between Alang and Mahuva even with 95% confidence limit.

Ni concentrations varied from non-detectable range at station SA1 during August 2002 and April 2003 to 19.0 µg L^{-1} at station SA1 during August 2001 in Alang. Average concentration of Ni in Alang as a whole varied from 0.35 µg L^{-1} during August 2002 to 10.15 µg L^{-1} during August 2001. In general, within the four stations of Alang, the average concentrations of Ni varied from 2.99 µg L^{-1} at station SA4 to 5.61 µg L^{-1} at station SA1 through out the study period. But, the concentration of Ni ranged from non-detectable range during Jun 2001 to 37.50 µg L^{-1} during February 2002 in Mahuva. The average concentration of Ni at Alang varied much as compared to Mahuva and it was found to be 86.16% less during 2002 and 43.39% more during April 2002. Ni did not show any considerable association with any metal at both the places, Alang and Mahuva. The Ni transport from particulate matter in seawater to it's dissolved form was observed 0.006% at Alang, whereas, it was noticed for the same 0.025% at Mahuva, which also may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 60 & 61). The concentration of Ni as dissolved in seawater did not show any significant difference between Alang and Mahuva.

Pb concentrations varied from non-detectable range at station SA1 during October and December 2002, at SA2 during Jun to December of 2002 and April of 2003, at SA3 during Jun and December of 2001, and at SA4 during Jun to October 2001 and October of 2002 to 71.05 µg L^{-1} at station SA4 during April 2002 in Alang. Average concentration of Pb in Alang as a whole varied from 0.4 µg L^{-1} during October 2001 to 57.51 µg L^{-1} during April 2002. In general, within the four stations of Alang, the average concentrations of Pb varied from 15.69 µg L^{-1} at station SA2, to 20.07 µg L^{-1} at station SA3 through out the study period. But, the concentration of Pb ranged from non-detectable range during October to December 2002 to 38.25 µg L^{-1} during August 2002 in Mahuva. The average concentration of Pb at Alang varied much as compared to Mahuva and it was found to be 92.25 % less during August 2001 and 600.00% more during Jun 2001. Pb showed a weak positive correlation with Cu (R=0.500) and a weak negative correlation with petroleum hydrocarbons (R= -0.528) in Alang. But, it did not show any considerable correlation with any metals in Mahuva. The Pb transport from particulate matter in seawater to it's dissolved form was observed 0.010% at Alang, whereas, it was noticed for the same 0.018% at Mahuva, which also may play an important role in the hydro-biological system at the coastal area of the Alang ship breaking yard area (Table 62 & 63). However, the concentration of Pb as dissolved in seawater matter did not show any significant difference between Alang and Mahuva.

4.3.6 Petroleum Hydrocarbons in seawater:

The details of data relating to petroleum hydrocarbons in seawater of Alang and Mahuva are depicted in table no 47 and the intensity of petroleum hydrocarbons showed during the study period are depicted in Fig- 2 to 13. The concentration of Petroleum hydrocarbons varied from 0.192 mg L^{-1} at station SA4 during Jun 2002 to 9.080 mg L^{-1} at station SA3 during October 2002 in Alang. Average concentration of Petroleum hydrocarbons in Alang seawater as a whole varied from 0.403 mg L^{-1} during Jun 2002 to 4.424 mg L^{-1} during April 2002. In general, within the four stations of Alang, the average concentrations of Petroleum hydrocarbons varied from 1.689 mg L^{-1} at station SA1, to 3.151 mg L^{-1} at station SA3 through out the study period. But, the concentration of Petroleum hydrocarbons ranged from 0.1076 mg L^{-1} during Jun 2002 to 1.3697 mg L^{-1} during August 2002 in Mahuva. The average concentration of Petroleum hydrocarbons at Alang varied much as compared to Mahuva and it was found to be 30.03 % less during August 2001 and 2077.17 % more during December 2001. Petroleum hydrocarbons showed only a weak negative correlation with Pb (R= -0.528) in Alang. But, it showed a weak positive correlation with Co (R= 0.584) at Mahuva. The most important aspect is that the concentration of Petroleum hydrocarbons as dissolved in seawater showed significant difference between Alang and Mahuva with 99% confidence limit. Thus, this may be an important regulating factor for controlling the phytoplankton growth, succession, community composition and their productivity in both the areas, Alang and Mahuva.

Table 21: Heavy Metals (mg Kg^{-1}) found in ship cuttings samples in Alang ship breaking yard.

	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Sample 1	904166.7	2438.7	13.7	110.7	187.7	276.7	179.3	187.7
Sample 2	934750.0	3706.0	26.0	170.5	254.0	430.5	219.0	258.0
Sample 3	923166.7	2470.7	17.3	113.7	169.3	287.0	146.0	172.0
Average	920694.5	2871.8	19.0	131.6	203.7	331.4	181.4	205.9
Smpl. Var.	± 15440.8	± 722.6	± 6.3	± 33.7	± 44.6	± 86.0	± 36.5	± 45.8

Note : Smpl. Var. = Sample Variation.

Table 22: Heavy Metal (mg Kg^{-1}) found in soil of Plots of Alang ship breaking Yard.

	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Sample 1	259750.0	943.3	17.3	84.0	171.5	475.5	186.5	77.0
Sample 2	256562.5	1021.3	16.3	145.8	250.0	992.5	212.3	180.0
Sample 3	306437.5	1208.0	13.3	56.8	203.8	965.3	198.8	256.8
Sample 4	443250.0	3052.5	18.0	196.8	408.8	1322.8	376.0	228.8
Sample 5	394812.5	1765.5	23.0	184.8	283.0	1376.8	275.0	153.0
Sample 6	476625.0	2575.0	23.3	100.5	277.3	1268.0	549.8	99.8
Sample 7	418812.5	2461.5	22.0	98.0	266.3	697.0	233.8	122.5
Sample 8	282687.5	1963.3	16.8	120.3	180.3	970.0	186.8	69.5
Sample 9	223250.0	1462.0	10.8	82.5	259.5	479.0	185.3	247.5
Sample 10	256625.0	2419.3	11.0	145.3	177.0	551.0	225.5	55.8
Sample 11	131437.5	4767.5	13.3	164.3	361.5	700.8	299.8	175.8
Sample 12	312375.0	3942.5	12.8	105.8	283.0	404.5	166.0	177.3
Average	313552.1	2298.5	16.5	123.7	260.1	850.3	257.9	153.6
Smpl. Var.	± 101267.1	± 1177.0	± 4.5	± 43.6	± 72.7	± 348.4	± 109.7	± 69.6

Note : Smpl. Var. = Sample Variation.

Table 23: Fe (mg Kg^{-1} of dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	68750.0	59500.0	55750.0	59750.0	60937.5	± 5520.3	68187.5
Aug-01	71437.5	70375.0	72125.0	151062.5	91250.0	± 39881.5	74562.5
Oct-01	76875.0	70062.5	75687.5	99125.0	80437.5	± 12807.8	63562.5
Dec-01	79812.5	69187.5	80125.0	92187.5	80328.1	± 9399.7	61937.5
Feb-02	78062.5	77062.5	69250.0	61312.5	71421.9	± 7806.6	77000.0
Apr-02	89875.0	69625.0	81500.0	109000.0	87500.0	± 16567.1	67125.0
Jun-02	33000.0	51812.5	43500.0	85437.5	53437.5	± 22679.5	7000.0
Aug-02	25312.5	71375.0	36062.5	92437.5	56296.9	± 31107.1	20250.0
Oct-02	25250.0	30875.0	14062.5	54687.5	31218.8	± 17135.4	16875.0
Dec-02	12687.5	26250.0	15312.5	71562.5	31453.1	± 27377.0	27500.0
Feb-03	43125.0	39312.5	30687.5	41500.0	38656.3	± 5537.4	39750.0
Apr-03	29500.0	27187.5	27937.5	25875.0	27625.0	± 1513.0	15875.0

Note : Smpl. Var. = Sample Variation.

Table 24: Mn (mg Kg^{-1} of dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	1044.3	1052.5	1068.0	1079.0	1060.9	± 15.6	1163.0
Aug-01	1016.0	1015.3	875.5	1246.8	1038.4	± 153.8	991.8
Oct-01	1153.3	1047.3	1124.8	1221.5	1136.7	± 72.1	1111.5
Dec-01	1011.5	973.0	1008.3	1082.5	1018.8	± 45.9	985.5
Feb-02	1185.5	1085.3	1070.3	1030.5	1092.9	± 65.9	1077.5
Apr-02	1122.0	1055.8	1081.0	1213.5	1118.1	± 69.2	970.0
Jun-02	1090.5	901.3	842.3	1753.3	1146.8	± 417.9	973.0
Aug-02	844.5	1473.3	845.8	1039.8	1050.8	± 296.2	1034.3
Oct-02	1021.3	937.5	721.8	1038.8	929.8	± 145.6	1053.0
Dec-02	894.5	906.0	856.8	1295.5	988.2	± 206.0	789.5
Feb-03	868.8	833.5	1078.0	924.8	926.3	± 107.9	794.8
Apr-03	861.3	763.5	849.8	837.0	827.9	± 44.0	908.5

Note : Smpl. Var. = Sample Variation.

Table 25: Cd (mg Kg^{-1} of dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	9.0	10.0	10.5	12.5	10.5	± 1.5	6.8
Aug-01	10.8	11.0	13.5	15.3	12.6	± 2.1	9.3
Oct-01	5.3	7.5	5.8	8.3	6.7	± 1.4	3.8
Dec-01	9.8	11.5	11.5	12.0	11.2	± 1.0	11.8
Feb-02	8.3	11.5	9.0	11.8	10.1	± 1.8	5.5
Apr-02	7.0	6.5	6.8	7.3	6.9	± 0.3	7.3
Jun-02	10.8	8.5	6.8	11.3	9.3	± 2.1	7.3
Aug-02	4.0	7.0	10.3	7.3	7.1	± 2.6	3.8
Oct-02	1.3	0.5	ND	6.0	1.9	± 2.8	0.8
Dec-02	8.5	12.5	7.5	7.3	8.9	± 2.4	8.5
Feb-03	8.5	4.0	4.8	9.0	6.6	± 2.6	5.3
Apr-03	3.8	7.0	7.0	4.8	5.6	± 1.6	2.0

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 26: Co (mg Kg^{-1} dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	64.8	64.0	31.5	42.3	50.6	± 16.5	64.5
Aug-01	75.5	70.0	62.5	70.5	69.6	± 5.4	68.8
Oct-01	70.8	96.8	95.5	96.0	89.8	± 12.7	89.5
Dec-01	109.8	85.5	97.0	103.8	99.0	± 10.4	87.3
Feb-02	78.5	64.5	77.5	80.3	75.2	± 7.2	80.5
Apr-02	81.8	82.8	75.5	71.8	77.9	± 5.2	73.5
Jun-02	59.3	61.5	50.5	67.0	59.6	± 6.9	53.0
Aug-02	64.8	79.3	57.3	79.3	70.1	± 11.0	91.8
Oct-02	46.3	49.0	35.8	34.3	41.3	± 7.4	49.5
Dec-02	50.0	57.8	46.3	66.8	55.2	± 9.1	69.0
Feb-03	51.0	56.8	54.8	65.5	57.0	± 6.1	53.0
Apr-03	73.3	73.3	80.5	70.8	74.4	± 4.2	49.8

Note : Smpl. Var. = Sample Variation.

Table 27: Cu (mg Kg^{-1} of dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	90.5	84.5	75.8	96.5	86.8	± 8.9	82.3
Aug-01	87.5	91.8	105.0	149.0	108.3	± 28.1	88.5
Oct-01	106.0	86.0	99.8	118.0	102.4	± 13.3	97.3
Dec-01	90.5	91.8	96.5	112.3	97.8	± 10.0	89.5
Feb-02	116.3	112.3	98.0	92.8	104.8	± 11.2	106.0
Apr-02	92.3	100.5	108.0	122.0	105.7	± 12.6	75.8
Jun-02	90.5	89.0	92.3	111.8	95.9	± 10.7	305.8
Aug-02	86.3	103.5	111.8	147.5	112.3	± 25.8	71.5
Oct-02	103.5	102.3	86.8	132.8	106.3	± 19.2	99.3
Dec-02	96.5	93.0	84.8	184.0	114.6	± 46.6	92.8
Feb-03	101.0	96.5	106.0	122.5	106.5	± 11.4	94.0
Apr-03	93.0	91.0	99.5	118.8	100.6	± 12.7	90.3

Note : Smpl. Var. = Sample Variation.

Table 28: Zn (mg Kg^{-1} of dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	115.8	128.8	91.0	179.5	128.8	± 37.3	95.8
Aug-01	121.8	150.0	103.0	458.0	208.2	± 167.7	96.3
Oct-01	162.5	164.8	209.0	308.3	211.1	± 68.2	122.8
Dec-01	135.8	114.5	140.0	200.5	147.7	± 36.9	107.0
Feb-02	175.8	222.8	158.5	159.0	179.0	± 30.2	136.0
Apr-02	154.0	160.3	144.3	285.0	185.9	± 66.4	112.3
Jun-02	170.8	113.0	102.5	215.8	150.5	± 52.8	247.3
Aug-02	110.0	200.3	123.5	250.0	170.9	± 66.0	119.8
Oct-02	135.5	118.8	92.8	181.0	132.0	± 37.1	103.0
Dec-02	163.5	151.8	184.0	369.0	217.1	± 102.2	102.5
Feb-03	126.5	116.8	129.0	184.8	139.3	± 30.8	98.3
Apr-03	142.8	144.5	110.0	139.0	134.1	± 16.2	88.5

Note : Smpl. Var. = Sample Variation.

Table 29: Ni (mg Kg^{-1} dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	80.5	92.0	83.8	79.0	83.8	± 5.8	81.0
Aug-01	97.3	104.8	103.3	121.0	106.6	± 10.2	93.8
Oct-01	105.5	91.8	93.3	104.3	98.7	± 7.2	80.3
Dec-01	86.3	81.5	83.5	91.8	85.8	± 4.4	91.8
Feb-02	103.0	111.3	103.3	105.5	105.8	± 3.8	96.3
Apr-02	91.3	89.3	82.0	92.0	88.6	± 4.6	77.0
Jun-02	64.8	87.8	80.8	118.5	87.9	± 22.5	38.8
Aug-02	97.8	101.0	100.5	107.3	101.6	± 4.0	101.8
Oct-02	110.5	149.3	97.3	126.8	120.9	± 22.4	103.0
Dec-02	91.3	132.5	71.5	164.8	115.0	± 41.8	76.8
Feb-03	107.8	192.0	112.3	126.8	134.7	± 39.1	120.3
Apr-03	100.0	140.5	90.0	124.5	113.8	± 23.0	98.3

Note : Smpl. Var. = Sample Variation.

Table 30: Pb (mg Kg^{-1} dry wt.) found in sediment sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	128.8	152.5	125.8	138.8	136.4	± 12.1	104.3
Aug-01	192.8	187.3	186.8	255.3	205.5	± 33.3	173.3
Oct-01	182.5	218.3	187.8	230.8	204.8	± 23.4	218.0
Dec-01	136.3	121.5	188.3	177.0	155.8	± 31.9	133.0
Feb-02	189.8	204.0	188.5	170.0	188.1	± 13.9	166.0
Apr-02	126.8	133.5	184.0	156.0	150.1	± 25.9	175.0
Jun-02	25.5	42.8	28.3	68.3	35.4	± 19.6	27.0
Aug-02	67.5	51.8	137.8	130.3	96.8	± 43.5	7.5
Oct-02	25.5	10.0	61.5	52.3	37.3	± 23.8	1.0
Dec-02	57.5	31.5	61.5	160.3	77.7	± 56.6	52.0
Feb-03	104.8	76.8	133.8	70.8	96.5	± 28.9	33.5
Apr-03	132.0	93.8	83.8	43.5	88.3	± 36.4	54.0

Note : Smpl. Var. = Sample Variation.

Table 31: Fe (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	63835.9	75842.9	54667.4	37012.7	57839.7	± 16369.7	58949.8
Aug-01	33614.1	47674.7	59809.8	29308.1	42601.7	± 13896.6	53658.0
Oct-01	15802.7	14432.1	12862.5	11007.5	13526.2	± 2064.6	15675.5
Dec-01	38426.8	24674.8	75269.9	58183.1	49138.6	± 22195.1	34466.4
Feb-02	125309.1	76356.3	97172.5	71765.3	92650.8	± 24418.1	50421.0
Apr-02	105441.5	94889.5	85936.6	58288.8	86139.1	± 20205.9	30805.7
Jun-02	41462.4	45725.8	40474.0	64536.6	48049.7	± 11225.0	38247.8
Aug-02	12210.0	7766.6	39130.8	44499.7	25901.8	± 18594.2	31224.4
Oct-02	57084.0	71010.1	89580.8	81984.6	74914.8	± 14121.6	24845.5
Dec-02	27192.4	93477.5	125667.2	43966.6	72575.9	± 45217.0	37389.2
Feb-03	13366.0	45747.0	24111.8	58531.3	35439.0	± 20453.5	14944.5
Apr-03	19257.8	18955.1	51318.8	35208.0	31184.9	± 15420.5	11948.0

Note : Smpl. Var. = Sample Variation.

Table 32: Mn (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	1095.79	1246.44	792.21	693.96	957.10	± 257.80	766.39
Aug-01	592.62	827.47	1099.40	515.52	758.75	± 263.01	1013.00
Oct-01	328.25	280.75	257.30	207.74	268.51	± 50.12	332.70
Dec-01	679.65	481.64	1898.90	1138.18	1049.59	± 629.44	628.04
Feb-02	2194.45	1522.95	2240.34	1142.44	1775.04	± 534.21	923.94
Apr-02	2021.66	2078.17	1720.77	1252.52	1768.28	± 377.93	587.61
Jun-02	895.75	930.54	898.07	1133.60	964.49	± 113.85	836.24
Aug-02	293.90	162.26	759.50	845.10	515.19	± 337.67	935.77
Oct-02	1020.06	1464.34	1568.55	2319.02	1592.99	± 539.29	398.56
Dec-02	470.89	1764.64	2701.09	839.69	1444.08	± 999.20	488.13
Feb-03	345.38	1477.57	1110.51	1881.17	1203.66	± 653.04	528.77
Apr-03	258.83	728.51	1209.23	1139.04	833.90	± 438.10	191.58

Note : Smpl. Var. = Sample Variation.

Table 33: Cd (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	8.8	0.3	2.6	1.9	3.4	± 3.7	10.0
Aug-01	2.7	5.5	11.2	3.8	5.8	± 3.8	4.9
Oct-01	2.4	2.3	2.7	2.8	2.6	± 0.2	2.8
Dec-01	6.7	6.0	24.2	14.1	12.8	± 8.5	5.2
Feb-02	23.3	14.1	21.1	14.2	18.2	± 4.7	6.7
Apr-02	16.3	19.3	15.5	12.2	15.8	± 2.9	5.3
Jun-02	6.5	6.4	6.2	8.5	6.9	± 1.1	7.0
Aug-02	1.8	1.5	6.5	8.4	4.6	± 3.4	7.7
Oct-02	6.6	12.6	11.9	12.9	11.0	± 3.0	2.0
Dec-02	2.5	13.1	11.0	4.7	7.8	± 5.1	1.5
Feb-03	2.2	9.5	11.3	14.4	9.4	± 5.2	2.8
Apr-03	2.0	3.4	10.8	13.4	7.4	± 5.5	1.6

Note : Smpl. Var. = Sample Variation.

Table 34: Co (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	62.5	70.0	39.1	17.7	47.3	± 23.8	42.9
Aug-01	29.3	49.2	55.7	27.0	40.3	± 14.3	49.4
Oct-01	28.0	24.2	19.0	17.9	22.3	± 4.7	24.4
Dec-01	48.3	28.1	178.7	102.1	89.3	± 67.3	47.8
Feb-02	148.8	112.2	108.8	75.0	111.2	± 30.2	67.2
Apr-02	118.0	99.1	124.5	80.1	105.4	± 20.0	25.9
Jun-02	66.9	74.7	65.0	90.6	74.3	± 11.6	56.5
Aug-02	19.3	11.8	68.7	77.1	44.2	± 33.4	63.6
Oct-02	52.8	94.9	130.5	120.5	99.7	± 34.7	23.7
Dec-02	23.0	74.0	120.1	37.2	63.6	± 43.4	27.4
Feb-03	13.6	60.0	61.8	93.3	57.2	± 32.8	36.3
Apr-03	18.6	36.8	47.4	38.8	35.4	± 12.1	21.9

Note : Smpl. Var. = Sample Variation.

Table 35: Cu (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	112.0	135.9	101.3	72.3	105.4	± 26.4	87.7
Aug-01	63.0	78.5	120.7	50.3	78.1	± 30.6	106.9
Oct-01	32.0	38.7	29.5	21.2	30.4	± 7.2	28.8
Dec-01	71.5	50.4	203.7	119.0	111.2	± 68.0	73.1
Feb-02	227.5	147.9	224.5	133.1	183.3	± 49.8	90.2
Apr-02	168.0	186.0	169.0	137.3	165.1	± 20.3	53.8
Jun-02	92.3	112.4	97.3	107.9	102.4	± 9.3	88.7
Aug-02	28.2	19.7	97.9	109.3	63.8	± 46.3	91.0
Oct-02	96.5	137.8	176.8	160.8	143.0	± 34.9	32.6
Dec-02	46.8	179.9	229.4	79.3	133.8	± 85.3	64.8
Feb-03	35.0	174.3	131.7	240.9	145.5	± 86.3	75.0
Apr-03	39.3	79.7	169.5	171.2	114.9	± 66.1	38.7

Note : Smpl. Var. = Sample Variation.

Table 36: Zn (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	348.5	284.0	192.9	152.9	244.6	± 88.4	577.3
Aug-01	300.9	201.6	240.0	114.5	214.2	± 78.0	146.3
Oct-01	139.4	72.8	111.6	92.1	104.0	± 28.5	76.6
Dec-01	105.7	201.7	267.4	137.4	178.1	± 71.7	154.7
Feb-02	402.4	264.6	325.4	324.9	329.3	± 56.4	116.0
Apr-02	247.0	373.9	380.5	259.7	315.3	± 71.8	183.5
Jun-02	140.3	169.1	211.7	174.9	174.0	± 29.3	250.9
Aug-02	140.4	128.3	211.5	199.3	169.9	± 41.6	135.8
Oct-02	298.0	290.3	367.4	342.5	324.6	± 36.7	113.2
Dec-02	154.3	482.9	504.1	158.6	325.0	± 194.8	132.0
Feb-03	635.5	203.3	164.0	243.7	311.6	± 218.4	76.1
Apr-03	100.3	113.7	229.0	269.6	178.2	± 84.0	69.8

Note : Smpl. Var. = Sample Variation.

Table 37: Ni (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	139.3	156.0	88.8	91.5	118.9	± 33.9	77.0
Aug-01	44.4	61.0	83.9	47.1	59.1	± 18.0	73.0
Oct-01	25.3	23.5	15.3	14.5	19.6	± 5.6	22.9
Dec-01	48.4	41.7	212.4	120.3	105.7	± 79.5	60.0
Feb-02	169.4	114.8	129.4	66.9	120.1	± 42.3	56.1
Apr-02	111.7	168.2	155.5	89.0	131.1	± 37.1	19.5
Jun-02	57.8	77.9	79.5	101.6	79.2	± 17.9	56.9
Aug-02	17.6	13.7	59.8	66.9	39.5	± 27.7	59.8
Oct-02	12.6	45.4	125.4	62.1	61.4	± 47.4	14.8
Dec-02	23.6	94.8	48.5	38.8	51.4	± 30.7	19.6
Feb-03	26.3	121.7	121.7	200.0	117.4	± 71.1	60.9
Apr-03	33.6	81.4	132.0	190.1	109.3	± 67.2	31.8

Note : Smpl. Var. = Sample Variation.

Table 38: Pb (µg L^{-1}) found in Particulate matter in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	215.6	428.4	290.4	135.2	267.4	± 124.7	194.3
Aug-01	92.0	163.1	229.2	86.0	142.6	± 67.5	148.2
Oct-01	52.1	57.7	51.0	33.1	48.5	± 10.6	54.1
Dec-01	98.6	110.9	365.6	196.3	192.8	± 123.1	132.3
Feb-02	363.5	287.1	396.1	227.8	318.6	± 75.8	147.8
Apr-02	298.7	289.8	260.1	165.2	253.5	± 61.1	74.1
Jun-02	119.8	154.3	181.3	192.7	162.0	± 32.4	132.8
Aug-02	66.1	38.8	219.4	228.8	138.3	± 99.8	185.3
Oct-02	196.2	207.7	287.1	194.8	221.5	± 44.2	52.3
Dec-02	54.8	222.3	321.3	87.1	171.4	± 123.5	173.6
Feb-03	47.7	185.9	166.1	117.8	129.4	± 61.5	51.0
Apr-03	4.8	78.4	139.7	161.0	96.0	± 70.2	8.1

Note : Smpl. Var. = Sample Variation.

Table 39: Fe ($\mu g\ L^{-1}$) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	9.5	3.8	6.1	8.2	6.9	± 2.5	ND
Aug-01	14.7	14.8	24.7	29.4	20.9	± 7.4	20.3
Oct-01	2344.0	1344.0	1296.5	1362.0	1586.6	± 505.7	4622.5
Dec-01	1234.5	827.0	858.5	449.4	842.3	± 320.8	1228.5
Feb-02	653.0	826.0	451.4	758.5	672.2	± 163.5	118.2
Apr-02	1255.5	220.9	1496.5	514.0	871.7	± 602.5	228.2
Jun-02	35.8	26.7	31.5	63.5	39.4	± 16.5	38.9
Aug-02	36.1	28.3	29.5	30.7	31.1	± 3.4	30.9
Oct-02	18.1	34.3	39.6	20.8	28.2	± 10.4	28.6
Dec-02	27.7	33.4	38.4	26.4	31.5	± 5.5	31.7
Feb-03	124.5	68.1	95.8	55.5	86.0	± 30.7	42.2
Apr-03	53.5	34.6	45.6	46.4	45.0	± 7.8	146.0

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 40: Mn ($\mu g\ L^{-1}$) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	3.3	2.8	4.6	2.5	3.3	± 0.9	2.8
Aug-01	1.1	5.6	6.8	7.2	5.2	± 2.8	3.1
Oct-01	59.6	27.4	63.2	20.7	42.7	± 21.8	58.9
Dec-01	18.8	14.2	36.3	9.8	19.8	± 11.6	30.8
Feb-02	25.6	27.6	92.3	80.2	56.4	± 34.8	1.2
Apr-02	4.2	0.0	94.2	17.3	28.9	± 44.1	1.6
Jun-02	5.6	7.0	5.8	0.9	4.8	± 2.7	7.9
Aug-02	0.8	0.9	1.2	1.7	1.1	± 0.4	4.0
Oct-02	1.9	1.9	1.1	3.6	2.1	± 1.0	0.3
Dec-02	7.7	19.3	19.5	35.9	20.6	± 11.6	9.8
Feb-03	5.8	3.7	4.9	3.8	4.5	± 1.0	12.1
Apr-03	0.8	2.3	1.6	4.7	2.3	± 1.7	10.2

Note : Smpl. Var. = Sample Variation.

Table 41: Cd ($\mu g\ L^{-1}$) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	8.1	6.3	5.7	3.5	5.9	± 1.9	0.3
Aug-01	2.3	0.5	0.7	0.2	0.9	± 0.9	0.7
Oct-01	0.6	2.0	0.1	0.4	0.8	± 0.8	ND
Dec-01	2.0	1.1	1.7	ND	1.6	± 0.5	0.5
Feb-02	2.0	2.9	3.2	2.5	2.6	± 0.5	2.4
Apr-02	1.3	2.6	2.7	3.4	2.5	± 0.9	2.6
Jun-02	2.0	2.1	0.3	2.2	1.6	± 0.9	1.0
Aug-02	0.8	0.7	0.5	0.3	0.5	± 0.2	0.7
Oct-02	0.8	0.9	0.8	1.4	0.9	± 0.3	1.9
Dec-02	1.0	0.8	1.7	0.5	1.0	± 0.5	0.8
Feb-03	1.3	1.6	1.2	0.9	1.2	± 0.3	0.7
Apr-03	1.7	1.3	0.9	1.0	1.2	± 0.4	0.4

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 42: Co ($\mu g\ L^{-1}$) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	16.1	11.9	10.2	9.6	11.9	± 3.0	12.0
Aug-01	5.7	ND	ND	ND	1.4	ND	16.4
Oct-01	ND	2.6	ND	6.9	2.4	± 3.0	ND
Dec-01	ND	2.7	14.0	ND	4.2	± 8.0	ND
Feb-02	0.4	8.1	4.3	ND	3.2	± 3.8	ND
Apr-02	ND	5.0	4.0	ND	2.3	± 0.7	7.0
Jun-02	ND	19.6	8.6	25.5	13.4	± 8.6	1.4
Aug-02	26.0	ND	ND	0.4	6.6	± 18.1	6.2
Oct-02	14.2	ND	ND	2.4	5.8	± 8.4	ND
Dec-02	ND	7.9	0.4	1.5	2.5	± 4.1	ND
Feb-03	4.7	2.6	ND	3.9	2.8	± 1.1	1.6
Apr-03	6.7	ND	ND	2.8	2.4	± 2.8	1.6

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 43: Cu (μg L^{-1}) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	5.0	3.6	4.1	3.8	4.1	± 0.6	2.0
Aug-01	2.1	1.0	0.7	ND	1.2	± 0.7	2.4
Oct-01	13.9	11.4	9.2	12.1	11.6	± 1.9	11.9
Dec-01	7.1	5.5	6.4	4.1	5.8	± 1.3	8.2
Feb-02	6.9	7.8	7.9	7.5	7.5	± 0.4	3.6
Apr-02	8.4	7.9	7.2	35.6	14.8	± 13.9	4.6
Jun-02	4.7	5.9	6.6	6.5	5.9	± 0.9	3.8
Aug-02	3.9	4.1	4.7	5.4	4.5	± 0.7	6.9
Oct-02	4.7	6.7	5.6	4.0	5.2	± 1.1	4.9
Dec-02	3.1	10.3	6.7	6.5	6.6	± 3.0	1.9
Feb-03	7.7	7.9	5.8	4.6	6.5	± 1.6	6.2
Apr-03	5.3	2.3	0.8	0.1	2.1	± 2.3	2.7

Note : Smpl. Var. = Sample Variation.

Table 44: Zn (μg L^{-1}) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	9.8	8.7	4.7	6.5	7.4	± 2.3	7.3
Aug-01	5.5	3.4	2.4	3.2	3.6	± 1.3	4.9
Oct-01	58.8	44.7	67.9	30.2	50.4	± 16.5	52.6
Dec-01	30.4	53.9	38.5	34.9	39.4	± 10.2	41.7
Feb-02	36.6	35.2	33.4	124.5	57.4	± 44.8	25.9
Apr-02	31.3	36.7	32.2	61.8	40.5	± 14.4	30.3
Jun-02	32.6	42.5	35.2	39.0	37.3	± 4.3	33.1
Aug-02	43.8	37.2	41.2	39.8	40.5	± 2.8	38.2
Oct-02	30.4	17.6	33.0	23.6	26.1	± 7.0	54.4
Dec-02	21.7	34.9	33.4	39.5	32.4	± 7.6	30.4
Feb-03	34.2	33.4	23.7	27.4	29.6	± 5.0	44.3
Apr-03	32.1	22.9	16.1	27.6	24.7	± 6.8	45.8

Note : Smpl. Var. = Sample Variation.

Table 45: Ni (µg L^{-1}) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	7.0	0.7	0.8	2.5	2.7	± 3.0	ND
Aug-01	19.0	14.0	5.0	2.7	10.2	± 7.6	23.1
Oct-01	2.9	2.6	6.8	2.3	3.6	± 2.1	11.1
Dec-01	6.6	9.3	12.6	7.2	8.9	± 2.7	6.2
Feb-02	8.2	8.7	2.0	2.0	5.2	± 3.7	37.5
Apr-02	8.6	2.4	3.8	4.9	4.9	± 2.7	6.8
Jun-02	9.2	7.2	9.0	6.5	7.9	± 1.3	11.5
Aug-02	ND	ND	1.4	ND	0.4	ND	3.0
Oct-02	1.1	0.5	5.4	3.2	2.5	± 2.2	7.8
Dec-02	4.8	3.8	3.8	3.4	3.9	± 0.6	4.6
Feb-03	0.3	2.7	ND	ND	0.8	± 1.7	1.1
Apr-03	ND	1.1	1.2	1.4	0.9	± 0.1	3.4

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 46: Pb (µg L^{-1}) found as dissolved in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	8.5	ND	ND	ND	2.1	ND	0.3
Aug-01	1.9	ND	3.8	ND	1.4	± 1.4	18.4
Oct-01	1.6	ND	ND	ND	0.4	ND	2.3
Dec-01	20.1	ND	37.3	11.6	17.3	± 13.1	11.4
Feb-02	2.8	10.9	5.9	30.6	12.5	± 12.5	6.4
Apr-02	50.3	62.4	46.4	71.1	57.5	± 11.3	36.0
Jun-02	33.1	38.7	45.3	64.7	45.4	± 13.8	37.5
Aug-02	59.3	44.1	10.7	22.4	34.1	± 21.7	38.3
Oct-02	ND	9.8	13.4	ND	5.8	± 2.5	ND
Dec-02	ND	18.7	46.8	9.4	18.7	± 19.5	ND
Feb-03	20.6	3.9	20.6	12.8	14.5	± 8.0	7.2
Apr-03	0.1	ND	10.9	12.2	5.8	± 6.6	6.5

Note : Smpl. Var. = Sample Variation. and ND = Not Detectable.

Table 47: Crude Petroleum Hydrocarbons (mg L^{-1}) found in seawater sample of Alang Ship breaking Yard and Mahuva during the study period.

	Alang Ship Breaking Yard						**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Smpl. Var.**	**SMc**
Jun-01	5.95	3.78	3.88	2.53	4.04	± 1.42	0.52
Aug-01	1.77	7.24	4.42	1.38	3.70	± 2.72	1.19
Oct-01	3.63	2.99	2.66	2.03	2.83	± 0.67	0.73
Dec-01	4.02	3.71	4.80	5.17	4.42	± 0.68	0.20
Feb-02	0.56	3.01	2.62	1.71	1.98	± 1.09	0.23
Apr-02	0.89	2.60	2.62	1.71	1.95	± 0.83	0.18
Jun-02	0.54	0.66	0.21	0.19	0.40	± 0.24	0.11
Aug-02	1.01	1.09	2.60	2.43	1.78	± 0.85	1.37
Oct-02	0.48	2.03	9.08	2.96	3.64	± 3.77	0.19
Dec-02	0.61	0.86	2.06	5.43	2.24	± 2.22	0.27
Feb-03	0.22	0.63	1.89	0.72	0.86	± 0.72	0.30
Apr-03	0.58	1.15	0.96	3.75	1.61	± 1.45	0.53

Note : Smpl. Var. = Sample Variation.

Table 48: Iron (Fe) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	60937.5	57839.7	6.9	0.09492	0.00001
Aug-01	91250.0	42601.7	20.9	0.04669	0.00005
Oct-01	80437.5	13526.2	1586.6	0.01682	0.01173
Dec-01	80328.1	49138.6	842.3	0.06117	0.00171
Feb-02	71421.9	92650.8	672.2	0.12972	0.00073
Apr-02	87500.0	86139.1	871.7	0.09844	0.00101
Jun-02	53437.5	48049.7	39.4	0.08992	0.00008
Aug-02	56296.9	25901.8	31.1	0.04601	0.00012
Oct-02	31218.8	74914.8	28.2	0.23997	0.00004
Dec-02	31453.1	72575.9	31.5	0.23074	0.00004
Feb-03	38656.3	35439.0	86.0	0.09168	0.00024
Apr-03	27625.0	31184.9	45.0	0.11289	0.00014
			Average	**0.10491**	**0.00133**
			Highest	0.23997	0.01173
			Lowest	0.01682	0.00001

Table 49: Iron (Fe) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	68187.5	58949.8	ND	0.08645	0.00000
Aug-01	74562.5	53658.0	20.3	0.07196	0.00004
Oct-01	63562.5	15675.5	4622.5	0.02466	0.02949
Dec-01	61937.5	34466.4	1228.5	0.05565	0.00356
Feb-02	77000.0	50421.0	118.2	0.06548	0.00023
Apr-02	67125.0	30805.7	228.2	0.04589	0.00074
Jun-02	7000.0	38247.8	38.9	0.54640	0.00010
Aug-02	20250.0	31224.4	30.9	0.15419	0.00010
Oct-02	16875.0	24845.5	28.6	0.14723	0.00011
Dec-02	27500.0	37389.2	31.7	0.13596	0.00008
Feb-03	39750.0	14944.5	42.2	0.03760	0.00028
Apr-03	15875.0	11948.0	146.0	0.07526	0.00122
			Average	**0.12056**	**0.00300**
			Highest	0.54640	0.02949
			Lowest	0.02466	0.00000

Table 50: Manganese (Mn) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	In TSS (µg/L)	As Dissolved form (µg/L)	Transport Sediment to TSS (%)	Transport TSS to dissolved form (%)
Jun-01	1060.94	957.10	3.28	0.09021	0.00034
Aug-01	1038.38	758.75	5.15	0.07307	0.00068
Oct-01	1136.69	268.51	42.69	0.02362	0.01590
Dec-01	1018.81	1049.59	19.75	0.10302	0.00188
Feb-02	1092.88	1775.04	56.43	0.16242	0.00318
Apr-02	1118.06	1768.28	28.91	0.15816	0.00163
Jun-02	1146.81	964.49	4.79	0.08410	0.00050
Aug-02	1050.81	515.19	1.14	0.04903	0.00022
Oct-02	929.81	1592.99	2.10	0.17132	0.00013
Dec-02	988.19	1444.08	20.58	0.14613	0.00143
Feb-03	926.25	1203.66	4.51	0.12995	0.00037
Apr-03	827.86	833.90	2.31	0.10073	0.00028
			Average	**0.10765**	**0.00221**
			Highest	0.17132	0.01590
			Lowest	0.02362	0.00013

Table 51: Manganese (Mn) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	In TSS (µg/L)	As Dissolved form (µg/L)	Transport Sediment to TSS (%)	Transport TSS to dissolved form (%)
Jun-01	1163.0	766.39	2.8	0.06590	0.00036
Aug-01	991.8	1013.00	3.1	0.10214	0.00030
Oct-01	1111.5	332.70	58.9	0.02993	0.01769
Dec-01	985.5	628.04	30.8	0.06373	0.00490
Feb-02	1077.5	923.94	1.2	0.08575	0.00013
Apr-02	970.0	587.61	1.6	0.06058	0.00026
Jun-02	973.0	836.24	7.9	0.08594	0.00094
Aug-02	1034.3	935.77	4.0	0.09048	0.00043
Oct-02	1053.0	398.56	0.3	0.03785	0.00006
Dec-02	789.5	488.13	9.8	0.06183	0.00200
Feb-03	794.8	528.77	12.1	0.06653	0.00228
Apr-03	908.5	191.58	10.2	0.02109	0.00531
			Average	**0.06431**	**0.00289**
			Highest	0.10214	0.01769
			Lowest	0.02109	0.00006

Table 52: Cadmium (Cd) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	10.5	3.4	5.89	0.03238	0.17324
Aug-01	12.6	5.8	0.91	0.04584	0.01572
Oct-01	6.7	2.6	0.75	0.03827	0.02930
Dec-01	11.2	12.8	0.95	0.11412	0.00744
Feb-02	10.1	18.2	2.61	0.17957	0.01435
Apr-02	6.9	15.8	2.49	0.22994	0.01574
Jun-02	9.3	6.9	1.63	0.07401	0.02366
Aug-02	7.1	4.6	0.54	0.06381	0.01187
Oct-02	1.9	11.0	0.93	0.56649	0.00846
Dec-02	8.9	7.8	0.99	0.08747	0.01266
Feb-03	6.6	9.4	1.21	0.14253	0.01294
Apr-03	5.6	7.4	1.23	0.13108	0.01667
			Average	**0.14213**	**0.02850**
			Highest	0.56649	0.17324
			Lowest	0.03238	0.00744

Table 53: Cadmium (Cd) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	6.8	10.0	0.3	0.14859	0.00299
Aug-01	9.3	4.9	0.7	0.05276	0.01332
Oct-01	3.8	2.8	ND	0.07413	0.00000
Dec-01	11.8	5.2	0.5	0.04417	0.00963
Feb-02	5.5	6.7	2.4	0.12109	0.03529
Apr-02	7.3	5.3	2.6	0.07269	0.04839
Jun-02	7.3	7.0	1.0	0.09669	0.01427
Aug-02	3.8	7.7	0.7	0.20507	0.00845
Oct-02	0.8	2.0	1.9	0.26667	0.09250
Dec-02	8.5	1.5	0.8	0.01788	0.04934
Feb-03	5.3	2.8	0.7	0.05238	0.02655
Apr-03	2.0	1.6	0.4	0.07750	0.02581
			Average	**0.10247**	**0.02721**
			Highest	0.26667	0.09250
			Lowest	0.01788	0.00000

Table 54: Cobalt (Co) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	50.6	47.32	11.91	0.09346	0.02517
Aug-01	69.6	40.29	ND	0.05786	0.00000
Oct-01	89.8	22.26	ND	0.02480	0.00000
Dec-01	99.0	89.30	1.65	0.09020	0.00185
Feb-02	75.2	111.18	0.39	0.14787	0.00035
Apr-02	77.9	105.45	ND	0.13530	0.00000
Jun-02	59.6	74.31	12.19	0.12476	0.01640
Aug-02	70.1	44.24	4.91	0.06308	0.01110
Oct-02	41.3	99.69	ND	0.24132	0.00000
Dec-02	55.2	63.56	0.33	0.11517	0.00052
Feb-03	57.0	57.17	1.49	0.10030	0.00261
Apr-03	74.4	35.40	2.14	0.04756	0.00605
			Average	**0.10347**	**0.00534**
			Highest	0.24132	0.02517
			Lowest	0.02480	0.00000

Table 55: Cobalt (Co) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	64.5	42.9	12.0	0.06651	0.02786
Aug-01	68.8	49.4	16.4	0.07184	0.03310
Oct-01	89.5	24.4	ND	0.02725	0.00000
Dec-01	87.3	47.8	ND	0.05482	0.00000
Feb-02	80.5	67.2	ND	0.08352	0.00000
Apr-02	73.5	25.9	7.0	0.03520	0.02706
Jun-02	53.0	56.5	1.4	0.10655	0.00239
Aug-02	91.8	63.6	6.2	0.06934	0.00967
Oct-02	49.5	23.7	ND	0.04784	0.00000
Dec-02	69.0	27.4	ND	0.03977	0.00000
Feb-03	53.0	36.3	1.6	0.06847	0.00427
Apr-03	49.8	21.9	1.6	0.04410	0.00720
			Average	**0.05960**	**0.00930**
			Highest	0.10655	0.03310
			Lowest	0.02725	0.00000

Table 56: Copper (Cu) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	86.81	105.39	4.09	0.12140	0.00388
Aug-01	108.31	78.13	0.11	0.07214	0.00014
Oct-01	102.44	30.35	11.61	0.02963	0.03825
Dec-01	97.75	111.17	5.76	0.11373	0.00518
Feb-02	104.81	183.25	7.51	0.17484	0.00410
Apr-02	105.69	165.08	14.75	0.15619	0.00894
Jun-02	95.88	102.44	5.88	0.10684	0.00574
Aug-02	112.25	63.79	4.50	0.05683	0.00705
Oct-02	106.31	142.97	5.24	0.13448	0.00367
Dec-02	114.56	133.85	6.64	0.11684	0.00496
Feb-03	106.5	145.48	6.46	0.13660	0.00444
Apr-03	100.56	114.92	2.11	0.11428	0.00184
			Average	**0.11115**	**0.00735**
			Highest	0.17484	0.03825
			Lowest	0.02963	0.00014

Table 57: Copper (Cu) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	82.3	87.7	2.0	0.10664	0.00222
Aug-01	88.5	106.9	2.4	0.12080	0.00224
Oct-01	97.3	28.8	11.9	0.02960	0.04116
Dec-01	89.5	73.1	8.2	0.08164	0.01115
Feb-02	106.0	90.2	3.6	0.08506	0.00394
Apr-02	75.8	53.8	4.6	0.07098	0.00855
Jun-02	305.8	88.7	3.8	0.02901	0.00423
Aug-02	71.5	91.0	6.9	0.12720	0.00753
Oct-02	99.3	32.6	4.9	0.03288	0.01502
Dec-02	92.8	64.8	1.9	0.06987	0.00293
Feb-03	94.0	75.0	6.2	0.07980	0.00827
Apr-03	90.3	38.7	2.7	0.04291	0.00684
			Average	**0.07303**	**0.00951**
			Highest	0.12720	0.04116
			Lowest	0.02901	0.00222

Table 58: Zinc (Zn) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	128.8	244.57	7.41	0.18996	0.00303
Aug-01	208.2	214.22	3.59	0.10290	0.00168
Oct-01	211.1	103.96	50.38	0.04924	0.04846
Dec-01	147.7	178.06	39.39	0.12056	0.02212
Feb-02	179.0	329.32	57.40	0.18398	0.01743
Apr-02	185.9	315.27	40.48	0.16963	0.01284
Jun-02	150.5	174.00	37.29	0.11561	0.02143
Aug-02	170.9	169.87	40.45	0.09937	0.02381
Oct-02	132.0	324.56	26.11	0.24588	0.00804
Dec-02	217.1	324.96	32.36	0.14971	0.00996
Feb-03	139.3	311.63	29.64	0.22379	0.00951
Apr-03	134.1	178.16	24.65	0.13290	0.01384
			Average	0.14863	0.01601
			Highest	0.24588	0.04846
			Lowest	0.04924	0.00168

Table 59: Zinc (Zn) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	95.8	577.3	7.3	0.60292	0.00126
Aug-01	96.3	146.3	4.9	0.15204	0.00335
Oct-01	122.8	76.6	52.6	0.06242	0.06859
Dec-01	107.0	154.7	41.7	0.14458	0.02692
Feb-02	136.0	116.0	25.9	0.08532	0.02228
Apr-02	112.3	183.5	30.3	0.16344	0.01652
Jun-02	247.3	250.9	33.1	0.10148	0.01317
Aug-02	119.8	135.8	38.2	0.11339	0.02809
Oct-02	103.0	113.2	54.4	0.10992	0.04805
Dec-02	102.5	132.0	30.4	0.12882	0.02299
Feb-03	98.3	76.1	44.3	0.07750	0.05818
Apr-03	88.5	69.8	45.8	0.07890	0.06552
			Average	**0.15173**	**0.03124**
			Highest	0.60292	0.06859
			Lowest	0.06242	0.00126

Table 60: Nickel (Ni) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (μg/L)**	**As Dissolved form (μg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	83.8	118.89	2.74	0.14186	0.00230
Aug-01	106.6	59.10	10.15	0.05546	0.01717
Oct-01	98.7	19.65	3.61	0.01991	0.01837
Dec-01	85.8	105.70	8.89	0.12327	0.00841
Feb-02	105.8	120.11	5.19	0.11358	0.00432
Apr-02	88.6	131.09	4.89	0.14792	0.00373
Jun-02	87.9	79.19	7.94	0.09005	0.01003
Aug-02	101.6	39.51	ND	0.03888	0.00000
Oct-02	120.9	61.36	2.51	0.05074	0.00409
Dec-02	115.0	51.41	3.93	0.04470	0.00764
Feb-03	134.7	117.43	ND	0.08719	0.00000
Apr-03	113.8	109.25	0.90	0.09604	0.00082
			Average	**0.08413**	**0.00641**
			Highest	0.14792	0.01837
			Lowest	0.01991	0.00000

Table 61: Nickel (Ni) Transport from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (μg/L)**	**As Dissolved form (μg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	81.0	77.0	ND	0.09505	0.00000
Aug-01	93.8	73.0	23.1	0.07783	0.03166
Oct-01	80.3	22.9	11.1	0.02847	0.04858
Dec-01	91.8	60.0	6.2	0.06543	0.01033
Feb-02	96.3	56.1	37.5	0.05824	0.06689
Apr-02	77.0	19.5	6.8	0.02535	0.03458
Jun-02	38.8	56.9	11.5	0.14676	0.02013
Aug-02	101.8	59.8	3.0	0.05875	0.00502
Oct-02	103.0	14.8	7.8	0.01437	0.05236
Dec-02	76.8	19.6	4.6	0.02555	0.02346
Feb-03	120.3	60.9	1.1	0.05065	0.00186
Apr-03	98.3	31.8	3.4	0.03240	0.01062
			Average	**0.05657**	**0.02546**
			Highest	0.14676	0.06689
			Lowest	0.01437	0.00000

Table 62: Lead (Pb) Transport from Sediment to TSS to seawater as dissolved form at Alang ship breaking yard.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	136.4	267.42	2.1	0.19600	0.00079
Aug-01	205.5	142.57	1.4	0.06938	0.00100
Oct-01	204.8	48.46	0.4	0.02366	0.00083
Dec-01	155.8	192.84	17.3	0.12381	0.00895
Feb-02	188.1	318.63	12.53	0.16943	0.00393
Apr-02	150.1	253.46	57.51	0.16891	0.02269
Jun-02	35.4	162.04	45.41	0.45722	0.02803
Aug-02	96.8	138.26	34.11	0.14282	0.02467
Oct-02	37.3	221.48	5.80	0.59362	0.00262
Dec-02	77.7	171.38	18.70	0.22059	0.01091
Feb-03	96.5	129.38	14.45	0.13407	0.01117
Apr-03	88.3	96.00	5.80	0.10878	0.00604
			Average	**0.20069**	**0.01013**
			Highest	0.59362	0.02803
			Lowest	0.02366	0.00079

Table 63: Lead (Pb) Trans port from Sediment to TSS to seawater as dissolved form at Mahuva.

	In Sediment (mg/Kg)	**In TSS (µg/L)**	**As Dissolved form (µg/L)**	**Transport Sediment to TSS (%)**	**Transport TSS to dissolved form (%)**
Jun-01	104.3	194.3	0.3	0.18636	0.00015
Aug-01	173.3	148.2	18.4	0.08552	0.01242
Oct-01	218.0	54.1	2.3	0.02483	0.00416
Dec-01	133.0	132.3	11.4	0.09944	0.00862
Feb-02	166.0	147.8	6.4	0.08902	0.00433
Apr-02	175.0	74.1	36.0	0.04236	0.04856
Jun-02	27.0	132.8	37.5	0.49174	0.02821
Aug-02	7.5	185.3	38.3	2.47093	0.02064
Oct-02	1.0	52.3	ND	5.23200	0.00000
Dec-02	52.0	173.6	ND	0.33387	0.00000
Feb-03	33.5	51.0	7.2	0.15233	0.01407
Apr-03	54.0	8.1	6.5	0.01507	0.08022
			Average	**0.76862**	**0.01845**
			Highest	5.23200	0.08022
			Lowest	0.01507	0.00000

Fig 2: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during Jun 2001.

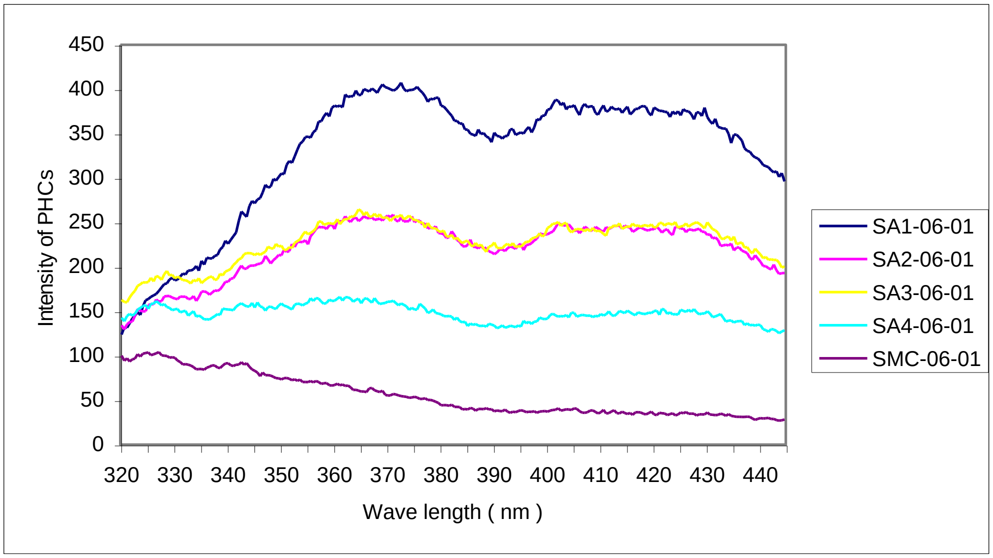


Fig 3: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during August 2001.

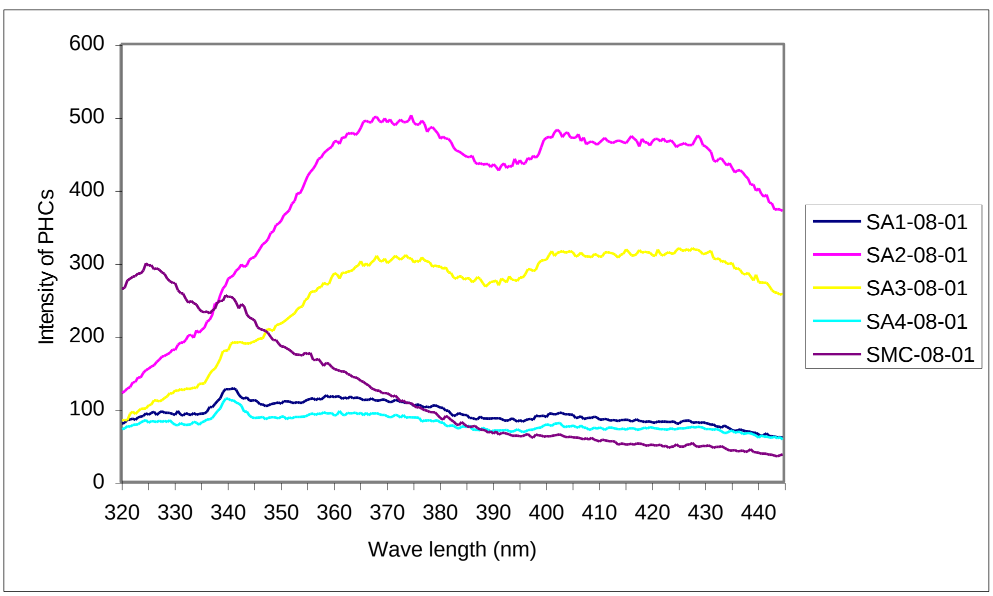


Fig 4: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during October 2001.

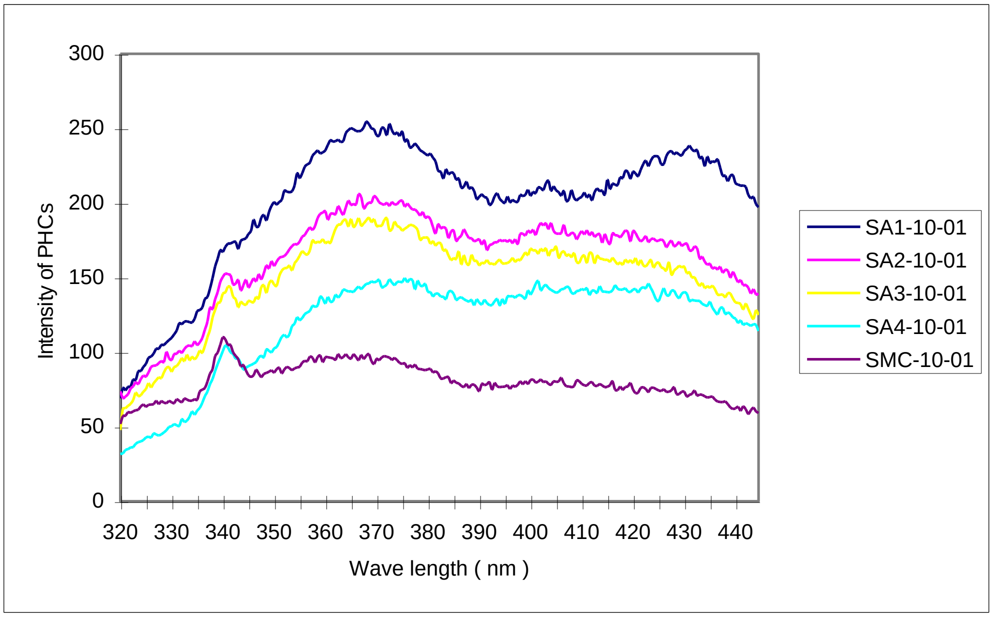


Fig 5: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during December 2001.

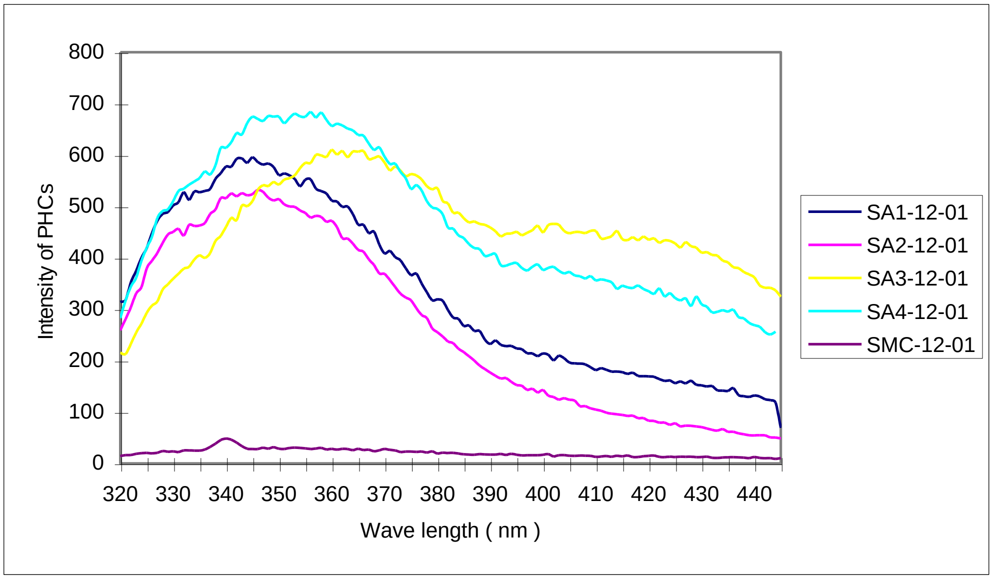


Fig 6: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during February 2002.

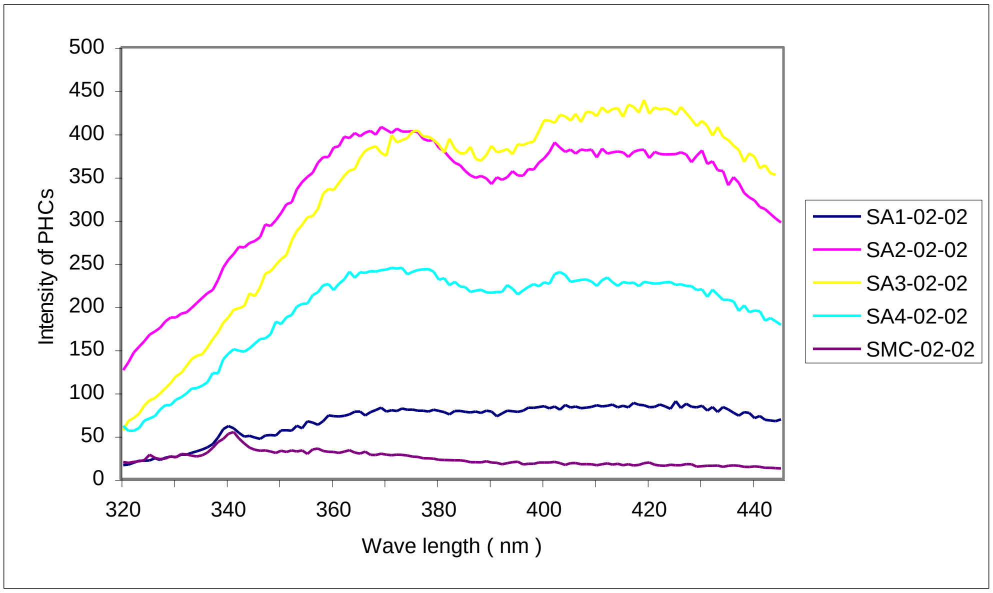


Fig 7: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during April 2002.

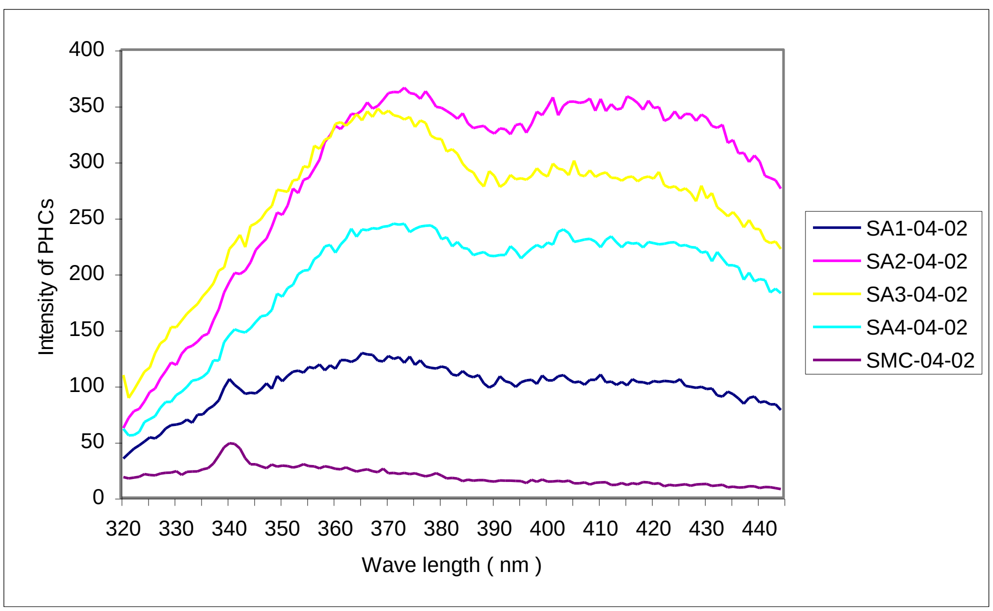


Fig 8: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during Jun 2002.

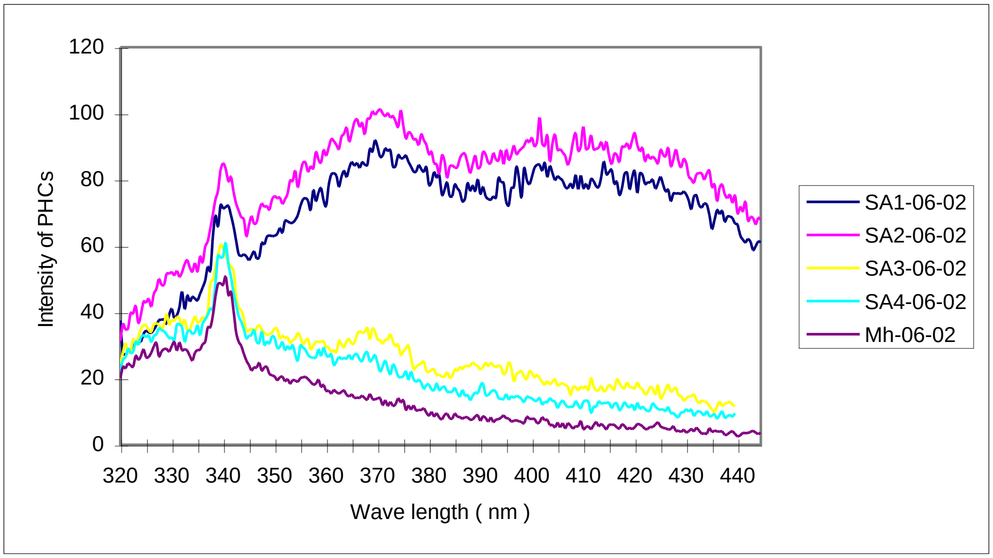


Fig 9: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during August 2002.

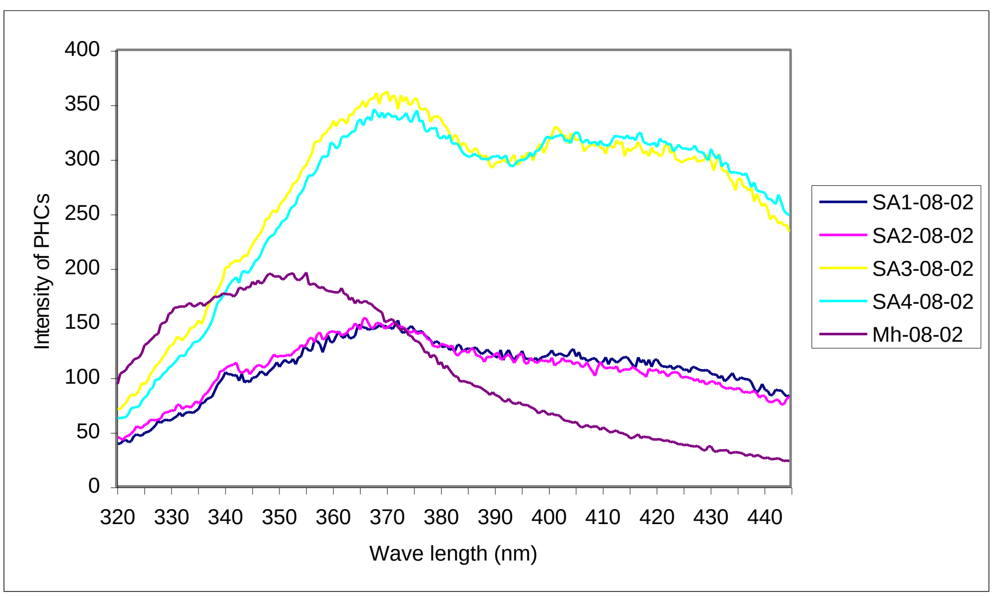


Fig 10: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during October 2002.

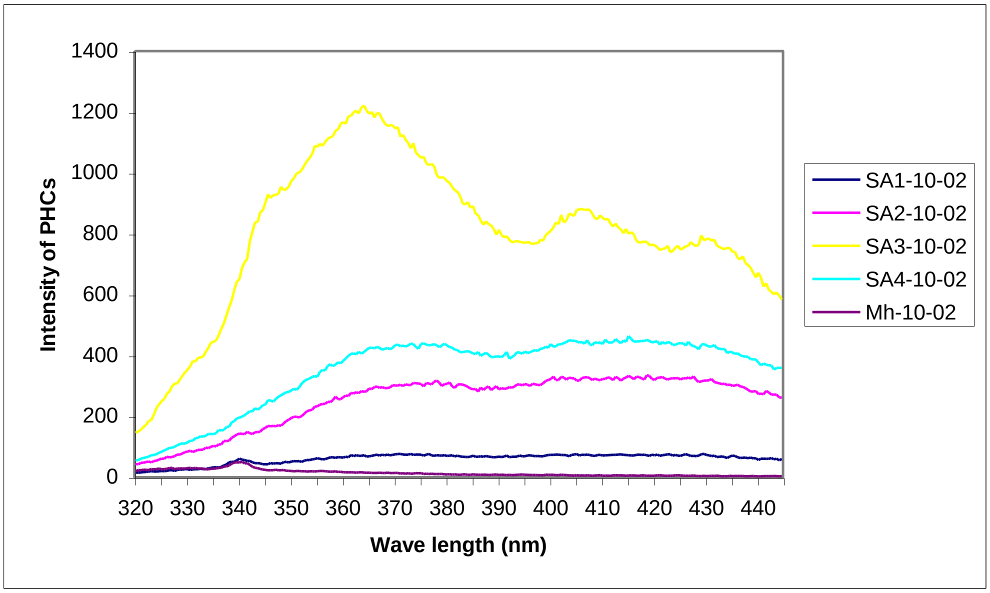


Fig 11: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during December 2002.

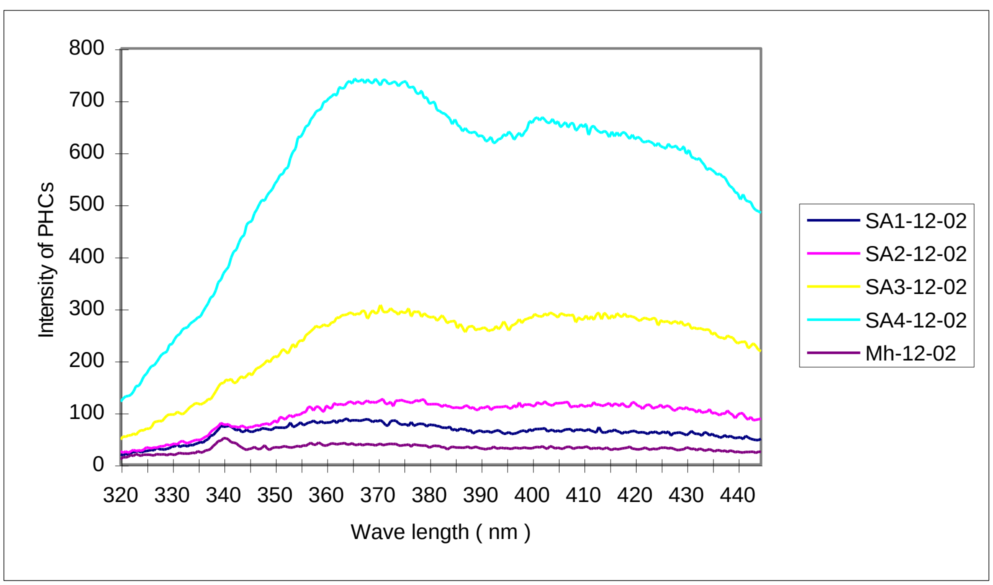


Fig 12: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during February 2003.

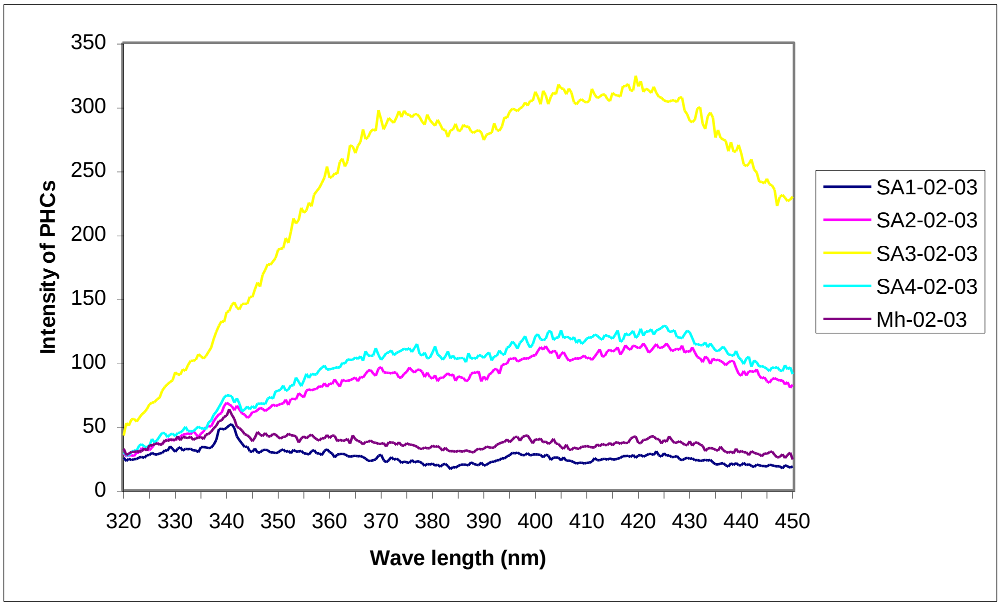
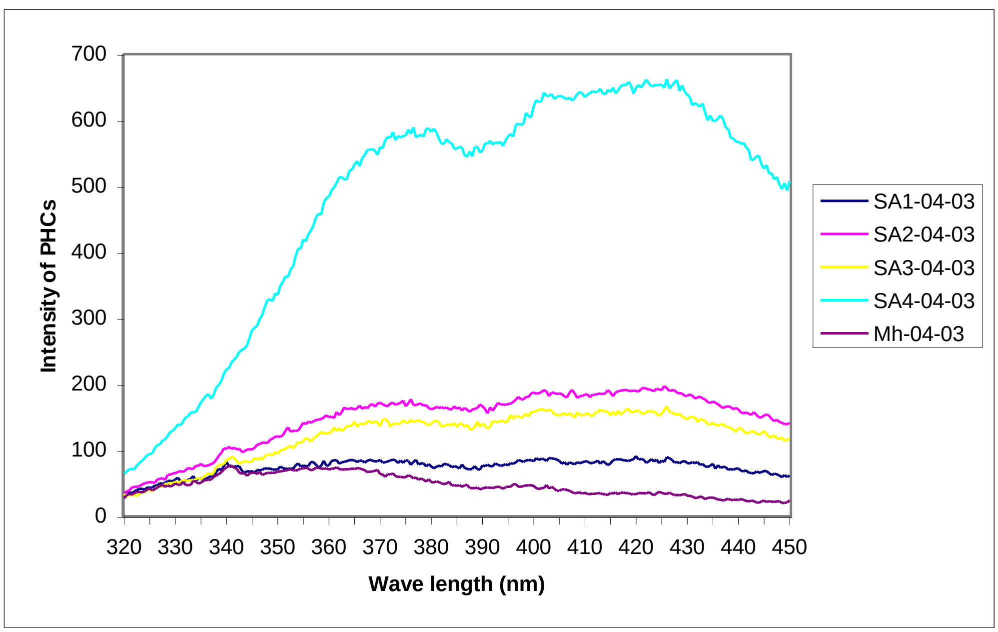


Fig 13: Intensity of Crude Petroleum Hydrocarbons found in Coastal seawater of Alang ship breaking yard and Mahuva during April 2003.



Chapter 5

Diversity of Marine Phytoplankton.

Chapter-5

DIVERSITY OF MARINE PHYTOPLANKTON

Phytoplankton are tiny single-celled ocean plants containing chlorophyll that use sunlight and carbon dioxide to create plant carbon. This plant carbon then becomes the beginning of the food chain for most of the planet. As phytoplankton grow and multiply, small fish and other animals eat them as food. Larger animals in turn feed on the smaller animals. The amount of carbon dioxide present in the atmosphere and dissolved in the ocean's surface layer determines the ocean-water absorption and emission of gas. The amount of gas dissolved in water in turn is influenced by the amount of phytoplankton which consumes C02 during photosynthesis. The most active occurrence of phytoplankton within the first 50 meters of the surface varies widely according to the season and location.

Phytoplankton carries gases and nutrients from the ocean surface to the deep. Phytoplankton create a chemical substance called di-methyl sulfide (DMS) that may promote the formation of clouds over the oceans which in turn creates changes in the plankton population. These changes in plankton population again may lead to changes in cloudiness. The more clouds would reduce the amount of solar radiation reaching the oceans, which could in turn reduce plankton activity. In this way climate has a large effect upon plankton.

Several ubiquitous types of industrial contaminants have also been found to block photosynthesis. Copper, cadmium, mercury, lead, zinc and possibly some other bivalent heavy metals reduce photosynthesis by causing structural damage to chloroplasts (Fitzgerald and Faust, 1963; Wong *et al*., 1979; Sivaswamy, 1990; Govindasamy *et al.* 1997; Ramaiah, et al. 1998; Panigrahi *et al*. 2001).

It has been reported that maximum phytoplankton production observed at the industrial discharge sites of the river (Nair, *et al*.,1988). A true phytoplankton Community well adapted to the microhabitat developed fully and maintains itself by active reproduction. (Valsamma and Ammini,1999). The high micro-algal biomass has suggested that the prolonged expose of the population to the industrial effluents and has developed a tolerance in the phytoplankton community. It is reported by Harikumar *et al*. (1997) that the river water contained rich nutrients and heavy metals inducing the tolerant phytoplankton like *Chlorella sp. Oscillatoria sp. and Nitzschia sp.* (Harikumar, *et al.*, 1997).

5.2 Materials and Methods:

Duding the field samples collection, 100 liter of surface seawater was filtered two times during low tide and high tide both by phytoplankton net of >20 µm mesh size. Two number of each samples were collected, one for qualitative and quantitative studies, preserved with 4% formaldehyde, another was preserved within ice box without addition of any acid just to maintain the live condition for performing the screening test for primary metal and petroleum hydrocarbon tolerance limit of marine phytoplankton. The phytoplankton net was made up of finer nylon materials. After collection of phytoplankton, utmost care was taken to minimize the quantitative and qualitative changes within the phytoplankton composition before further treatment of the samples. The live samples were kept in a cool pack containing ice, below 2°C even in summer, for maintaining the physiological activity of the phytoplankton samples low. To keep the samples alive in the laboratory, they were kept in a refrigerator for a while and after washing and changing seawater the samples were kept in culture laboratory where they were maintained under fluorescent light with at 10:14 LD regime and temperature at 25 ± 2°C. To avoid rapid decay of the marine phytoplankton due to high cell density, fixation has been done immediately after the collection of each sample. For fixation of the phytoplankton samples the most widely used fixatives such as formaldehyde and potassium iodide plus iodine (Lugol's iodine) were used so that final concentration of HCHO was 0.4% (Sournia 1978). The samples were being shaked immediately to facilitate an instantaneous fixation and brought to the laboratory. The chemically preserved samples were kept within the laboratory under temperature 25±2 °C for a short period till evaluation the qualitative and quantitative estimation of the collected sample. For the qualitative estimation, Sedgewick Rafter counting cell was used and for qualitative evaluation standard methods were followed, as described by Husted, F., (1930); Peragallo, (1965); Deshikachari (1986, 1987, 1988 and 1989); Trivedi and Goel, 1984; R. Tomas (1998). For identification of phytoplankton and photography, the help of light microscope (Nikon Model No. Labphoto-2,) (Plate–VIII to Plate-XXI) and Scanning Electron Microscope (SEM Model No. LEO 1430 VP) (Plate-XXII to Plate-XXIV) andrespectively was taken. Biological indices are aimed at providing numerical versions of the biological information especially species composition, the diversity of species, and their distribution pattern using the standard methods are described by Trivedy and Goel (1986).

5.3 Results and Discussion:

During Jun 2001, total 49 genera comprising 75 species were identified from Alang and Mahuva. The spatial distribution of phytoplankton showed a wide range of community composition in Alang at station SA3 comprising the lowest (11) number of genera with 18 number of species to 20 genera with 36 number of species, whereas, Mahuva comprised 14 genera with 14 number of species. *Coscinodiscus perforatus* Ehrneb. and *Leptocylindrus danicus* Cleve. were present at all the four stations of Alang. *Coscinodiscus marginatus* Ehrneb., *Endictya oceanica* Ehrneb., *Licmophora abbreviata* Wm. Sm., *Nitzschia insignis* and *Rhoicosigma oceanicum* were recorded only from Mahuva and were absent at Alang (Table 64).

During August 2001, total 29 genera comprising 69 species were identified from Alang and Mahuva. The spatial distribution of phytoplankton showed a similar trend at three stations SA2, SA3 and SA4 in Alang and it was a quite different situation than what was found at Mahuva. SA2, SA3 and SA4 comprised 16, 19 and 17 number of genera with 36, 34 and 35 number of species respectively. SA1 showed a lower number of genera (11) comprising 22 number of species which almost showed a similar condition with Mahuva having 14 number of genera comprising 22 number of species. SA1 showed just an opposite situation during Jun 2001, which may be due to the effect of addition of fresh water to the surface water column as a result of rainfall. *Coscinodiscus perforatus* Ehrneb., *Leptocylindrus danicus* Cleve., *Coscinodiscus apiculatus* Ehrneb., *Melosira moniliformes* (Muller) Agardh., *Navicula miniscula* Grun., *Noctiluca milliaris* Suriray., *Pleurosigma attenuatum* var. *scalpurum* Grun., *Pleurosigma brebisonii* Grun., *Pleurosigma diminutum* Grun., *Stephanopyxis turris* (Grev. & Arnot) Ralfs. and *Thalassiothrix longissima* Cleve & Grun. were present at all the four stations of Alang. *Coscinodiscus radiatus* Ehrneb., *Dytillum intricum* Ehrneb., *Pleurosigma accuminatum* and *Raphoneis surirella* (Ehrneb) Grun. were recorded only from Mahuva and were absent at Alang (Table 65).

Total 28 genera comprising 72 species were identified from Alang and Mahuva during October 2001. SA1 and SA2 showed comparatively better situation than SA3 and SA4 as well as Mahuva. SA1 and SA2 showed 17 and 14 number of genera comprising respectively with respective 34 and 31 number of species, whereas, 16 genera comprising 24 number of species were recorded from Mahuva. However, SA3 and SA4 showed 8 and 11 number genera comprising 12 and 24 number of species. Only *Pleurosigma balticum* var. *wansbeckii* Donk. was present at all the four stations of Alang. *Biddulphia mobiliensis*(Bailey) Grun., *Campylodiscus latus* Schmidt., *Chaetoceros curvisetus* Cleve., *Coscinodiscus apiculatus* Ehrneb., *Melosira numuloides* (Dillw) Agardh. *Pleurosigma affine* Grun. *Rhizosolenia delicatula* Cleve. *Toxonoidea insignis* Donk. were present only at Mahuva but not at Alang during October 2001. There was no specific phytoplankton which was present only at Mahuva but not at Alang (Table 66).

Total 29 genera comprising 69 species were identified from Alang and Mahuva during December 2001. It was just opposite situation as compared to October 2001. SA3 and SA4 showed a better species composition than SA1 and SA2 at Alang. 19 genera comprising 40 species and 15 genera comprising 31 species were recorded from SA3 and SA4 respectively, whereas, SA1 and SA2 showed stress condition as 10 genera comprising 12 species and 13 genera comprising 26 species were recorded respectively from both the stations in Alang and 11 genera comprising 14 species only noticed at Mahuva. Only *Melosira moniliformes* (Muller) Agardh., *Melosira numuloides* (Dillw.) Agardh., and *Thalassiothrix longissima* Cleve & Grun.

were present at all the stations at Alang. Only *Gunardia flaecida* (Castr) Perag. was recorded from Mahuva but was absent in Alang during December 2001 (Table 67).

During February 2002, total 31 genera comprising 74 species were identified from Alang and Mahuva. Due to the seasonal effect, low temperature promoted the increase of the species composition at Alang with 28 genera comprising 70 species were identified, but only 9 genera comprising 12 species were recorded from Mahuva. There was no much variation among the different stations at Alang as it varied from 13 genera comprising 27 species observed at SA3 to 17 genera comprising 31 species found at SA1 during February 2002. The other two stations SA3 and SA4 showed 16 genera each comprising 22 and 32 species respectively. *Licmophora dalmatica* var., *Nitzschia sigma* (Kutz) Wm. Sm., *Pleurosigma spenceri* Wm. Sm., *Pleurosigma tenuissimum* Sm., and *Surirella striatula* Turpin. were present all the four stations at Alang. *Gunardia flaecida* (Castr) Perag., *Coscinodiscus stillaris* Ropper (Gurtel)., *Isthmia enervis* Ehrneb., *Rhabdonema adriaticum* (Kutz. Harv. & Bail) Stodder., were present only at Mahuva but were absent in Alang (Table 68).

During April 2002, the situation in both the areas were deteriorating as overall 20 genera comprising 31 species were recorded from Alang and Mahuva. There were no much more differences among the four stations at Alang as species composition varied from 6 genera with 6 species at SA2 to 9 genera with 12 species. The species composition at Mahuva also decreased as it showed only 6 genera comprising 7 species. Only *Thalassiothrix longissima* Cleve and Grun. was present all the four stations at Alang. *Coscinodiscus radiatus* Ehrneb., *Podocystis spathulata* Shadb. and *Rhizosolenia delicatula* Cleve. were present only at Mahuva but not at Alang. The reduction of species composition during summer season might be due to increasing air and seawater temperatures which in terms would increase the concentration of pollutants due to evaporation and increasing the metabolic rate of live organisms. Besides these parameters, the biochemical oxygen loads by degrading the dead organic matter, leading to a less dissolved oxygen content of coastal seawater, might also contributed to lesser species composition (Table 69).

During Jun 2002 the situation of the phytoplankton composition of both the areas was also far less as only 17 genera comprising 29 species were recorded from Alang and Mahuva. SA4 among all the four stations of Alang was comparatively better than other three stations as it comprised of 12 genera with 19 specie, whereas, only 4 genera comprising 4 species were recorded from both SA2 and SA3 and 6 genera with 6 species were observed at SA1. A similar trend was observed at Mahuva as only 4 genera comprising 7 species during Jun 2002 was recorded. Only *Thalassiothrix longissima* Cleve and Grun. was present at all the four stations of Alang. *Coscinodiscus apiculatus* Ehrneb., *Ethmodiscus rex* Henedy., *Podocystis adriatica* Kuetz., and *Podocystis spathulata* Shadb., were present at Mahuva only and were absent in Alang. The overall decreasing the species composition at both the areas might be due to addition of fresh water during rainy season, leads a lower pH caused more dissolution of heavy metals in seawater (Table 70).

During August 2002 the habitat conditions got improved at Alang and Mahuva as compared to Jun 2002. Overall 26 genera comprising 55 species were recorded from both the areas, Alang and Mahuva. The species composition within four stations in Alang varied from 11 genera with 18 species at SA2 to 17 genera with 36 species at SA4. The other two stations SA1 and SA3 showed 12 genera comprising 20 species and 15 genera comprising 24 species respectively, whereas, Mahuva continued to show the same situation as noticed in Jun 2002 regarding species composition, as only 4 genera comprises 6 species were recorded during August 2002. *Coscinodiscus perforatus* Ehrneb., *Navicula miniscula* Grun., *Coscinodiscus stillaris* Ropper (Gurtel)., and *Pleurosigma formosum* Wm. Sm. (Grun). were present at all the four stations in Alang. Only *Biddulphia mobiliensis* (Bailey) Grun. *Ceratium lineatum* (Ehrneb.) and *Coscinodiscus radiatus* Ehrneb were present at Mahuva but not in Alang (Table 71).

During October 2002, again the situation of the species composition of the coastal areas got reduced as only 21 genera comprising 42 species were recorded from Alang and Mahuva as a whole. The species composition varied from 3 genera containing 5 species at SA2 to 13 genera containing 23 species at SA4 at Alang. The other two stations SA1 and SA3 showed a species composition of 11 genera comprising 17 species and 6 genera comprising 10 species respectively, whereas, Mahuva showed some what improved diversity of phytoplankton community with 9 genera comprising 12 species, as compared to the situation of August 2002. Only *Thalassiothrix longissima* Cleve and Grun. was present at all the four stations of Alang and *Biddulphia aurita* (Lyngbye) Breb. & Godey., *Biddulphia mobiliensis* (Bailey) Grun., *Leptocylindrus danicus* Cleve., *Nitzschia obtusa* var. and *Surirella intercedens* var. were present only at Mahuva but not in Alang. The adverse effect on biodiversity of Marine phytoplankton in Alang might be due to the high concentration of crude petroleum oils present in seawater due to ship scrapping activities at Alang (Table 72).

During December 2002, only 19 genera comprising 40 species were identified from Alang and Mahuva. The species composition of phytoplankton community of Alang continued to show the similar pattern of October2002 with a bit improvement as it varied from 9 genera with 19 species at SA3 to 18 genera with 23 species at SA4. The other stations SA1 and SA2 in Alang showed same 12 genera containing 18 and 22 species respectively, whereas, Mahuva showed a lesser number of 4 genera with 6 species during December 2002 and might be due the effect of oils spill that takes time to spread over here (Table 73).

In February 2003, the species composition of marine phytoplankton still remaind unchanged at Alang, although overall 28 genera comprising 50 species were recorded from Alang and Mahuva, Alang shared a less amount of the total species composition during February 2002. Only at stations SA1 it showed 8 genera with 10 species and rest of the stations SA2, SA3 and SA4 showed 7 genera with 14 species, whereas Mahuva showed comparatively better situation than Alang as 17 genera containing 24 species were noticed. There were only three species commonly present among all four stations in Alang and they were *Coscinodiscus perforatus* Ehrneb., *Pleurosigma spenceri* Wm.Sm., and *Thalassiothrix longissima* Cleve & Grun. There were many uncommon species viz; *Actinocyclus confluens* Grun., *Actinocyclus spiralis* Perag., Caloneis linearis (Grun.) Boyer., *Campylodiscus limbatus* Breb., *Campylodiscus triamphans* Schimdt. *Coscinodiscus conciniformes* Simonsen., *Coscinodiscus coscinodiscus* Ehrneb., *Coscinodiscus oculusiridis* Ehrneb. *Cyamatonitzschia marina* (Lewis) Simonsen., *Grammatophora longissima* Tetit., *Leptocylindrus danicus* Cleve. *Licmophora dalmatica* var., *Pinnularia braunii* Husted., *Pseudopodossira westii* (Wm. Sm.) Sheshukov. *Pyxidicula reniformes* Desik & Ranjitha. *Tracheneis antillarum* (Cl. & Grun.) Cleve. and *Triceratium pentacrinum* f. *quardrata* Hust. were observed only at Mahuva and might be due to the tide and wave actions into the mouth of the Gulf of Cambay and most the above reputed phytoplankton entered during February 2003 as the fresh water flow becomes absent during winter season (Table 74).

During April 2003, the phytoplankton composition of the coastal areas of Alang and Mahuva showed overall 23 genera comprising 45 species. The community composition of marine phytoplankton varied from 6 genera containing 12 species at SA2 to 11 genera containing 16 species at SA1, whereas, the other two stations SA3 and SA4 showed 9 genera comprising 14 species and 7 genera comprising 15 species respectively in Alang. Mahuva also showed a bit decrease in community composition of marine phytoplankton with 12 genera comprising 18 species, which was less than February 2003. Only *Coscinodiscus perforatus* Ehrneb., and *Thalassiothrix longissima* Cleve & Grun. were present at all four stations in Alang. *Actinocyclus pruniosus* Castr., *Campylodiscus gavilli* (Wm. Sm.) Grun., *Campylodiscus latus* Shadbolt., *Ceratium furca* Ehrneb., *Diploneis smithi* (Brev) Cleve. *Dytillum brightwelli* (West) Grun. *Pseudoaulacodiscus petitii* L-F. *Rhizosolenia delicatula* Cleve., *Triceratium broeckii* Leuduger & Fortmorel. and *Triceratium pentacrinum* f. *quardrata* Hust. were present at Mahuva but not at Alang (Table 75).

During the study period, total of 55 genera comprising 190 species were identified from Alang as a whole whereas total 44 genera comprising 85 species were identified from Mahuva. There was more variation in phytoplankton composition in Alang than Mahuva. The number of genera varied from 3 at station SA2 during October 2002 to 20 at station SA1 and SA2 during Jun 2001in Alang, whereas, the same varied from 4 during Jun, August and December of 2002 to 17 during February 2003 in Mahuva. On average, the number of genera varied from 6 during Jun 2002 to 16 during Jun to August 2001 and February 2002 in Alang. In general, within the four station of Alang seawater, the number of genera ranged from 15 during Jun 2002 and April 2003 to 39 during Jun 2001 and SA2 comprise the lowest number of genera 10 and SA4 contained the highest number of genera 14 during the study period (Table 76 and Fig. 14).

The wide range of species variation also showed a similar trend as that of the number of genera in Alang and Mahuva. Total number of species varied from 4 at station SA2 and SA3 during Jun 2002 to 40 at station SA3 during December 2001in Alang, whereas, the same varied from 6 during August and December 2002 to 24 during February 2003 at Mahuva. On average, the number of species varied from 8 during Jun 2002 to 32 during August of 2001 in Alang. In general, within the four station of Alang seawater, the number of species ranged from 22 during February 2003 to 70 during Jun 2001 and February 2002 and SA3 comprises the lowest number of species 18 and SA4 contained the highest number of species 24 during the study period (Table 77).

Total count of phytoplankton ranged from 54.7 x 10^3 No. m^{-3} at station SA2 during Jun 2002 to 35244 x 10^3 No. m^{-3} at station SA4 during December 2002 in Alang, whereas, the same varied from 45.9 x 10^3 No. m^{-3} during Jun 2002 to 1689.2 x 10^3 No. m^{-3} during October 2001 at Mahuva. On average, the total count of phytoplankton varied from 108.8 x 10^3 No. m^{-3} during Jun 2002 to 10278.3 x 10^3 No. m^{-3} during December of 2002 in Alang. In general, within the four stations of Alang, SA2 comprised the lowest count of phytoplankton 1060.5 x 10^3 No. m^{-3} and SA4 contained the highest count of phytoplankton 5204 x 10^3 No. m^{-3} during the study period (Table 78 and Fig. 15).

Diatom indices were originally developped to indicate " Water Quality" and were therefore affected both by organic and inorganic sources of pollution (Descy 1979, Cemagref 1982). These indices have been used to asses organic pollution (Kelly et al. 1995 ; Prygiel et al 1999) but less evident is their potential use when other types of environmental stress (heavy metal pollution at shear stress caused by transport of particulate matter) influence water quality (Barbour et al. 1999). The value of the Indices of dominance varied from 0.0003 at SA1 during August 2002 to 0.92 at SA3 during August 2002. On average, in Alang the value of the Indices of dominance varied from 0.017 during August 2002 to 0.234 during April 2002. Among the four stations in Alang, the lowest average value of the indices of dominance, 0.137 was observed at SA1 and the highest value of the indices of dominance 0.232 was observed at SA3 during the study period. However, in Mahuva the value of the indices of dominance varied from 0.0002 during August 2002 to 0.976 during Jun 2002 (Table 79).

The value of the Shannon Weaver index of species diversity varied from 0.124 at SA4 during October 2001 to 4.735 at SA1 during October 2001 in Alang. On average the value of the Shannon Weaver indices of species diversity varied from 0.572 during August 2002 to 2.621 during October 2002. Among the four stations in Alang the lowest average value of 0.85 was noticed at SA2 and the highest value 1.15 was observed at SA1 during the study period. However, the value of the Shannon Weaver indices ranged from 0.070 during August 2002 to 3.466 during October 2002 in Mahuva (Table 80). Both the areas Alang and Mahuva almost fall under the polluted zone, while, the maximum values of Shannon Weaver Index of Phytoplankton for clean waters is around 6 (six). Decrease in the value of index might be taken as indicator of pollution. The index values of 3 and above are generally considered healthy condition of water bodies. The values between 1 and 3 and less than 1 are representative of semi and poor productivity respectively (NEERI EIA Report 2000).

The abundance of marine phytoplankton was highly influenced with the seawater condition of coastal environment of Alang ship breaking yard. As Mahuva is only 40 kms (approx.) far from Alang the accidental release of crude petroleum oil spills and heavy metal pollution also affect the coastal environment of Mahuva over a time. Some genera like *Coscinodiscus*, *Melosira*, *Nitzschia*, *Pleurosigma*, *Surirella* and *Thalassiothrix* including *Coscinodiscus* perforatus Ehrneb., *Melosira moniliformes* (Muller) Agardh., *Thallassiothrix longissima*, *Pleurosigma spenceri* were very common in the coastal area of Alang ship breaking yard. This might be due to tolerance of the heavy metals and petroleum hydrocarbon pollution generated by the ship scrapping activities at Alang and some of them might be endemic and opportunistic species, which were adopted to that polluting area over a period of time. The similar type of species dominance was observed by Raman, 1996 included *Pleurosigma sp., Nitzschia sp.* and *Surirella sp.* at Alang, Gulf of Cambay, Saurashtra-Gujarat Coast of India.

Table 64: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during Jun 2001.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	-	-	58.24	14.56	-
2	*Amphiprora meditica* Perag.	-	-	-	1.04	0.26	1.16
3	*Amphora costata* Wm. Sm.	-	-	-	3.12	0.78	-
4	*A. inflexa* Breb.	-	2.88	3.12	-	1.5	-
5	*Asterionella notata* Grun.	-	1.44	-	-	0.36	1.16
6	*A. japonica* Cleve.	-	1.44	1.56	-	0.75	-
7	*Bacillaria paradoxa* Sm. & Ehrneb.	5.76	-	-	-	1.44	-
8	*Odontella aurita (Lyngbye)* Breb & Godey.	5.76	-	-	-	1.44	6.96
9	*Odontella mobiliensis* (Bailey) Grun.	0.96	-	3.12	-	1.02	-
10	*Odontella pulchella* Gray.	-	-	1.56	-	0.39	-
11	*Campylodiscus eximius* Var.	-	-	3.12	-	0.78	-
12	*Cerataulina bergonii* Perag.	-	4.32	-	-	1.08	-
13	*Chaetoceros willei*	-	2.88	-	-	0.72	-
14	*Climacoshenia molinigera* Ehrneb.	-	1.44	-	-	0.36	-
15	*Corethron hystris* Hensen.	3.84	-	-	-	0.96	-
16	*Coscinodiscus apiculatus* Ehrneb.	2.88	2.88	-	9.36	3.78	-
17	*C. centralis* Ehrneb.	4.80	4.32	-	6.24	3.84	2.32
18	*C. concinnus* Wm. Sm.	0.96	4.32	-	-	1.32	-
19	*C. janischii* A.S.	-	4.32	-	1.04	1.34	1.16
20	*C. lineatus* Ehrneb.	-	-	7.80	-	1.95	-
21	*C. marginatus* Ehrneb.	-	-	-	-	-	3.48
22	*C. obscurus* A. S.	-	-	3.12	12.48	3.9	-
23	*C. perforatus* Ehrneb.	0.96	12.96	1.56	3.12	4.65	3.48
24	*C. radiatus* Ehrneb.	-	-	6.24	11.44	4.42	-
25	*C. stellaris* Raper.	1.92	2.88	-	-	1.2	-
26	*C. subtilis* Ehrneb.	-	-	10.92	8.32	4.81	1.16
27	*Endictya oceanica* Ehrneb.	-	-	-	-	-	1.16
28	*Exuviella marina*	-	-	3.12	-	0.78	-
29	*Grammatophora angulosa* Var.	-	1.44	-	-	0.36	-

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Table 64: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
30	*Gyrosigma* sp.	-	1.44	-	-	0.36	-
31	*Hyalodiscus laevis* Ehr.	-	2.88	-	-	0.72	-
32	*Lauderia borealis* Gran.	1.92	-	-	-	0.48	-
33	*Leptocylindrus danicus* Cleave.	7.68	11.52	15.60	4.16	9.74	3.48
34	*Licmophora abbreviata* Wm. Sm.	-	-	-	-	-	-
35	*L. dalmatica V*ar.	17.28	-	-	-	4.32	-
36	*Melosira moniliformes* (Muller) Agardh.	26.88	-	-	18.72	11.4	13.92
37	*M. numuloides* (Dillw.) Agardh .	17.28	-	-	-	4.32	-
38	*Navicula directa* Wm. Sm.	1.92	-	-	-	0.48	-
39	*Nitzschia Commutata*	4.80	-	-	2.08	1.72	-
40	*N. incerta Grun.*	-	4.32	-	-	1.08	-
41	*N. insignis*	-	-	-	-	-	3.48
42	*N. longissima* (Breb.) Ralfs.	-	-	1.56	-	0.39	-
43	*N. lorenziana* Grun.	-	4.32	3.12	-	1.86	-
44	*N. obtusa* Var.	3.84		-	-	0.96	-
45	*N. striata* Cleve.	0.96	4.32	-	4.16	2.36	-
46	*Noctiluca* miliaris Suriray.	-	1.44	4.68	1.04	1.79	-
47	*Pediastrum sp.*	-	1.44	-	-	0.36	-
48	*Peridinium depressum* Bail.	-	-	1.56	-	0.39	-
49	*P. exiguum* Cleave.	-	1.44	-	-	0.36	-
50	*Pleurosigma affine* Grun.	4.80	1.44	-	-	1.56	-
51	*P. attenuatum* Var. *scalpurum* Grun.	0.96	-	-	-	0.24	-
52	*P. balticum* var. *wansbeckii* Donk.	5.76	-	-	-	1.44	-
53	*P. brebisonii* Grun.	-	-	-	15.60	3.9	-
54	*P. decorum* Sm.	2.88	-	-	-	0.72	-
55	*P. distortum* Sm.	-	2.88	-	-	0.72	-
56	*P. lineari* Grun.	4.80	-	-	-	1.2	-
57	*P. normani* Gupp.	3.84	-	-	-	0.96	-
58	*P. spencerii* Wm. Sm.	1.92	1.44	-	-	0.84	-
59	*Podocystis spathulata* Shadb.	-	1.44	-	-	0.36	-

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Table 64: (Contd….)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
		Count (No. x 10^3 m^{-3})					
60	*Pseudo-nitzschia subcurvata* Wm. Sm.	1.92	1.44	-	-	0.84	-
61	*Pyrocystis lunula* Var.	0.96	-	-	-	0.24	-
62	*Rhoicosigma oceanicum*	-	-	-	-		1.16
63	*Rhopaloidea gibberula* Ehr.	0.96	-	-	-	0.24	-
64	*Spinodiscus javonicus* Comb.	0.96	-	-	-	0.24	-
65	*Staureneis spicula* Hick.	0.96	-	-	-	0.24	-
66	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	13.44	-	-	-	3.36	-
67	*Surirella fastuosa* var. *cuneata* (A.S.) Perag.	0.96	-	-	1.04	0.5	-
68	*Synedra longissima* Sm.	-	2.88	-	-	0.72	-
69	*Thalassiosira gravida* Cleve.	2.88	-	4.68	-	1.89	-
70	*T. lineata* Jouse'	1.92	-	-	-	0.48	-
71	*T. subtilis*	0.96	-	-	-	0.24	-
72	*T. longissima*	-	86.40	56.16	18.72	40.32	-
73	*Torpedoneis lepidoptera* var. *minor* Cleve.	-	-	-	1.04	0.26	2.32
74	*Toxonoidea insignis* Donk.	-	1.44	-	2.08	0.88	-
75	*Triceratium favus* Ehrneb.	0.96	-	-	-	0.24	-
	BLUE-GREEN ALGAE and Others	5.76	2.88	6.24	3.12	4.5	2.32
	Total count of Phytoplankton	168.00	182.88	138.84	186.16	168.97	48.72

Table 65: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during August 2001.

No	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	-	-	61.60	15.40	328.68
2	*A. brevipes* var. *angulata (Grey.) Cleve.*	-	-	11.64	-	2.91	-
3	*Amphiprora sulcata* Cleve.	-	8.48	-	-	2.12	-
4	*Amphora arnicola*var. (Perag.)	-	-	3.88	-	0.97	-
5	*A. costata* Wm. Sm.	10.08	12.72	-	-	5.70	-
6	*Bacillaria paradoxa* Sm. & Ehrneb.	26.88	-	-	83.16	27.51	26.56
7	*Biddulphia mobiliensis* (Bailey) Grun.	-	-	-	6.16	1.54	3.32
8	*Climachosphenia elongata* Bail.	-	-	-	3.08	0.77	-
9	*Coscinodiscus. apiculatus* Ehrneb.	13.44	8.48	3.88	12.32	9.53	-
10	*C. centralis* Ehrneb.	-	4.24	-	6.16	2.60	3.32
11	*C. concinnus* Wm. Sm.	-	-	-	6.16	1.54	3.32
12	*C. excentricus* Ehrneb.	-	-	-	3.08	0.77	56.44
13	*C. marginatus* Ehrneb.	10.08	-	-	-	2.52	-
14	*C. perforatus* Ehrneb.	6.72	4.24	34.92	6.16	13.01	19.92
15	*C. radiatus* Ehrneb.	-	-	-	-	-	6.64
16	*C. stellaris* Raper.(Gurtel.)	-	4.24	7.76	24.64	9.16	26.56
17	*C. subtilis* Ehrneb.	-	-	-	3.08	0.77	-
18	*Ditylum intricum* Ehrneb.	-	-	-	-	-	3.32
19	*Grammatophora angulosa* var.	-	-	11.64	-	2.91	-
20	*G. longissima* Petit.	-	-	31.04	24.64	13.92	-
21	*G. serpentina* Ehrneb.	-	4.24	-	18.48	5.68	3.32
22	*G. solea* Breb.	-	-	-	3.08	0.77	-
23	*Hyalodiscus laevis* Ehr.	-	-	42.68	-	10.67	-
24	*Leptocylindrus danicus* Cleave.	13.44	29.68	50.44	21.56	28.78	23.24
25	*Licmophora dalmatica* var.	-	-	-	12.32	3.08	-
26	*Melosira moniliformes* (Muller) Agardh.	40.32	93.28	19.40	255.64	102.16	56.44
27	*M. numuloides* (Dillw.) Agardh .	-	127.20	-	-	65.68	19.92
28	*Navicula directa* Wm. Sm.	-	178.08	46.56	9.24	58.47	23.24

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Table 65: (Contd..)

No	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*N. miniscula* Grun.	3.36	25.44	42.68	18.48	22.49	-
30	*Nitzschia angularis* var. *affinis* Grun.	6.72	-	-	-	1.68	-
31	*N. Commutata Grun.*	77.28	4.24	3.88	-	21.35	-
32	*N. insignis*	10.08	-	-	-	2.52	-
33	*N. linearis* Var.	-	-	11.64	-	2.91	-
34	*N. recta* Htz.	13.44	-	-	-	3.36	-
35	*N. seriata* Cleve.	20.16	72.08	3.88	-	24.03	6.64
36	*N. sigma* (Kutz) Wm. Sm.	-	4.24	3.88	-	2.03	-
37	*N. socialis* Greg.	16.80	-	-	-	4.20	-
38	*N. valida* Grun.	-	38.16	19.40	9.24	16.70	-
39	*Noctiluca* miliaris Suriray.	10.08	8.48	23.28	6.16	12.00	3.32
40	*P. accuminatum*	-	-	-	-	-	3.32
41	*P. accutum* Norm.	-	12.72	-	30.80	10.88	-
42	*P. angulatum* Sm.	-	8.48	-	-	2.12	-
43	*P. attenuatum* Var. *scalpurum* Grun.	13.44	42.40	15.52	9.24	20.15	3.32
44	*P. balticum* var. *wansbeckii* Donk.	-	46.64	-	73.92	30.14	9.96
45	*P. brebisonii* Grun.	20.16	55.12	54.32	40.04	42.41	-
46	*P. caspidatum* Cleve.	-	4.24	-	-	1.06	-
47	*P. decorum* Sm. (Perag.)	-	89.04	46.56	18.48	38.52	-
48	*P. delicatulum* Wm. Sm.	-	-	3.88	-	0.97	-
49	*P. diminutum* Grun.	10.08	21.20	11.64	15.40	14.58	-
50	*P. formosum* Wm. Sm.(Grun.)	-	-	-	15.40	3.85	-
51	*P. lanceolatum* Donk.	-	16.96	-	-	4.24	-
52	*P. lineari* Grun.	23.52	-	-	-	5.88	-
53	*P. majus Grun.*	-	-	-	3.08	0.77	-
54	*P. spaciosum* Wm. Sm.	-	25.44	-	-	6.36	-
55	*P. spencerii* Wm. Sm.	-	42.40	7.76	-	12.54	-
56	*P. tenuissimum* Sm.	-	4.24	-	-	1.06	-
57	*Podosira argus* Grun.	-	-	3.88	-	0.97	-
58	*Raphoneis surirella* (Ehrneb.) Grun.	-	-	-	-	-	9.96

Contd..

Table 65: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
		Count (No. x 10^3 m^{-3})					
59	*Rhabdonema adriaticum* Kutz Harv. & Bail) Stodder.	-	-	31.04	-	7.76	-
60	*Rhoicosigma oceanicum*	-	-	15.52	15.40	7.73	-
61	*R. robustum* Grun.	3.36	25.44	15.52	-	11.08	-
62	*Rhizosolenia delicatula* Cleve.	-	-	31.04	-	7.76	-
63	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	33.60	50.88	31.04	80.08	48.90	-
64	*Surirella striatula* Turpin.	-	4.24	-	15.40	4.91	-
65	*Thalassiosira gravida* Cleve.	-	8.48	7.76	-	4.06	3.32
66	*Thalassiothrix longissima*	120.96	203.52	287.12	98.56	177.54	-
67	*Torpedoneis lepidoptera* var. *minor* Cleve.	-	4.24	3.88	-	2.03	-
68	*Toxonoidea insignis* Donk.	-	12.72	-	12.32	6.26	-
69	*Tropidoneis elegans*	-	-	7.76	-	1.94	-
			-	-	-	-	-
	BLUE-GREEN ALGAE & Others	13.44	21.20	46.56	-	20.30	-
	Total count of Phytoplankton	517.44	1327.12	993.28	1022.56	998.98	644.08

Table 66: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during October 2001.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	12.40	-	-	3.10	-
2	*Amphiprora* gigantea var. *sulcata* Cleve.	127.20	18.60	-	-	36.45	-
3	*Amphora costata* Wm. Sm.	-	-	10.56	92.40	25.74	41.20
4	*A. cymbifera* Greg.	-	18.60	10.56	-	7.29	-
5	*A. hyalina* K.	-	-	-	30.80	7.70	20.60
6	*A. turgida* Greg.	-	43.40	-	-	10.85	61.80
7	*Bacillaria paradoxa* Sm. & Ehrneb.	848.00	-	-	-	212.00	-
8	*Biddulphia aurita (Lyngbye)* Breb & Godey.	-	-	10.56	-	2.64	-
9	*B. mobiliensis* (Bailey) Grun.	-	-	-	-	-	20.60
10	*Campylodiscus echeneis* Ehrneb.	21.20	-	-	-	5.30	-
11	*C. latus* Schmidt.	-	-	-	-	-	20.60
12	*C. samoensis* Grun.	42.40	-	-	-	10.60	-
13	*Chaetoceros curvisetus* Cleve.	-	-	-	-	-	865.20
14	*C. javanicum* Cleve.	-	-	-	154.00	38.50	-
15	*Coscinodiscus apiculatus* Ehrneb.	-	-	-	-	-	20.60
16	*C. centralis* Ehrneb.	-	18.60	31.68	-	12.57	-
17	*C. concinnus* Wm. Sm.	-	18.60	21.12	-	9.93	41.20
18	*C. perforatus* Ehrneb.	21.20	37.20	-	-	14.60	41.20
19	*C. radiatus* Ehrneb.	21.20	6.20	-	-	6.85	41.20
20	*C. stellaris* Raper.(Gurtel.)	-	6.20	-	-	1.55	-
21	*Diploneis crabro* (Cleve) Var.	-	-	137.28	30.80	42.02	-
22	*Grammatophora serpentina* Ehrneb.	21.20	6.20	-	-	6.85	-
23	*Gunardia* sp.	42.40	-	-	-	10.60	-
24	*Leptocylindrus danicus* Cleave.	-	55.80	-	-	13.95	20.60
25	*Licmophora dalmatica* var.	21.20	-	-	30.80	13.00	-
26	*Melosira moniliformes* (Muller) Agardh.	593.60	186.00	-	-	194.90	-
27	*M. numuloides* (Dillw.) Agardh .	-	-	-	135.52	33.88	103.00
28	*Navicula concellata* Donk.	-	-	116.16	61.60	44.44	41.20
29	*N. directa* Wm. Sm.	21.20	12.40	-	61.60	23.80	41.20

Contd..

Table 66: (Contd….)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
		Count (No. x 10^3 m^{-3})					
30	*N. miniscula* Grun.	63.60	12.40	-	61.60	34.40	41.20
31	*N. salinarum*	-	-	-	61.60	15.40	-
32	*Nitzschia angularis* var. *affinis* Grun.	-	-	-	61.60	15.40	-
33	*N. insignis*	-	-	-	61.60	15.40	-
34	*N. longissima* (Breb.) Ralfs.	42.40	6.20	-	-	12.15	20.60
35	*N. lorenziana* Grun.	42.40	-	-	92.40	33.70	-
36	*N. obtusa* Var.	-	-	-	30.80	7.70	-
37	*N. seriata* Cleve.	190.80	-	21.12	92.40	76.08	-
38	*N. sigma* (Kutz) Wm. Sm.	-	6.20	-	-	1.55	-
39	*N. socialis* Greg.	-	-	-	30.80	7.70	-
40	*N. striata* Cleve.	-	12.40	-	-	3.10	-
41	*Noctiluca* miliaris Suriray.	-	31.00	-	-	7.75	61.80
42	*Pleurosigma affine* Grun.	-	-	-	-	-	20.60
43	*P. attenuatum* Var. *scalpurum* Grun.	402.80	-	10.56	-	103.34	-
44	*P. balticum* var. *wansbeckii* Donk.	148.40	24.80	31.68	92.40	74.32	20.60
45	*P. compactum* Grun.		6.20			1.55	-
46	*P. decorum* Sm. (Perag.)	190.80	-	-	-	47.70	-
47	*P. diminutum* Grun.	572.40	-	63.36	308.00	235.94	-
48	*P. formosum* Wm. Sm.(Grun.)	63.60	31.00	-	30.80	31.35	-
49	*P. latum* Cleve.	-	-	-	30.80	7.70	-
50	*P. longum* var. *lanceolata* Perag.	360.40	-	-	-	90.10	-
51	*P. marinum* Donk.	127.20	18.60	-	-	36.45	-
52	*P. obscurum* var.*diminuta* H.P.	445.20	62.00	-	-	126.80	-
53	*P. spaciosum* Wm. Sm.	-	18.60	-	215.60	58.55	-
54	*P. spencerii* Wm. Sm.	63.60	-	-	-	15.90	-
55	*P. tenuissimum* Sm.	63.60	-	-	-	15.90	-
56	*Podosira steliger* Bail.	21.20	-	-	-	5.30	-
57	*Rhoicosigma compactum*	-	6.20	-	-	1.55	-
58	*R. curvata* (K.) *Grun.*	-	6.20	-	-	1.55	-
59	*R. oceanicum* H. P.	233.20	24.80	-	-	64.50	-
60	*R. robustum* Grun.	63.60	12.40	-	-	19.00	-

Contd..

Table 66: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
61	*Rhizosolenia delicatula* Cleve.	-	-	-	-	-	20.60
62	*Schroederlla schroedri* Berg.	-	12.40	-	-	3.10	-
63	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	-	-	-	61.60	15.40	-
64	*Surirella brightwelli* Wm. Sm.	42.40	-	-	-	10.60	-
65	*S. intercedens* Var.	-	-	-	30.80	7.70	20.60
66	*S. robusta* Ehrneb.	63.60	-	-	-	15.90	-
67	*S. striatula* Turpin.	42.40	-	-	-	10.60	-
68	*Thalassiosira gravida* Cleve.	42.40	-	-	-	10.60	41.20
69	*Thalassiothrix longissima*	-	37.20	10.56	-	11.94	-
70	*T. nitzschioides* Var.	21.20	-	-	-	5.30	-
71	*Torpedoneis lepidoptera* var. *minor* Cleve.	21.20	6.20	-	30.80	14.55	41.20
72	*Toxonoidea insignis* Donk.	-	-	-	-	-	20.60
	BLUE-GREEN ALGAE & Others	-	-	-	220.00	55.00	-
	Total count of Diatoms	5109.20	775.00	475.20	2111.12	2117.63	1689.20

Table 67: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during December 2001.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	-	68.80	-	17.20	49.20
2	*Amphora costata* Wm. Sm.	-	-	25.80	28.20	13.50	24.60
3	*A. surpentina*	-	-	-	28.20	7.05	-
4	*A. valida* Perag.	-	-	146.20	-	36.55	-
5	*Asterionella notata* Grun.	-	12.60	-	-	3.15	-
6	*Bacillaria paradoxa* Sm. & Ehrneb.	-	-	-	2002.20	500.55	-
7	*Biddulphia mobiliensis* (Bailey) Grun.	22.40	-	-	-	5.60	-
8	*B. pulchella* Gray.	-	-	-	366.60	91.65	24.60
9	*Campylodiscus echeneis* Ehrneb.	22.40	-	-	-	5.60	-
10	*Chaetoceros javanicum* Cleve.	268.80	-	-	-	67.20	-
11	*Coscinodiscus centralis* Ehrneb.	-	-	8.60	-	2.15	-
12	*C. compactum*	-	-	8.60	-	2.15	-
13	*C. concinnus* Wm. Sm.	-	18.90	17.20	-	9.03	98.40
14	*C. janischii* A.S.	-	6.30	-	-	1.58	-
15	*C. lineatus* Ehrneb.	-	-	8.60	-	2.15	-
16	*C. perforatus* Ehrneb.	44.80	12.60	-	56.40	28.45	24.60
17	*C. radiatus* Ehrneb.	-	6.30	34.40	-	10.18	24.60
18	*C. stellaris* Raper.(Gurtel.)	44.80	6.30	-	-	12.78	-
19	*C. suspectus* Jan.	-	6.30	-	-	1.58	-
20	*Diploneis crabro* (Cleve) Var.	-	-	8.60	-	2.15	-
21	*Exuviella (Prorocentrum) marina* Che.	22.40	-	-	-	5.60	-
22	*Gunardia* sp.	-	-	-	-	-	24.60
23	*Hyalodiscus subtilis* Bail.	-	6.30	-	-	1.58	-
24	*H. laevis* Ehr.	22.40	-	34.40	-	14.20	24.60
25	*Leptocylindrus danicus* Cleave.	44.80	25.20	-	-	17.50	24.60
26	*Licmophora dalmatica* var.	-	-	17.20	282.00	74.80	24.60
27	*Melosira moniliformes* (Muller) Agardh.	313.60	126.00	395.60	874.20	427.35	-
28	*M. numuloides* (Dillw.) Agardh .	89.60	44.10	77.40	535.80	186.73	

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Table 67 : (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*Navicula directa* Wm. Sm.	-	-	8.60	-	2.15	-
30	*N. miniscula* Grun.	-	12.60	8.60	-	5.30	-
31	*Nitzschia incerta Grun.*	-	-	-	28.20	7.05	-
32	*N. insignis*	-	-	-	141.00	35.25	-
33	*N. lanceolata*	-	-	-	84.60	21.15	-
34	*N. longissima* (Breb.) Ralfs.	-	6.30	-	28.20	8.63	-
35	*N. lorenziana* Grun.	-	6.30	34.40	112.80	38.38	-
36	*N. obtusa* Var.	-	-	-	84.60	21.15	-
37	*N. seriata* Cleve.	-	-	8.60	-	2.15	24.60
38	*N. sigma* (Kutz) Wm. Sm.	-	12.60	8.60	84.60	26.45	73.80
39	*Noctiluca* miliaris Suriray.	134.40	-	-	-	33.60	-
40	*Pleurosigma affine* Grun.	-	6.30	-	-	1.58	-
41	*P. angulatum* Sm.	-	6.30	8.60	-	3.73	-
42	*P. attenuatum* Var.*scalpurum* Grun.	-	-	17.20	-	4.30	-
43	*P. balticum* var. *wansbeckii* Donk.	-	6.30	8.60	366.60	95.38	-
44	*P. clevi* Grun.	-	-	-	141.00	35.25	-
45	*P. delicatulum* Wm. Sm.	-	-	-	84.60	21.15	-
46	*P. diminutum* Grun.	-	6.30	8.60	56.40	17.83	24.60
47	*P. faciola* Wm. Sm.	-	-	-	28.20	7.05	-
48	*P. formosum* Wm. Sm.(Grun.)	-	-	8.60	-	2.15	-
49	*P. lineari* Grun.	-	-	25.80	-	6.45	-
50	*P. spaciosum* Wm. Sm.	-	-	43.00	112.80	38.95	-
51	*P. spencerii* Wm. Sm.	-	-	17.20	-	4.30	-
52	*P. sulcatum* Grun.	-	-	-	56.40	14.10	-
53	*P. tenuissimum* Sm.	-	37.80	17.20	28.20	20.80	-
54	*Podosira adriatica* K.	-	-	-	28.20	7.05	-
55	*P. argus* Grun.	-	-	8.60	-	2.15	-
56	*Rhoicosigma compactum*	-	-	8.60	-	2.15	-
57	*R. oceanicum* H. P.	-	6.30	17.20	28.20	12.93	-
58	*Staureneis spicula* Hick.	-	-	8.60	56.40	16.25	-
59	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	-	-	-	112.80	28.20	-

Contd..

Table 67:(Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
60	*Surirella brightwelli* Wm. Sm.	-	31.50	-	-	7.88	-
61	*S. gemma* Ehrneb.	-	-	25.80	-	6.45	-
62	*S. intercedens* Var.	-	-	51.60	169.20	55.20	-
63	*S. striatula* Turpin.	-	18.90	189.20	225.60	108.43	-
64	*Synedra longissima* Sm.	-	69.30	51.60	-	30.23	-
65	*Thalassiosira gravida* Cleve.	-	18.90	17.20	-	9.03	-
66	*Thalassiothrix longissima*	492.80	485.10	438.60	451.20	466.93	934.80
67	*Torpedoneis lepidoptera* var. *minor* Cleve.	-	-	17.20	141.00	39.55	-
68	*T. recta* Greg.	-	-	17.20	-	4.30	-
69	*Toxonoidea insignis* Donk.	-	-	17.20	-	4.30	-
	BLUE-GREEN ALGAE & Others	358.40	25.20	-	-	95.90	-
	Total count of Phytoplankton	1881.60	1026.90	1943.60	6824.40	2919.13	1402.20

Table 68: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during February 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	33.60	-	-	-	8.40	-
2	*Amphora costata* Wm. Sm.	16.80	31.20	-	33.60	20.40	-
3	*A. ostrearia* Var.	-	31.20	-	-	7.80	-
4	*Asterionella japonica* Cleve.	16.80	-	-	-	4.20	-
5	*Bacillaria paradoxa* Sm. & Ehrneb.	571.20	561.60	-	-	283.20	-
6	*Biddulphila aurita (Lyngbye)* Breb & Godey.	134.40	-	-	-	33.60	-
7	*B. pulchella* Gray.	-	62.40	-	-	15.60	-
8	*B. rhombus* Ehrneb.	117.60	31.20	-	-	37.20	-
9	*Campylodiscus eximius* Var.	-	-	8.40	-	2.10	-
10	*Coscinodiscus centralis* Ehrneb.	-	31.20	-	-	7.80	-
11	*C. concinnus* Wm. Sm.	16.80	-	-	-	4.20	78.40
12	*C. lineatus* Ehrneb.	16.80	-	-	-	4.20	-
13	*C. perforatus* Ehrneb.	-	-	25.20	134.40	39.90	-
14	*C. radiatus* Ehrneb.	16.80	-	8.40	-	6.30	-
15	*C. stellaris* Raper.(Gurtel.)	-	-	-	-	-	11.20
16	*Ethmodiscus rex* Hand.	-	-	8.40	-	2.10	-
17	*Gunardia flaecida* (Castr.) Perag.	-	-	-	-	-	22.40
18	*Isthmia enervis* Ehrneb.	-	-	-	-	-	11.20
19	*Leptocylindrus danicus* Cleve.	67.20	-	33.60	-	25.20	33.60
20	*Licmophora communis*	16.80	-	-	-	4.20	-
21	*L. crystallina* K.	-	93.60	-	-	23.40	-
22	*L. dalmatica* var.	201.60	62.40	16.80	33.60	78.60	-
23	*Melosira moniliformes* (Muller) Agardh.	268.80	249.60	-	1176.00	423.60	67.20
24	*M. numuloides* (Dillw.) Agardh .	-	-	268.80	1612.80	470.40	179.20
25	*Navicula campylodiscus*	-	-	84.00	-	21.00	-
26	*N. concellata* Donk.	84.00	-	-	-	21.00	-
27	*N. directa* Wm. Sm.	50.40	-	-	-	12.60	-
28	*N. quadratarea* Cleve.	16.80	62.40	-	-	19.80	-

Contd..

Table 68:(Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
		Count (No. x 10^3 m^{-3})					
29	*Nitzschia angularis* var.*affinis G*run.	-	31.20	-	-	7.80	-
30	*N. incerta Grun.*	-	31.20	-	-	7.80	-
31	*N. insignis*	-	-	-	235.20	58.80	-
32	*N. longissima* (Breb.) Ralfs.	-	31.20	8.40	-	9.90	22.40
33	*N. lorenziana* Grun.	33.60	62.40	-	-	24.00	-
34	*N. obtusa* Var.	-	-	-	100.80	25.20	-
35	*N. seriata* Cleve.	-	31.20	33.60	-	16.20	-
36	*N. sigma* (Kutz) Wm. Sm.	16.80	93.60	8.40	33.60	38.10	33.60
37	*N. subtilis* Var.	16.80	-	-	-	4.20	-
38	*Noctiluca* miliaris Suriray.	-	-	25.20	33.60	14.70	11.20
39	*Peridinium ovalum* Shutt.	-	31.20	-	-	7.80	-
40	*P. pentagonum* Gran.	-	31.20	-	-	7.80	-
41	*Pleurosigma angulatum* Sm.	16.80	31.20	-	-	12.00	-
42	*P. attenuatum* Var. *scalpurum* Grun.	-	-	-	100.80	25.20	-
43	*P. balticum* var. *wansbeckii* Donk.	16.80	62.40	-	100.80	45.00	-
44	*P. brebisonii* Grun.	-	-	-	134.40	33.60	-
45	*P. caspidatum* Cleve.	33.60	-	-	-	8.40	-
46	*P. clevi* Grun.	-	-	-	201.60	50.40	-
47	*P. compactum* Grun.	-	-	-	67.20	16.80	-
48	*P. decorum* Sm. (Perag.)	-	-	-	134.40	33.60	-
49	*P. delicatulum* Wm. Sm.	-	-	-	67.20	16.80	-
50	*P. diminutum* Grun.	33.60	-	-	67.20	25.20	-
51	*P. japonica*	-	31.20	-	-	7.80	-
52	*P. lineari* Grun.	-	-	-	168.00	42.00	-
53	*P. majus Grun.*	16.80	-	-	-	4.20	-
54	*P. salinarum* Grun.	-	-	-	33.60	8.40	-
55	*P. spaciosum* Wm. Sm.	-	-	-	33.60	8.40	-
56	*P. spencerii* Wm. Sm.	33.60	62.40	109.20	302.40	126.90	-
57	*P. tenuissimum* Sm.	84.00	31.20	142.80	235.20	123.30	-
58	*Phaeocystis sp.*	-	-	58.80	302.40	90.30	-
59	*Podocystis spathulata* Shadb.	50.40	-	-	-	12.60	-

Contd..

Table 68:(Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
60	*Podosira adriatica* K.	33.60	-	-	33.60	16.80	-
61	*Rhabdonema adriaticum* (Kutz Harv. & Bail) Stodder.	-	-	-	-	-	134.40
62	*Rhoicosigma oceanicum* H. P.	-	-	-	33.60	8.40	-
63	*R. robustum* Grun.	67.20	-	-	-	16.80	-
64	*Staureneis spicula* Hick.	-	-	8.40	-	2.10	-
65	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	67.20	-	-	-	16.80	-
66	*Surirella fastuosa* var. *cuneata* (A.S.) Perag. & Perag.	-	-	33.60	100.80	33.60	-
67	*S. gemma* Ehrneb.	-	31.20	-	-	7.80	-
68	*S. intercedens Grun*.	-	-	33.60	-	8.40	-
69	*S. striatula* Turpin.	168.00	156.00	50.40	235.20	152.40	-
70	*Synedra longissima* Sm.	-	31.20	8.40	67.20	26.70	-
71	*Thalassionema* sp.	-	-	-	33.60	8.40	-
72	*Thalassiosira gravida* Cleve.	-	-	8.40	33.60	10.50	-
73	*Thalassiothrix longissima*	-	-	823.20	1948.80	693.00	436.80
74	*Torpedoneis lepidoptera* var. *minor* Cleve.	-	31.20	-	33.60	16.20	-
	BLUE-GREEN ALGAE & Others	-	-	-	-	-	-
	Total count of Phytoplankton	2335.20	2028.00	1806.00	7862.40	3507.90	1041.60

Table 69: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during April 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Asterionella bleakeleyi Wm. Sm.*	-	-	-	3.12	0.78	-
2	*Bacillaria paradoxa* Sm. & Ehrneb.	-	-	-	81.12	20.28	-
3	*Campylodiscus eximius* Var.	-	-	36.96	-	9.24	-
4	*Coscinodiscus centralis* Ehrneb.	-	-	18.48	-	4.62	-
5	*C. perforatus* Ehrneb.	-	156.80	6.16	12.48	43.86	-
6	*C. radiatus* Ehrneb.	-	-	-	-	-	31.04
7	*C. stellaris* Raper.(Gurtel.)	-	-	-	15.60	3.90	-
8	*Ethmodiscus rex* Hand.	-	78.40	-	-	19.60	31.04
9	*Leptocylindrus danicus* Cleve.	42.24	-	-	-	10.56	-
10	*Licmophora dalmatica* var.	-	-	6.16	-	1.54	-
11	*Melosira moniliformes* (Muller) Agardh.	-	-	-	12.48	3.12	-
12	*Navicula quadratarea* Cleve.	56.32	-	-	-	14.08	-
13	*Nitzschia seriata* Cleve.	-	-	55.44	-	13.86	-
14	*N. sigma* (Kutz) Wm. Sm.	-	-	6.16	-	1.54	31.04
15	*Pleurosigma balticum* var. *wansbeckii* Donk.	14.08	-	-	3.12	4.30	-
16	*P. diminutum* Grun.	14.08	-	-	-	3.52	-
17	*P. distortum* Sm.	14.08	-	-	-	3.52	-
18	*P. faciola* Wm. Sm.	-	-	6.16	-	1.54	-
19	*P. spaciosum* Wm. Sm.	-	-	-	3.12	0.78	-
20	*P. spencerii* Wm. Sm.	14.08	-	-	3.12	4.30	-
21	*P. tenuissimum* Sm.	14.08	-	-	-	3.52	-
22	*Podocystis spathulata* Shadb.	-	-	-	-	-	62.08
23	*Podosira adriatica* K.	-	78.40	6.16	-	21.14	-
24	*Rhoicosigma oceanicum* H. P.	14.08	-	-	-	3.52	-
25	*R. robustum* Grun.	-	-	12.32	-	3.08	-
26	*Rhizosolenia delicatula* Cleve.	-	-	-	-	-	31.04
27	*Surirella striatula* Turpin.	14.08	-	-	3.12	4.30	-

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Table 69 : (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
28	*Synedra crystallina* Var.	-	-	-	6.24	1.56	-
29	*Thalassiosira gravida* Cleve.	-	78.40	-	-	19.60	-
30	*Thalassiothrix longissima*	14.08	470.40	117.04	215.28	204.20	93.12
31	*Triceratium pentacrinum* f. *quardrata* Hust.	-	78.40	-	-	19.60	-
		-	-	-	-	-	-
	BLUE-GREEN ALGAE & Others	-	-	-	-	-	31.04
	Total count of Phytoplankton	211.2	940.8	271.04	358.8	445.46	310.4

Table 70: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during Jun 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	-	-	10.64	2.66	-
2	*A. brevipes* var. *angulata (Grey) Cleve.*	-	-	-	1.52	0.38	-
3	*Coscinodiscus apiculatus* Ehrneb.	-	-	-	-	-	3.28
4	*C. centralis* Ehrneb.	1.92	-	-	1.52	0.86	-
5	*C. concinnus* Wm. Sm.	-	0.96	-	-	0.24	-
6	*C. perforatus* Ehrneb.	-	-	107.92	3.04	27.74	3.28
7	*C. stellaris* Raper.	-	-	-	3.04	0.76	3.28
8	*Ethmodiscus rex* Hendey.	-	-	-	-	-	3.28
9	*Leptocylindrus danicus* Cleave.	2.88	-	36.92	3.04	10.71	-
10	*Licmophora dalmatica* var.	-	-	-	1.52	0.38	-
11	*L. crystalina* K.	-	-	-	9.12	2.28	-
12	*Melosira moniliformes* (Muller) Agardh.	-	-	-	9.12	2.28	-
13	*Navicula directa* Wm. Sm.	-	-	-	4.56	1.14	-
14	*Nitzschia longissima* (Breb.) Ralfs.	2.88	-	-	-	0.72	-
15	*N. obtusa* Var.	-	-	-	1.52	0.38	-
16	*Noctiluca* miliaris Suriray.	-	10.56	-	-	2.64	-
17	*Pleurosigma affine* Grun.	11.52	-	-	-	2.88	-
18	*P. decorum* Sm.	-	-	-	10.64	2.66	-
19	*P. scalproides* Rab.	-	-	-	3.04	0.76	-
20	*P. tennuissimum*	-	-	-	3.04	0.76	-
21	*Podocystis adriatica* Kuetz..	-	-	-	-	-	3.28
22	*P. spathulata* shadb.	-	-	-	-	-	3.28
23	*Rhabdonema adriaticum* Kuetz.,	-	-	22.72	-	5.68	-
24	*Scoliopleura latestriata*Breb.	-	-	-	1.52	0.38	-
25	*Staureneis spicula* Hick.	-	-	-	30.40	7.60	-
26	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	-	-	-	6.08	1.52	-
27	*Surirella striatula* Turpin.	0.96	0.96	-	-	0.48	-
28	*Thalassiothrix longissima*	49.92	42.24	22.72	13.68	32.14	26.24
29	*T. nitzschioides*	-	-	-	3.04	0.76	-
	BLUE-GREEN ALGAE & Others	-	-	-	-	-	-
	Total count of Phytoplankton	70.08	54.72	190.28	120.08	108.79	45.92

Table 71: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during August 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	43.68	-	-	-	10.92	-
2	*A. brevipes* var. *angulata (Grey.) Cleve.*	-	-	-	3.08	0.77	-
3	*Amphora costata* Wm. Sm.	-	-	15.52	3.08	4.65	-
4	*Bacillaria paradoxa* Sm. & Ehrneb.	-	-	-	231.00	57.75	-
5	*Biddulphia (Odontella) mobiliensis* (Bailey) Grun.	-	-	-	-	-	13.28
6	*Campylodiscus echeneis* Ehrneb.	3.36	-	-	-	0.84	-
7	*Ceratium fusus*	10.08	-	-	-	2.52	-
8	*C. lineatum* (Ehrneb) Cleve.	-	-	-	-	-	9.96
9	*C. longipes* Gran.	3.36	-	-	-	0.84	-
10	*Coscinodiscus apiculatus* Ehrneb.	-	4.24	3.88	-	2.03	-
11	*C. centralis* Ehrneb.	6.72	12.72	-	-	4.86	-
12	*C. concinnus* Wm. Sm.	3.36	-	7.76	-	2.78	-
13	*C. excentricus* Ehrneb.	3.36	4.24	3.88	-	2.87	6.64
14	*C. perforatus* Ehrneb.	6.72	12.72	7.76	6.16	8.34	3.32
15	*C. radiatus* Ehrneb.	-	-	-	-	-	3.32
16	*C. stellaris* Raper.(Gurtel.)	13.44	4.24	19.40	3.08	10.04	-
17	*C. subtilis* Ehrneb.	-	-	-	3.08	0.77	-
18	*Cyamatopleura solea*Breb.	3.36	-	-	-	0.84	-
19	*Gyrosigma balticum* Ehrneb.	-	-	-	3.08	0.77	-
20	*Leptocylindrus danicus* Cleave.	-	-	7.76	-	1.94	-
21	*Licmophora dalmatica* var.	-	-	7.76	6.16	3.48	-
22	*Melosira moniliformes* (Muller) Agardh.	10.08	271.36	-	545.16	206.65	-
23	*M. numuloides* (Dillw.) Agardh .	16.80	76.32	-	348.04	110.29	-
24	*Navicula clavata* var.	-	-	3.88	3.08	1.74	-
25	*N. directa* Wm. Sm.	-	-	58.20	3.08	15.32	-
26	*N. miniscula* Grun.	3.36	4.24	31.04	9.24	11.97	-
27	*Nitzschia Commutata* Grun.	-	-	-	3.08	0.77	-

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Table 71: (Contd…)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
28	*N. incurvata*Grun.	-	4.24	-	3.08	1.83	-
29	*N. incerta*Grun.	-	4.24	-	-	1.06	-
30	*N. insignis*	-	-	-	6.16	1.54	-
31	*N. longissima*	-	8.48	-	3.08	2.89	-
32	*N. lorenziana*	-	21.20	3.88	12.32	9.35	-
33	*N. seriata* Cleve.	-	-	-	9.24	2.31	-
34	*N. valida* Grun.	-	-	-	3.08	0.77	-
35	*Noctiluca* miliaris Suriray.	6.72	-	-	3.08	2.45	-
36	*Pleurosigma accutum* Norm.	-	-	-	9.24	2.31	-
37	*P. balticum* var. *wansbeckii* Donk.	-	-	15.52	-	3.88	-
38	*P. decorum* Sm. (Perag.)	-	-	-	12.32	3.08	-
39	*P. diminutum* Grun.	-	-	-	6.16	1.54	-
40	*P. formosum* Wm. Sm.(Grun.)	23.52	8.48	3.88	9.24	11.28	-
41	*P. lineari* Grun.	-	-	7.76	-	1.94	-
42	*P. spaciosum* Wm. Sm.	-	-	-	6.16	1.54	-
43	*P. spencerii* Wm. Sm.	-	-	-	6.16	1.54	-
44	*P. tenuissimum* Sm.	-	4.24	-	12.32	4.14	-
45	*Podocystis spathulata*	-	-	46.56	6.16	13.18	-
46	*Rhoicosigma angularis*	-	8.48	-	9.24	4.43	-
47	*R. oceanicum*	-	-	3.88	6.16	2.51	-
48	*R. robustum* Grun.	-	-	3.88	6.16	2.51	-
49	*Staureneis spicula* Hick.	-	-	3.88	-	0.97	-
50	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	-	8.48	42.68	80.08	32.81	-
51	*Surirella striatula* Turpin.	-	21.20	7.76	104.72	33.42	-
52	*Synedra gigantea* Lab.	-	8.48	-	70.84	19.83	-
53	*Thalassiosira gravida* Cleve.	3.36	16.96	7.76	-	7.02	16.60
54	*Thalassiothrix longissima*	63.84	139.92	104.76	-	77.13	-
55	*Toxonoidea insignis* Donk.	3.36	-	3.88	21.56	7.20	-
	BLUE-GREEN ALGAE & Others	-	-	-	-	-	-
	Total count of Phytoplankton	228.48	644.48	422.92	1577	718.21	53.12

Table 72: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during October 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	-	-	-	14.08	3.52	-
2	*Amphora turgida* Greg.	56.40	-	-	-	14.10	-
3	*Asterionella bleakleyi* Sm.	150.40	-	-	-	37.60	13.24
4	*Biddulphia aurita (Lyngbye)* Breb & Godey.	-	-	-	-	-	26.48
5	*B. mobiliensis* (Bailey) Grun.	-	-	-	-	-	39.72
6	*B. sinensis* Greville.(Dead)	18.80	-	-	-	4.70	13.24
7	*Chaetoceros curvisetus* Cleve.	150.40	-	-	-	37.60	-
8	*Coscinodiscus centralis* Ehrneb.	56.40	-	-	-	14.10	-
9	*C. concinnus* Wm. Sm.	37.60	54.00	40.80	-	33.10	-
10	*C. janischii* A. S.	-	-	-	56.32	14.08	-
11	*C. perforatus* Ehrneb.	244.40	198.00	20.40	-	115.70	172.12
12	*C. stellaris* Raper.(Gurtel.)	18.80	-	13.60	-	8.10	-
13	*Cyamatopleura* sp.	-	-	-	21.12	5.28	-
14	*Dictyoneis marginata*	-	-	-	7.04	1.76	-
15	*Gyrosigma balticum* Ehrneb.	18.80	-	-	14.08	8.22	-
16	*Hyalodiscus laevis* Ehrneb.	-	-	-	7.04	1.76	-
17	*Leptocylindrus danicus* Cleave.	-	-	-	-	-	13.24
18	*Licmophora communis*	56.40	-	-	-	14.10	-
19	*L. dalmatica* var.	75.20	-	-	7.04	20.56	-
20	*Melosira moniliformes* (Muller) Agardh.	-	216.00	306.00	344.96	216.74	-
21	*M. numuloides* (Dillw.) Agardh .	-	144.00	-	197.12	85.28	-
22	*Nitzschia incurvata*	18.80	-	-	7.04	6.46	-
23	*N. insignis*	-	-	-	14.08	3.52	-
24	*N. obtusa* Var.	-	-	-	-	-	13.24
25	*N. striata* Cleve.	18.80	-	-	-	4.70	-
26	*Noctiluca* miliaris Suriray.	37.60	-	-	-	9.40	-
27	*Peridinium thorianum* Paulsen.	-	-	13.60	-	3.40	-
28	*Pleurosigma attenuatum* Var. *scalpurum* Grun.	-	-	6.80	7.04	3.46	-

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Table 72:(Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*P. compactum* Grun.	-	-	-	7.04	1.76	-
30	*P. decorum* Sm. (Perag.)	-	-	-	7.04	1.76	-
31	*P. diminutum* Grun.	-	-	-	21.12	5.28	-
32	*P. latum* Cleve.	-	-	-	7.04	1.76	-
33	*P. longum* var. *lanceolata* Perag.	-	-	-	28.16	8.74	-
34	*P. spaciosum* Wm. Sm.	-	-	-	7.04	1.76	-
35	*P. spencerii* Wm. Sm.	-	-	-	28.16	7.04	13.24
36	*P. tenuissimum* Sm.	-	-	-	7.04	1.76	13.24
37	*Rhoicosigma robustum* Grun.	-	-	-	7.04	1.76	-
38	*Surirella brightwelli* Wm. Sm.	37.60	-	6.80	-	11.10	-
39	*S. intercedens* Var.	-	-	-	-	-	13.24
40	*S. striatula* Turpin.	37.60	-	13.60	-	12.80	-
41	*Thalassiosira gravida* Cleve.	-	-	6.80	21.12	6.98	52.96
42	*Thalassiothrix longissima*	319.60	576.00	136.00	168.96	300.14	13.24
	BLUE-GREEN ALGAE & Others	-	-	-	-	-	-
	Total count of Phytoplankton	1353.60	1188.00	564.40	1006.72	1029.88	397.20

Table 73: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during December 2002.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Acantheses brevipes* Agardh.	26.64	125.4	-	237.6	97.41	-
2	*Amphora costata* Wm. Sm.	-	-	-	475.2	118.80	-
3	*Bacillaria paradoxa* Sm. & Ehrneb.	53.28	91.2	21.5	1267.2	358.30	-
4	*Biddulphia mobiliensis* (Bailey) Grun.	8.88	-	-	79.2	22.02	-
5	*Chaetoceros javanicum* Cleve.	-	-	-	2772.0	693.00	-
6	*Coscinodiscus concinnus*Wm. Sm.	4.44	45.6	107.5	-	39.39	92.80
7	*C. janischii* A.S.	4.44	-	-	-	1.11	-
8	*C. perforatus* Ehrneb.	53.28	22.8	129.0	79.2	71.07	580.00
9	*C. radiatus* Ehrneb.	8.88	-	21.5	-	7.60	185.60
10	*C. stellaris* Raper.(Gurtel.)	8.88	-	-	-	2.22	-
11	*Hyalodiscus laevis* Ehr.	-	57.0	-	-	14.25	-
12	*Leptocylindrus danicus* Cleave.	-	22.8	-	1425.6	362.10	185.60
13	*Licmophora dalmatica* var.	13.32	22.8	-	237.6	68.43	-
14	*Melosira moniliformes* (Muller) Agardh.	35.52	136.8	258.0	15444.0	3968.58	-
15	*(Syn.M. borreri Grev.)*	-	-	-	-	-	-
16	*M. numuloides* (Dillw.) Agardh .	-	22.8	-	4514.4	1134.30	-
17	*Navicula directa* Wm. Sm.	-	-	-	79.2	19.80	23.20
18	*Nitzschia incuvata* Grun.	-	-	21.5	-	5.38	-
19	*N. lorenziana* Grun.	-	11.4	-	-	2.85	-
20	*N. obtusa* Var.	-	-	21.5	-	5.38	-
21	*N. seriata* Cleve.	4.44	22.8	-	-	6.81	-
22	*N. sigma* (Kutz) Wm. Sm.	-	-	21.5	79.2	25.18	-
23	*Pleurosigma angulatum* Sm.	-	11.4	-	-	2.85	-
24	*P. attenuatum* Var. *scalpurum* Grun.	-	-	21.5	-	5.38	-
25	*P. balticum* var. *wansbeckii* Donk.	-	250.8	193.5	237.6	170.48	-
26	*P. diminutum* Grun.	-	34.2	43.0	79.2	39.10	-
27	*P. lineari* Grun.	-	-	-	79.2	19.80	-
28	*P. spaciosum* Wm. Sm.	4.44	102.6	86.0	79.2	68.06	-

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Table 73: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*P. spencerii* Wm. Sm.	-	11.4	-	-	2.85	-
30	*P. tenuissimum* Sm.	-	-	21.5	633.6	163.78	-
31	*Rhoicosigma oceanicum* H. P.	4.44	-	-	158.4	40.71	-
32	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	93.24	148.2	322.5	1425.6	497.39	-
33	*Surirella brightwelli* Wm. Sm.	4.44	22.8	21.5	-	12.19	-
34	*S. gemma* Ehrneb.	4.44	11.4	-	-	3.96	-
35	*S. intercedens* Var.	-	22.8	43.0	-	16.45	-
36	*S. striatula* Turpin.	13.32	22.8	279.5	1029.6	336.31	-
37	*Synedra longissima* Sm.	-	-	-	712.8	178.20	-
38	*Thalassiothrix longissima*	239.76	456.0	1483.5	3722.4	1475.42	533.60
39	*Torpedoneis lepidoptera* var. *minor* Cleve.	-	-	-	396.0	99.00	-
40	*Toxonoidea insignis* Donk.	-	-	21.5	-	5.38	-
	BLUE-GREEN ALGAE & Others	-	102.6	365.5	-	117.03	-
	Total count of Phytoplankton	586.08	1778.40	3504.50	35244.00	10278.25	1600.80

Table 74: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during February 2003.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Actinocyclus confluens* Grun.	-	-	-	-	-	13.76
2	*A. spiralis* Perag.	-	-	-	-	-	13.76
3	*Amphiprora gigantea* var. *sulcata* Cleve.	-	21.40	-	-	5.35	-
4	*Amphora laevissima* Greg.	32.64	-	-	-	8.16	-
5	*Bacillaria paradoxa* Sm. & Ehrneb.	-	-	440.96	390.32	207.82	-
6	*Biddulphia reticulata*Roper.	-	21.40	-	-	5.35	-
7	*Caloneis linearis* (Grun) Boyer.	-	-	-	-	-	13.76
8	*Campylodiscus limbatus* Breb.	-	-	-	-	-	13.76
9	*C. triamphans* Schimdt.	-	-	-	-	-	13.76
10	*Coscinodiscus argus* Ehrneb.	-	21.40	-	-	5.35	-
11	*C. asterophalus* Ehrneb.	-	-	-	27.88	6.97	-
12	*C. biangulatus* Schmidt.	-	-	-	27.88	6.97	-
13	*C. conciniformes* Simonsen.	-	-	-	-	-	13.76
14	*C. concinnus* Wm. Sm.	65.28	21.40	55.12	-	35.45	13.76
15	*C. coscinodiscus* Ehrneb.	-	-	-	-	-	13.76
16	*C. gigus* Ehrneb.	-	-	27.56	-	6.89	-
17	*C. granii* Gouch.	32.64	-	-	-	8.16	-
18	*C. oculusiridis* Ehrneb.	-	-	-	-	-	13.76
19	*C. perforatus* Ehrneb.	65.28	321.00	220.48	139.40	186.54	41.28
20	*C. radiatus* Ehrneb.	-	42.80	27.56	-	17.59	41.28
21	*C. stellaris* Raper.(Gurtel.)	-	85.60	82.68	55.76	56.01	-
22	*Cyamatonitzschia marina* (Lewis) Simonsen.	-	-	-	-	-	13.76
23	*Grammatophora longissima* Petit.	-	-	-	-	-	13.76
24	*Hyalodiscus nobilis* Pant.	32.64	-	-	-	8.16	-
25	*H. subtilis* Bail.	-	-	27.56	-	6.89	-
26	*Leptocylindrus danicus* Cleve.	-	-	-	-	-	13.76
27	*Licmophora dalmatica* var.	-	-	-	-	-	13.76
28	*Melosira moniliformes* (Muller) Agardh.	-	-	-	390.32	97.58	41.28

Contd..

Table 74: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*M. numuloides* (Dillw.) Agardh .	-	-	-	111.52	27.88	-
30	*Nitzschia incurvata*	-	42.80	27.56	27.88	24.56	-
31	*N. lorenziana* Grun.	-	-	27.56	-	6.89	-
32	*N. panduriformes* Greg.	-	21.40	-	-	5.35	-
33	*N. seriata* Cleve.	-	-	-	55.76	13.94	-
34	*Peridinium depressum* Bailey.	32.64	-	-	-	8.16	-
35	*Pinnularia braunii* Husted.	-	-	-	-	-	13.76
36	*Pleurosigma attenuatum* Var. *scalpurum* Grun.	-	64.20	-	-	16.05	-
37	*P. lineari* Grun.	-	-	-	55.76	13.94	-
38	*P. rigidum* Wm. Sm.	-	-	27.56	-	6.89	-
39	*P. spencerii* Wm. Sm.	97.92	85.60	137.80	83.64	101.24	27.52
40	*P. tenuissimum* Sm.	-	64.20	27.56	27.88	29.91	-
41	*Pseudopodosira westii* (Wm. Sm.) Sheshukov.	-	-	-	-	-	13.76
42	*Pyxidicula reniformes* Desik & Ranjitha.	-	-	-	-	-	13.76
43	*Rhabdonema punctatum* (Harb & Bail) Stodder.		85.60	-	-	21.40	-
44	*Stephanopyxis turris* (Grev. & Arnot.) Ralfs.	-	-	165.36	-	41.34	-
45	*Surirella striatula* Turpin.	-	-	-	278.80	69.70	-
46	*Synedra longissima* Sm.	32.64	-	-	-	8.16	-
47	*Thalassiosira gravida* Cleve.	65.28	-	-	-	16.32	13.76
48	*Thalassiothrix longissima*	391.68	1005.80	413.40	167.28	494.54	55.04
49	*Trachyneis antillarum* (Cl. & Grun) Cleve.	-	-	-	-	-	13.76
50	*Triceratium pentacrinus f. Quadrata.* Hust.	-	-	-	-	-	13.76
		-	-	-	-	-	-
	BLUE-GREEN ALGAE & Others	620.16	-	192.92	167.28	245.09	27.52
	Total count of Phytoplankton	1468.80	1904.60	1901.64	2007.36	1820.60	495.36

Table 75: Qualitative and Quantitative abundances of Marine Phytoplankton at the coastal area of Alang Ship breaking Yard and Mahuva during April 2003.

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
1	*Actinocyclus pruniosus* Castr.	-	-	-	-	-	24.00
2	*Biddulphia biddulphiana* (Sm) Boyer.	18.00	-	-	-	4.50	-
3	*Campylodiscus gravilli (*Wm. Smith.) Grun.	-	-	-	-	-	24.00
4	*C. latus* Shadbolt.	-	-	-	-	-	24.00
5	*Ceratium furca* Ehrneb.	-	-	-	-	-	24.00
6	*Coscinodiscus centralis* Ehrneb.	-	23.04	-	-	5.76	24.00
7	*C. concinnus*	18.00	-	-	24.96	10.74	24.00
8	*C. jonesianus* (Grev.) Ostenfeld.	-	-	18.48	-	4.62	-
9	*C. Kruzii* Grun.	18.00	-	-	-	4.50	-
10	*C. perforatus* Ehrneb.	18.00	138.24	73.92	74.88	76.26	24.00
11	*C. radiatus* Ehrneb.	-	-	18.48	49.92	17.10	24.00
12	*C. stellaris* Raper.(Gurtel.)	-	23.04	-	-	5.76	24.00
13	*Diploneis smithi* (Brev) Cleve.	-	-	-	-	-	24.00
14	*Dytillum brighwelli* (West) Grun.	-	-	-	-	-	24.00
15	*Licmophora dalmatica* var.	18.00	-	-	-	4.50	-
16	*Melosira moniliformes* (Muller) Agardh.	486.00	-	-	-	121.50	-
17	*Navicula dersa f. delicatula* Hemidal.	18.00	-	-	-	4.50	-
18	*Nitzschia longissima* (Breb) Ralfs.	-	-	55.44	49.92	26.34	-
19	*N. seriata* Cleve.	18.00	-	-	-	4.50	-
20	*N. sigma* (Kutz) Wm. Sm.	-	23.04	18.48	-	10.38	-
21	*N. sigmoidea* (Nitz.) Wm. Sm.	-	23.04	-	-	5.76	-
22	*Pleurosigma angulatum*	-	-	-	49.92	12.48	-
23	*P. balticum* var. *wansbeckii* Donk.	-	-	-	24.96	6.24	-
24	*P. diminutum* Grun.	18.00	-	-	-	4.50	24.00
25	*P. distortum* Sm.	18.00	-	-	-	4.50	-
26	*P. faciola* Wm. Sm.	18.00	23.04	-	-	10.26	-
27	*P. lineari*	-	46.08	-	24.96	17.76	-
28	*P. spaciosum* Wm. Sm.	-	-	18.48	74.88	23.34	-

Contd..

Table 75: (Contd..)

No.	Name of the Phytoplankton	Alang Ship Breaking Yard					Mahuva
		SA1	SA2	SA3	SA4	Average	SMc
		Count (No. x 10^3 m^{-3})					
29	*P. spencerii* Wm. Sm.	-	23.04	18.48	49.92	22.86	-
30	*P. tenuissimum* Sm.	-	23.04	55.44	74.88	38.34	-
31	*Podocystis spathulata* shadb.	-	-	18.48	-	4.62	-
32	*Podosira adriatica* K.	-	-	18.48	-	4.62	-
33	*Pseudoaulacodiscus petitii* L-F.	-	-	-	-	-	24.00
34	*Rhoicosigma oceanicum* H. P.	-	23.04	-	49.92	18.24	-
35	*R. robustum* Grun.	36.00	-	-	74.88	27.72	24.00
36	*Rhizosolenia delicatula* Cleve.	-	-	-	-	-	24.00
37	*Skeletonema costatum*	432.00	-	-	-	108.00	-
38	*Surirella striatula* Turpin.	108.00	-	18.48	49.92	44.10	-
39	*Synedra fulgens* (Grev.) Wm. Sm.	-	-	18.48	-	4.62	-
40	*Thalassiosira gravida* Cleve.	-	46.08	18.48	-	16.14	-
41	*T. leptopus* Grun.	-	-	-	24.96	6.24	-
42	*Thalassiothrix longissima*	108.00	552.96	665.28	2246.40	893.16	96.00
43	*Toxonoidea insignis*	18.00	-	-	-	4.50	-
44	*Triceratium broeckii* Leuduger & Fortmorel.	-	-	-	-	-	24.00
45	*T. pentacrinum* f. *quardrata* Hust.	-	-	-	-	-	24.00
	BLUE-GREEN ALGAE & Others	90.00	506.88	1681.68	1173.12	862.92	192.00
	Total count of Phytoplankton	1458.00	1474.56	2716.56	4118.40	2441.88	696.00

Table 76: Generic abundances of marine phytoplankton in the coastal area of Alang ship breaking yard Mahuva.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Common**	**SMc**
Jun-01	20	20	12	13	16	39	14
Aug-01	11	16	19	17	16	26	14
Oct-01	17	14	8	11	13	26	16
Dec-01	10	13	19	15	14	29	11
Feb-02	17	13	16	16	16	28	9
Apr-02	6	6	8	9	7	18	6
Jun-02	6	4	4	12	7	15	4
Aug-02	12	11	15	17	14	24	4
Oct-02	11	3	6	13	8	20	9
Dec-02	12	12	9	18	13	21	4
Feb-03	8	7	7	7	7	16	17
Apr-03	11	6	9	7	8	15	12

Table 77: Species abundances of marine phytoplankton in the coastal area of Alang ship breaking yard Mahuva.

	Alang Ship Breaking Yard						Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**Common**	**SMc**
Jun-01	36	30	18	20	26	70	14
Aug-01	22	36	34	35	32	66	22
Oct-01	34	31	12	24	25	65	24
Dec-01	12	26	40	31	27	68	14
Feb-02	31	27	22	32	28	70	12
Apr-02	10	6	10	12	10	29	7
Jun-02	6	4	4	19	8	25	7
Aug-02	18	20	24	36	25	52	6
Oct-02	17	5	10	23	14	38	12
Dec-02	18	22	19	23	21	39	6
Feb-03	10	14	14	14	13	22	24
Apr-03	16	12	14	15	14	28	18

Table 78: Total count of marine phytoplankton in the coastal area of Alang ship breaking yard Mahuva.

	Alang Ship Breaking Yard					Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
	Count (No. x 10 ^{3} m $^{-3}$)					
Jun-01	168.0	182.9	138.8	186.2	169.0	48.7
Aug-01	517.4	1327.1	993.3	1022.6	999.0	644.1
Oct-01	5109.2	775.0	475.2	2110.5	2117.6	1689.2
Dec-01	1882.0	1027.0	1944.0	6824.4	2919.0	1402.2
Feb-02	2335.2	2028.0	1806.0	7862.4	3507.9	1041.6
Apr-02	211.2	940.8	271.0	371.3	448.6	310.4
Jun-02	70.1	54.7	190.3	120.1	108.8	45.9
Aug-02	228.5	644.5	422.9	1577.0	718.2	53.1
Oct-02	1354.0	1188.0	564.4	1007.0	1029.9	397.2
Dec-02	586.1	1178.4	3504.5	35244.0	10278.3	1600.8
Feb-03	1469.0	1904.6	1902.0	2007.0	1734.0	495.0
Apr-03	1458.0	1475.0	2716.6	4118.4	2407.0	696.0

Table 79: Indices of dominances of marine phytoplankton in the coastal area of Alang ship breaking yard Mahuva.

	Alang Ship Breaking Yard					Mahuva
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
Jun-01	0.07	0.24	0.16	0.14	0.08	0.13
Aug-01	0.10	0.07	0.11	0.09	0.05	0.28
Oct-01	0.08	0.09	0.18	0.08	0.05	0.28
Dec-01	0.13	0.25	0.11	0.13	0.09	0.46
Feb-02	0.10	0.11	0.25	0.13	0.09	0.24
Apr-02	0.15	0.31	0.26	0.42	0.23	0.17
Jun-02	0.39	0.64	0.05	0.14	0.06	0.98
Aug-02	0.00	0.17	0.92	0.16	0.02	0.00
Oct-02	0.13	0.31	0.36	0.19	0.15	0.23
Dec-02	0.22	0.11	0.21	0.23	0.19	0.27
Feb-03	0.08	0.27	0.13	0.11	0.11	0.05
Apr-03	0.21	0.15	0.06	0.30	0.14	0.04

Table 80: Shannon weaver indices of species diversity of marine phytoplankton in the coastal area of Alang ship breaking yard Mahuva.

	Alang Ship Breaking Yard					**Mahuva**
	SA1	**SA2**	**SA3**	**SA4**	**Average**	**SMc**
Jun-01	1.30	0.99	0.91	1.02	1.40	0.96
Aug-01	1.13	1.27	1.19	1.42	1.37	0.84
Oct-01	4.74	1.28	0.88	0.12	1.62	0.94
Dec-01	0.76	0.89	1.20	1.15	1.28	0.62
Feb-02	1.22	1.20	0.88	1.11	1.36	0.80
Apr-02	0.92	0.64	0.74	0.56	0.96	0.70
Jun-02	0.42	0.29	0.50	1.10	0.97	0.63
Aug-02	0.11	0.77	1.04	0.87	0.57	0.07
Oct-02	0.92	0.59	1.56	0.93	2.62	3.47
Dec-02	0.88	1.04	0.80	0.88	0.95	0.63
Feb-03	0.60	0.72	0.86	0.93	1.00	1.02
Apr-03	0.78	0.58	0.41	0.46	0.67	0.98

Figure 14: No. of generic abundances marine phytoplankton in the coastal area of Alang ship breaking yard (Common) and Mahuva.

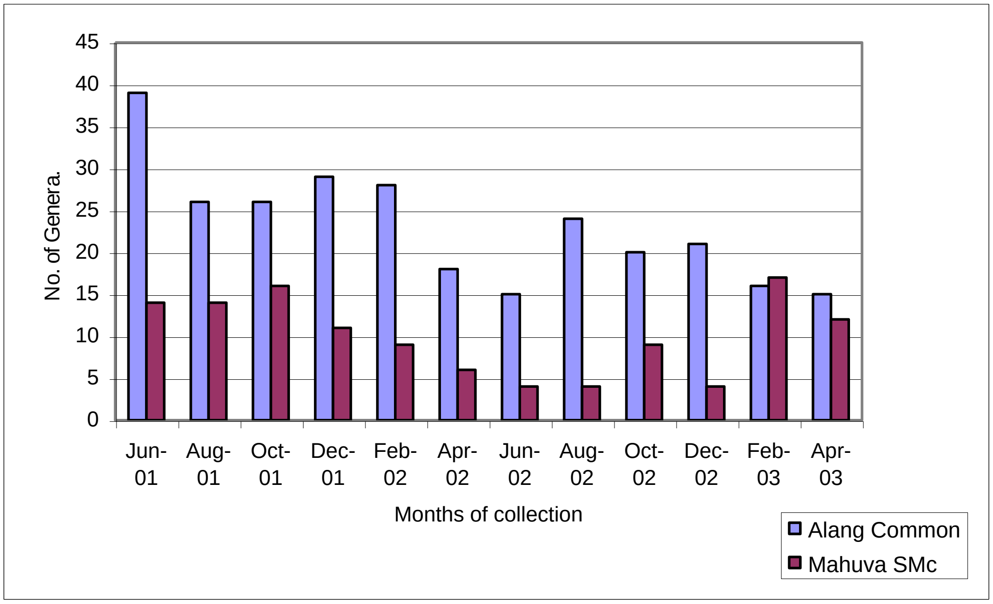


Figure 15: Total count of marine phytoplankton in the coastal area of Alang ship breaking yard (Average) and Mahuva.

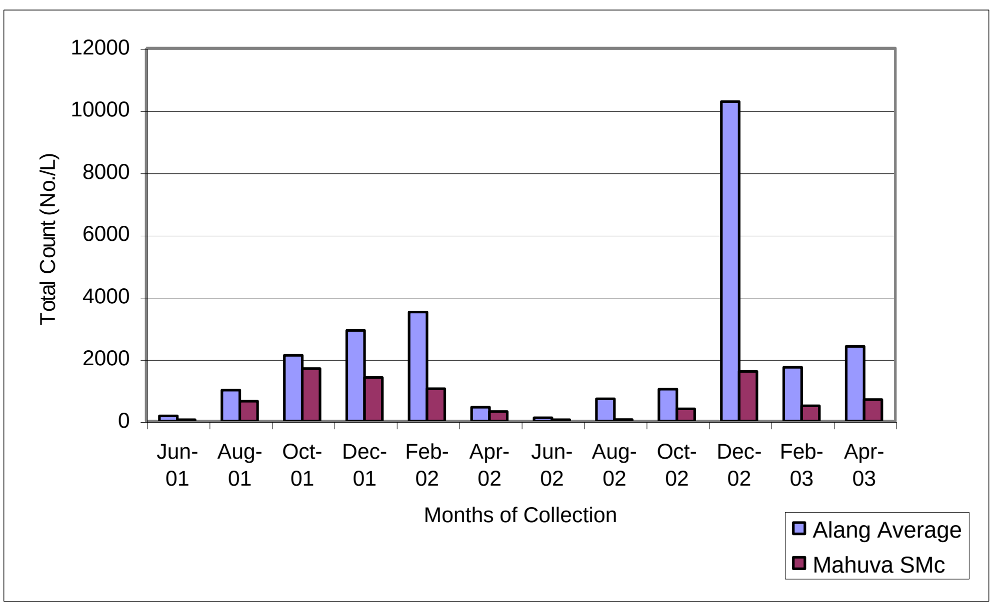


Plate : VIII

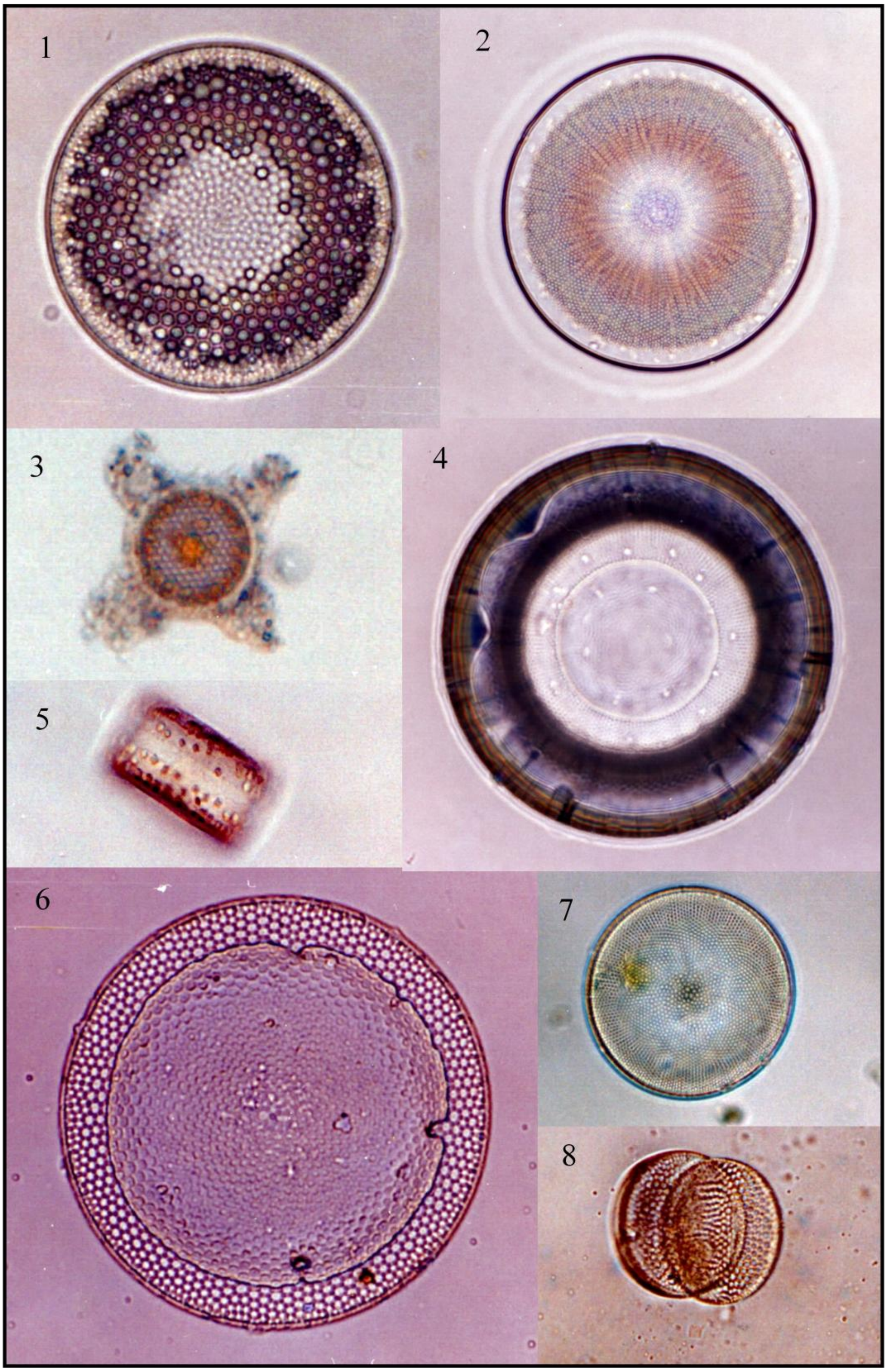


Plate : IX

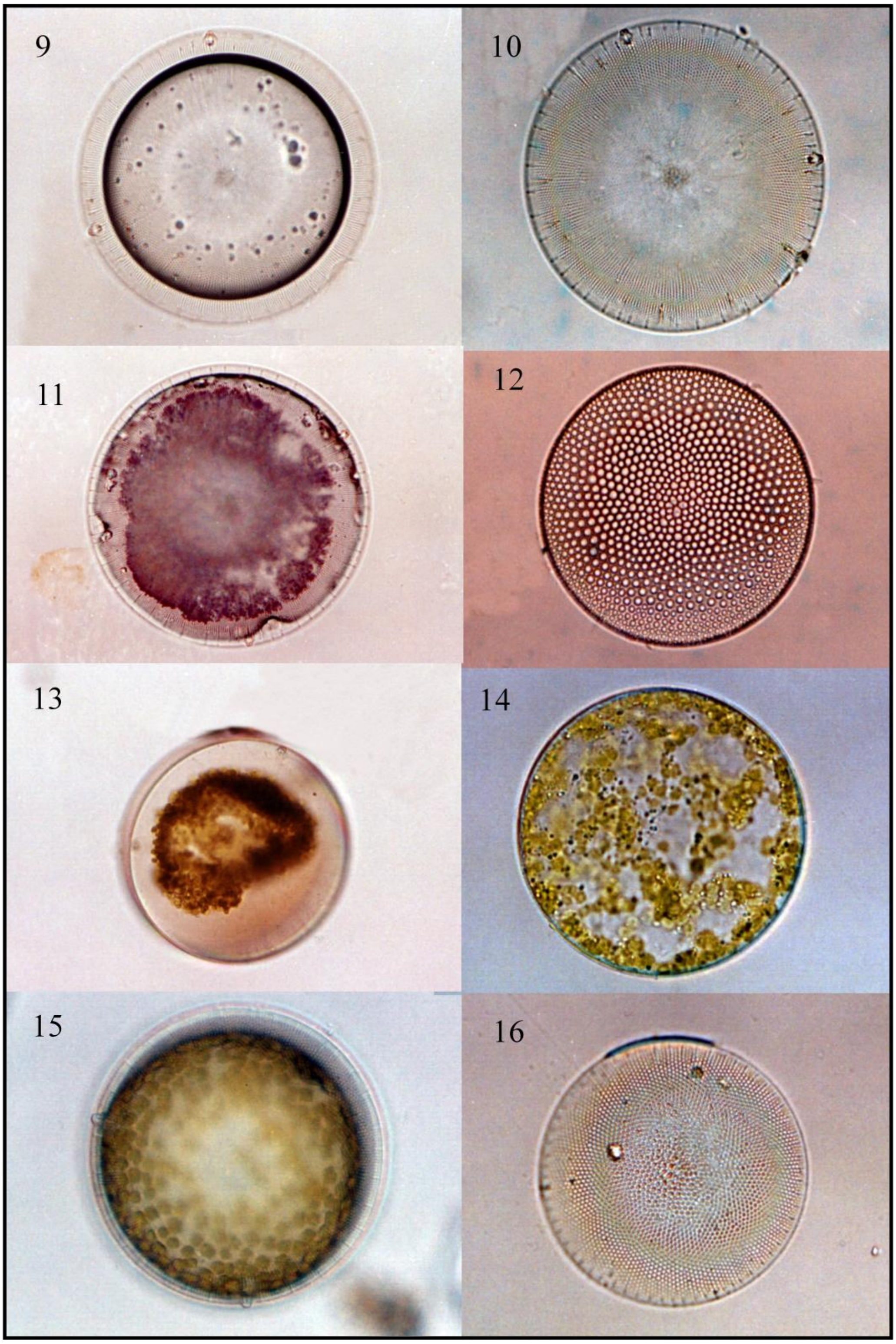


Plate : X

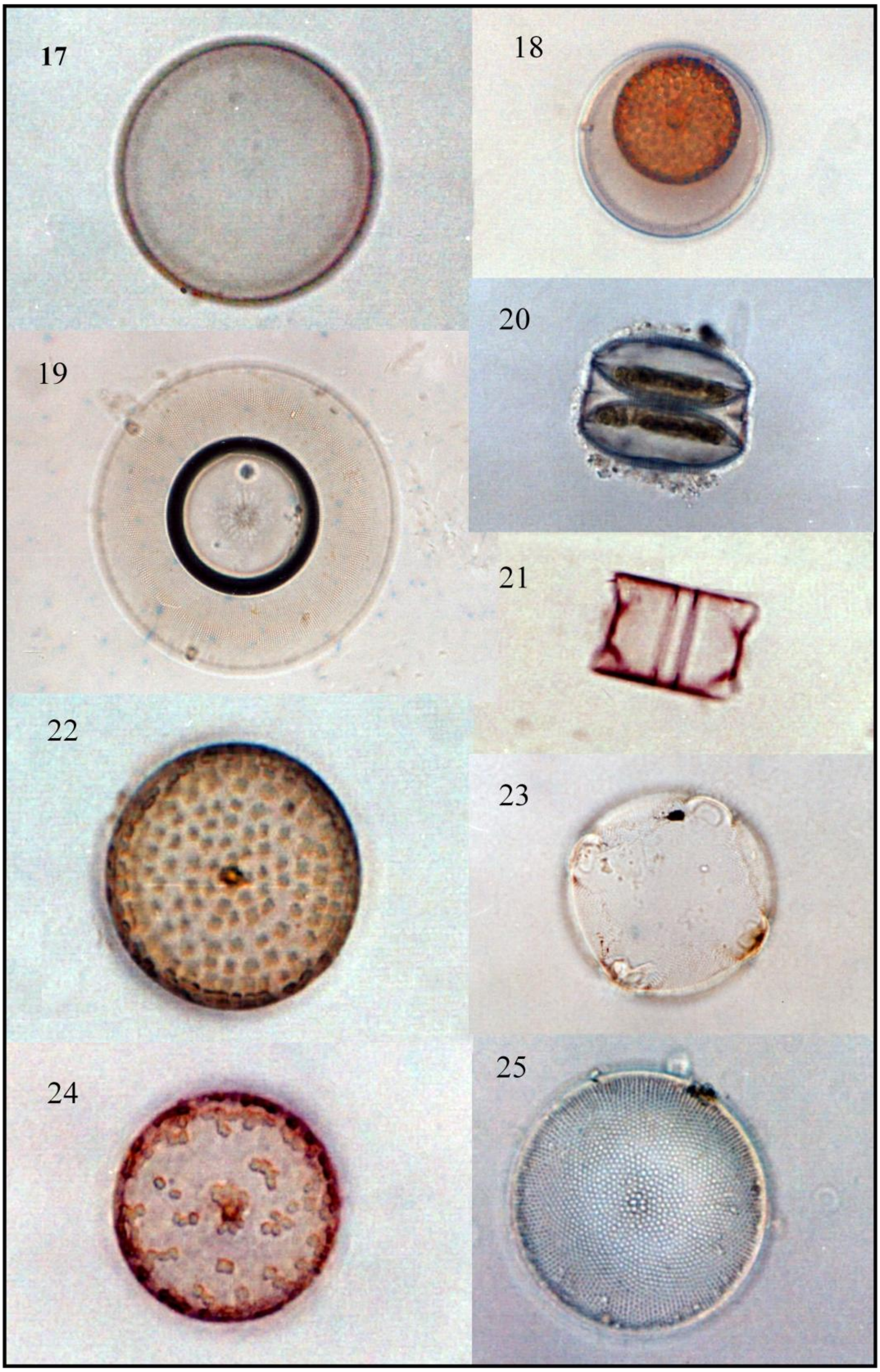


Plate : XI

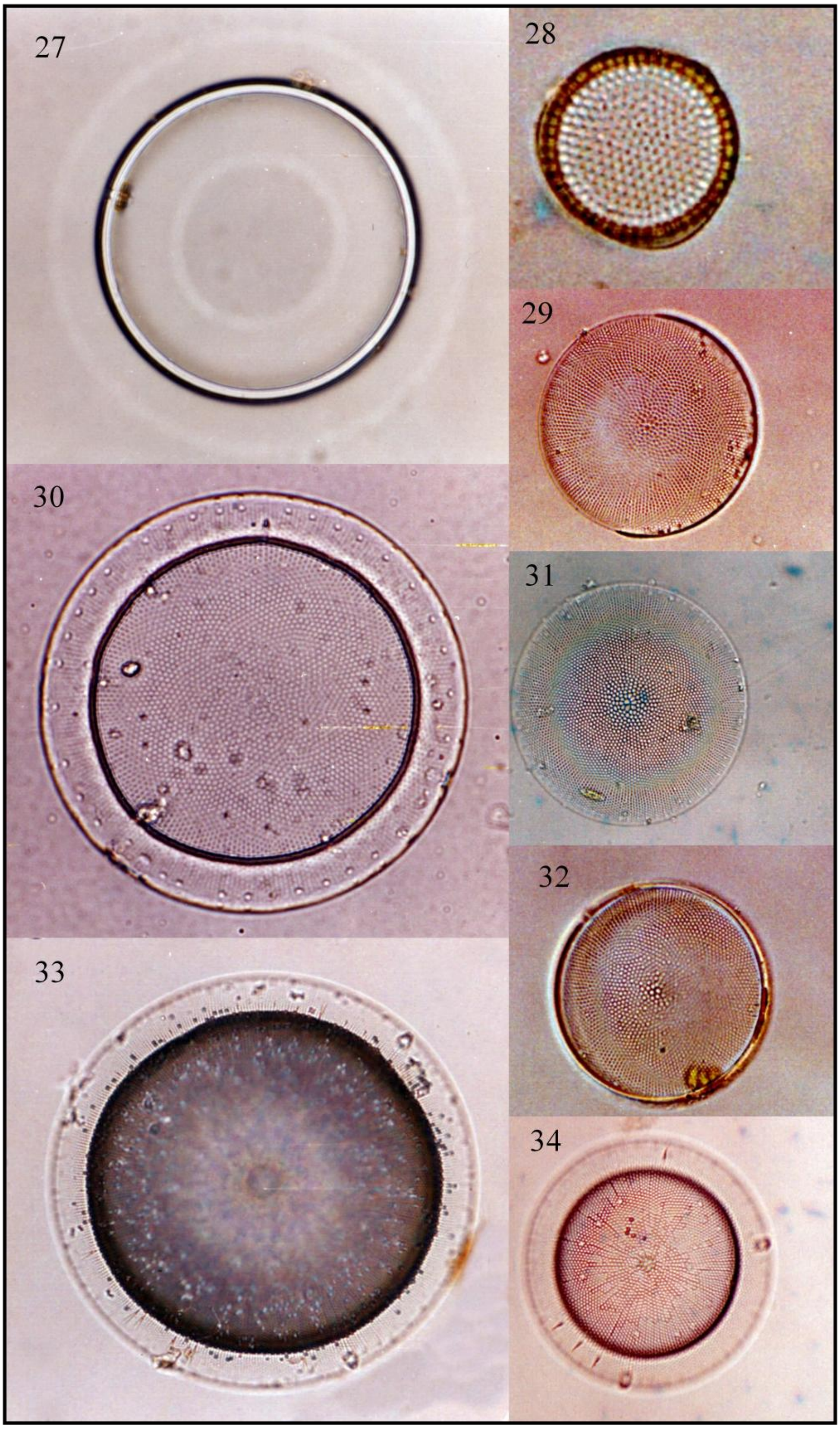


Plate : XII

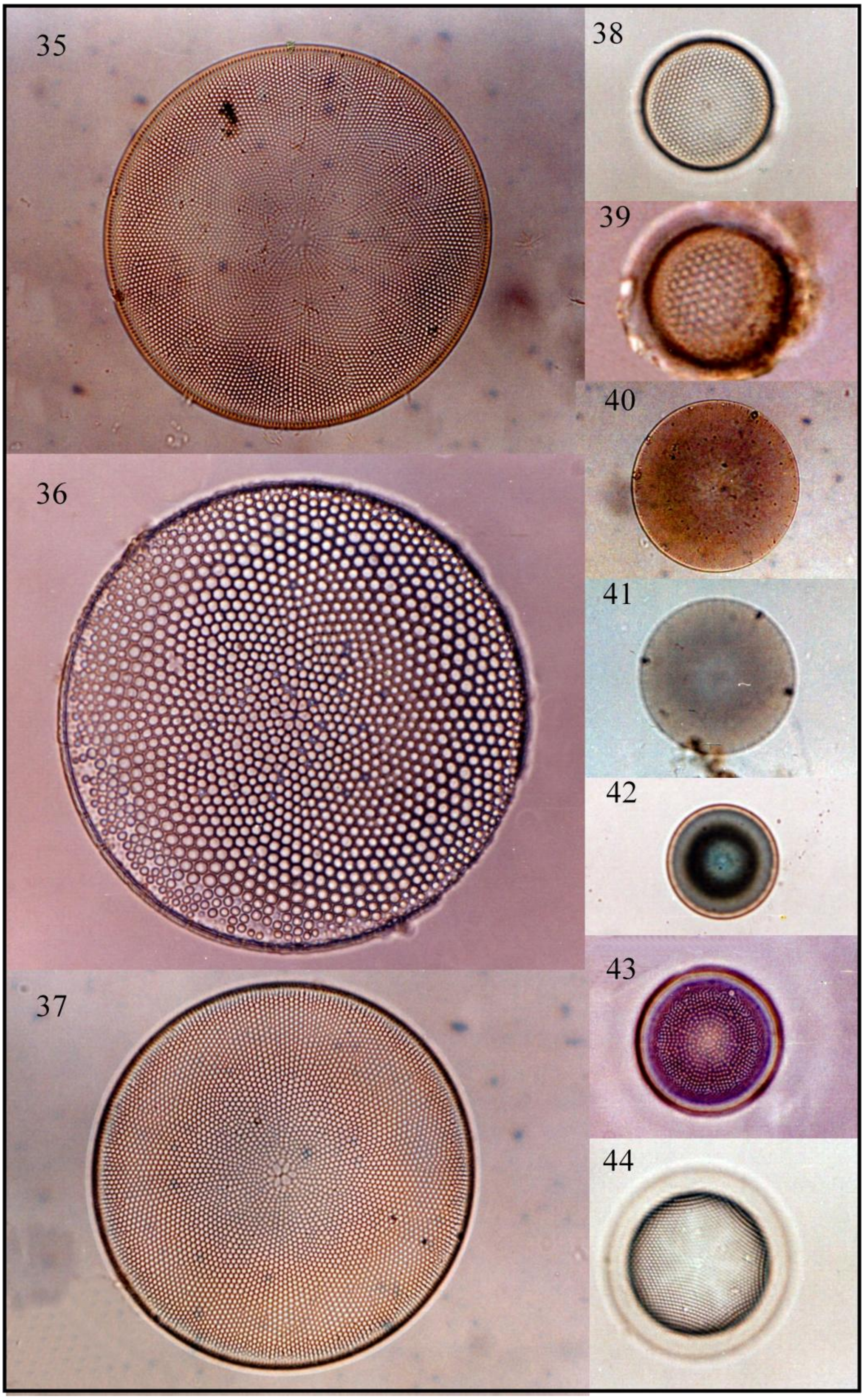


Plate : XIII

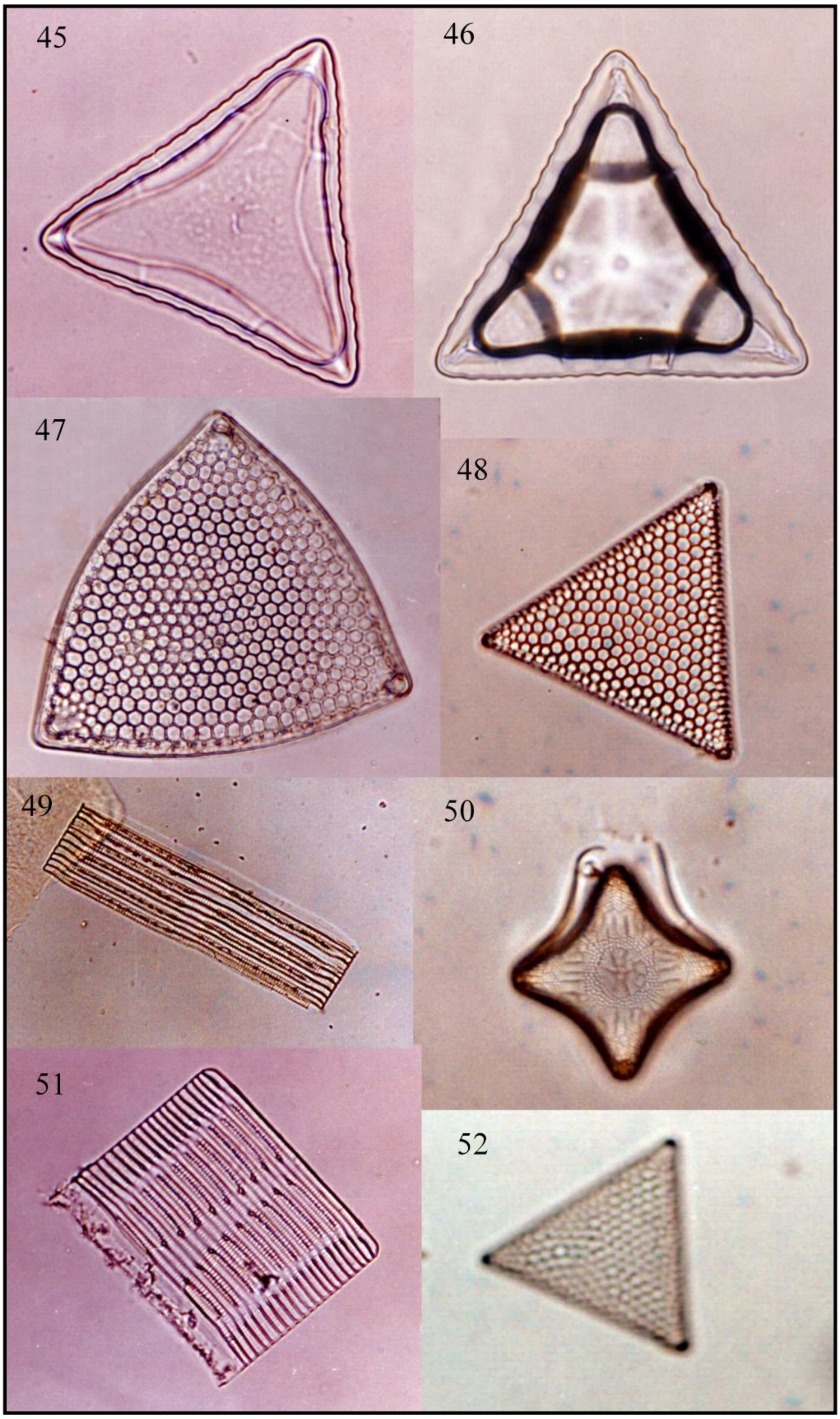


Plate : XIV

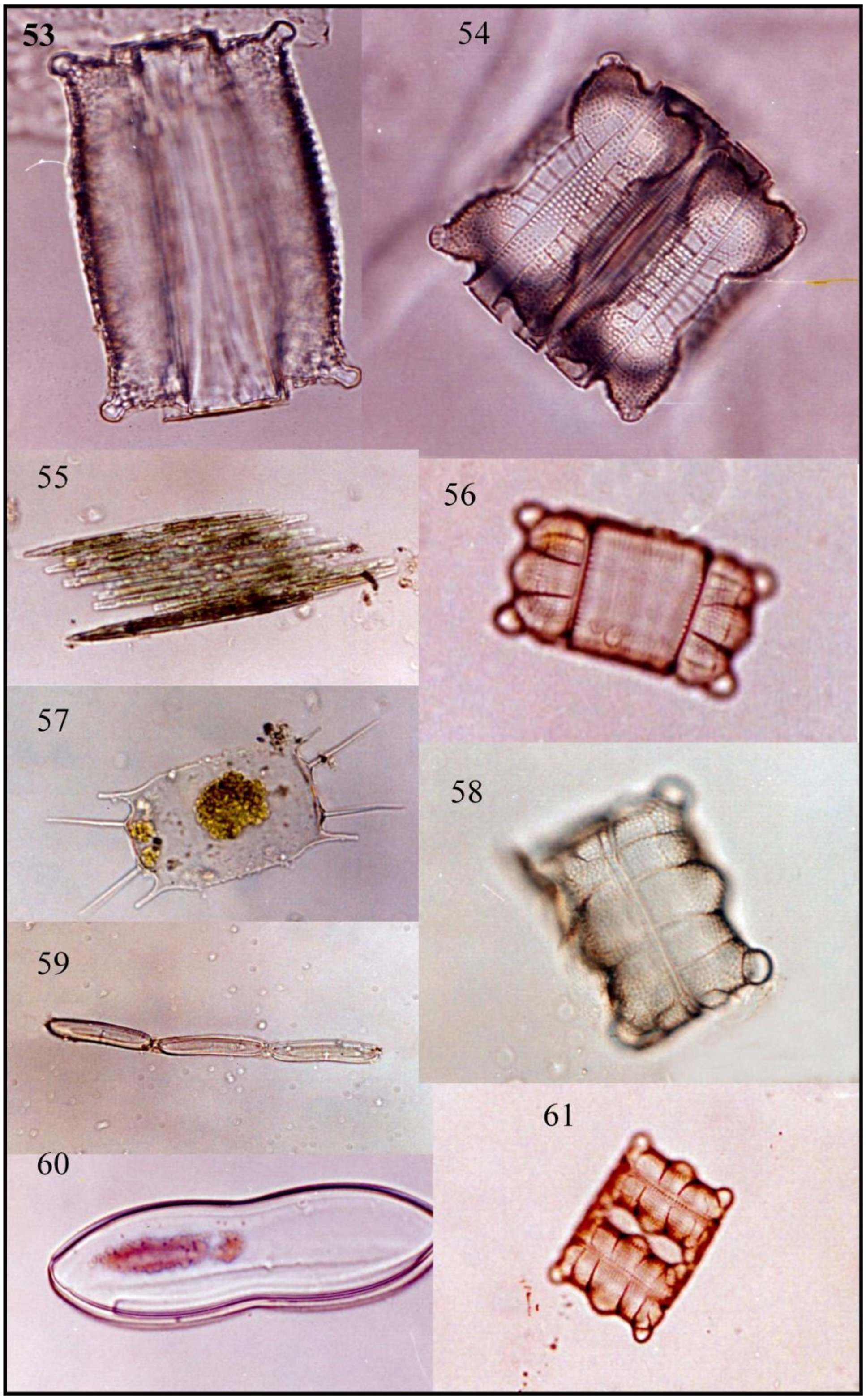


Plate : XV

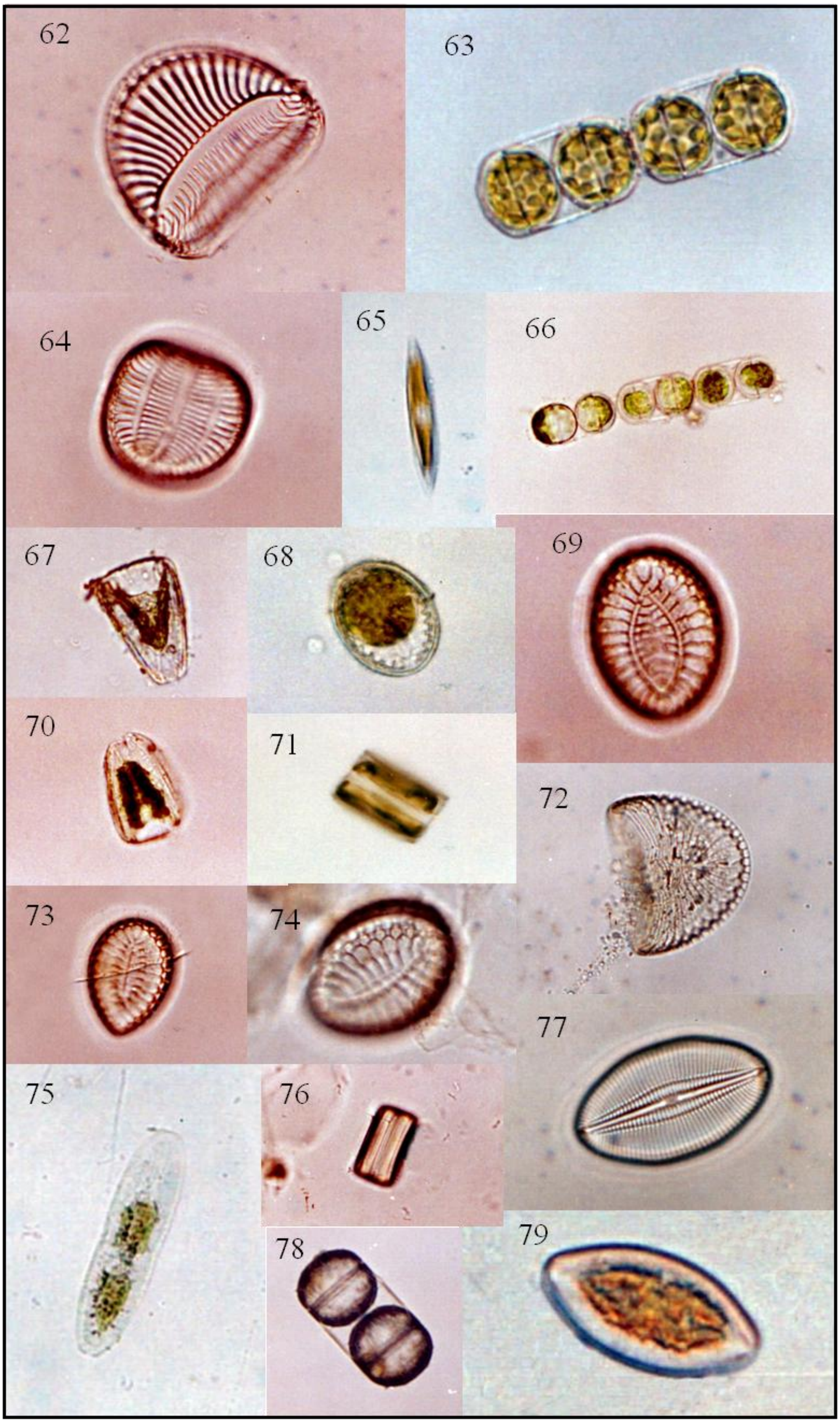


Plate : XVI

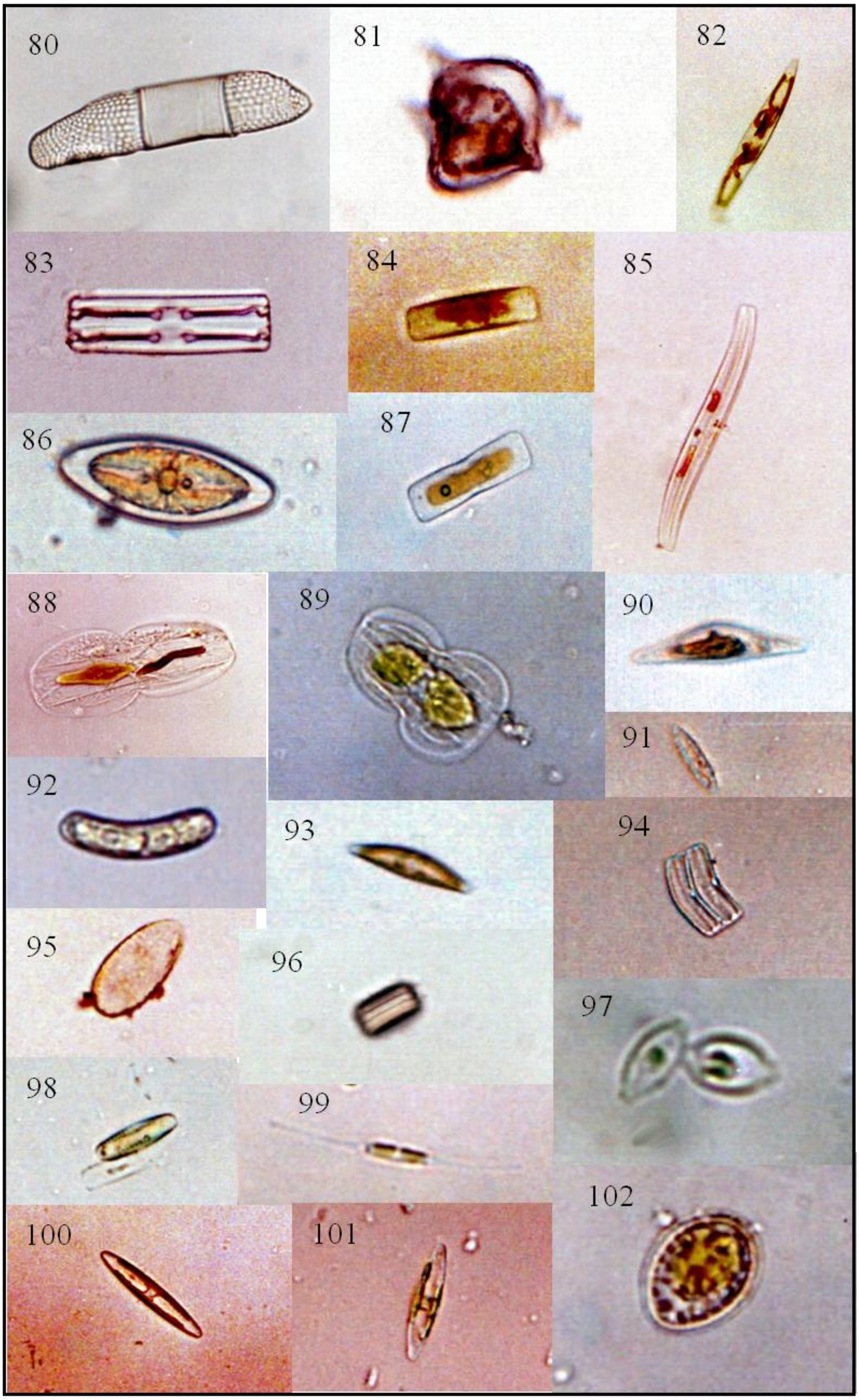


Plate : XVII

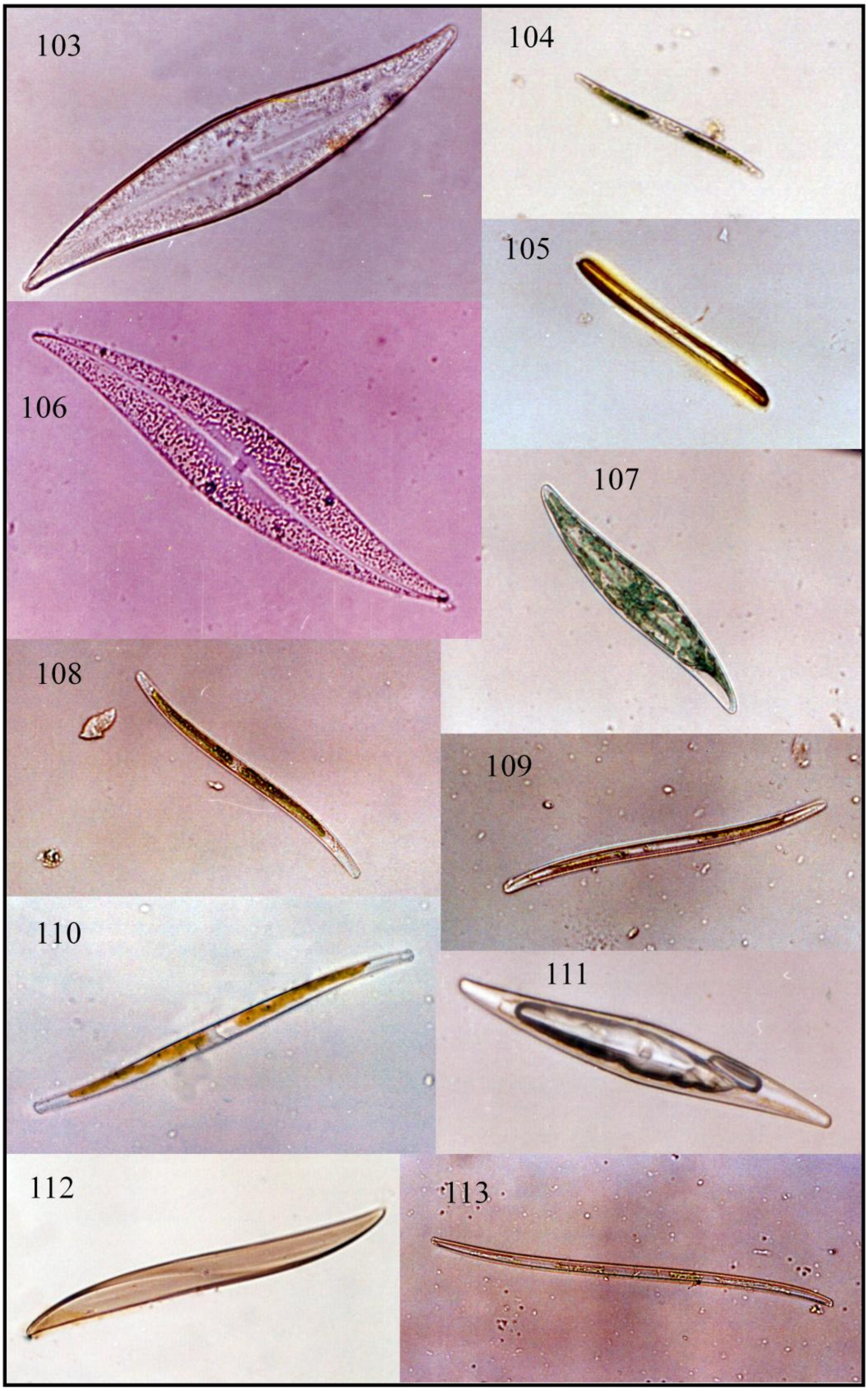


Plate : XVIII

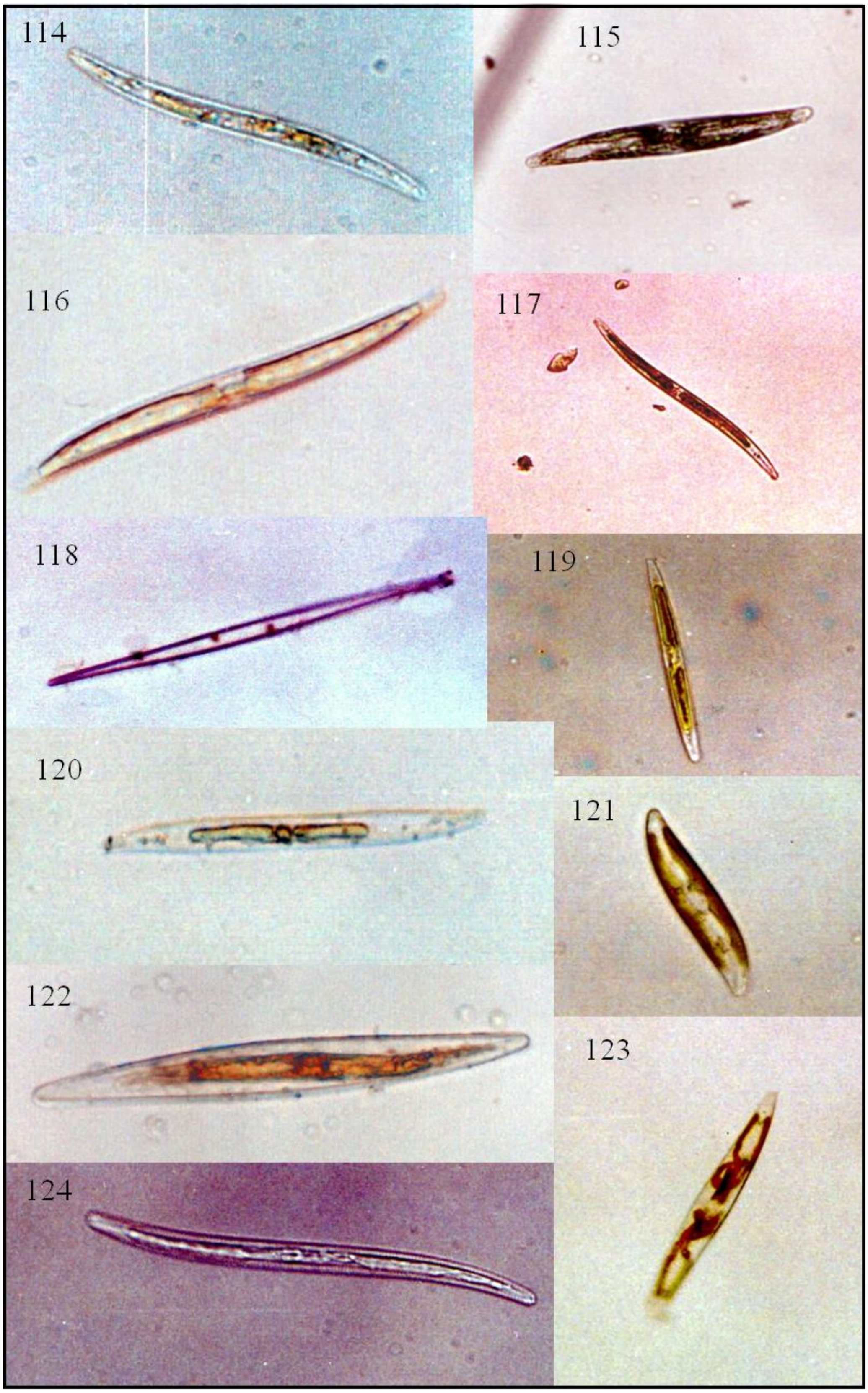


Plate :XIX

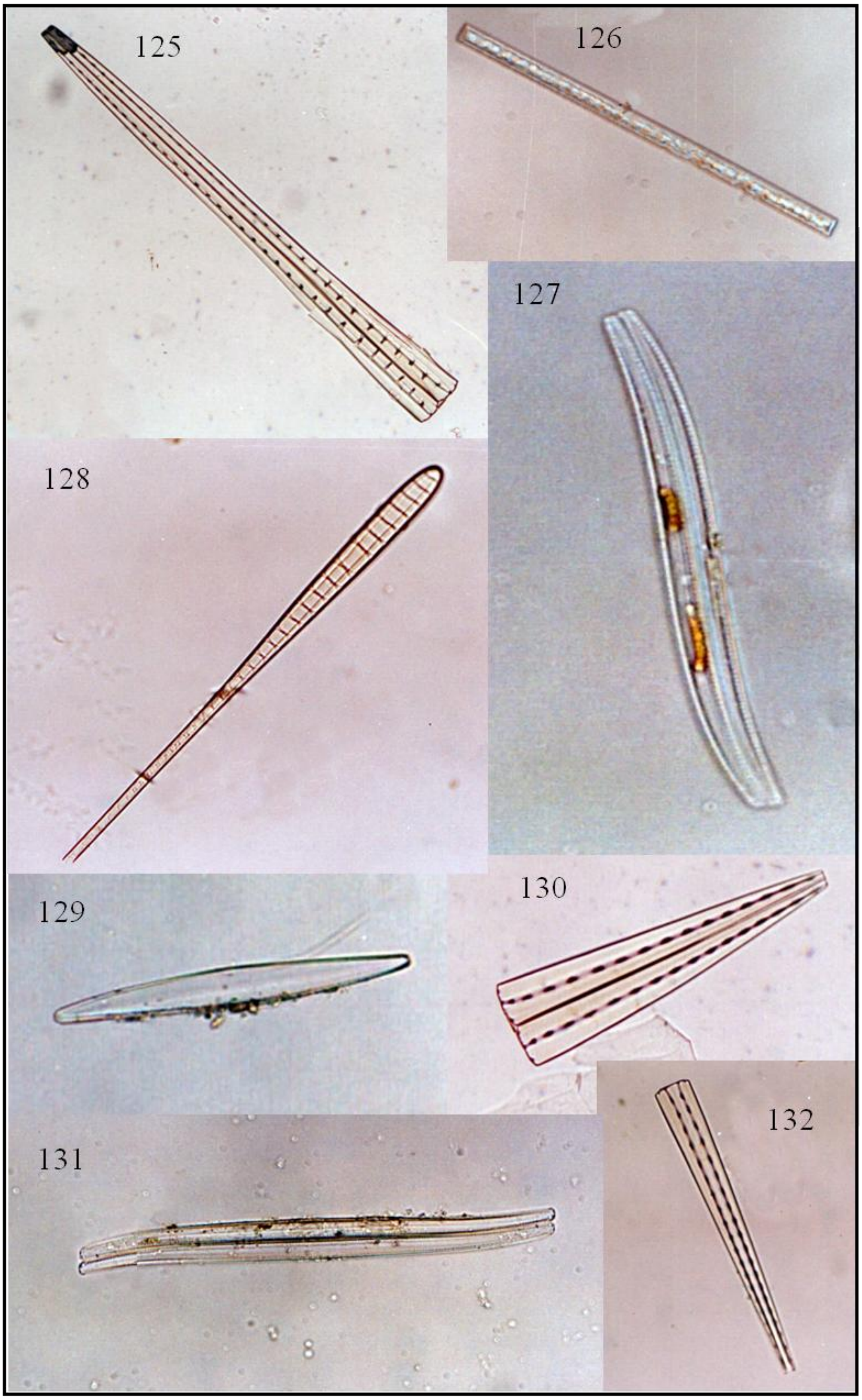


Plate: XX

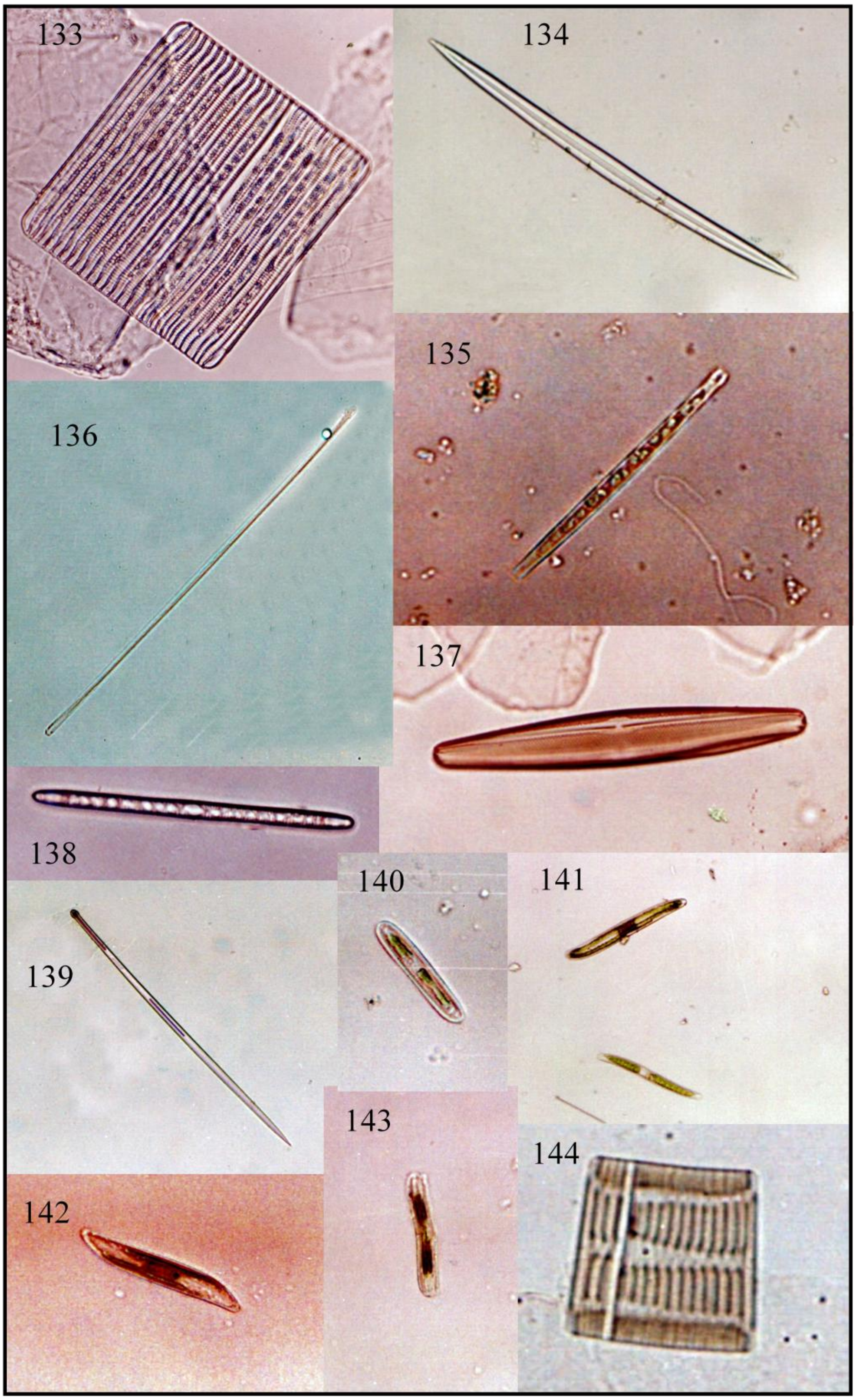
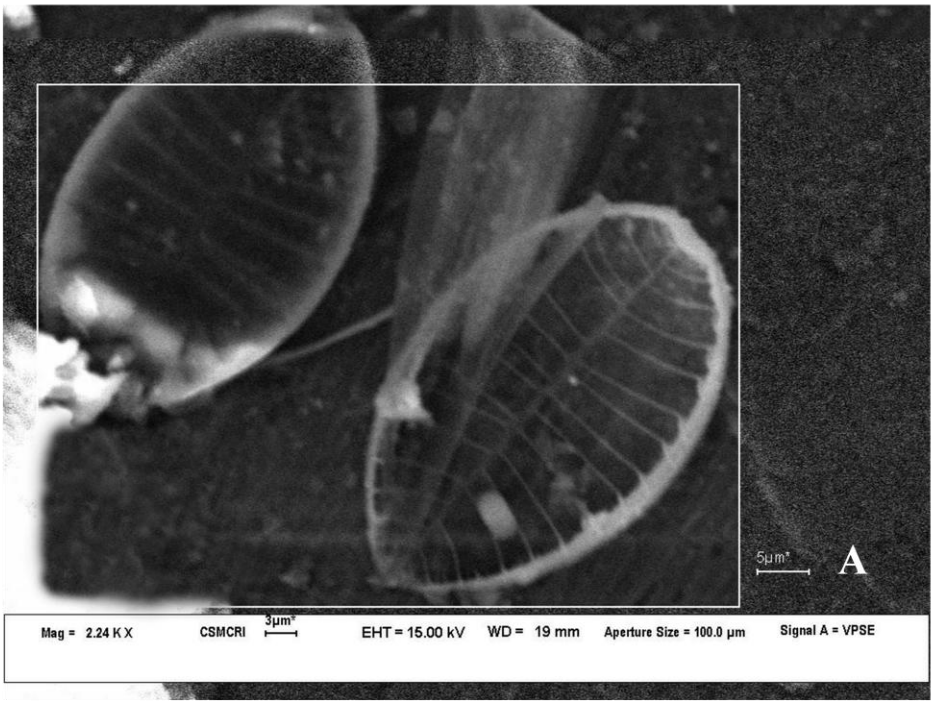


Plate : XXI

Plate : XXII



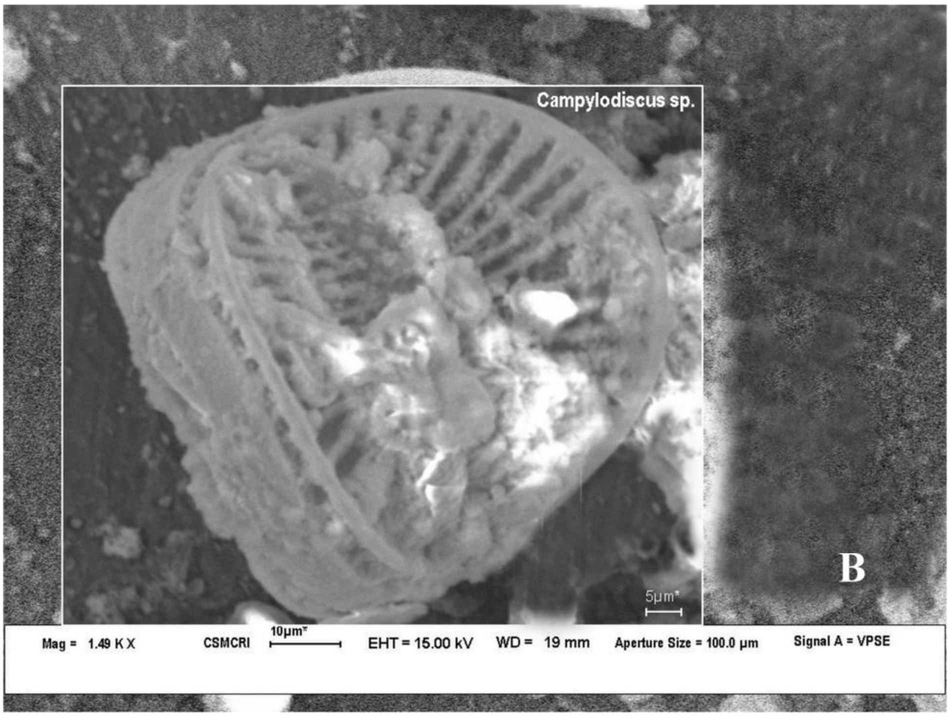
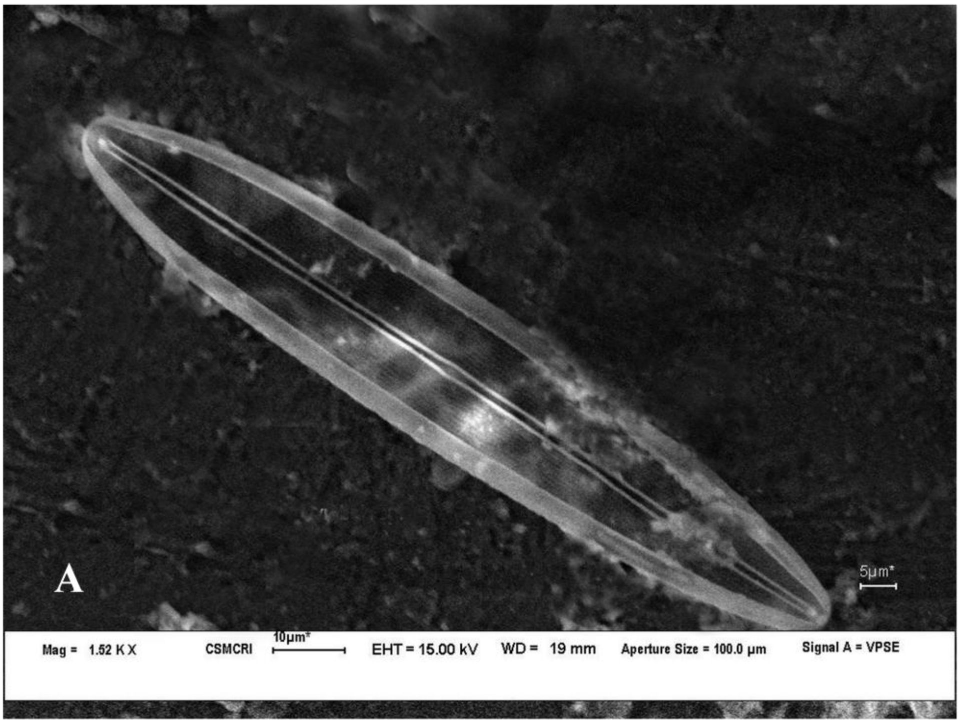


Plate : Scanning Electron Microscopy Photograph of A: ***Surirella biseriata*** Ehrneb. B : ***Campylodiscus limbatus*** Breb.

Plate : XXIII



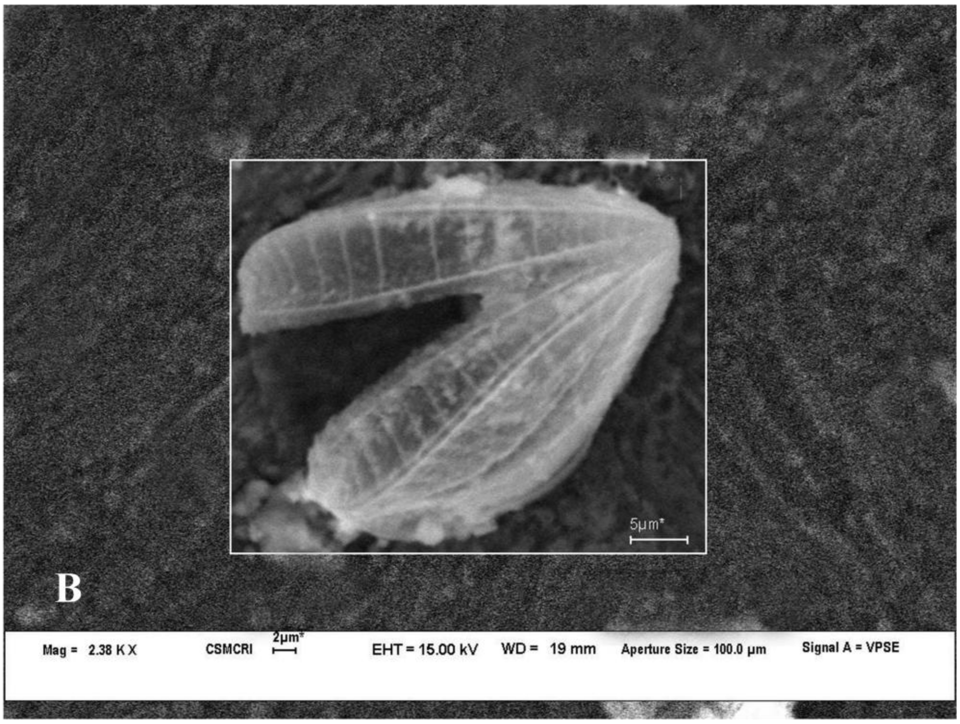
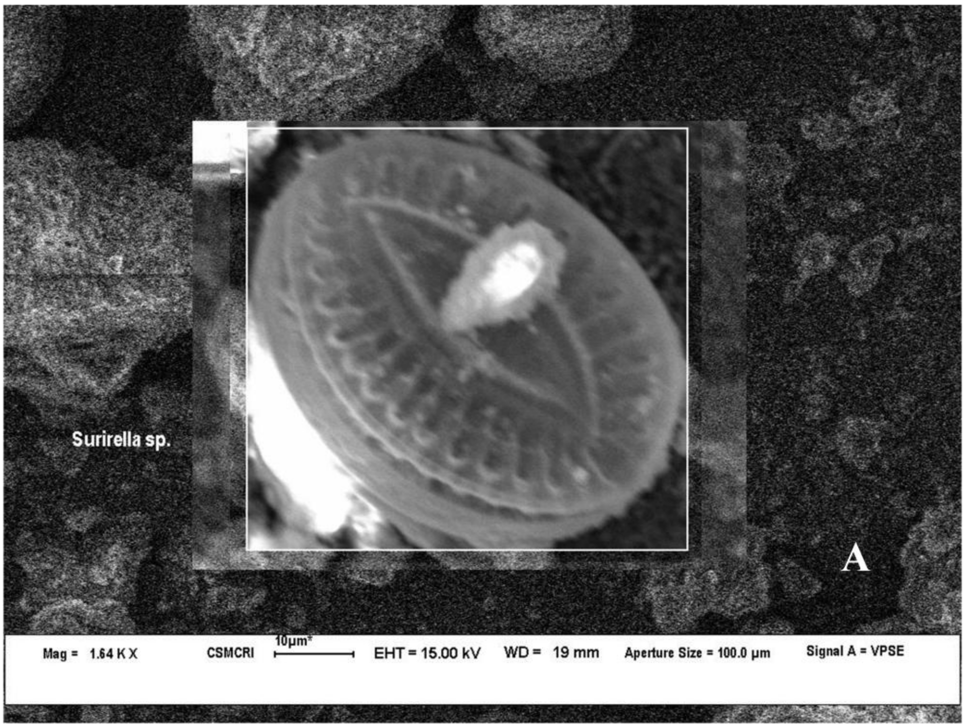


Plate : Scanning Electron Microscopy Photograph of A : ***Nitzschia seriata*** Cleve. B : ***Licmophora abbreviata*** Ehrneb.

Plate : XXIV



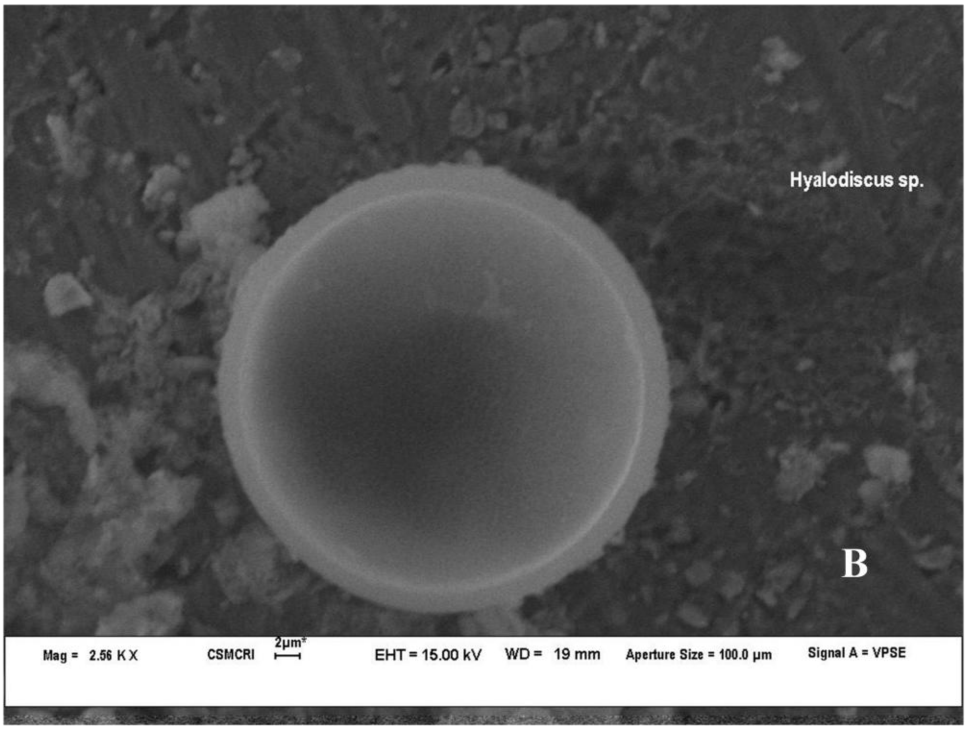


Plate : Scanning Electron Microscopy Photograph of A : ***Surirella fastuosa*** **Ehrneb.** Cleve. B : ***Hyalodiscus subtilis*** Bail.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
	Plate No. VIII		
1	Coscinodiscus marginatus Ehrneb.	Dia 88 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 538., Fig. No. 2.
2	Actinocyclus spiralis Perag.	Dia 136 µm	Ref: Desikachari (1988). Vol.V., Pl. No. 408., Fig. No. 1.
3	Thalassiosira leptotopus(Grun) Husted.	Dia. 55 µm.	Ref: Desikachari (1987). Vol.II., Pl. No. 202., Fig. No. 8.
4	Thalassiosira gracilis Husted.	Dia 54 µm.	Ref: Desikachari (1989). Vol.VI., Pl. No. 746., Fig. No. 6.
5	Coscinodiscus stellaris Ropper.	Dia 88 µm.	Ref: Gerhard Drebes (1974) Page No.33,Pl. 19. Fig. No. c.
6	Craspidodiscus coscinodiscus Ehrneb.	Dia 112 µm.	Ref: Desikachari (1986). Vol.I., Pl. No. 40., Fig. No. 4.
7	Coscinodiscus biangulatus Schmidt.	Dia 214 µm.	Ref: Desikachari (1986). Vol.I., Pl. No. 28., Fig. No. 1.
8	Coscinodiscus kurzii Grun.	Dia 105 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 533., Fig. No. 3 & 4.
	Plate No. IX		
9	Coscinodiscus concinnus Wm. Sm.	Dia 146 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 518., Fig. No. 1.
10	Coscinodiscus concinnus Wm. Sm.	Dia 288 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 518., Fig. No. 2.
11	Coscinodiscus jonesianus Grev.) Ostenfeld.	Dia 120 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 530., Fig. No. 4.
12	Coscinodiscus argus Ehrneb.	Dia 142 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 508., Fig. No. 4.
13	Coscinodiscus suspectus Jan.	Dia 84 µm.	Ref: Desikachari (1987). Vol.III, Pl. No. 272., Fig. No. 1.
14	Coscinodiscus concinniformis Simonsen.	Dia 266 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 528., Fig. No. 3.
15	Coscinodiscus jonesianus (Grev.) Ostenfeld.	Dia 85 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 532., Fig. No. 3.
16	Coscinodiscus jonesianus Grev.) Ostenfeld.	Dia 175 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 530., Fig. No. 3.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
	Plate No. X		
17	*Coscinodiscus concinniformis* Simonsen.	Dia 255 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 528., Fig. No. 3.
18	*Hyalodiscus subtilis* Bail.	Dia 94 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 603., Fig. No. 1.
19	*Coscinodiscus concinnus* Wm. Smith.	Dia 215 µm.	Ref: Desikachari (1987). Vol.IV., Pl. No. 367., Fig. No. 1.
20	*Coscinodiscus centralis* Ehrneb.	Dia 120 µm.	Ref: Gerhard Drebes (1974) Page No.35,Pl. 22. Fig. No. a.
21	*Biddulphia aurita var. obtusa*(Kuetz) Hust.	Length 66 µm.	Ref: Desikachary (1988) Vol. V . Pl. 469. Fig. No. 8.
22	*Coscinodiscus stellaris* Ropper.	Dia 110 µm.	Ref: Gerhard Drebes (1974) Page No.33,Pl. 19. Fig. No. d.
23	*Pseudoaulacodiscus petitii* L-F.	Dia 66 µm.	Ref: Desikachari (1987). Vol.III., Pl. No. 239., Fig. No.1 & 2.
24	*Coscinodiscus stellaris* Ropper.	Dia 110 µm.	Ref: Gerhard Drebes (1974) Page No.33,Pl. 19. Fig. No. d.
25	*Coscinodiscus asteromphalus* Ehrneb.	Dia 166 µm.	Ref: Desikachari (1987). Vol.IV., Pl. No. 358., Fig. No. 4.
	Plate No. XI		
27	*Hyalodiscus subtilis* Bail.	Dia 94 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 603., Fig. No. 1.
28	*Endictya oceanica* Ehrneb.	Dia 44 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 514., Fig. No. 3.
29	*Coscinodiscus jonesianus* Grev.) Ostenfeld.	Dia 175 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 530., Fig. No. 3.
30	*Actinocyclus pruniosus* Castr.	Dia 184 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 406., Fig. No. 12.
31	*Coscinodiscus jonesianus* Grev.) Ostenfeld.	Dia 175 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 530., Fig. No. 3.
32	*Coscinodiscus jonesianus* Grev.) Ostenfeld.	Dia 175 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 530., Fig. No. 3.
33	*Actinocyclus confluens* Grun.	Dia 100 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 406., Fig. No. 1.
34	*Actinocyclus spiralis* Perag.	Dia 85 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 408., Fig. No. 1.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
	Plate No. XII		
35	*Coscinodiscus gigus* Ehrneb.	Dia 160 µm.	Ref: Desikachari (1986). Vol.I., Pl. No. 31., Fig. No. 2.
36	*Coscinodiscus oculusiridis* Ehrneb.	Dia 350 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 540., Fig. No. 2.
37	*Coscinodiscus asteromphalus* Ehrneb.	Dia 206 µm.	Ref: Desikachari (1987). Vol.IV., Pl. No. 359., Fig. No. 7.
38	*Thalassiosira leptopa* (Grun.) Hasle & Fryxell.	Dia 84 µm.	Ref: Desikachari (1989). Vol.VI., Pl. No. 747., Fig. No. 2.
39	*Thalassiosira leptopus* (Grun.) Hasle.	Dia 42 µm.	Ref: Desikachari (1987). Vol.II., Pl. No. 202., Fig. No. 10.
40	*Coscinodiscus concinnus* Wm. Smith.	Dia 185 µm.	Ref: Desikachari (1988). Vol.V, Pl. No. 517., Fig. No. 3.
41	*Coscinodiscus concinnus* Wm. Sm.	Dia 137 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 517., Fig. No. 2.
42	*Hyalodiscus nobilis* Pant.	Dia 64 µm.	Ref: Desikachari (1986). Vol.I., Pl. No. 26, Fig. No. 4.
43	*Actinocyclus cholonki*Van Land.	Dia 45 µm.	Ref: Desikachari (1987). Vol.III., Pl. No. 284., Fig. No. 2.
44	*Coscinodiscus kolbei* Jouse.	Dia 72 µm.	Ref: Desikachari (1987). Vol.III., Pl. No. 282., Fig. No. 2.
	Plate No. XIII		
45	*Dytilum brightwellii (West) Grun.*	Arm Length 97 µm	Ref: Desikachary (1987) Vol. III . Pl. 289. Fig. No. 4.
46	*Dytilum brightwellii (West) Grun.*	Arm Length 97 µm	Ref: Desikachary (1987) Vol. III . Pl. 289. Fig. No. 4.
47	*Triceratium broeckii* Leuduger & Fortmorel.	Arm Length 98 µm.	Ref: Desikachary (1986) Vol. I . Pl. 72. Fig. No. 4. and
48	*Triceratiuum favus* Ehrneb.	Arm Length 68 µm	Ref: Desikachary (1989) Vol. VI . Pl. 768. Fig. No. 4.
49	*Rhabdonema adriaticum* Kutz (Harv. & Bail.) Stodder.	Length 200 µm.	Ref: Desikachary (1989) Vol. VI . Pl. 692. Fig. No. 1-3, 5-8.
50	*Triceratium pentacrinus f. Quadrata* Hust.	Arm Length 28 µm.	Ref: Desikachary (1987) Vol. III . Pl. 329. Fig. No. 7.
51	*Rhabdonema punctatum* (Harv. & Bail.) Stodder.	Length 98 µm	Ref: Desikachary (1989) Vol. VI . Pl. 691. Fig. No. 1-9.
52	*Triceratiuum favus* Ehrneb.	Arm Length 68 µm.	Ref: Desikachary (1989) Vol. VI . Pl. 769. Fig. No. 9.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
	Plate No. XIV		
53	*Biddulphia reticulata* Roper.	Length 90 µm. Width 62 µm.	Ref: Desikachari (1988). Vol.V., Pl. No. 468., Fig. No. 1.
54	*Biddulphia aurita* (Lyngbye) Breb & Godey.	Length 50 µm. Width 22 µm	Ref: Desikachary (1988) Vol. V . Pl. 469. Fig. No. 2-3.
55	*Bacillaria paradoxa* Ehrneb.	Dia 35 µm.	Ref: Gerhard Drebes (1974) Pl. No. 87 Fig. No. a.
56	*Biddulphia biddulphiana* (Sm) Boyer.	Length 100 µm. Width 58 µm.	Ref: Desikachari (1987). Vol.III., Pl. No. 246., Fig. No. 4.
57	*Biddulphia mobiliensis* (Bailey) Grrunow. Syn.	Length 100 µm. Width 58 µm	Ref: R. Thomas (1999). Page No. 239.
58	*Biddulphia pulchela* Gray. Syn.	Length 120 µm. Width 78 µm.	Ref: Peragallo (1965)., Pl. No. XCIII., Fig. No. 1. and
59	*Achanthes brevipes* var. *angustata* (Grey) Cl.	Length 90 µm.	Ref: Desikachary (1987) Vol. III . Pl. 222. Fig. No. 5.
60	*Nitzschia panduriformis* Greg.	Length 180 µm.	Ref: Desikachary (1989) Vol. VI. Pl. 657. Fig. No. 12.
61	*Biddulphia pulchela* Gray. Syn.	Length 82 µm. Width 48 µm	Ref: Peragallo (1965)., Pl. No. XCIII., Fig. No. 1. and
	Plate No. XV		
62	*Campylodiscus limbatus* Breb.	Dia. 77 µm.	Ref: Desikachary (1986) Vol. I. Pl. 24 , Fig. No. 1 & 2.
63	*Stephanopyxis turris* (Grev. & Arnot) Ralfs.	Dia 60 µm.	Ref: Gerhard Drebes (1974) Pl. 12. Fig. No. b & c.
64	*Campylodiscus triumphans* Schmidt.	Dia. 71 µm.	Ref: Desikachary (1986) Vol. I. Pl. 24 , Fig. No. 4 & 5.
65	*Mastogloia labuensis* Cleve.	Length 39 µm.	Ref: Desikachary (1987) Vol. IV . Pl. No. 375 Fig. No. 15.
66	*Melosira moniliformes* (Muller) Agardh.	Dia 45 µm.	Ref: Gerhard Drebes (1974) Pl. 10. Fig. No. b.
67	*Surirella robusta* Ehrneb.	Length 106 µm.	Ref: Desikachary (1987) Vol. III . Pl.319. Fig. No. 5.
68	*Campyloneis grevillei* (Wm. Smith) Grun.	Dia 34 µm.	Ref: Desikachary (1987) Vol. III . Pl. 265. Fig. No. 4.
69	*Surirella fastuosa* Ehrneb.	Dia 66 µm.	Ref: Desikachary (1989) Vol.VI Pl. 721. Fig. No. 4.
70	*Surirella robusta* Ehrneb.	Length 106 µm.	Ref: Desikachary (1987) Vol. III . Pl.319. Fig. No. 5.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
71	*Grammatophora longissima* Petit.	Length 55 µm.	Ref: Desikachary (1986) Vol. I . Pl. 45. Fig. No. 12.
72	*Campylodiscus latus* Shadbolt.	Dia. 60-88 µm.	Ref: Desikachary (1986) Vol. I. Pl. 23 , Fig. No.3, 4 & 5.
73	*Surirella fastuosa* Ehrneb.	Dia 66 µm.	Ref: Desikachary (1989) Vol.VI Pl. 721. Fig. No. 4.
74	*Surirella fastuosa* var. *cuneata* (A.S.) Perag. & Perag,	Dia 66 µm.	Ref: Desikachary (1989) Vol.VI. Pl. 723. Fig. No. 6.
75	*Torpedoneis lepidoptera* Grun.	Dia 86 µm.	Ref: Peragallo (1965). Pl. No. XXXIX, Fig. No. 8.
76	*Thalassiosira* sp.	Dia 36 µm.	Ref: Desikachary (1987) Vol.IV. Pl. 395. Fig. No. 8.
77	*Diploneis smithi* (Breb) Cleve.	Dia 45 µm.	Ref: Desikachary (1987) Vol. III. Pl. 287. Fig. No. 4.
78	*Melosira numuloides* (Dillw) Agardh. Syn.	Dia 28 µm.	Ref: Gerhard Drebes (1974) Pl. 10. Fig. No. a.
79	*Navicula clavata* Var. *impressa* Perg.	Dia 46 µm.	Ref: Peragallo (1987). Plate-XXIV Fig 11.
	Plate No. XVI		
80	*Isthmia enervis* Ehrneb.	Dia 275 µm.	Ref: Peragallo (1965) Pl. No. XCII Fig. No. 2.
81	*Peridinium depressum*, Bailey	Dia 126 µm.	Ref: Gerhard Drebes (1974)Page 137 Pl. 119. Fig. No. a.
82	*Pleurosigma salinarum* Grun.	Length 28 µm.	Ref: Peragallo (1965) Pl. No. XXXIII Fig. No. 16.
83	*Grammatophora oceanica* (Wm. Sm.) Grun.	Length 85 µm.	Ref: Desikachary (1988) Vol.V., Pl. 588. Fig. No. 16.
84	*Plagiogramma obesum* Grev.	Length 25 µm.	Ref: Desikachary (1987) Vol.II., Pl. 177. Fig. No. 8.
85	*Nitzschia sigma* (Kuetz.) Wm. Sm.	Length 208 µm	Ref: Desikachary (1989) Vol. VI . Pl. 664. Fig. No. 2.
86	*Navicula clavata* var. *elongata* H.P.	Dia 62 µm.	Ref: Peragallo (1965) Pl. No. XXIV Fig. No. 9.
87	*Pinnularia brauni* var. amphicephala (Mayer) Hust.	Dia 46 µm.	Ref: Desikachari (1987). Vol.III., Pl. No. 307., Fig. No. 6.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
88	*Amphiprora gigantea* var.*sulcata* Cleve.	Dia 116 µm	Ref: Desikachari (1987). Vol.IV., Pl. No. 338, Fig. No. 7
89	*Amphiprora gigantea* var.*sulcata* Cleve.	Dia 128 µm	Ref: Desikachari (1987). Vol.IV., Pl. No. 338, Fig. No. 7
90	*Amphora laevissima* Greg.	Length 37 µm.	Ref: Peragallo (1965) Pl. XXXII. Fig. No. 22.
91	*Cyamatonitzschia marina* (Lewis) Simonsen.	Length 22 µm.	Ref: Desikachary (1987) Vol. IV . Pl. No. 374 Fig. No. 13.
92	*Pyxidicula reniformes* Desik & Ranjitha Devi.	Length 58 µm.	Ref: Desikachary (1987) Vol. III . Pl. 321. Fig. No. 7 & 10
93	*Amphora turgida* Greg	Length 52 µm	Ref: Desikachary (1987) Vol. IV . Pl. 370. Fig. No. 21.
94	*Achanthes brevipes* var. *angustata* (Grey) Cl.	Length 84 µm.	Ref: Desikachary (1987) Vol. III . Pl. 222. Fig. No. 5.
95	*Surirella biseriata* Ehrneb.	Length 73 µm.	Ref: Desikachary (1989) Vol. VI . Pl. 718. Fig. No. 7.
96	*Thalassiosira* sp.	Dia 36 µm	Ref: Desikachary (1987) Vol. IV. Pl. 395. Fig. No. 8.
97	*Amphora costata* Wm. Sm.	Length 64 µm.	Ref: Peragallo (1965) Pl. No. L Fig. No. 50.
98	*Amphora hyanlina* Wm. Sm.	Length 28 µm.	Ref: Peragallo (1965) Pl. No. XXIV Fig. No. 7.
99	*Niytzschia longissima* (Breb) Ralfs.	Length 67 µm.	Ref: Gerhard Drebes (1974) . Pl. 88. Fig. No. c.
100	*Navicula directa* Wm. Sm.	Length 55 µm.	Ref: C. R. Tomas (1998) Pl. 63.pp.279.
101	*Navicula transitrans* var. dersa Hemidal (1970).	Length 55 µm.	Ref: C. R. Tomas (1998) Pl. 63. Pp. 279.
102	*Campyloneis grevillei* (Wm. Smith) Grun.	Dia 34 µm.	Ref: Desikachary (1987) Vol. III . Pl. 265. Fig. No. 4.
	Plate No. XVII		
103	*Rhoicosigma robustum* Grun.	Length- 247 µm.	Ref: Peragallo (1965) Pl. No. XXXV Fig. No. 1.
104	*Pleurosigma salinarum* Grun.	Length- 126 µm.	Ref: Peragallo (1965) Pl. No. XXXIII Fig. No. 16.

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
105	*Niytzschia obtusa* Wm. Sm.	Length 40 µm.	Ref: Desikachary (1987) Vol. IV . Pl. No. 379 Fig. No. 11
106	*Rhoicosigma robustum* Grun.	Length- 225 µm.	Ref: Peragallo (1965) Pl. No. XXXV Fig. No. 1.
107	*Pleurosigma majus* Grun.	Length- 287 µm.	Ref: Peragallo (1965) Pl. No. XXXIII Fig. No. 1.
108	*Pleurosigma spenceri* Wm. Sm.	Length- 82 µm.	Ref: Peragallo (1965) Pl. No. XXX IV Fig. No. 18.
109	*Niytzschia insignis* Greg.	Length 185 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 657 Fig. No. 38
110	*Nitzschia sigmoidea* (Nitz.) Wm. Sm.	Length 244 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 663 Fig. No. 3.
111	*Pleurosigma rigidum* Wm. Sm.	Length- 82 µm.	Ref: Peragallo (1965) Pl. No. XXX III Fig. No. 14.
112	*Pleurosigma formosum* Wm. Sm.	Length- 370 µm.	Ref: Peragallo (1965) Pl. No. XXX Fig. No. 4.
113	*Nitzschia incurva* var. *lorenziana* (Grun.) Ross.	Length- 446 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 663 Fig. No. 19.
	Plate No. XVIII		
114	*Nitzschia lorenziana* (Grun.) var. *subtilis.*	Length- 144 µm.	Ref: Peragallo (1965) Pl. No.LXXIV Fig. No. 24.
115	*Pleurosigma longum* var. *lanceolata* Perag.	Length- 307 µm.	Ref: Peragallo (1965) Pl. No. XXXIII Fig. No. 1.
116	*Nitzschia panduriformis* Greg.(Side View)	Length 180 µm.	Ref: Desikachary (1989) Vol. VI. Pl. 657. Fig. No. 12.
117	*Pleurosigma spenceri* Wm. Sm.	Length- 165 µm	Ref: Peragallo (1965) Pl. No. XXX IV Fig. No. 18.
118	*Nitzschia sigma* (Kuetz.) Wm. Sm.	Length 180 µm	Ref: Peragallo (1965) Pl. No.LXXIV Fig. No. 5.
119	*Synedra crystalina* var. *dalmatica* (Kuetz) Perag. And Perag.	Length- 160 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 735 Fig. No. 11.
120	*Pleurosigma angulatum* (Wm. Sm.) var. Heurch.	Length- 175 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 674 Fig. No. 8.
121	*Pleurosigma attenuatum* var. *scalpurum* Grun.	Length 76 µm.	Ref: Peragallo (1965) Pl. XXXIV. Fig. No. 2.

Details of Phytoplankton Photographs

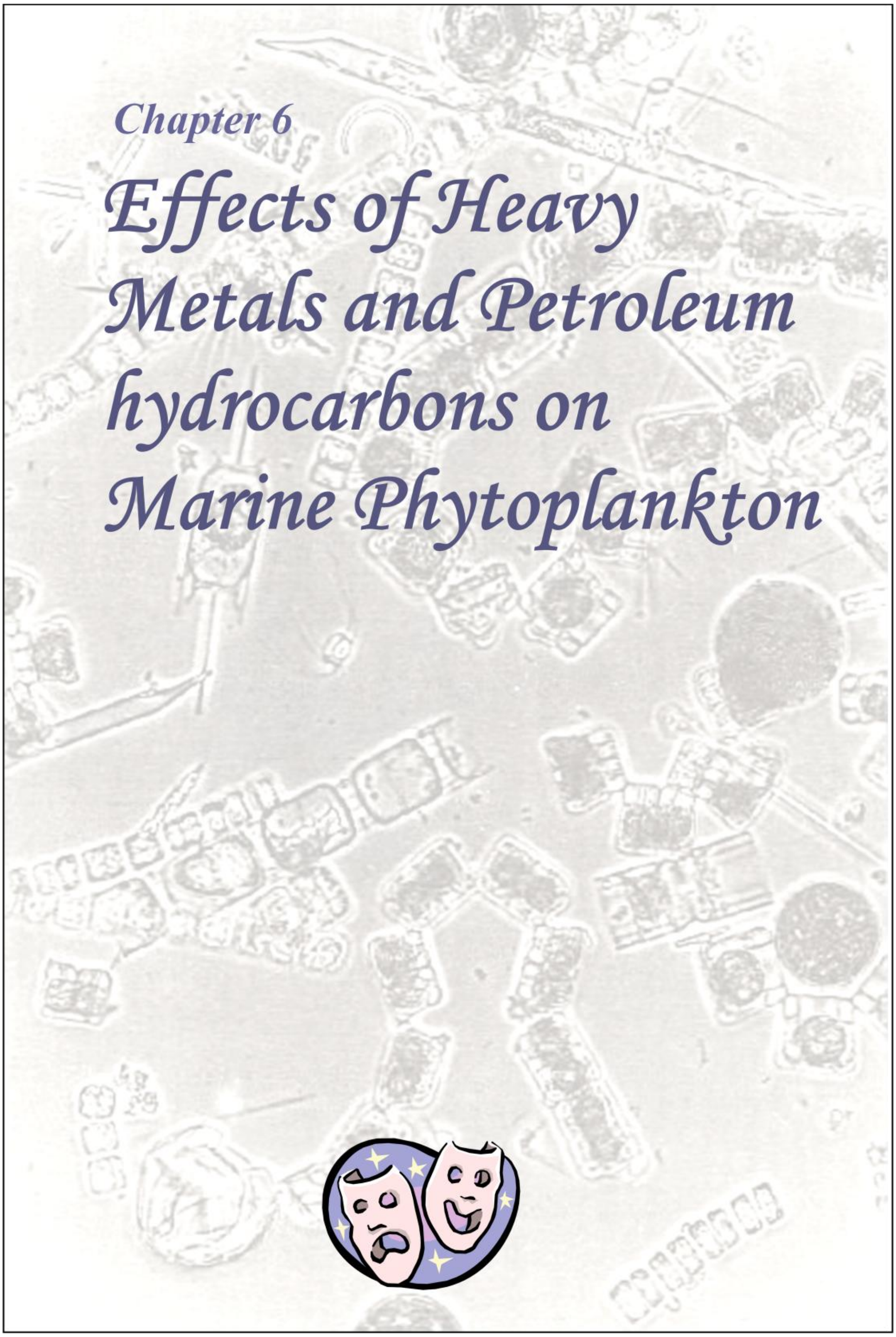
Fig. No.	Name of the Phytoplankton	Measurements	References in brief
122	*Pleurosigma angulatum* (Wm. Sm.) var. Heurch.	Length- 206 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 674 Fig. No. 8.
123	*Pleurosigma salinarum* Grun.	Length 28 µm.	Ref: Peragallo (1965) Pl. No. XXXIII Fig. No. 16.
124	*Nitzschia lorenziana* (Grun.) var. *subtilis.*	Length- 168 µm.	Ref: Peragallo (1965) Pl. No.LXXIV Fig. No. 24.
	Plate No. XIX		
125	*Climacosphaenia elongata* Bail.	Length 416 µm.	Ref: Desikachary (1987) Vol. III . Pl. No. 264 Fig. No. 7.
126	*Thalassiothrix nitzschioides* var. *javanica* Grun.	Length 160 µm	Ref: Peragallo (1965) Pl. No.LXXXI Fig. No. 17.
127	*Nitzschia sigma* (Kuetz.) Wm. Sm.	Length 220 µm	Ref: Desikachary (1989) Vol. VI . Pl. 664. Fig. No. 2.
128	*Climacosphaenia elongata* Bail. (Side View)	Length 416 µm.	Ref: Desikachary (1987) Vol. III . Pl. No. 264 Fig. No. 7.
129	*Pleurosigma angulatum* (Wm. Sm.) var. Heurch.	Length- 120 µm.	Ref: Peragallo (1965) Pl. No.XXXIII Fig. No. 1.
130	*Climacosphaenia moniligera* Ehrneb.	Length 173 µm.	Ref: Desikachary (1988) Vol. V . Pl. No. 503 Fig. No. 6.
131	*Nitzschia sigma* (Kuetz.) Wm. Sm.	Length 400 µm	Ref: Desikachary (1989) Vol. VI . Pl. 664. Fig. No. 3.
132	*Climacosphaenia moniligera* Ehrneb.	Length 130 µm.	Ref: Desikachary (1988) Vol. V . Pl. No. 503 Fig. No. 6.
	Plate No. XX		
133	*Rhabdonema adriaticum* Kutz (Harv. & Bail.) Stodder.	Length 188 µm.	Ref: Desikachary (1989) Vol. VI . Pl. 692. Fig. No. 1-3, 5-8.
134	*Synedra fulgens* (Grev) Wm. Sm.	Length 175 µm.	Ref: Desikachary (1987) Vol. IV . Pl. No. 390 Fig. No. 5.
135	*Rhabdonema adriaticum* Kutz (Harv. & Bail.) Stodder. (Single cell)	Length 188 µm.	Ref: Desikachary (1989) Vol. VI . Pl. 692. Fig. No. 1-3, 5-8.
136	*Synedra crystalina* Lyngb.	Length- 355 µm.	Ref: Peragallo (1965) Pl. No.LXXIX Fig. No. 1.
137	*Trachyneis antillarum* (Cl. & Grun) Cleve.	Length 200 µm.	Ref: Desikachary (1989) Vol. VI . Pl. No. 757 Fig. No. 1

Details of Phytoplankton Photographs

Fig. No.	Name of the Phytoplankton	Measurements	References in brief
138	*Thalassionema nitzschioides* Grun. (Side view)	Length- 220 µm.	Ref: Peragallo (1965) Pl. No.LXXXI Fig. No. 17.
139	*Asterionella notata* Grun.	Length- 168 µm.	Ref: Peragallo (1965) Pl. No.LXXXI Fig. No. 12.
140	*Caloneis linearis* (Grun) Boyer.	Dia 74 µm.	Ref: Desikachary (1988) Vol. V . Pl. No. 479 Fig. No. 6.
141	*Pleurosigma spenceri* Wm. Sm.	Length- 132 µm	Ref: Peragallo (1965) Pl. No. XXX IV Fig. No. 22.
142	*Gyrosigma balticum* (Ehr.) Rabenh.	Length 84 µm	Ref: Desikachary (1987) Vol. IV . Pl. No. 383 Fig. No. 2
143	*Gyrosigma balticum* (Ehr.) Rabenh.	Length 94 µm	Ref: Desikachary (1988) Vol. V . Pl. No. 590 Fig. No. 5
144	*Rhabdonema punctatum* (Harv. & Bail.) Stodder.	Length 67 µm	Ref: Desikachary (1989) Vol. VI . Pl. 691. Fig. No. 1-9.
	Plate No. XXI		
145	*Phormidium* sp.	Width 12 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 45, Fig. 16.
146	*Oscillatoria* sp.	Width 8 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 41, Fig. 8.
147	*Leptocylindrus danicus* Cleve.	Length 16 µm	Ref: Gerhard Drebes (1974) . Pl. 13. Fig. No. b.
148	Lyngbya sp.	Width 3.5 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 50, Fig. 8.
149	*Thalassiothrix longissima*	Width 2.5 µm	Ref: C. R. Tomas (1998) Pl. 58. Fig. No. a, pp.264.
150	*Trichodesmium* sp.	Width 15 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 42, Fig. 11.
151	*Arthrospira* sp.	Width 20 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 35, Fig. 9.
152	*Synedra fulgens* (Grev) Wm. Sm.	Dia 175 µm.	Ref: Desikachary (1987) Vol. IV . Pl. No. 390 Fig. No. 5.
153	*Spirulina* sp.	Width 16 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 36, Fig. 12.
154	*Trichodesmium sp.*	Width 15 µm	Ref: Desikachary (1959),In Cyanophyta, Plate 42, Fig. 16-17.

Chapter 6

Effects of Heavy Metals and Petroleum hydrocarbons on Marine Phytoplankton



Chapter 6

Effects of Heavy Metals and Crude Petroleum Hydrocarbons on Marine Phytoplankton

Most of the metals are transition elements with incompletely filled 'd' orbitals. These orbitals provide heavy metal cations with ability to form complex compounds, which may or may not be redox-active. Thus heavy metal cations play an important role as trace elements in biochemical reactions. At higher concentrations, however heavy metal ions form unspecific complex compounds in the cell, which lead to toxic effects (Nies, 1999). Many of the metals like Aluminum, cadmium and Lead have no known biological function (Rai *et al*., 1981). The wide spread pollution of aquatic ecosystems with heavy metals has its effects on phototrophic microorganisms and Rai *et al*., (1981); Sorentino (1979), Whitton (1970); Rice *et al*., (1973); Davies (1978) have reviewed this aspect.

Phytoplankton affects trace metal chemistry in natural and oceanic waters not only by surface reactions, but also by metal uptake and by production of extracellular organic matter with metal complexing properties. The release of extra cellular organic matter from marine phytoplankton appears to be a major source of liable substrate to the dissolved organic matter (DOM) in ocean (Duursma, 1961; Wangersky, 1978; Zhou, and Wangersky, 1989a). Both the extracellular exudation products and the secondary products after biochemical modification have been demonstrated to have the ability to complex trace metals (Fogg and Westlake, 1955; Swallow *et al*., 1978; van den berg, 1979; Mantoura, 1981; Fisher and Fabris, 1982; Imber *et al*., 1985; Zhou, and Wangersky, 1989b; Seritti *et al*., 1986). A large part of this type of organic matter is surface active and represent the main part of surfactant activity in the sea. (Zutic *et al*.,1981). Extracellular production of organic ligands by phytoplankton may be the most important factor in controlling the effects of biological activity on the trace metal-organic interactions. This production may therefore be the key to understanding the dynamics of these compounds in the oceans. The production of extra-cellular organic compounds by phytoplankton depends on the physical state of the cells as well as on environmental factor such as temperature, salinity, nutrient concentrations, light intensity, etc. and on the presence of the toxic compounds in the medium (Jensen, 1984; Zhou, and Wangersky, 1989a). In this context, there has been much speculation about the influence of trace metals on primary productivity in the marine environment. A deficiency of the bioactive trace metals Mn, Fe, Co, Ni, Cu, and Zn, may limit oceanic plankton production (Brand *et al*., 1983).

Based on the results of bioassay experiments (Sunda and Guillard, 1976; Anderson and Morel, 1978 and 1982; Sunda and Ferguson, 1983; Folsom *et al*., 1986) and theoretical models (Jackson and Morgan 1978; Hirose and Sugimura, 1983; Wood and wang, 1985), it was assumed that the chemical parameters controlling metal-organism interactions are the free metal ion's activities and not the metal concentration. Thus, chemical speciation plays an important role in the bioactive metals in oceanic chemistry, which controls planktons production and influences plankton species composition in the ocean (Morel and Hudson, 1985).

Recent studies with closely related freshwater cyanobacteria have described the sequence and basic regulation of a putative metallothionein gene (smtA) in these organisms (Robinson *et al* 1991, Gupta *et al* 1993). That gene was induced by acute metal exposure and undergoes a novel re-arrangement upon long-term chronic exposure. Besides, these molecular attributes make this gene a good candidate as a sensitive molecular bio-marker of toxic exposure and stress (Chang, 1994).

The adsorption processes were carried out in two steps:

1) Rapid physical adsorption first, and then
2) Slow chemical adsorption.

6.1.1 Heavy Metal Toxicity:

Many of the toxic metals strongly adhere to proteins, and frequently their toxicity is due to the displacement of useful metals from metallo-enzymes, with a consequent loss or modification of enzyme function. Another result of this affinity to proteins is that the metals can be accumulated from repeated small doses and can be concentrated upto food chains. Trace elements at natural concentrations either constitute the prosthetic group of enzyme or function as enzyme activators, and at higher concentration they act as inactivator of enzyme and protein precipitants. Most of the heavy metals are often reported to be enzyme blockers (Fulkerson, 1973). While there are conflicting opinions on the exact mechanism of toxic action of individual elements, it is generally recognized that the toxicity of metals is related to their electro-negativities, and more electronegative a metal, the more toxic it is. The heavy metals are generally toxic to micro-algae as these inactivate the enzyme particularly through functional sulfahydryl group present at the reactive site of many enzymes (Bowen, 1966). They may function as anti-metabolite, catalyst, chelating agent or substances combining with cell membrane by replacing structurally important elements in cell (Bowen, 1966; Hughes, 1975).

All metals exhibit similar inhibitory effect with increasing activity. These effects include the depression of net growth rate and morphological changes in cell and eventually death (Sorentino, 1979). The biological variables used to measure biological inhibition include induced cell counts, net photosynthesis and respiration rates, chlorophyll and other pigments content, ATP, DNA, RNA and dry organic matter content, net weight and carbon balance.

Apart from acting as enzyme inhibitors and protein precipitants, some of the other possible modes of toxic action of metal has been outlined by Auberg (1948). They may act as anti-metabolites e.g. chlorate, fluoride, bromate, borate, permanganate, occupying sites for phosphate and nitrate. Substances forming stable precipitates or chelates with essential metabolites e.g. Zn reacts with phosphate and Fe with ATP. Some substances combine with cell membranes and affect its permeability e.g. Cu, Cd and Pb. These may effect the transport of sodium, potassium, chloride ions and other organic molecules across the membranes or even rupture the membrane completely. Some of the metals replace electronically important elements, in the cell e.g. Li replacing Cl.

The relative toxicity of heavy metals has been reported by Rzewaska and Wernikowska-Ukleja, (1974) and Sorentino, (1979). In diatoms Amphora sp. and *Navicula* sp. copper is localized intra-cellularly in electron-dense spherical bodies resembling to polyphosphate granules and electron-dense irregular bodies may maintain low cyto-plasmic levels of copper, thus may reduce the toxicity. Phosphates precipitate or co-precipitate most of the heavy metals forming complexes resulting in their partial detoxification (Eichenberger, 1979) and thus reduce their availability and toxicity (Skaar et al. 1974).

Another aspect of internal compartmentalization of the synthesis of metal-binding components, which may function in detoxification.

Heavy metal exerts its harmful effects in many ways, although all the major mechanism of toxicity is the consequences of the strong coordinating properties of metal ions (Ochiai, 1987). The effects of heavy metal toxicity in algae include:

1) An irreversible increase in plsmalemma permeability, leading to the loss of cell solutes and changes in cell volume (Christensen *et al*., 1979).
2) A reduction in photosynthetic electron transport (Shioi *et al*., 1978) and photosynthetic carbon fixation (Davies and Sleep, 1980).
3) The inhibition of respiratory oxygen consumption (Rivikin, 1979).
4) The disruption and nutrient uptake processes (Harrission and Morel, 1983).
5) Enzyme inhibition, due to the displacement of essential metal ions (Rebun and Ben, 1984).
6) The inhibition of protein synthesis (Kremer and Markham, 1982).
7) Abnormal morphological development (Rosko and Rachlin, 1977).
8) The impairment, mortality and loss of flagella in certain micro-algae (Nakono *et al*., 1978)

9) The degradation of photosynthetic pigments, coupled with reduction in growth (Monahan, 1976).

6.1.2 Toxic Effects of Petroleum Hydrocarbons:

Sebastian (1981) reported that some species of phytoplankton can tolerate a range of petroleum oil concentration viz., *Ditylum brightwelli*, (5-50 mg /L), *Coscinodiscus granii* (5-100 mg /L), and Minorv and Lanskaya (1969) *Chaetoceros curvisetus* (100-1000 mg /L) *Melosira moniliformes* (1000 mg /L).

There is also a growing concern about the widespread occurrence of oil pollution in the sea. There is considerable evidence that petroleum and its products become toxic in varying degrees to different organisms in the food chain (Anderson, *et al*., 1974; Batterson, *et. al*.,1978; Corner, *et. al*.,1978; Karydis, *et al.*,1979).

Ansari (1997) studied the effects of water soluble fraction of Bombay High crude oil and heavy duty marine diesel on the growth of a micro-alga. Most concentrations of the oil depressed the growth rate in *Isochrysis* sp. Marine diesel prevented the growth of the alga in a concentration above 10% while crude oil at a similar concentration had little effect on the growth. Hydrocarbon would cause environmental damage through selective effects on natural biota in the marine environment.

Phytoplanktons are sensitive to oil spill and the sensitivity varies among major groups and sometimes within species. A few species particularly *Nitzschia clostarium., Ditylum brightwelli, Trichodesmium* sp., *Rhizosolenium* sp., *Surirella* sp., *Chaetoceros* sp., and *Biddulphia sinensis* were damaged with a coating of black layer attributed to PHC, around the cell (Gajbhiye *et al*. 1995).

6.2 Materials and Methods:

To detect the close association of different pollutants like heavy metals and petroleum hydrocarbons with the marine phytoplankton and to find out the regulatory factors for community composition and productivity of that region, the methods of biometry measurements were followed as described by Mead and Curnow (1986); Wawiye,-O. *et al.*, (1997); Nagar and Das (2000). For all the statistical measurements related to correlation coefficients for understanding the statistically considerable association with the different independent variables and the dependent variables and within independent variables with each other, one-way ANOVA test had been done to observe whether any statistically significant differences were seen between Alang and Mahuva for the same parameter and Multiple Regression analysis was carried out to establish the cause and effect relationships within different parameters by using different statistical computer programming such as Origin, Statistica, Statview, SPSS 9.0 and Microsoft Excel 98. The minimum value of the calculated correlation coefficient (R) is 0.500, which showed a weak association within the related parameters and the significant value based on at least 95% confidence limit for one-way ANOVA test is given importance for discussion.

6.3 Results and Discussion:

Correlation between aquatic physico-chemical conditions and the occurrence of planktonic and benthic diatom species in the field has been used traditionally, to interpret the preference of taxa to single selected environmental factor and, likewise, the distribution of diatom taxa has been used to infer certain environmental characteristics of aquatic systems (Hustedt 1938-1939; Birks *et al*. 1990; Ter Braak and van Dom 1989; Kouwe and van der Aalst 1991; Agbeti 1992; Anderson *et al*. 1993; van Dom *et. al*., 1994; Kelly and Whitton 1995; Stevenson and Pan 1999). Correlation analysis between the diatoms and the environmental variables confirmed that heavy metals in the water and sediment had a marked and lasting effect on the diatom communities. (Sergi Sabater, 2000). The details results related to correlation coefficient between Phytoplankton and heavy metals are given for Alang in the table no. 81 and for Mahuva in the table no. 82.

6.3.1 Iron (Fe):

The controversy surrounding the question of whether iron limits phytoplankton production in high-nutrient, and low-chlorophyll regions of the world's oceans has stimulated research on numerous fronts, including the search for diagnostic indicators of phytoplankton iron nutritional status. The statistically significant different (at 95% significant limit) of the iron concentration in sediment between Alang and Mahuva indicates that the ship-scrapping activities at Alang might be the principal source of additional iron concentration in sediment and seawater at Alang. In this situation iron probably would occur as suspended ferric hydroxide or ferric chloride or in some form of an organic complex. The water initially contains dissolved ferrous iron, which is slowly oxidized to ferric hydroxide in the presence of dissolved oxygen. This precipitate imparts turbidity to the water.

Iron has long been known to be essential to the growth of micro-algae. It is a key element in metabolism being a constituent of the cytochrome molecule. The rate of photosynthesis may lowered by iron deficiency. Iron is necessary in chlorophyll construction. Iron showed statistically considerable positive correlation with 30 species out of 170 marine phytoplankton species, recorded at Alang ship breaking yard and there was no remarkable species which shows considerable negative correlation with Fe. Out of 30 species, 22 species showed strong correlation ($R>=0.700$), 3 species showed a moderate correlation ($R>=0.600$) and rest showed weak association ($R>=0.500$) with dissolved iron at Alang. There were 19 species showing statistically significant positive correlation only with Fe and did not show any significant correlation with any other metals. Only ten (10) species, out of 30 showed remarkable positive correlation with Fe along with Mn and the other 6 species showed the positive correlation with Fe, Mn and Zn and there was only one species positively correlated with Fe, Mn, and Zn and negatively correlated with Cd. This might be attributed to Fe, which acts as one of the strong limiting factors of marine phytoplankton in Alang. In Mahuva, 15 species showed a considerable positive correlation and no considerable species was recorded to correlate negatively with dissolved Fe. Among the 15 species, 11 species showed a very strong association ($R>=0.900$), 3 species showed a strong association ($R>=0.700$) and only remaining one showed a moderate correlation with dissolved Fe at Mahuva. There were no species, which showed positive or negative significant correlation only with Fe. Fourteen species (14), out of 15 species showed remarkable positive correlation with Fe accompanied with Mn and the other showed the positive correlation with Fe and Ni. *Amphora hyalina* K., *Navicula concellata* Donk., and *Navicula miniscula* Grun. showed a strong association with Fe in both the places Alang and Mahuva reveals that they might be considered as high Fe concentration indicator species.

Flavodoxin (Flv), an iron-independent protein capable of catalyzing many of the same reactions as the non-heme, iron-sulfur protein ferredoxin (Fd), is produced by certain prokaryotic and eukaryotic organisms in response to iron stress.

6.3.2 Manganese:

Manganese and iron together have been considered as water quality parameters. However, their aquatic chemistries are considerably different and they should be evaluated and treated separately; But, manganese is not similar to iron from its water quality effects as manganese is less abundant than iron in the earth's crust but is a common constituent of rocks and soils. Ferromagnesian minerals as biotite and hornblende frequently contain some manganese. In sediments, manganese is found as rhodochrosite ($MnCO_3$), rhodonite ($MnSiO_3$), Hausmanite (Mn_3O_4), bixbyte (Mn_2O_3), pyrolusite (MnO_2) and manganosite (MnO). The oxides and hydroxides of manganese are the most commonly found constituents in rocks and soils. Since manganese is essential in plant metabolism, it frequently appears in surface waters as a result of decaying vegetation (leaves, aquatic plants, soil organic matters, etc.).

Manganese concentration in Sediment and Total Suspended Solids showed statistically significant (at 95% significant limit) differences between Alang and Mahuva region, but dissolved Mn concentration in seawater did not show any considerable difference between study areas, Alang and Mahuva. Manganese concentration as dissolved in seawater correlated positively with 36 phytoplankton species in Alang and 14 species in Mahuva. No species correlated negatively with Mn, which was statistically significant, in Alang and Mahuva. In Alang, out of 36 phytoplankton species only 9 species correlated significantly exclusively with Mn and did not show any considerable correlation with other metals. But in Mahuva none of the species showed any considerable correlation with exclusively Mn. Manganese showed a typical association with Fe. In Alang, it showed positive correlation along with Fe with 10 species out of 36 species and in Mahuva, it showed significant positive correlation with 14 species out of 15 species. Manganese also showed positive correlation with copper only with one species at Alang but with 13 species at Mahuva, and just opposite type of relationship was observed with zinc. Manganese showed co-variance with zinc for 20 species where both of the metals showed positive correlations with all species at Alang, whereas, Manganese showed a close associations with zinc only in one species at Mahuva. Manganese never showed any considerable negative correlation with any species of in both the places, Alang and Mahuva and might be due to following reasons.

Manganese plays an important role in nitrogen metabolism and is probably an important essential requirement for micro-algae. Mn compounds get involved with different physiological activities in micro-algae viz. photosynthesis, respiration, nitrogen metabolism and assimilation, as

Mn compounds are deposited on and in the cell walls of some algae. Mn^{2+} forms only weak coordination complexes, and there is no evidence for significant organic chelating of this metal (Roitz and Burland, 1997).

6.3.3 Copper:

Copper is widely distributed in the environment. It is a common constituent of rocks and soils, it is found in a plant available form at levels of 0.06 to 0.3 ppm (Aubert and Pinta, 1977). In open ocean waters its concentration ranges from 2 to 30 ppb (Rice et al. 1973).

Copper concentration in sediment and as dissolved condition in seawater did not show any significant differences between Alang and Mahuva. But it showed a significant difference (at 95% confidence limit) at Mahuva with total suspended solids, which means it is carried with total suspended solids and readily used by marine phytoplankton. The reduction of dissolved copper concentration in seawater gets compensated from the total suspended solid loads in that region. This indices have been used to asses organic pollution by Kelly *et al.* (1995) and Prygiel *et al* (1999) but their potential use is less evident when other types of environmental stress (heavy metal pollution at shear stress caused by transport of particulate matter) influence water quality (Barbour *et al*. 1999). In general, copper toxicity towards algae is related to the free cupric ion activity (Sunda and Guillard, 1976; Sunda and Lewis, 1978; Anderson and Morel, 1978; Peterson, 1982), although some algae may be effected significantly by insoluble copper complexes (Fitzgerald and Feaust, 1963).

Copper showed considerable association with 14 phytoplankton species in Alang, out of which it showed positive correlation with only 6 species and negative correlation with rest of the 7 species. In cases, where copper showed negative correlations, zinc showed also negative correlation and where copper showed positive correlations, lead (Pb) also showed positive correlations. The observed positive or negative correlation of copper with marine phytoplankton might be due to it being influenced by Pb or Zn, in all cases except one, where positive correlation of copper was influenced by Mn at Alang. In Mahuva, copper showed considerable correlation with 14 species, where it showed only positive correlation and no significant negative correlation with any other phytoplankton species. The positive correlation of copper with the 14 species at Mahuva was accompanied with the positive correlation with Mn and Iron.

In general copper exerts its influence either on the oxidizing site of photosynthesis II (Cedeno-Maldonado, 1972) or on the reducing site of photosystem I (Shioi *et al.*, 1978) although photosystem II is the most sensitive. Wu and Lorenzen (1984) suggested modes of action for Cu^{2+} toxicity that include an alteration of chlorophyll properties by the displacement of Mg^{2+} at the center of chlorophyll molecules (Gross *et al.*, 1970). The inhibition of photosynthetic energy conversion is due to the oxidation of sulphydryl groups on coupling factors I (III) (Uribe and Sark,1982) and the peroxidation of photosynthetic membranes (Sandmann and Boger, 1980). Inhibition of photosynthesis may also be linked with an inhibition of the oxygen evolution process (Wu and Lorenzen 1984). It is most probable that copper toxicity involves several sequential steps (Sorentino, 1979). Cyanobacteria are also very sensitive to Cu^{2+} and are among the first autotrophs affected by copper based algicide applications (Wurtsbaugh and Horne, 1982). The high susceptibility of the blue-green algae to copper seems to be related to the sensitivity of N_2 – fixation , which is inhibited at Cu^{2+} levels < 5 ppb (Horne and Goldman, 1974); Elder and Horne, 1978).

As copper is an essential micronutrient for phototrophic microorganism and is a constituent of plastocyanins, it effects electron transport in photosystem I of photosynthesis (Sorentino, 1979). The electrochemical potential of Cu^{2+}/Cu^{+} is –268 mv, which is well with in the physiological range. Copper easily interacts with radicals, best with molecular oxygen. This radical character makes copper very toxic (Nies, 1999), and it is reported that the synthesis of Chl-a being inhibited more than that of Chl-b at all concentration of Cu^{2+} and Cd^{2+} (Muthuchelian *et al.*, 1988). Kennedy and Gonsalves (1989) have shown that Cu^{2+} shows the inhibitory effect on the ATPase activity of a plasma membrane functions. Considerable variation exists among algae in copper sensitivity (Berland *et al*., 1976) but most algae are inhibited by the levels in the low ppm range. Copper also induces the presence of irregularly shaped electron dense Cu-bodies within algae (Daniel and Chaberlain, 1981). Most of the copper causes on efflux of K^{+} from cells (Overnell, 1975) due to disruption of the cellular diffusion barrier (Nielson, 1971). It also induces giant cell formation in *Nitzschia* sp. (Lumsden and Florence, 1983) and pigment degradation (Thomas *et al*., 1980), and possibly the primary effect of Cu by causing early cell membrane damage (Nielson, 1971).

6.3.4 Cadmium:

Cadmium occurs in environment mainly as component of minerals in the earth's crust at an average concentration of 0.18 ppm (Babich and Stotzky, 1978). Cadmium levels in soil usually average between 0.06 and 0.4 ppm, (Iverson and Brinkman, 1978; Fleisher *et al.,* 1974). Its concentration in seawater is 0.1 ppb (Iverson and Brinkman, 1978). Cadmium is also one of the most toxic pollutants in biosphere, and it enters the hydrosphere from various natural and anthropogenic sources and gets recycled through geological and biological processes (Forstner and Whitmann, 1979). Cadmium occurs in air as a result of the industries engaged in extraction, refining, electroplating and welding of cadmium containing materials and also from those industries occupied in refining of copper, lead and zinc. Cadmium is also used in alkaline accumulated alloys, paints and even in particles. The burning of oil and wastes and scrap metal treatment also contribute to cadmium source for pollution.

Cadmium concentration did not show any remarkable differences in sediment, total suspended solid loads, and seawater between Alang and Mahuva. Cadmium concentration in Alang showed positive correlation with 19 phytoplankton species and negative correlation with one species at Alang. It showed positive correlation with the 16 species where it was accompanied with Cobalt. In Mahuva, Cd showed positive correlation with only 3 phytoplankton species within which 2 species showed positive correlation accompanied with Zn. Cadmium is a relatively rare element (Wood, 1974) with no known biological function (Babich and Stotzky, 1978). The solubility product of CdS is 1.4×10^{-29}. Cadmium is known to be a potential toxicant. Cadmium ranks close to lead in toxicologic importance and can induce a wide range of toxicity (Mukherjee *et al*., 1984). Chronic effects of cadmium compounds are highly toxic and dangerous. Cadmium environmental pollutants from industries were first recognized by Nordberg., (1974). Cadmium has been reported to be phyto-toxic at extremely low concentrations (Page *et al.,* 1981). What makes cadmium particularly hazardous is the fact that physically it resembles calcium in size and imitates zinc in chemical reactions. It is available freely where calcium and zinc are present, and it tends to accumulate in selected tissues of biota. The toxic effect of cadmium is believed to be its ability to substitute Zn in the enzyme system.

The Chl-a concentration was observed more at Alang than Mahuva. But the productivity of that region was less as compared to Mahuva and might be due to the production of phytochelatins. Phytochelatins are small metal-binding polypeptides synthesized by algae in response to high metal concentrations. Using a very sensitive HPLC method, phytochelatins were quantified from phytoplankton in laboratory room cultures at environmentally relevant metal concentrations and in marine field samples. Intracellular concentrations of phytochelatin, in the diatom *Thalassiosira weissflogii*, exhibited a distinct dose-response relation with free Cd^{2+}

concentration in the medium--not with total Cd^{2+} and is detectable even when the free Cd^{2+} concentration is less than 1 pM. In Massachusetts Bay, phytochelatin levels (normalized to chlorophyll-*a*) in the particulate fraction are similar to those measured in laboratory cultures exposed to picomolar free Cd^{2+} concentrations and exhibited a decreasing seaward trend. Incubations of natural samples with added Cd^{2+} confirmed the induction of the peptides by this metal. Ambient phytochelatin concentrations thus appear to provide a measure of the metal stress resulting from the complex mixture of trace metals and cheaters in natural waters (Ahner, *et. al.* 1994)

Muthuchelian *et al.*, (1988) studied the inhibition of chlorophyll biosynthesis by cadmium in Vigna sinensis (Savi). The synthesis of Chlorophyll-*a* was inhibited more than that of Chl-*b* in all concentration of Cu^{2+} and Cd^{2+}. It reduces the ATPase activity of plasma membrane (Kennedi and Gonsalves, 1989). Most studies on cadmium and phototrophic microbes emphasized comparative toxicity sequences of heavy metals (Rai *et al*., 1981; Sorentino, 1979) determining Cd uptake and bioaccumulation (Babich and Stozky, 1978). Cadmium effects are dependent upon both organism used and the toxicity criteria resulted although specific trends in sensitivity are usually less and are difficult to identify. Most establish trend is that marine algae are usually less sensitive to cadmium than are freshwater algae (Berland *et al*., 1976; Kuiper, 1981). This is probably due to differences in Cd speciation since less Cd is available in seawater because of complexing with chlorides etc. (Rebun and Ben-Amotz., 1984). Cadmium toxicity is a function of the free metal ion concentration, not total metal ion level (Foster and Morel, 1982). Differences in sensitivity between freshwater and marine water algae can be pronounced. In contrast ions such as Cu, Zn and Ni may have specific reactions with particular enzymes at rather low concentration, by complexing with chemical groups, such as sulphydryl. But, Cadmium (Cd) ions cause almost total inhibition of nitrate reductase (Fitter and Hay, 1970). Although cadmium is known to be very toxic, it exhibits nutrient like vertical concentration profiles in the open ocean, However, recent work has shown that under conditions of zinc limitation, cadmium enhances the growth of the marine diatom *Thalassiosira weissflogii* (Lee and Roberts, 1995).

6.3.4 Zinc:

Zinc generally occurs around zinc smelters and scrap zinc refineries. Copper, lead and steel refineries also release some zinc in the air. Open hearth furnaces emit 20-25 g Zn/hr in refining the galvanized iron scrap. Zinc occurs exclusively as a divalent cation with completely filled ‘d’ orbitals. Zinc in air occurs mostly as zinc oxide. Zinc serves as an activator in some enzymatic reactions and plays an important role in photosynthesis. Another metabolic role of zinc is in the synthesis of protein. In Alang, zinc was the third highest element found in sampled plots due to ship scrapping activitie. There was significant difference (at 99.9 % significance limit) in the Zn concentration between sediment of Alang and Mahuva. But in case of total suspended solids, no significant difference was found. That means, the Zn easily enters into the biological process and get transferred through total suspended solid loads.

Zinc is an extremely essential element for many enzymatic activities (Cheblowski and Coleman, 1976) in plants and animals. Kennedy and Gonsalves, (1989) and Hussain *et al*.,(1993) studied the effect of Zn ions on the ATPase activity of a plasma membrane. Zinc is an important micronutrient for the growth and metabolism of various algae (Rai et al. 1981). It's toxicity is related to the concentration of free Zn^{2+} ion (Peterson 1982, Allen et al., 1980). The zinc cation is not able to undergo redox changes under biological conditions, and it is used to complex polypeptide chains (Coleman 1998). In plants particularly grown in aquatic condition, the Zn-metalloprotein enzyme carbonic–anhydrase plays a vital role in CO_2 assimilation.

Zinc concentration as dissolved in seawater showed significant correlation with 58 phytoplankton species in Alang and 19 species at Mahuva. Zn showed its close association with the highest number phytoplankton species at both the places, Alang and Mahuva. Zn showed positive correlation with 21 species and negative correlation with 37 species at Alang . Zn also showed the similar trend at Mahuva, as it showed positive correlation with only 3 species but it negatively correlated with 16 species at Mahuva. At both the places, Alang and Mahuva, Zn showed negative correlation with more number of phytoplankton species than the positively correlated species. Higher concentration of Chlorophyll-*a* in Alang than Mahuva showed less primary productivity and might be due to the environmental stress condition caused by Zn. At 15 ppb Zn^{2+} causes a significant reduction in chlorophyll level and primary productivity associated with plankton communities in lake Mischigan (Marchall *et al*., 1983) and most Algae require Zn^{2+} concentration in the low ppm range for significant inhibition. It is observed that there is about 20% inhibition in chlorophyll-a content at 7.2 mg L^{-1}dose (Arjunan et al., 1996). Various morphological effects are also induced by zinc. Some algae however are quite sensitive to zinc, 2.5 ppm Zn^{2+} causes 80% reduction in N_2 fixation and marked effects are noted at as low as 0.5 ppb (Kostyaev, 1981). Zinc at toxic concentration affects the growth and mechanism of green plants (Rosen et al., 1977, Shrotri et al., 1981). In higher plants, elevated levels of Zn are known to inactivate water oxidation complex by releasing manganese ions involved in photosynthetic water oxidation (Tripathy and Mohanty, 1980).

In Alang, Zn showed a typical relationship with Ni as in 13 species, Zn showed negative correlation, whereas Ni showed positive correlation with the same phytoplankton species. But in Mahuva Zn did not show such type of relationship with Ni. The above said 13 species may survives at Alang due to Ni concentration, which is another essential metal for algal growth and gets fatality in Mahuva as Ni did not show any positive correlation for that species. Sublethal effects of zinc have also been investigated in several algae. A concentration of 1 mM $ZnCl_2$ causes a reduction of RNA, DNA and protein levels in chlorella sp. (De Filippis and Pallaghy, 1976b) as well as lowering of pigment content, cell division rates and metabolic activity (De Filippis and Pallaghy, 1976b). In Euglena sp. 1 mM $ZnCl_2$ affects mainly cell division and motility, but severe effects on photosynthesis are also observed (De Filippis *et al*., 1981). Zinc at 0.1 ppm causes broken chains, curved cells and elongated cells in the diatom, Thalassiosira sp. (Kayser, 1997) but induces no morphological changes in *Chorella salina* (Wong *et al*., 1979). In the cyanobacteria, Zn^{2+} causes increase in the surface area of thylakoids, the number and relative volume of lipid bodies, the relative volume of inter thylakoid spaces while causing a reduction in the number and relative volume of cyanophycin granules (Rachlin *et al*., 1985). Zn^{2+} is often localized in cell sectors containing poly phosphate bodies (Jensen *et al*., 1982) but its significance is unclear. Zinc may inhibit the final steps in pigment synthesis in *Asterionella japonica* (Gillan *et al*., 1983) and Euglena sp. (De Filippis *et al*., 1981). It also reacts with the electron transport chain, the water splitting site and oxido reductase reaction of photosynthesis in the latter algae (De Filippis *et al* 1981) like other heavy metals, however high concentration of zinc effects the permeability of cells membranes, leading to the leakage of cations such as K^+ from the cell (Passaw *et al*., 1961).

6.3.5 Cobalt Nickel and Lead:

Cobalt, Nickel and Lead did not show any significant differences of their concentrations in sediment, total suspended solids and as dissolved condition in seawater between Alang and Mahuva. Cobalt is an essential element for growth and biomass production for marine phytoplankton as Co is a co-factor in biomolecules, vitamin B_{12} (cyanocobalamin) which is required for N_2 fixation and the growth of many algal (diatom) species where Ni is reported as both essential and non essential for selective species of marine phytoplankton and Pb as non-essential and toxic for phytoplankton growth and productivity. The nutrient metals, notably Co, Ni and Pb can act as toxicants at elevated concentrations (Sunda and Huntsman 1998). The other metals (Fe, Mn, Cu and Pb) showed some what inducing effect on growth. In seawater, the majority of Ni, Mn, Zn, Co and Fe are present as free aquo-metal ions, while other metals are heavily complexed by chloride [Cd], carbonate [Cu and Pb] (Byrne *et al.*, 1988). Certain metals not only affect the physiology of the cells, but also causes different ultrastructural alterations (Soyer *et al*., 1981). Morelli., and Scarano (2001) observed Cd, Pb and Zn can cause significant growth inhibition in *Phaeodactylum tricornutum* at 5 µM and higher metal concentration (25% less as compared to control).

Cobalt showed positive correlation with 24 species and negative correlation with only 2 species in Alang, and in Mahuva, it showed positive correlation with 8 phytoplankton species and negative correlation with only 1 species. Multiple regression calculation showed cobalt is one of the most important independent variables for chlorophyll-a production at Alang. Nickel never showed any negative correlation with any phytoplankton species at Alang and Mahuva, but it showed positive correlation with 18 species in Alang and 5 species at Mahuva. Pb showed the lowest number of species with which it correlated of the 8 metal tested at Alang and Mahuha. All metals tested by Rachlin *et al*., (1982) and Soyer *et al*., (1981) caused the production of membrane whorls on the cell wall. Electrochemical measurements indicate that the tendency of zinc to make organic ligands in oceanic surface water is 98-99% (Bruland, 1989; Donat and Bruland, 1990) whereas, Ni and Co has less tendency to make complexsation as compared to Zn and may be due to reason that free ions concentration of Zn with in the medium reduced fast as compare to Ni and Co by complexing with the organic decries (dead phytoplankton cells due to long exposure in metal doses).

The cell's ability to increase transport rates in response to decreases in available nutrient concentration ultimately is subject to limits related to diffusion of labile metal species to the cell surface and to maximum rates of metal transport across the membrane. Such limits are readily observed for Fe and Zn uptake by marine phytoplankton. Both Pb and Cu may present in their free ionic forms (Pb^{2+} and Cu^{2+}) at pH less than 5.0 (Matheickal *et al.*, 1999). As Pb is having the complexation tendency (67-94%) with organic ligands in higher pH and is added in very low concentrations as compared to other metal concentrations, showed a less toxic effect as compared to other metals.

6.3.7 PETROLEUM HYDROCARBONS

Petroleum hydrocarbons showed a very few considerable correlations between the appearance of phytoplankton and the concentration of petroleum hydrocarbon in the same sampling time. As it showed positive correlation only with 4 species and negative correlation with two species in Alang and only 9 species with which this showed positive correlation and no negative correlation at Mahuva. But interesting results were observed when the concentration of petroleum hydrocarbon were correlated with the appearances of phytoplankton collected in the subsequent sampling time as it showed positive correlation with 41 species and negative correlation with 11 species at Alang. In the similar way petroleum hydrocarbon showed positive correlation with 20 species and no negative correlation with any other species at Mahuva, which might be due to the effects of petroleum hydrocarbons that act very soon on the physiological activities of marine phytoplankton as it gets spread out very fast and makes a thin layer of the seawater surface, which prevent to mix up the essential gases like O_2 and CO_2 and reduce the photosynthetic activities but it needs a time to get dissolved a fraction within seawater, and to produce different derivatives in presence of sunlight and which might influence the succession of marine phytoplankton and community composition of the primary producers of that region. The higher concentration of petroleum hydrocarbons at Alang may be the cause of increasing cyanobacterial community and as a result it showed higher concentration of chlorophyll-a due to organic pollution of that area.

As air and seawater temperatures showed comparatively higher values than the other coastal regions of India and might be due to its geographical position. Hot weather might decrease the viscosity of the oil, allowing it to penitrate more easily into the water column (Sheilla Ottway 1971). During summer season, the number of genera or species available in Alang and Mahuva showed a sharp reduction and might be due to increasing weather and seawater temperatures. Hot sunny weather may increase the formation of toxic acids and peroxides in the oil. The light transmitting properties of oils indicate that different crude oils vary widely in this respect. The light absorbing properties of oil alone would affect the ecology of rock pools, where the photosynthesis of plants is a crucial factor in maintaining ecological stability. The blackest and thickest crude oils are the least toxic while the translucent thin, brown oils are the most toxic at 16 ° C . This is a very important fact, since a thick, black oil, when washed on to a shore, is very conspicuous and therefore usually readily dealt with. Thin brown oil washed in the same way, however, is virtually transparent and may therefore go unnoticed, even though its toxicity may be 90 times as great as that of the thick black oil. Certain photosynthetic pigments of marine algae have absorption spectra showing maximum absorption towards the blue end of the spectrum (eg. Chl-a, Chl-b, B-Carotin). The photosynthetic activity of these pigments would therefore be impeded by the presence of an oil film over the surface of water. (Sheilla Ottway 1971). The oil tested vary widely in toxicity from 1 to 89 percent. Toxicity clearly varies with temperature, but not in a consistent way for all oils. This implies that for any given crude oil, the toxic effluents, differ in the event of a washed oil spill (Sheilla Otway 1971). The various hydroperoxides, phenols, carboxylic acids and ketones, which are produced as a result of solar radiation on oil slicks, are thought to be the cause of observed toxicity of photo-oxidized oil (Hansen, 1975; Herbes & Whitley, 1983; Larson *et al*., 1976, 1977 and 1979; National Academy of Sciences, 1985; Winters *et al.* 1977).

Table 81: Correlation coefficient of the phytoplankton species with the heavy metals concentration in seawater of Alang Ship breaking Yard during the study period of Jun 2001 to April 2003.

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Acantheses brevipes Agardh.	-0.212	-0.271	-0.095	-0.095	-0.097	-0.16	-0.174	-0.291
Acantheses brevipes var. *angulata (Grey.) Cleve.*	-0.289	-0.277	-0.228	-0.082	***-0.532**	***-0.521**	0.493	-0.281
Amphiprora gigantea var. *sulcata* Cleve..	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Amphiprora meditica Perag.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Amphiprora sulcata Cleve.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
*Amphora arnicola*var. (Perag.)	-0.204	-0.186	0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Amphora costata Wm. Sm.	0.014	0.291	-0.188	-0.272	0.114	0.157	0.035	-0.017
Amphora cymbifera Greg.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Amphora hyalina K.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Amphora inflexa Breb.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Amphora laevisssima Greg.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Amphora ostrearia Var.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Amphora surpentina	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.0436	0.025
Amphora turgida Greg.	0.314	0.096	-0.259	-0.3	0.212	0.125	-0.171	-0.392
*Amphora valida*Perag.	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025
Asterionella bleakeleyi Wm. Sm.	-0.193	-0.234	-0.156	-0.209	-0.065	-0.124	-0.16	-197
Asterionella notata Grun.	0.274	0.04	-0.053	-0.017	-0.057	0.083	0.422	-0.017
Asterionella japonica Cleve.	0.155	****0.657**	0.359	-0.065	0.073	0.411	0.065	-0.062

Contd…

Table 81: (Contd..)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Bacillaria paradoxa Sm. & Ehrneb.	0.418	***0.506**	-0.254	-0.38	0.189	0.46	0.225	-0.023
Biddulphia aurita (Lyngbye) Breb & Godey.	0.245	*****0.728**	0.223	-0.167	0.132	***0.511**	0.08	-0.039
Biddulphia bidulphiana (Sm.) Boyer.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Biddulphia mobiliensis (Bailey) Grun.	-0.146	0.073	-0.156	-0.189	-0.018	-0.03	0.115	0.026
Biddulphia pulchella Gray.	0.329	0.183	-0.118	-0.116	-0.02	0.223	0.452	0.024
Biddulphia reticulata Roper.	-0.1639	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Biddulphia rhombus Ehrneb.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Biddulphia sinensis Griville.	-0.199	-0.239	-0.159	-0.204	-0.079	-0.127	-0.161	-0.209
Campylodiscus echeneis Ehrneb.	*****0.736**	0.335	-0.197	-0.135	0.256	0.337	0.235	-0.239
Campylodiscus eximius Var.	0.357	0.379	0.217	-0.243	**0.71**	0.274	0.082	***0.585**
Campylodiscus samoensis Grun.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Cerataulina bergonii Perag.	-0.212	-0.218	*****0.898**	**0.63**	-0.172	***-0.502**	-0.139	-0.367
Ceratium fusus	-0.197	-0.255	-0.243	0.14	-0.139	0.161	-0.396	0.284
Ceratium longipes Gran.	-0.197	-0.255	-0.243	0.14	-0.139	0.161	-0.396	0.284
Chaetoceros curvisetus Cleve.	-0.199	-0.239	-0.159	-0.204	-0.079	-0.127	-0.161	-0.209
Chaetoceros javanicum Cleve.	-0.128	0.112	-0.174	-0.204	0.055	0.032	0.011	0.049
Chaetoceros willei	-0.212	-0.218	*****0.898**	****0.603**	-0.172	***-0.502**	-0.139	-0.367
Climachosphenia elongata Bail.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Climacoshenia molinigera Ehrneb.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367

Contd…

Table 81: (Contd..)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Corethron hystris Hensen.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	0.367
Coscinodiscus apiculatus Ehrneb.	-0.318	-0.315	0.136	0.073	***-0.571**	*****-0.716**	0.4	-0.48
*Coscinodiscus argus*Ehrneb.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Coscinodiscus asteromphalus Ehrneb	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Coscinodiscus biangulantus Schmidt.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Coscinodiscus centralis Ehrneb.	0.42	0.311	-0.09	-0.325	0.234	0.266	-0.226	-0.36
Coscinodiscus compactum	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025
Coscinodiscus concinnus Wm. Sm.	-0.243	-0.147	-0.349	-0.401	-0.022	-0.04	-0.398	-0.15
Coscinodiscus excentricus Ehrneb.	-0.249	-0.302	-0.283	0.084	-0.269	0	-0.244	0.171
Coscinodiscus gigus Ehrneb.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Coscinodiscus granii Gouch.	-0.164	-0.197	-0.1	-0.1	0.019	0.056	-0.396	0.029
Coscinodiscus janischii A.S.	-0.205	-0.249	-0.104	-0.171	-0.099	-0.161	-0.129	-0.239
Coscinodiscus jonesianus (Grev.) Ostenfeld.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Coscinodiscus kruzii Grun.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Coscinodiscus lineatus Ehrneb.	0.321	0.333	0.136	-0.03	-0.024	0.253	0.42	-0.053
Coscinodiscus marginatus Ehrneb.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Coscinodiscus obscurus A. S.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Coscinodiscus perforatus Ehrneb.	-0.279	-0.224	-0.252	-0.331	0.011	-0.036	-0.472	0.041

Contd…

Table 81: (Contd…)

Name of the Phytoplankton	**Fe**	**Mn**	**Cd**	**Co**	**Cu**	**Zn**	**Ni**	**Pb**
Coscinodicus radiatus Ehrneb.	0.035	0.016	-0.1	-0.211	-0.115	0.052	-0.38	-0.189
Coscinodiscus stellaris Raper.	-0.195	-0.31	-0.231	-0.178	-0.088	-0.119	-0.348	0.01
Coscinodiscus subtilis Ehrneb.	-0.278	-0.291	**0.898**	****0.623**	-0.0275	***-0.572**	-0.115	-0.39
Coscinodiscus suspectus Jan.	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025
*Cyamatopleura solea*Breb.	-0.231	-0.28	-0.198	-0.183	-0.102	-0.101	-0.224	-0.164
Dictyoneis marginata	-0.199	-0.239	-0.159	-0.204	-0.079	-0.127	-0.161	-0.209
Diploneis crabro (Cleve) Var.	*****0.768**	0.464	-0.206	-0.21	0.435	0.368	-0.036	-0.342
Ethmodiscus rex Hand.	0.337	0.298	0.196	-0.224	*****0.704**	0.216	0.072	***0.59**
Exuviella (Prorocentrum) marina Che.	0.268	0.035	-0.03	-0.001	-0.062	0.07	0.418	-0.026
Grammatophora angulosa var.	-0.231	-0.214	-0.053	-0.127	***-0.518**	****-0.643**	***0.539**	-0.46
Grammatophora longissima Petit.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Grammatophora serpentina Ehrneb.	0.469	0.246	-0.269	-0.302	0.021	-0.096	0.324	***-0.553**
Grammatophora solea Breb.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Gyrosigma balticum Ehrneb.	0.48	0.208	-0.258	-0.277	0.299	0.214	-0.181	-0.415
Hyalodiscus laevis Ehr.	-0.119	-0.093	-0.315	-0.328	-0.27	-0.256	0.426	-0.176
Hyalodiscus nobilis Pant.	-0.169	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Hyalodiscus subtilis Bail.	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.426	0.025
Lauderia borealis Gran.	-0.212	-0.218	**0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Leptocylindrus danicus Cleave.	-0.164	0.131	-0.137	-0.196	-0.32	0.003	0.049	0.043
Licmophora communis	-0.139	-0.031	-0.098	-0.253	-0.048	0.022	-0.132	-0.204

Contd…

Table 81: (Contd….)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Licmophora crystallina K.	0.175	****0.683**	0.199	-0.114	0.102	***0.512**	0.124	0.046
Licmophora dalmatica var.	0.252	***0.58**	-0.12	-0.365	0.084	0.455	0.299	-0.017
Melosira moliniformes (Muller) Agardh.	-0.132	0.206	-0.205	-0.26	0.077	0.108	-0.019	0.021
Melosira numuloides (Dillw.) Agardh .	-0.096	0.331	-0.139	-0.287	0.035	0.208	0.051	0.048
Navicula campylodiscus	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Navicula clavata var.	-0.197	-0.255	-0.243	0.14	-0.139	0.161	-0.396	0.284
Navicula concellata Donk.	*****0.789**	*****0.739**	-0.097	-0.27	0.455	***0.559**	-0.014	-0.319
Navicula dersa f. *delicatula* Hemidal.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Navicula directa Wm. Sm.	0.03	0.105	-0.306	-0.328	-0.315	-0.273	0.448	-0.439
Navicula miniscula Grun.	***0.521**	0.225	-0.365	-0.255	0.051	0.054	0.213	-0.442
Navicula quadratarea Cleve.	0.315	0.223	0.173	-0.204	**0.69**	0.161	0.062	***0.587**
Navicula salinarum	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Navicula quadratarea Cleve.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Nitzschia angularis var. *affinis* Grun.	*****0.771**	*****0.739**	-0.107	-0.296	0.406	***0.514**	0.045	-0.36
Nitzschia Commutata Grun.	-0.229	-0.214	-0.101	-0.15	***-0.517**	***-0.617**	***0.533**	-0.436
Nitzschia incerta Grun.	0.321	**0.547**	0.119	-0.12	0.022	0.459	0.326	0.011
*Nitzschia incurvata*Grun.	-0.271	-0.258	-0.188	-0.184	-0.003	-0.079	-0.468	0.006
Nitzschia insignis	0.497	*****0.756**	0.034	-0.277	0.154	***0.587**	0.318	-0.092
Nitzschia lanceolata	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025

Contd….

Table 81: (Contd…)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Nitzschia linearis Var.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Nitzschia longissima (Breb.) Ralfs.	0.284	0.215	-0.166	-0.207	-0.115	0.239	-0.195	-0.202
Nitzschia lorenziana Grun.	*****0.765**	****0.629**	-0.195	-0.272	0.294	****0.607**	0.208	-0.167
Nitzschia obtusa Var.	***0.506**	*****0.736**	0.009	-0.262	0.169	***0.583**	0.355	-0.06
Nitzschia panduriformes Greg.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
*Nitzschia recta*Htz.	-0.204	-0.186	-0.164	-0.204	-0.494	**-0.578**	***0.554**	-413
Nitzschia seriata Cleve.	*****0.769**	***0.583**	-0.182	-0.35	0.41	0.304	0.125	-0.375
Nitzschia sigma (Kutz) Wm. Sm.	0.205	****0.613**	-0.034	-0.329	0.024	0.447	0.262	0.022
Nitzschia sigmoidea (Nitz) Wm Sm.	-0.164	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Nitzschia socialis Greg.	***0.584**	0.327	-0.262	-0.289	0.152	0.041	0.223	***-0.519**
Nitzschia striata Cleve.	0.258	0.056	-0.253	-0.296	0.181	0.097	-0.174	-0.379
Nitzschia subtilis Var.	0.193	****0.696**	0.199	-0.177	0.104	**0.501**	0.09	0.004
Nitzschia valida Grun.	-0.223	-0.208	-0.16	-0.2	***-0.502**	***-0.603**	***0.634**	-0.399
Noctiluca miliaris Suriray.	0.38	0.293	-0.185	-0.246	-0.11	0.19	***0.599**	-0.221
Pediastrum sp.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Peridinium depressum Bail.	-0.175	-0.208	-0.57	**-0.7**	0.011	-0.08	-0.404	0.011
Peridinium exiguum Cleave.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Peridinium ovalum Shutt.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Peridinium pentagonum Gran.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Peridinium thorianum Paulsen.	-0.199	-0.239	-0.159	-0.204	-0.079	-0.127	-0.161	-0.209

Contd..

Table 81: (Contd….)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Phaeocystis sp.	0.193	***0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Pleurosigma accutum Norm.	-0.245	-0.239	-0.214	-0.174	***-0.522**	***-0.542**	0.469	-0.352
Pleurosigma affine Grun.	-0.125	-0.237	0.338	*****0.813**	-0.122	-0.084	0.441	0.211
Pleurosigma angulatum Sm.	0.005	0.343	-0.009	-0.255	-0.25	0.21	-0.005	-0.106
Pleurosigma attenuatum Var. *scalpurum* Grun.	***0.742**	**0.572**	-0.218	-0.328	0.373	0.368	0.022	-0.43
Pleurosigma balticum var. *wansbeckii* Donk.	0.282	0.422	-0.271	-0.371	0.133	0.242	0.27	-0.118
Pleurosigma brebisonii Grun.	-0.058	0.285	0.063	-0.237	-0.354	-0.188	***0.507**	-0.367
Pleurosigma caspidatum Cleve.	0.168	***0.675**	0.179	-0.204	0.042	0.429	0.161	-0.049
Pleurosigma clevi Grun.	***0.676**	*****0.791**	0.053	-0.239	0.14	****0.606**	0.334	-0.029
Pleurosigma compactum Grun.	0.244	*****0.72**	0.163	-0.219	0.137	***0.525**	0.068	-0.05
Pleurosigma decorum Sm. (Perag.)	***0.528**	***0.583**	-0.152	-0.343	0.073	0.192	0.336	-0.495
Pleurosigma delicatulum Wm. Sm.	0.363	***0.502**	-0.004	-0.197	0.019	0.421	0.439	0.007
Pleurosigma diminutum Grun.	***0.764**	***0.547**	-0.233	-0.288	0.432	0.396	0.003	-0.36
Pleurosigma distortum Sm.	0.019	-0.08	0.153	-0.095	0.149	**-0.92**	-0.238	0.257
Pleurosigma faciola Wm. Sm.	0.105	-0.098	-0.122	-0.159	-0.104	-0.004	0.008	0.109
Pleurosigma formosum Wm. Sm.(Grun.)	***0.663**	0.343	-0.31	-0.182	0.317	0.35	-0.101	-0.284
Pleurosigma japonica	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
*Pleurosigma lanceolatum*Donk.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413

Contd…

Table 81: (Contd….)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Pleurosigma latum Cleve.	**0.7**	0.402	-0.233	-0.25	0.415	0.329	-0.095	-0.388
Peurosigma lineari Grun.	-0.031	***0.513**	0.023	-0.323	-0.096	0.335	-0.062	-0.044
Pleurosigma longum var. *lanceolata* Perag.	*****0.734**	0.438	-0.214	-0.225	0.43	0.349	-0.074	-0.364
Pleurosigma majus Grun.	0.156	****0.662**	0.169	-0.215	0.014	0.395	0.192	-0.072
Pleurosigma marinum Donk.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Pleurosigma normani Gupp.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Pleurosigma obscurum var. *diminuta* H.P.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Pleurosigma rigidum Wm. Sm.	-0.1614	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Pleurosigma salinarum Grun.	0.193	****0.696**	0.199	0.177	0.104	***0.501**	0.09	0.004
Pleurosigma scalproides Rab.	-0.192	-0.192	-0.01	****0.65**	-0.028	0.097	0.347	0.43
Pleurosigma spaciosum Wm. Sm.	0.441	0.392	-0.349	-0.377	0.194	0.276	0.092	-0.221
Pleurosigma spencerii Wm. Sm.	0.089	0.456	0.045	-0.286	0.07	0.36	-0.201	-0.054
Pleurosigma sulcatum Grun.	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025
Pleurosigma tenuissimum Sm.	-0.006	0.493	-0.072	-0.338	0.073	0.339	-0.054	0.043
Podocystis spathulata shadb.	-0.064	0.245	-0.047	-0.024	-0.122	0.435	-0.322	0.186
Podosira adriatica K.	0.436	****0.619**	0.215	-0.321	***0.57**	0.474	0.175	0.48
Podosira argus Grun.	0.194	-0.018	-0.216	-0.171	-0.246	-0.115	****0.648**	-0.152
Podosira steliger Bail.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Pseudo-nitzschia subcurvata Wm. Sm.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367

Contd…

Table :81: (Contd…)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Pyrocystis lunula Var.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Rhabdonema adriaticum Kutz Harv. & Bail) Stodder.	-0.291	-0.276	-0.144	0.229	-0.435	-0.428	****0.683**	-0.083
Rhabdonema punctatum (Harb & Bail) Stodder.	-0.164	-0.197	-0.100	-0.100	0.019	-0.056	-0.396	0.029
Rhizosolenia delicatula Cleve.	-0.204	-0.186	-0.164	-0.204	-0.494	***-0.578**	***0.554**	-0.413
Rhoicosigma angularies	-0.197	-0.255	-0.243	0.14	-0.139	0.161	-0.396	0.284
Rhoicosigma compactum	*****0.75**	0.46	-0.198	-204	0.436	0.36	-0.058	-0.342
Rhoicosigma curvata (K.) *Grun.*	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
Rhoicosigma oceanicum H. P.	****0.6**	0.492	-0.319	-0.379	0.32	0.331	-0.01	-0.306
Rhoicosigma robustum Grun.	0.308	0.349	-0.159	-0.342	-0.092	0.158	-0.096	-0.347
Rhopaloidea gibberula Ehr.	0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Schroederlla schroedri Berg.	*****0.75**	0.46	-0.198	-0.204	0.436	0.36	-0.058	-0.342
*Scoliopleura latestriata*Breb.	-0.192	-0.192	-0.01	****0.65**	-0.028	0.097	0.347	0.43
Skeletonema costatum	-0.189	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Spinodiscus javonicus Comb.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Staureneis spicula Hick.	0.207	0.044	-0.129	0.2	-0.045	0.241	***0.558**	0.227
Stephanopyxis turris (Grev. & Arnot.) Ralfs.	-0.205	0.069	-0.194	-0.217	-0.009	-0.02	-0.007	0.037
Surirella brightwelli Wm. Sm.	0.313	0.204	-0.379	-0.405	0.213	0.193	0.038	-0.274
Surirella fastuosa var. *cuneata* (A.S.) Perag. & Perag.	0.19	****0.694**	0.212	-0.168	0.102	0.494	0.088	-0.002
Surirella gemma Ehrneb.	0.266	**0.62	-0.003	-0.269	0.071	0.483	0.343	0.045
Surirella robusta Ehrneb.	*****0.784**	*****0.761**	*****-0.85**	-0.274	0.451	***0.573**	-0.01	-0.313

Contd….

Table 81: (Contd….)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Surirella intercedens Var.	0.339	0.151	-0.224	-0.17	0.033	0.187	0.416	-0.003
Surirella striatula Turpin.	-0.075	0.32	-0.174	-0.32	0.028	0.252	-0.007	0.08
Synedra crystallina Var.	0.315	0.223	0.173	-0.204	****0.69**	0.161	0.062	***0.587**
Synedra fulgens (Grev.) Wm. Sm.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Synedra gigantea Lab.	-0.22	0.051	-0.174	-0.166	0.018	0.017	-0.072	0.097
Synedra longissima Sm.	0.331	0.493	0.012	-0.204	0.044	0.44	0.322	0.022
Thalassionema sp.	0.193	****0.696**	0.199	-0.177	0.104	***0.501**	0.09	0.004
Thalassiosira gravida Cleve.	0.405	0.244	-0.132	***-0.508**	0.444	0.312	-0.352	0.235
Thalassiosira leptopus Grun.	-0.188	-0.235	-0.095	-0.054	-0.333	-0.156	-0.312	-0.092
Thalassiosira lineata Jouse'	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Thalassiosira subtilis	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Thalassiothrix longissima	-0.211	0.154	-0.205	-0.405	-0.11	0.089	-0.14	0.029
Thalassiothrix nitzschioides Var.	*****0.725**	0.433	-0.2	-0.112	0.433	0.375	-0.08	-0.281
Torpedoneis lepidoptera var. *minor* Cleve.	0.053	0.272	-0.184	-0.26	0.084	0.162	0.158	0.008
Torpedoneis recta Greg.	0.297	0.065	-0.155	-0.089	-0.037	0.14	0.436	0.025
Toxonoidea insignis Donk.	***0.584**	0.29	-0.388	-0.271	0.159	0.215	-0.018	-0.385
Triceratium favus Ehrneb.	-0.212	-0.218	*****0.898**	****0.63**	-0.172	***-0.502**	-0.139	-0.367
Triceratium pentacrinum f. *quardrata* Hust.	0.315	0.223	0.173	-0.204	****0.69**	0.161	0.062	***0.587**
Tropidoneis elegans	-0.185	-0.171	-0.151	-0.229	***-0.599**	***-0.574**	0.263	-0.446

Table 82: Correlation coefficient of the phytoplankton species with the heavy metals concentration in seawater of Mahuva during the study period of Jun 2001 to April 2003.

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Actinocyclus confluens Grun.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Actinocyclus pruniosus Castr.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Actinocyclus spiralis Perag.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Acantheses brevipes Agardh.	-0.100	-0.111	-0.153	****0.691**	-0.214	**-0.56**	0.381	0.091
Amphiprora meditica Perag.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Amphora costata Wm. Sm.	*****0.952**	*****0.969**	-0.433	-0.316	*****0.846**	0.412	-0.017	-0.238
Amphora hyalina K.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238
Amphora turgida Greg.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238
Asterionella bleakeleyi Wm. Sm.	-0.122	-0.215	0.335	-0.221	0	0.406	-0.056	-0.284
Asterionella notata Grun.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Bacillaria paradoxa Sm. & Ehrneb.	-0.124	-0.164	-0.126	*****0.722**	-0.265	***-0.582**	0.395	0.098
Biddulphia (Odontella) aurita (Lyngbye) Breb & Godey.	-0.155	-0.257	0.263	-0.097	-0.081	0.263	-0.13	-0.354
Biddulphia (Odontella) mobiliensis (Bailey) Grun.	0.303	0.161	0.081	-0.212	0.398	***0.533**	-0.062	-211
Biddulphia (Odontella) pulchella Gray.	0.162	0.352	-0.183	-0.221	0.346	0.152	-0.102	-0.047
Biddulphia (Odontella) sinensis Griville.	-0.122	-0.215	0.335	-0.221	0	0.406	-0.056	-0.284
Caloneis linearis (Grun) Boyer.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
*Campylodiscus gravilli (*Wm. Smith.) Grun.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Campylodiscus latus Schmidt.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238

Contd…

Table 82: (Contd…)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Campylodiscus limbatus Breb.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Campylodiscus triamphans Schimdt.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Ceratium furca Ehrneb.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Ceratium lineatus Ehrneb.	-0.122	-0.146	-0.126	0.134	0.208	0.082	-0.196	***0.511**
Chaetoceros curvisetus Cleve.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238
Coscinodiscus apiculatus Ehrneb.	*****0.949**	*****0.862**	-0.374	-0.244	*****0.721**	0.367	0.051	-0.159
Coscinodiscus centralis Ehrneb.	-0.125	-0.071	-0.266	0.016	-0.308	0.102	-0.159	-0.163
Coscinodiscus conciniformes Simonsen.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Coscinodiscus concinnus Wm. Sm.	0.240	0.373	-0.054	***-0.529**	0.141	0.126	0.264	-0.43
Coscinodiscus coscinodiscus Ehrneb.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Coscinodiscus excentricus Ehrneb.	-0.139	-0.181	-0.141	*****0.741**	-0.242	***-0.574**	0.374	0.159
Coscinodiscus janischii A.S.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.534**	-0.284	-0.278
Coscinodiscus marginatus Ehrneb.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Coscinodiscus perforatus Ehrneb.	-0.102	-0.036	-0.045	-0.302	-0.265	0.082	-0.183	-0.4
Coscinodicus radiatus Ehrneb.	0.059	0.163	-0.156	-0.297	-0.124	0.075	-0.245	-0.313
Coscinodiscus stellaris Raper.	-0.208	-0.221	-0.08	0.385	-0.433	-0.344	0.452	-0.03
Coscinodiscus subtilis Ehrneb.	-0.165	-0.216	-0.21	*****0.861**	-0.364	*****-0.747**	0.288	0.001
Cyamatonitzschia marina (Lewis) Simonsen.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Diploneis smithi (Brev) Cleve.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149

Contd…

Table 82: (Contd…)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Dytillum brighwelli (West) Grun.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Ethmodiscus rex Hand.	-0.134	-0.186	0.361	0.056	-0.191	0.087	-0.186	0.335
Exuviella (Prorocentrum) marina Che.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Grammatophora serpentina Ehrneb.	-0.124	-0.164	-0.126	*****0.722**	-0.265	***-0.582**	0.395	0.098
Gunardia flaecida (Castr.) Perag.	0.054	0.133	0.23	-0.327	0.167	0.002	0.499	-0.144
Grammatophora longissima Petit.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Hyalodiscus laevis Ehr.	0.162	0.352	-0.183	-0.221	0.346	0.152	-0.102	-0.047
Hyalodiscus subtilis Bail.	-0.101	-0.198	***0.526**	-0.221	-0.143	-0.164	*****0.819**	-0.151
Leptocylindrus danicus Cleave.	-0.049	0.031	-0.064	-0.251	-0.255	-0.084	0.013	-0.383
Licmophora abbreviata Wm. Sm.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Licmophora dalmatica var.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Melosira moliniformes (Muller) Agardh.	-0.236	-0.284	0.238	0.311	-0.269	-0.492	**0.725**	-0.162
Melosira numuloides (Dillw.) Agardh .	0.401	0.26	0.27	-0.243	0.23	-0.014	*****0.808**	-0.252
Navicula concellata Donk.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238
Navicula directa Wm. Sm.	*****0.707**	****0.647**	-0.422	0.053	0.35	0	0.155	-0.292
Navicula miniscula Grun.	*****0.967**	*****0.872**	-0.375	-0.221	*****0.739**	0.37	0.042	-0.238
Nitzschia insignis	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Nitzschia longissima (Breb.) Ralfs.	****0.608**	0.466	0.14	-0.327	0.414	0.136	****0.662**	-0.285
Nitzschia obtusa Var.	-0.122	-0.215	0.335	-0.221	0	0.406	-0.056	-0.284

Contd…

Table 82: (Contd….)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Nitzschia seriata Cleve.	0.127	0.304	-0.214	-0.026	0.271	-0.005	0.005	-0.21
Nitzschia sigma (Kutz) Wm. Sm.	0.077	0.166	0.284	-0.224	0.245	0.042	0.215	0.072
Noctiluca miliaris Suriray.	***0.946**	***0.831**	-0.287	-0.223	***0.702**	0.31	0.213	-0.261
Pinnularia braunii Husted.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Pleurosigma accuminatum	-0.124	-0.164	-0.126	***0.722**	-0.265	*-0.582**	0.395	0.098
Pleurosigma affine Grun.	***0.967**	***0.872**	-0.375	-0.221	***0.739**	0.37	0.042	-0.238
Pleurosigma attenuatum Var. *scalpurum* Grun.	-0.124	-0.164	-0.126	***0.722**	-0.265	*-0.582**	0.395	0.098
Pleurosigma balticum var. *wansbeckii* Donk.	***0.847**	***0.741**	-0.407	0.12	**0.571**	0.082	0.218	-0.178
Pleurosigma diminutum Grun.	0.052	0.241	-0.3	-0.261	0.085	0.285	-0.212	-0.144
Pleurosigma spencerii Wm. Sm.	-0.166	-0.094	0.062	-0.222	0.13	0.374	-0.26	-0.254
Pleurosigma tenuissimum Sm.	-0.122	-0.215	0.335	-0.221	0	0.406	-0.056	-0.284
Podocystis spathulata shadb.	-0.082	-0.196	**0.605**	0.176	-0.038	-0.076	-0.083	0.492
Podosira adriatica K.	-0.120	-0.074	0.009	-0.143	-0.122	-0.02	0.053	0.494
Pseudoaulacodiscus petitii L-F.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Pseudopodosira westii (Wm. Sm.) Sheshukov.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Pyxidicula reniformes Desik & Ranjitha.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Raphoneis surirella (Ehrneb.) Grun.	-0.124	-0.164	-0.126	***0.722**	-0.265	*-0.582**	0.395	0.098
Rhabdonema adriaticum Kutz Harv. & Bail) Stodder.	-0.101	-0.198	*0.526**	-0.221	-0.143	-0.164	***0.819**	-0.151
Rhizosolenia delicatula Cleve.	0.493	0.337	0.308	0.032	0.4	0.148	-0.05	0.267

Contd….

Table 82: (Contd…)

Name of the Phytoplankton	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb
Rhoicosigma oceanicum H. P.	-0.129	-0.169	-0.26	0.469	-0.313	***-0.535**	-0.284	-0.278
Surirella intercedens Var.	*****0.780**	****0.644**	-0.14	-0.319	****0.649**	***0.554**	0.005	-0.369
Thalassiosira gravida Cleve.	0.466	0.344	-0.024	-0.286	***0.556**	****0.621**	-0.106	-0.285
Thalassiothrix longissima	0.015	0.19	0.045	-0.418	0.086	0.061	0.14	-0.225
Torpedoneis lepidoptera var. *minor* Cleve.	*****0.963**	*****0.866**	-0.391	-0.195	*****0.724**	0.341	0.026	-0.254
Toxonoidea insignis Donk.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Trachyneis antillarum (Cl. & Grun) Cleve.	-0.119	0.004	-0.095	-0.131	0.139	0.205	-0.251	-0.135
Triceratium broeckii Leuduger & Fortmorel.	-0.095	-0.031	-0.221	-0.13	-0.239	0.234	-0.185	-0.149
Triceratium pentacrinus f. Quadrata. Hust.	-0.147	-0.026	-0.249	-0.185	-0.144	0.317	-0.297	-0.204

Table 83: Correlation coefficient of the marine phytoplankton species with the petroleum hydrocarbons concentration of coastal seawater of Alang Ship breaking yard during the study period from Jun 2001 to April 2003.

Name of the Phytoplankton	Correl. Coeff. - I	Correl. Coeff. - II
Acantheses brevipes Agardh.	0.115	0.348
Acantheses brevipes var. *angulata* (Grey.) Cleve.	0.197	0.219
Amphiprora gigantea var. *sulcata* Cleve.	0.092	0.297
Amphiprora meditica Perag.	0.390	0.000
Amphiprora sulcata Cleve.	0.308	0.381
*Amphora arnicola*var. (Perag.)	0.308	0.381
Amphora costata Wm. Sm.	0.013	0.444
Amphora cymbifera Greg.	0.092	0.297
Amphora hyalina K.	0.092	0.297
Amphora inflexa Breb.	0.390	0.000
Amphora laevisssima Greg.	-0.393	-0.074
Amphora ostrearia Var.	-0.118	0.479
Amphora surpentina	0.486	0.076
Amphora turgida Greg.	0.302	0.032
*Amphora valida*Perag.	0.486	0.076
Asterionella bleakeleyi Wm. Sm.	0.290	-0.194
Asterionella notata Grun.	0.532	0.076
Asterionella japonica Cleve.	-0.049	0.479
Bacillaria paradoxa Sm. & Ehrneb.	0.213	***0.520**
Biddulphia aurita (Lyngbye) Breb & Godey.	-0.095	***0.505**
Biddulphia bidulpiana (Sm.) Boyer.	-0.208	-0.423
Biddulphia mobiliensis (Bailey) Grun.	0.110	0.326
Biddulphia pulchella Gray.	0.468	0.157
Biddulphia reticulata Roper.	-0.393	-0.074
Biddulphia rhombus Ehrneb.	-0.118	0.479
Biddulphia sinensis Griville.	0.292	-0.190
Campylodiscus echeneis Ehrneb.	0.468	0.213
Campylodiscus eximius Var.	-0.150	-0.032
Campylodiscus samoensis Grun.	0.092	0.297

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05

Contd….

Table 83: (Contd…)

Name of the Phytoplankton	Correl. Coeff. - I	Correl. Coeff. - II
Cerataulina bergonii Perag.	0.390	0.000
Ceratium fusus	-0.166	***-0.539**
Ceratium longipes Gran.	-0.166	***-0.539**
Chaetoceros curvisetus Cleve.	0.292	-0.190
Chaetoceros javanicum Cleve.	-0.001	0.307
Chaetoceros willei	0.390	0.000
Climachosphenia elongata Bail.	0.308	0.381
Climacoshenia molinigera Ehrneb.	0.390	0.000
Corethron hystris Hensen.	0.390	0.000
Coscinodiscus apiculatus Ehrneb.	0.412	0.266
*Coscinodiscus argus*Ehrneb.	-0.393	-0.074
Coscinodiscus asteromphalus Ehrneb	-0.393	-0.074
Coscinodiscus biangulantus Schmidt.	-0.393	-0.074
Coscinodiscus centralis Ehrneb.	0.296	0.007
Coscinodiscus compactum	0.486	0.076
Coscinodiscus concinnus Wm. Sm.	-0.066	0.046
Coscinodiscus excentricus Ehrneb.	-0.083	-0.433
Coscinodiscus gigus Ehrneb.	-0.393	-0.074
Coscinodiscus granii Gouch.	-0.393	-0.074
Coscinodiscus janischii A.S.	0.385	-0.161
Coscinodiscus jonesianus (Grev.) Ostenfeld.	-0.208	-0.423
Coscinodiscus kruzii Grun.	-0.208	-0.423
Coscinodiscus lineatus Ehrneb.	0.484	0.290
Coscinodiscus marginatus Ehrneb.	0.308	0.381
Coscinodiscus obscurus A. S.	0.390	0.000
Coscinodiscus perforatus Ehrneb.	-0.343	-0.181
Coscinodicus radiatus Ehrneb.	-0.193	-0.023
Coscinodiscus stellaris Raper.	-0.261	-0.165
Coscinodiscus subtilis Ehrneb.	0.415	-0.118

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05

Contd….

Table 83: (Contd…)

Name of the Phytoplankton	**Correl. Coeff. - I**	**Correl. Coeff. - II**
Coscinodiscus suspectus Jan.	0.486	0.076
*Cyamatopleura solea*Breb.	0.266	-0.277
Dictyoneis marginata	0.292	-0.190
Diploneis crabro (Cleve) Var.	0.118	0.302
Ethmodiscus rex Hand.	-0.137	-0.090
Exuviella (Prorocentrum) marina Che.	0.542	0.076
Grammatophora angulosa var.	0.357	0.381
Grammatophora longissima Petit.	0.308	0.381
Grammatophora serpentina Ehrneb.	0.281	0.497
Grammatophora solea Breb.	0.308	0.381
Gyrosigma balticum Ehrneb.	0.268	0.092
Hyalodiscus laevis Ehr.	0.372	0.416
Hyalodiscus nobilis Pant.	-0.393	-0.074
Hyalodiscus subtilis Bail.	0.486	0.076
Lauderia borealis Gran.	0.390	0.000
Leptocylindrus danicus Cleave.	-0.019	0.357
Licmophora communis	0.253	-0.047
Licmophora crystallina K.	-0.168	0.467
Licmophora dalmatica var.	0.271	***0.553**
Melosira moliniformes (Muller) Agardh.	-0.005	0.365
Melosira numuloides (Dillw.) Agardh .	-0.005	0.456
Navicula campylodiscus	-0.118	0.479
Navicula clavata var.	-0.166	***-0.539**
Navicula concellata Donk.	0.034	0.492
Hyalodiscus nobilis Pant.	-0.393	-0.074
Navicula directa Wm. Sm.	0.263	***0.554**
Navicula miniscula Grun.	0.265	0.327
Navicula quadratarea Cleve.	-0.124	-0.141
Navicula salinarum	0.092	0.297

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05

Contd….

Table 83: (Contd…)

Name of the Phytoplankton	Correl. Coeff. - I	Correl. Coeff. - II
Navicula quadratarea Cleve.	-0.118	0.479
Nitzschia angularis var. *affinis* Grun.	0.062	***0.546**
Nitzschia Commutata Grun.	0.336	0.363
Nitzschia incerta Grun.	0.279	0.375
*Nitzschia incurvata*Grun.	-0.337	-0.097
Nitzschia insignis	0.207	***0.556**
Nitzschia lanceolata	0.486	0.076
Nitzschia linearis Var.	0.308	0.381
Nitzschia longissima (Breb.) Ralfs.	-0.059	-0.133
Nitzschia lorenziana Grun.	0.312	0.407
Nitzschia obtusa Var.	0.257	***0.571**
Nitzschia panduriformes Greg.	-0.393	-0.074
*Nitzschia recta*Htz.	0.308	0.381
Nitzschia seriata Cleve.	0.149	0.494
Nitzschia sigma (Kutz) Wm. Sm.	0.117	***0.525**
Nitzschia sigmoidea (Nitz) Wm Sm.	-0.208	-0.423
Nitzschia socialis Greg.	0.238	0.463
Nitzschia striata Cleve.	0.308	0.005
Nitzschia subtilis Var.	-0.118	0.479
Nitzschia valida Grun.	0.281	0.460
Noctiluca miliaris Suriray.	0.608	0.385
Pediastrum sp.	0.390	0.000
Peridinium depressum Bail.	-0.375	-0.074
Peridinium exiguum Cleave.	0.390	0.000
Peridinium ovalum Shutt.	-0.118	0.479
Peridinium pentagonum Gran.	-0.118	0.479
Peridinium thorianum Paulsen.	0.292	-0.190
Phaeocystis sp.	-0.118	0.479
Pleurosigma accutum Norm.	0.272	0.266

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05

Contd….

Table 83: (Contd..)

Name of the Phytoplankton	**Correl. Coeff. - I**	**Correl. Coeff. - II**
Pleurosigma affine Grun.	-0.025	-0.096
Pleurosigma angulatum Sm.	-0.106	0.150
Pleurosigma attenuatum Var. *scalpurum* Grun.	0.093	***0.502**
Pleurosigma balticum var. *wansbeckii* Donk.	0.250	***0.578**
Pleurosigma brebisonii Grun.	0.207	****0.628**
Pleurosigma caspidatum Cleve.	-0.080	***0.530**
Pleurosigma clevi Grun.	0.205	***0.531**
Pleurosigma compactum Grun.	-0.080	0.492
Pleurosigma decorum Sm. (Perag.)	0.181	****0.692**
Pleurosigma delicatulum Wm. Sm.	0.334	0.392
Pleurosigma diminutum Grun.	0.130	0.419
Pleurosigma distortum Sm.	-0.202	-0.442
Pleurosigma faciola Wm. Sm.	0.072	-0.362
Pleurosigma formosum Wm. Sm.(Grun.)	0.102	0.153
Pleurosigma japonica	-0.118	0.479
*Pleurosigma lanceolatum*Donk.	0.308	0.381
Pleurosigma latum Cleve.	0.159	0.252
Peurosigma lineari Grun.	-0.231	0.437
Pleurosigma longum var. *lanceolata* Perag.	0.121	0.280
Pleurosigma majus Grun.	-0.062	***0.550**
Pleurosigma marinum Donk.	0.092	0.297
Pleurosigma normani Gupp.	0.390	0.000
Pleurosigma obscurum var. *diminuta* H.P.	0.092	0.297
Pleurosigma rigidum Wm. Sm.	-0.393	-0.074
Pleurosigma salinarum Grun.	-0.118	0.479
Pleurosigma scalproides Rab.	-0.507	-0.146
Pleurosigma spaciosum Wm. Sm.	0.200	0.417
Pleurosigma spencerii Wm. Sm.	-0.344	0.354
Pleurosigma sulcatum Grun.	0.486	0.076

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05 and **=P<0.01

Contd….

Table 83: (Contd…)

Name of the Phytoplankton	**Correl. Coeff. - I**	**Correl. Coeff. - II**
Pleurosigma tenuissimum Sm.	-0.173	0.494
Podocystis spathulata shadb.	-0.260	-0.175
Podosira adriatica K.	-0.084	0.145
Podosira argus Grun.	0.590	0.234
Podosira steliger Bail.	0.092	0.297
Pseudo-nitzschia subcurvata Wm. Sm.	0.390	0.000
Pyrocystis lunula Var.	0.390	0.000
Rhabdonema adriaticum Kutz Harv. & Bail) Stodder.	-0.053	0.233
Rhabdonema punctatum (Harb & Bail) Stodder.	-0.393	-0.074
Rhizosolenia delicatula Cleve.	0.308	0.381
Rhoicosigma angularies	-0.166	***-0.539**
Rhoicosigma compactum	0.092	0.297
Rhoicosigma curvata (K.) *Grun.*	0.092	0.297
Rhoicosigma oceanicum H. P.	0.099	0.427
Rhoicosigma robustum Grun.	-0.087	0.127
Rhopaloidea gibberula Ehr.	0.390	0.000
Schroederlla schroedri Berg.	0.092	0.297
*Scoliopleura latestriata*Breb.	-0.507	-0.146
Skeletonema costatum	-0.208	-0.423
Spinodiscus javonicus Comb.	0.390	0.000
Staureneis spicula Hick.	0.219	0.035
Stephanopyxis turris (Grev. & Arnot.) Ralfs.	-0.040	0.315
Surirella brightwelli Wm. Sm.	0.409	0.284
Surirella fastuosa var. *cuneata* (A.S.) Perag. & Perag.	-0.113	0.479
Surirella gemma Ehrneb.	0.201	***0.543**
*Surirella hybrida*Var.	0.028	***0.508**
Surirella intercedens Var.	0.478	0.199
Surirella striatula Turpin.	-0.058	0.406
Synedra crystallina Var.	-0.124	-0.141

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05

Contd….

Table 83: (Contd…)

Name of the Phytoplankton	**Correl. Coeff. - I**	**Correl. Coeff. - II**
Synedra fulgens (Grev.) Wm. Sm.	-0.208	-0.423
Synedra gigantea Lab.	-0.072	0.222
Synedra longissima Sm.	0.226	0.382
Thalassionema sp.	-0.118	0.479
Thalassiosira gravida Cleve.	-0.231	-0.257
Thalassiosira leptopus Grun.	-0.208	-0.423
Thalassiosira lineata Jouse'	0.390	0.000
Thalassiosira subtilis	0.390	0.000
Thalassiothrix longissima	-0.137	0.208
Thalassiothrix nitzschioides Var.	0.020	0.277
Torpedoneis lepidoptera var. *minor* Cleve.	0.148	0.434
Torpedoneis recta Greg.	0.486	0.076
Toxonoidea insignis Donk.	0.188	0.225
Triceratium favus Ehrneb.	0.390	0.000
Triceratium pentacrinum f. *quardrata* Hust.	-0.124	-0.141
Tropidoneis elegans	0.300	0.373

Correl. Coeff.-I= Data of the same month correlated., Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling.

Table 84: Correlation coefficient of the marine phytoplankton species with the petroleum hydrocarbons concentration of coastal seawater of Mahuva during the study period from Jun 2001 to April 2003.

Name of the Phytoplankton	**Correl. Coeff. - I**	**Correl. Coeff. - II**
Acantheses brevipes Agardh.	***0.503**	0.061
Actinocyclus confluens Grun.	-0.141	-0.164
Actinocyclus pruniosus Castr.	0.036	-0.138
Actinocyclus spiralis Perag.	-0.141	-0.164
Amphiprora meditica Perag.	0.028	0.000
Amphora costata Wm. Sm.	0.054	***0.589**
Amphora hyalina K.	0.188	***0.540**
Amphora turgida Greg.	0.188	***0.540**
Asterionella bleakeleyi Wm. Sm.	-0.222	****0.678**
Asterionella notata Grun.	0.028	0.000
Bacillaria paradoxa Sm. & Ehrneb.	***0.534**	0.032
Biddulphia aurita (Lyngbye) Breb & Godey.	-0.212	****0.678**
Biddulphia mobiliensis (Bailey) Grun.	0.134	*****0.806**
Biddulphia pulchella Gray.	-0.215	0.192
Biddulphia sinensis Griville.	-0.222	****0.678**
Caloneis linearis (Grun) Boyer.	-0.141	-0.164
*Campylodiscus gravilli (*Wm. Smith.) Grun.	0.036	-0.138
Campylodiscus latus Schmidt.	0.188	***0.540**
Campylodiscus limbatus Breb.	-0.141	-0.164
Campylodiscus triamphans Schimdt.	-0.141	-0.164
Ceratium furca Ehrneb.	0.036	-0.138
Ceratium lineatus Ehrneb.	***0.672**	-0.286
Chaetoceros curvisetus Cleve.	0.188	***0.540**
Coscinodiscus apiculatus Ehrneb.	0.143	***0.505**
Coscinodiscus centralis Ehrneb.	0.113	-0.135
Coscinodiscus conciniformes Simonsen.	-0.141	-0.164
Coscinodiscus concinnus Wm. Sm.	-0.324	-0.011
Coscinodiscus coscinodiscus Ehrneb.	-0.141	-0.164
Coscinodiscus excentricus Ehrneb.	***0.615**	-0.002

Correl. Coeff.-I= Data of the same month correlated. Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05, **=P<0.01 and ***=P<0.001

Contd….

Table 84: (Contd…)

Name of the Phytoplankton	Correl. Coeff. - I	Correl. Coeff. - II
Coscinodiscus janischii A.S.	0.028	0.000
Coscinodiscus marginatus Ehrneb.	0.028	0.000
Coscinodiscus perforatus Ehrneb.	-0.218	0.009
Coscinodicus radiatus Ehrneb.	-0.194	-0.174
Coscinodiscus stellaris Raper.	0.349	-0.166
Coscinodiscus subtilis Ehrneb.	***0.529**	0.032
Cyamatonitzschia marina (Lewis) Simonsen.	-0.141	-0.164
Diploneis smithi (Brev) Cleve.	0.036	-0.138
Dytillum brighwelli (West) Grun.	0.036	-0.138
Ethmodiscus rex Hand.	-0.194	-0.273
Exuviella (Prorocentrum) marina Che.	0.028	0.000
Grammatophora longissima Petit.	-0.141	-0.164
Grammatophora serpentina Ehrneb.	***0.534**	0.032
Gunardia flaecida (Castr.) Perag.	-0.305	-0.001
Hyalodiscus laevis Ehr.	-0.215	0.192
Hyalodiscus subtilis Bail.	-0.196	-0.213
Leptocylindrus danicus Cleave.	-0.175	-0.139
Licmophora abbreviata Wm. Sm.	0.028	0.000
Licmophora dalmatica var.	-0.141	-0.164
Melosira moliniformes (Muller) Agardh.	0.132	-0.221
Melosira numuloides (Dillw.) Agardh .	-0.026	0.093
Navicula concellata Donk.	0.188	***0.540**
Navicula directa Wm. Sm.	0.338	0.374
Navicula miniscula Grun.	0.188	***0.540**
Nitzschia insignis	0.028	0.000
Nitzschia longissima (Breb.) Ralfs.	-0.018	0.220
Nitzschia obtusa Var.	-0.222	****0.678**
Nitzschia seriata Cleve.	-0.070	0.199
Nitzschia sigma (Kutz) Wm. Sm.	-0.367	0.013

Correl. Coeff.-I= Data of the same month correlated. Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05, **=P<0.01 and ***=P<0.001

Contd….

Table 84: (Contd…)

Name of the Phytoplankton	Correl. Coeff. - I	Correl. Coeff. - II
Noctiluca miliaris Suriray.	0.182	***0.506**
Pinnularia braunii Husted.	-0.141	-0.164
Pleurosigma accuminatum	***0.534**	0.032
Pleurosigma affine Grun.	0.188	***0.540**
Pleurosigma attenuatum Var. *scalpurum* Grun.	***0.534**	0.032
Pleurosigma balticum var. *wansbeckii* Donk.	0.417	**0.521**
Pleurosigma diminutum Grun.	0.135	0.043
Pleurosigma spencerii Wm. Sm.	-0.232	0.152
Pleurosigma tenuissimum Sm.	-0.222	****0.678**
Podocystis spathulata shadb.	-0.246	-0.207
Podosira adriatica K.	-0.288	-0.227
Pseudoaulacodiscus petitii L-F.	0.036	-0.138
Pseudopodosira westii (Wm. Sm.) Sheshukov.	-0.141	-0.164
Pyxidicula reniformes Desik & Ranjitha.	-0.141	-0.164
Raphoneis surirella (Ehrneb.) Grun.	***0.534**	0.032
Rhabdonema adriaticum Kutz Harv. & Bail) Stodder.	-0.196	-0.213
Rhizosolenia delicatula Cleve.	-0.091	0.144
Rhoicosigma oceanicum H. P.	0.028	0.000
Surirella intercedens Var.	0.040	*****0.861**
Thalassiosira gravida Cleve.	0.111	*****0.827**
Thalassiothrix longissima	-0.400	-0.067
Torpedoneis lepidoptera var. *minor* Cleve.	0.191	***0.540**
Toxonoidea insignis Donk.	0.036	-0.138
Trachyneis antillarum (Cl. & Grun) Cleve.	-0.141	-0.164
Triceratium broeckii Leuduger & Fortmorel.	0.036	-0.138
Triceratium pentacrinus f. Quadrata. Hust.	-0.141	-0.211

Correl. Coeff.-I= Data of the same month correlated. Correl. Coeff.-II= Data of PHC correlated with data of phytoplankton species of the next sampling and *=P<0.05, **=P<0.01 and ***=P<0.001

Table 85: Correlation coefficient within the average heavy metals concentration, petroleum hydrocarbons, and different biological parameters in relation to marine phytoplankton at the coastal area of Alang ship breaking yard during study period Jun 2001 to April 2003.

	Fe	Mn	Cd	Co	Cu	Zn	Ni	Pb	PHC	No. of Gen.	No. of Spp.	Total count	Ind. of Dom.	Spp. Div.	Chl-a	GPP	NPP
Fe	1																
Mn	***0.778	1.000															
Cd	-0.104	0.039	1.000														
Co	-0.385	-0.423	*0.565	1.000													
Cu	***0.726	**0.633	0.053	-0.242	1.000												
Zn	**0.639	***0.728	-0.294	-0.256	**0.663	1.000											
Ni	0.195	0.208	-0.048	0.008	-0.079	-0.086	1.000										
Pb	0.022	0.009	-0.048	0.209	*0.500	0.370	0.093	1.000									
PHC	0.177	0.013	0.208	-0.169	-0.203	-0.376	0.339	*-0.528	1.000								
No Genera	0.122	0.304	0.247	0.001	-0.292	-0.093	0.288	-0.457	*0.583	1.000							
No. Species	0.184	0.284	0.079	-0.170	-0.328	-0.110	0.292	*-0.554	**0.634	***0.966	1.000						
Total count	-0.010	0.306	-0.246	-0.387	0.038	0.192	-0.012	-0.152	-0.009	0.206	0.167	1.000					
Dominance	-0.008	0.098	0.070	-0.378	0.430	0.007	-0.116	0.298	-0.072	*-0.500	*-0.532	0.380	1.000				
Diversity	0.154	0.104	0.045	-0.222	0.033	-0.108	0.143	-0.462	*0.567	0.049	0.102	-0.137	0.059	1.000			
Chl-a	0.071	0.349	-0.304	-0.436	0.111	0.427	-0.259	-0.247	0.060	0.056	0.039	***0.713	0.308	0.337	1.000		
GPP	*0.525	*0.567	-0.138	-0.271	*0.569	0.611	0.365	0.504	-0.172	-0.312	-0.326	-0.021	0.409	0.018	0.137	1.000	
NPP	*0.500	*0.577	-0.260	-0.308	0.346	0.600	0.387	0.175	-0.050	-0.145	-0.146	0.349	0.327	0.022	0.423	***0.841	1.000

Note: No. of Gen=Number of Genera, No. of Spp.=Number of Species, Ind. Of Dom.= Index of Dominance, Spp. Div.= Species Diversity, Chl-a= Chlorophyll-a, GPP= Gross Primary Productivity, NPP= Net Primary Productivity ,***=P<0.001, **=P<0.01 and *=<0.05

Table 86: Correlation coefficient within the average heavy metals concentration, petroleum hydrocarbons, and different biological parameters in relation to marine phytoplankton at the coastal area of Mahuva during study period Jun 2001 to April 2003.

	Fe	**Mn**	**Cd**	**Co**	**Cu**	**Zn**	**Ni**	**Pb**	**PHC**	**No. of Gen.**	**No. of Spp.**	**Total count**	**Ind. of Dom.**	**Spp. Div.**	**Chl-a**	**GPP**	**NPP**
Fe	1																
Mn	*****0.950**	1.000															
Cd	-0.390	**-0.541**	1.000														
Co	-0.283	-0.374	-0.116	1.000													
Cu	***0.820	*****0.821**	-0.256	-0.388	1.000												
Zn	0.413	0.464	-0.023	*****-0.807**	****0.631**	1.000											
Ni	0.023	-0.104	0.449	0.034	-0.114	-0.302	1.000										
Pb	-0.234	-0.262	0.250	0.259	0.027	-0.127	-0.005	1.000									
PHC	0.117	**0.051**	-0.448	***0.584**	0.137	-0.254	0.010	0.237	1.000								
No Genera	0.403	0.422	-0.433	0.190	0.281	-0.004	-0.012	***-0.558**	0.138	1.000							
No. Species	0.459	0.485	-0.460	0.128	0.336	0.090	0.076	-0.472	0.224	**0.953**	1.000						
Total count	****0.609**	****0.677**	-0.222	-0.464	0.379	0.267	0.228	***-0.539**	-0.140	0.201	0.279	1.000					
Dominance	0.071	0.134	0.019	-0.198	-0.001	-0.046	0.218	0.306	-0.400	-0.327	-0.251	0.016	1.000				
Diversity	-0.053	-0.142	0.281	-0.204	-0.036	0.367	-0.028	-0.467	-0.321	0.174	0.141	-0.088	-0.062	1.000			
Chl-a	0.225	0.134	-0.001	0.019	0.155	-0.289	0.397	-0.117	0.275	-0.071	-0.134	0.281	-0.191	-0.415	1.000		
GPP	0.412	0.390	-0.151	-0.021	0.017	-0.356	0.433	***-0.509**	-0.228	0.320	0.217	*0.546	0.237	-0.148	0.487	1.000	
NPP	****0.688**	****0.688**	-0.035	***-0.599**	***0.516**	0.364	0.333	-0.404	-0.267	0.174	0.178	*****0.791**	0.043	-0.131	0.420	****0.648**	1.000

Note: No. of Gen=Number of Genera, No. of Spp.=Number of Species, Ind. Of Dom.= Index of Dominance, Spp. Div.= Species Diversity, Chl-a= Chlorophyll-a, GPP= Gross Primary Productivity, NPP= Net Primary Productivity ,***=P<0.001, **=P<0.01 and *=<0.05.

Table 87: Multiple Regression Analysis within GPP (depended variable) and Physio-chemical parameters (independent variables) at Alang.

Independent Variables	Prob>ItI value	Prob> F value
W T pH T SS Salinity NO_2-N NO_3-N NH_4-N PO_4-P	0.51017 0.61619 0.37468 0.39999 0.17592 0.62315 0.79763 0.37922	0.2141
W T TSS Salinity NO_3-N NH_4-N PO_4-P	0.52413 0.33081 0.39571 0.54253 0.81863 0.48103	0.62074
W T Salinity NO_3-N NH_4-N PO_4-N	0.64071 0.45655 0.67787 0.72504 0.43157	0.65342
W T Salinity NO_3-N NH_4-N	0.40934 0.37067 0.68988 0.408	0.61264
W T NO_3-N NH_4-N PO_4-P	0.93745 0.56047 0.90824 0.34895	0.59667
W T NO_3-N NH_4-N	0.6672 0.31448 0.70094	0.60858
W T NH_4-N	0.55067 0.53737	0.6981

Table 88: Multiple Regression Analysis within GPP (depended variable) and Heavy Metals (independent variables) at Alang.

Independent Variables	Prob>ItI value	Prob> F value
Fe Mn Cd Co Cu Zn Ni Pb	0.65716 0.72087 0.75721 0.69047 0.62127 0.60115 0.46214 0.71445	0.54967
Fe Mn Cd Co Cu Pb	0.37548 0.52344 0.61451 0.41083 0.48675 0.10848	0.29747
Mn Cd Co Cu	0.40778 0.715 0.96788 0.42681	0.38359
Cd Co	0.90361 0.88322	0.95954

Note: WT= Water Temperature.
TSS=Total Suspended Solids.

Table 89: Multiple Regression Analysis within GPP (depended variable) and Physio-chemical parameters (independent variables) at Mahuva.

Independent Variables	Prob>ItI value	Prob> F value
W T	0.53379	0.7333
pH	0.72158	
T S S	0.95541	
Salinity	0.80286	
NO_2-N	0.88465	
NO_3-N	0.80251	
NH_4-N	0.739	
PO_4-P	0.50586	
TSS	0.8211	0.88772
NO_2-N	0.51481	
NH_4-N	0.89331	
TSS	0.86145	0.91866
NH_4-N	0.77736	

Note: WT= Water Temperature.
TSS=Total Suspended Solids.

Table 90: Multiple Regression Analysis within GPP (depended variable) and Heavy Metals (independent variables) at Mahuva.

Independent Variables	Prob>ItI value	Prob> F value
Fe	0.19474	0.58924
Mn	0.52318	
Cd	0.21299	
Co	0.42809	
Cu	0.50025	
Zn	0.9935	
Ni	0.98771	
Pb	0.42711	
Mn	0.97668	0.82059
Co	0.83045	
Cu	0.80713	
Zn	0.6511	
Ni	0.59109	
Pb	0.75456	
Co	0.99978	0.95064
Cu	0.62492	
Pb	0.66217	

Table 91: Multiple Regression Analysis within GPP (depended variable) and Physio-chemical parameters and heavy metals (independent variables) combined at Mahuva.

Independent Variables	Prob>ItI value	Prob> F value
Co	0.746	0.99728
Cu	0.91667	
Pb	0.73639	
TSS	0.74889	
NO_2-N	0.64977	
NH_4-N	0.8929	
PHC	0.98433	
Co	0.95972	0.99781
Cu	0.68038	
Pb	0.74258	
TSS	0.87324	
NH_4-N	0.82455	
PHC	0.95419	
Co	0.95929	0.99818
Pb	0.82703	
TSS	0.80273	
NH_4-N	0.8889	
PHC	0.99494	

Table 92: Multiple Regression Analysis within GPP (depended variable) and Physio-chemical parameters and heavy metals (independent variables) combined at Alang.

Independent Variables	Prob>ItI value	Prob> F value
Cd	0.1931	0.47828
Co	0.43012	
W T	0.7753	
NO_3-N	0.07533	
NH_4-N	0.3638	
PHC	0.54233	
Co	0.72307	0.89987
W T	0.75434	
NH_4-N	0.51091	
PHC	0.62901	
Co	0.72307	0.90182
W T	0.73945	
PHC	0.6621	
Co	0.825	0.8245
W T	0.58417	

Note: WT= Water Temperature.
TSS=Total Suspended Solids.
PHC=Petroleum Hydrocarbons.

Table 93: Multiple Regression Analysis within Chl-a (depended variable) and Physio-chemical parameters (independent variables) at Alang.

Independent Variables	Prob>ItI value	Prob> F value
W T	0.53379	0.7333
pH	0.72158	
T SS	0.95541	
Salinity	0.80286	
NO_2-N	0.88465	
NO_3-N	0.80251	
NH_4-N	0.739	
PO_4-P	0.50586	
TSS	0.8211	0.88772
NO_2-N	0.51481	
NH_4-N	0.89331	
TSS	0.86145	0.91866
NH_4-N	0.77736	

Note: WT= Water Temperature.
TSS=Total Suspended Solids.

Table 94: Multiple Regression Analysis within Chl-a depended variable) and Heavy Metals (independent variables) at Alang.

Independent Variables	Prob>ItI value	Prob> F value
Fe	0.19474	0.58924
Mn	0.52318	
Cd	0.21299	
Co	0.42809	
Cu	0.50025	
Zn	0.9935	
Ni	0.98771	
Pb	0.42711	
Mn	0.97668	0.82059
Co	0.83045	
Cu	0.80713	
Zn	0.6511	
Ni	0.59109	
Pb	0.10848	
Co	0.99978	0.95064
Cu	0.62492	
Pb	0.66217	

Table 95: Multiple Regression Analysis within Chl-a (depended variable) and Physio-chemical parameters (independent variables) at Mahuva.

Independent Variables	**Prob>ItI value**	**Prob> F value**
W T	0.28808	
pH	0.61447	
T SS	0.86441	
Salinity	0.55125	0.56878
NO_2-N	0.47737	
NO_3-N	0.99619	
NH_4-N	0.47552	
PO_4-P	0.99092	
pH	0.22531	
TSS	0.25492	
Salinity	0.58655	0.65584
NO_3-N	0.47719	
NH_4-N	0.7744	
PO_4-P	0.27706	
Salinity	0.70501	
NO_3-N	0.64034	0.89232
NH_4-N	0.61939	

Note: WT= Water Temperature.
TSS=Total Suspended Solids.

Table 97: Multiple Regression Analysis within Chl-a depended variable) and Physio-chemical parameters and Heavy Metals (independent variables) combined at Mahuva.

Independent Variables	**Prob>ItI value**	**Prob> F value**
Fe	0.45819	
Cd	0.92989	
Co	0.92525	0.82395
NO_3-N	0.71834	
NH_4-N	0.48607	
PHC	0.55445	

Note: WT= Water Temperature.
TSS=Total Suspended Solids.
PHC=Petroleum Hydrocarbons.

Table 96: Multiple Regression Analysis within Chl-a depended variable) and Heavy Metals (independent variables) at Mahuva.

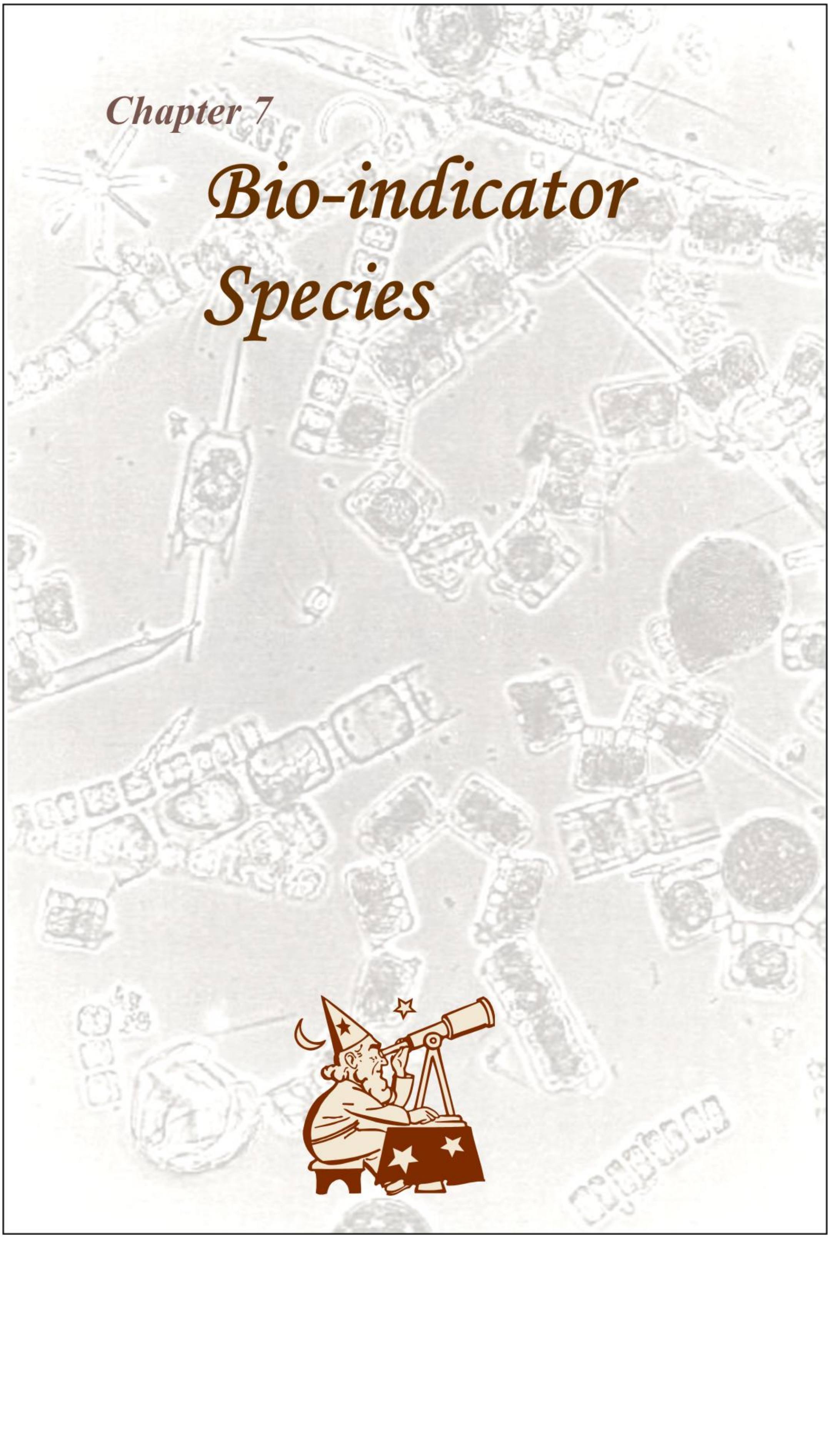
Independent Variables	**Prob>ItI value**	**Prob> F value**
Fe	0.96142	
Mn	0.97649	
Cd	0.96291	
Co	0.90798	0.96322
Cu	0.88155	
Zn	0.80517	
Ni	0.62538	
Pb	0.80142	

Table 98 : Multiple Regression Analysis within Chl-a depended variable) and Physio-chemical parameters and Heavy Metals (independent variables) combined at Alang.

Independent Variables	**Prob>ItI value**	**Prob> F value**
Co	0.746	
Cu	0.91667	
Pb	0.73639	
T SS	0.74889	0.99728
NO_2-N	0.64977	
NH_4-N	0.8929	
PHC	0.98433	
Co	0.95972	
Cu	0.68038	
Pb	0.74258	0.99781
T SS	0.87324	
NH_4-N	0.82455	
PHC	0.95419	
Co	0.95929	
Pb	0.82703	
T SS	0.80273	0.99818
NH_4-N	0.8889	
PHC	0.99494	

Chapter 7

Bio-indicator Species



Chapter-7

Bio-indicator Species

Phytoplankton are microscopic plants that live in the ocean. Since phytoplankton depend upon certain conditions for growth, they are a good indicator of change in their environment. For these reasons, phytoplankton are of primary interest to oceanographer and Earth scientist around the world. The response of marine phytoplankton to toxic pollutants is encouraging and indicates a good biological model for the detection of toxic pollutants in water (Chang,1995). Diatoms is another useful group of indicators, particularly for oligotrophic and eurotrophic conditions (Steiner,1993). It is well known that periphyton among the diatoms, are suitable indicators of heavy metal toxicity (Genter 1996).

The diatom based methods for biological monitoring are subject to development and standardization for application to all kinds of waters in different countries (Prygiel *et. al*., 1999; Hill *et. al*., 2000). Yet, interactions may affect the distribution of taxa and may therefore be a source of discrepancies between studies (Winther and Duthie 2000; Cox 1991). This is most probably due to two main reasons, firstly the different diatom indices and methodologies do not integrate parameters in the same way (Prygiel and Coste 1993; van de Vijver and Beyens 1998);

and secondly, the autecology of taxa has been rarely verified by experiment (Cox 1991; Cox 1993; Winther and Duthie 2000; van Dom *et. al*., 1994). Cox (1993) concluded from culture experiments with four diatom taxa grown under contrasting light, temperature and pH conditions that the physiological ranges were not consistent with the field distributional data of the species, which indicated different capacities of the species. Although the assessment of water quality with diatom indices might fulfill some of the objectives for environmental management, i.e. deriving overall indications for the ecological quality of the surface water, field observations should be verified by experimental research to gain specificity.

The uptake of contaminants from water by algal cells may be the result of several processes. The chemical may be metabolically active, and act as an essential nutrients or mineral, and be transported across the cell membrane and thereby entering into the biochemical processes. The bio-concentration potential for organic compounds has been linked to the n-octanol water partition coefficient. This partition coefficient has been related to the aqueous solubility of a wide variety of compounds, including aliphatic and aromatic hydrocarbons, aromatic acids, organo-chlorine and organophosphate pesticides, and polychlorinated biphenyls and there is a functional correlation between the amount of lipid in an organism, the bio-concentration factor, and the aqueous solubility of chemical (Chiou *et al*., 1977) is found.

The process of bioaccumulation and uptake of different heavy metals by phytoplankton were studied both under field and laboratory conditions by earlier workers (Hasall, 1963; Hutchinson 1973, 1975; Button and Hostetter 1977; Hart and Scaife 1977; Methuus *et al*., 1978 Kaiser and Sperling 1980; Falmi and Whitton 1981; Gnassia Baralli and Harsted, 1985). Sakaguchi *et al*., (1979) reported that metal uptake was shown to depend on the species considered. But Riley and Roth, (1971) suggested that distribution of metals in phytoplankton was not correlated to their taxonomic position. Cationic uptake mechanisms were developed by algae to absorb and concentrate nutrients from the surrounding medium even when metal concentrations were very low. These mechanisms might also be used to uptake essential or non-essential or toxic elements. Most algae had the capacity to uptake most heavy metals to some extent.

The effects of a bunker oil spill on the marine environment were assessed through investigation of the rocky shore fauna, and phytoplankton population over a study period of 150 days (Shin, 1986). Konig (1968) experienced the biological effects of a north sea refining waste, where oil content concentrated in the creeks, and exceeded the initial waste water value by 100 times or more. Blue - green algae predominated due to oil spill effects (Cowell 1971).

7.1.1 Heavy Metal Interactions with Marine Phytoplankton:

Most studies on heavy metal interactions in algae were preliminary attempts to identify simple synergistic and antagonistic responses (Rai *et al*., 1981). For example, copper and nickel interacted synergistically towards growth (cell number) in *Chlorella* sp. (Christensen *et al*., 1979; Hutchinson, 1973; Hutchinson and Stokes, 1975) where as copper and selenium interacted antagonistically in the same alga (Hutchinson and Stokes, 1975; Hutchinson, 1973). It is possible that this is due to the formation of insoluble metal complexes that do not react in reality with sulphydryl groups (Gotsis, 1982). Christensen et al., (1979) found that Mn and Pb acted antagonistically towards *Selenastrum* sp. while Mn and Cu elicited synergism in the same alga. Stratton and Corke (1979) noted that interaction responses were dependent upon both the toxicity criterion used and the order of metal addition in the blue green alga *Anabenna* sp. In this organism Hg and Cd interacted synergistically towards photosynthesis and nitrogenase activity but acted antagonistically towards growth. Hg and Ni were additive towards photosynthesis and yielded mixed synergistic and antagonistic results with growth and nitrogenase activity depending upon the metal concentration used. Ni^{2+} and Cd^{2+} interacted antagonistically towards all criteria studied (Stratton and Corke, 1979). Singh and Pandey (1981b) also investigated pretreatement effects in *Nostoc* sp. but arrived at different conclusions. They found that Cd^{2+}- Ca^{2+} and Cd^{2+}-Zn^{2+} mixtures interacted antagonistically towards nitrogenase activity in this cyanobacterium, while Cd^{2+}-Mn^{2+} combination yielded synergism. When cells were pre-exposed to sub-lethal or lethal levels of Cd^{2+} and treated with Cd^{2+} or Zn^{2+}, a protective effect was observed eliminating Cd^{2+} toxicity.

Among the several detoxification mechanisms observed, most important were the binding of metals to the sulphydryl proteins and production of metal binding peptides known as Metallothioneins (MTS) and Phytochelatins (PCS) (Grill *et al*., 1985, 1987) for internal detoxification. The initial increase in protein content indicates the production of metal binding proteins, which effectively did chelate the metal ions and did not allow the ions to interfere in metabolism.

i) Metallothioneins:

Metallothioneins (MTS) was discovered in 1975 as a Cadmium binding protein in the renal cortex of the horse and was characterized by its low molecular weight (6,000-8,000 daltons) metal binding proteins. These polypeptides were abundant in cysteine residues and often possesed a characteristic pattern of sulfur containing aminoacids (Turner and Robinson, 1995). Mettaloproteins could be characterized in to three classes;

Class I-Contains most animal metallotheoneins with locations of cystein closely resembling those of equine renal MTS.

Class II- consists of metallothioneins whose cysteine locations in the polypeptide are distantly related to those found in equine renal cortex and

Class III- metallothioneins are characterized by a typical non-translationally synthesized metal thiolate polypeptide.

Cyanobacterial metallothioneins belong to Class II. They possess approximately 56 aminoacids including 9 cysteine residues. They are commonly found in association with essential metal ions such as zinc and copper, but have also been shown to bind toxic metals like cadmium, and lead. Metallothioneins chelate metals in the cytoplasm and thereby reduce the concentration of cytotoxic free metal ions. Increased synthesis of Class II MTS in *Synechococcus* sp., following exposure to Cd and Zn was regulated at transcriptional level (Olafson, 1984).

Further ClassII MTS are involved in the detoxification of excess Cd. Since *Synechococcus* MTS binds Cd and Zn (Olafson et al., 1986) amplification of ClassII MTS genes in these cyanobacteria would lead to a different spectrum of metal tolerance.

ii) Bio remediation :

Accumulation of heavy metals by Phytoplankton had been studied extensively for bio-monitoring or bioremediation purposes. Having the advantages of low cost raw material, enormous absorbing capacity, no secondary pollution, etc., algae could be used to treat industrial water containing heavy metals. Their selection affinity for heavy metals is the major criteria for the screening of a biological adsorbent to be used in water treatment. The surface complex formation model (SCFM) can solve the equilibrium and kinetic problems in the bio-sorption.

iii) Biomolecules:

As living organisms evolved, new biomolecules of greater complexity and variety are believed to have evolved from the primordial biomolecules. Apart from nucleic acids and proteins, these biomolecules consist of amino acids, sugars, polysaccharides, fatty acids, lipids, alkaloids, hormones and antibiotics.

All biomolecules are potential chelating agents, and in a biological system they will form simple as well as mixed ligand chelates with metal ions. Metal chelates have a very important role in various biological systems, in which they exist as simple or mixed ligand chelates. Chlorophyll-a found in plants is the metal chelates (Chacherek and Martell, 1959). The metal chelates act as carries of the essential metal ions. In soil conditions in presence of moisture or in aquatic conditions, many chelating anions (e.g. citrate, tartrate, malate and amino acids) from soluble metal chelates containing essential metal ions, are assimilated by plants.

iv) Bio-sorption:

When heavy metals are introduced into the environment, the biological activity plays an important role in their removal (Beveridge, 1989). This natural activity of the organisms is being exploited for the treatment of industrial wastewater (Gadd and white, 1993). Microbial biomass can passibly bind large amounts of metals, and a phenomenon commonly referred to as bio-sorption (Mc hale and Mc hale, 1994; and Gadd, 1988) thus providing cost effective solution for industrial wastewater management (Volesky and holan, 1995). However, on prolonged contact with the metal bearing solution, the living biomass is also able to sequester metal intra-cellularly by an active process called bioaccumulation. Biosorption is possible both by living and non-living biomass, however bio-accumulation is mediated only by living biomass. Further bio-sorption is a growth dependent process.

The role of various groups of microorganisms in the removal and recovery of heavy metals by bio-sorption has been well understood (Gadd and Driffiths, 1978; Volesky, 1990; Wase and Foster, 1997; Greene and Darnall, 1990; gadd, 1988). A large number of microorganisms belonging to various groups, viz. cyanobacteria and algae have been reported to bind a variety of heavy metals to different extent (Volesky and Holan, 1995).

Cell walls of Cyanobacteria are principally composed of peptidoglycans, which consist of linear chains of the disaccharide N-acetyl glucosamine –B 1,4 –N-acetyl muramic acid with peptide chains. Glycoproteins present on the outer side of gram–positive bacterial cell walls are suggested to have more potential binding sites for Cd^{2+} than the phospholipids and polysaccharide and hence are responsible for the observed difference in capacity.

Extracellular polymeric substances have also been shown to bind metal ions and some times form capsules or loose aggregates around cell, and make better absorption site for Cd^{2+} than the phospholipids and polysaccharide and hence are responsible for the observed difference in capacity (Norberg and Persson, 1984; Norberg and Rydin 1984).

A number of methods have been employed for cell wall modification of microbial cells in order to enhance the metal binding capacity of biomass and to elucidate the mechanism of bio-sorption. These modifications can be introduced either during growth of a biomass of a microorganism or in the pre grown biomass.

The metal binding in many studies is suggested to be an ion exchange phenomenon. Greene *et al.,* (1987) demonstrated the binding of Cu^{2+}, Pb^{2+}, Zn^{2+}, Ni^{2+} and Cd^{2+} to *Spirulina* sp. to be accompanied by the liberation of protons suggesting an ion exchange reaction. Similar results were obtained in Cd^{2+}, Cu^{2+} and Zn^{2+} binding by previously protonated biomass of macroalge where the metal binding was coupled with the release of H^{+} ions (Volesky and Holan, 1995).

pH is the major factor influencing the adsorption. The uptake decreased with increasing ionic strength. The principal mechanism of metallic cation sequestration involves the formation of complexes between a metal ion and functional groups on the surface or inside the porous structure of the biological material. The carboxyl groups of alginate play a major role in the complexation. Different species of micro-algae and the micro-algae of the same species may have different adsorption capacity.

v) Metabolic uptake:

Metal ion uptake, resulting from metabolic activity has been demonstrated for a number of organisms and metals. In general, metabolic dependent uptake proceeds via a number of steps:

Firstly the cation is absorbed into the outer cell membrane. Secondly, it is transported into the cytoplasm by ionic pumps (Burkett, 1975; De Filippis and Palaghly, 1976a; Fujita *et al*., 1976; Kayser; 1976). Passive uptake mechanism depends on the capacity of cell membranes and intercellular substances to complex the cations. Cell metabolism plays a part only insofar as it modified the chemistry of these binding substances (Skipeners *et al*., 1975).

Metabolic uptake of metals have been dependent on a number of external factors, such as the pH, background metal concentration, light intensity and the chemical species of the medium. It has also been shown to be dependent on biological variables, such as the growth phase and cell division stages. Sunda and Guillard (1976) showed that copper uptake in *Thalassiosira* sp. was related to copper ion activity rather than to total copper ion concentration. This uptake is modified by the pH and chelating capacity of the medium. Such relationship may well apply to other cations.

7.2 Materials and Methods:

7.2.1 Experiment I:

During the field collection of marine phytoplankton, live phytoplankton are also collected from both the collection site throughout the study period and kept within ice pack, so that the sample should not get any stress due to high temperature and brought to the laboratory. A series of 10 test tubes, out of which eight test tubes containing all eight heavy metals in 2 ppm concentration and the other two containing petroleum hydrocarbons in 5 and 10 ppm concentration (Series-A) was prepared for inoculating the phytoplankton collected from Mahuva only. Another two series also prepared for inoculating the phytoplankton population collected from Alang. One of them contains 10 test tubes, out of which eight test tubes containing all eight heavy metals in 2 ppm concentration and the other two containing petroleum hydrocarbons in 5 and 10 ppm concentration (Series-B) same as series-A. The another series contains higher range of heavy metals (5 ppm) and petroleum hydrocarbons (15 and 20 ppm). The collected live phytoplankton were filtered again with cleaned seawater and washed with sterilized seawater. Then the washed phytoplankton was inoculated in equal concentration in each sterilized medium containing the said heavy metals and petroleum hydrocarbons. The succession of marine phytoplankton were observed during the month together. The heavy metal and petroleum hydrocarbons tolerant species were repeatedly inoculated three to four times within the same concentration of metal and petroleum hydrocarbons to sort out the opportunistic species.

7.2.2 Experiment II:

Artificial Alang seawater has been made by preparing artificial seawater with addition of different concentration of heavy metals found in Alang seawater. Each test tube contains a minute quantity of Gf/2 media for supporting the growth of the treated phytoplankton for minimum a fortnight exposure to observe the effect of different heavy metals individually, and the mixtures of the different heavy metals and crude petroleum hydrocarbons of the same ratio present in the Alang coastal seawater, but in three different concentrations one was the actual concentration, and another two were lower and higher than the actual concentration, found in Alang seawater.

There were three test tubes for each heavy metal and petroleum hydrocarbons concentration containing approximately the actual concentration of heavy metal and crude petroleum hydrocarbons found in Alang seawater, except in case of Fe where it was distributed in six different test tubes. The heavy metal concentrations in different test tubes were as follows: Fe (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 ppm); Mn (50, 100, and 200 ppb); Cd (5, 10, 15 ppb); Co (10, 25 and 50 ppb); Cu (25, 50 and 100 ppb); Zn (100, 150 and 200 ppb); Ni (10, 20 and 50 ppb); Pb (25, 50 and 100 ppb) and petroleum hydrocarbons (5, 10 and 15 ppm). There were two series of test tubes containing mixture of different heavy metals set up for observing the effect of all metals detected in Alang and their interactions with Marine phytoplankton. Series I contained Fe (1 ppm), Mn (50 ppb), Cd (5 ppb), Co (10 ppb), Cu (25 ppb), Zn (100 ppb), Ni (10 ppb) and Pb (25 ppb). Series II contained Fe (2 ppm), Mn (100 ppb), Cd (10 ppb), Co (25 ppb), Cu (50 ppb), Zn (150 ppb), Ni (20 ppb) and Pb (50 ppb). There were another two sets of three test tubes containing Series I and Series II mixtures of heavy metals with addition of three different concentrations of petroleum hydrocarbons such as 5, 10 and 15 ppm. Each of the said concentrations was kept in triplicate. All test tubes, contains media were sterilized in autoclave in 121°C under 15 psi pressure for 20 minutes before inoculation of phytoplankton.

Phytoplankton were collected from Diu, free from ship scrapping wastes pollution and filtered through phytoplankton net with mesh size 20 micron. The live phytoplankton were kept immediately within a cool pack containing ice. After reaching laboratory in CSMCRI, the phytoplankton were washed with the cool sterilized artificial seawater and concentrated by filtering again the phytoplankton through handy phytoplankton net. Inoculation was done under sterile condition by using Laminar flow. The culture test tubes were kept in culture room (25±2°C) with a constant light intensity under 10 : 14 LD regime. The growth of different phytoplankton was observed after 5 days of interval up to 15 days.

7.3 Results and Discussion:

7.3.1 Experiment I:

There were very few species that can tolerate a high concentration of heavy metal and petroleum hydrocarbons were identified. No species was identified that can tolerate heavy metal and petroleum hydrocarbons (PHC) from Mahuva region. The most heavy metals tolerant species were identified from Alang was *Amphora costata* Wm. Sm. A. costata could tolerate Co (2 ppm), Fe (1ppm), Cu (1 ppm), Ni (2 ppm), Pb (2 ppm) and PHC (10 ppm). There were another diatoms *Raphoneis surirella* Ehrneb. could tolerate Cu (3 ppm). The other diatoms *Melosira moniliformes* could tolerate 5 ppm of petroleum hydrocarbons. In case of petroleum hydrocarbons toxicity, there were mostly cyanobacterial species were dominant. Synechococcus species (1 ppm Pb), Lyngbya species (10 ppm of PHC tolerant) Phormidium species (3 ppm Cd) and another phormidium species (10 ppm of PHC) were identified from the Alang ship breaking yard (Plate VII).

7.3.2 Experiment II:

The collected samples contained the following phytoplankton organisms, which were inoculated: *Amphora costata* Wm. Sm *Asteroniella japonica* Cleve., *Biddulphia aurita* (Lyngbye) Breb and Godey*Bidduphia biddulphiana* (Sm) Boyer., , *Biddulphia pulchella* Gray, *Biddulphia sinensis Coscinidiscus radiatus* Ehrneb, *Coscinodiscus conciniformes* Simonsen,, *Coscinodiscus perforatus* Ehrneb., *Dytillum brightwelli* (West) Grun., *Grammatophora granulosa* Ehrneb., *Gyrodinium britannia* Ventr., *Hyalodiscus lavies* Ehrneb, *Hyalodiscus substilis* Bail, *Leptocylindrus danicus Cleave*. *Melosira moniliformes* (Muller) Agardh., *Melosira numuloides Nitzschia insignis* *Oscillatoria* species *Planktoniellla* species, *Rhoicosigma robustum* Grun., *Skeletonem costatum* (Grev.) Cleve., *Synecoccus* speciesand *Thalassiosira gravida* Cleve., etc.

Diu seawater was used as a control for observing the normal growth process of the collected marine phytoplankton. Only *Biddulphia puchella* Gray, and *Dytillum brightwelli* (West) Grun. showed a remarkable growth but *Skeletonema costatum* (Grev) Cleve, or *Melosira moniliformes* (Muller) Agardh. showed lack of growth. The other diatoms like *Coscinodiscus radiatus* Ehrneb, *Coscinodiscus perforetus* Ehrneb, *Biddulphia aurita* (Lyngbye) Breb and Godey, and *Planktoniella* also did not show fast growth like *Biddulphia pulchella* Gray,or *Dytillum brightwelli* (West) Grun.

Artificial seawater with Gf/2 media was used as another control for observing the induced growth of marine phytoplankton. In this media, *Skeletonema costatum* (Grev) cleve, showed some what fast growth as compared to other phytoplankton and might be due to the high nutrient concentration, which supported the fast growth of *Skeletonema costatum* (Grev) Cleve, and maintained the same in metal treated media. The other diatoms and cyanobacterial population showed a slow but steady growth in the artificial seawater media containing Gf/2 media.

Biddulphia aurita (Lyngbye) Breb and Godey, showed a normal growth in 0.5 ppm with a reduction of growth in 1.0 ppm concentration of Fe. *Biddulphia aurita* (Lyngbye) Breb and Godey, showed morphological anomalies at 1.0 ppm concentration and lack of growth abobe 1.5 ppm of iron concentration. *Melossira moniliformes* (Muller) Agardh. showed a fast growth at 0.5 ppm of Fe concentration but reduction of the same above 1.0 ppm of Fe concentration. *Synecoccus* species also showed an elevated growth up to 1.0 ppm of Fe concentration and at the higer concentration than 1.0 ppm it showed lack of growth. The other phytoplankton did not show any remarkable growth. *Biddulphia aurita* (Lyngbye) Breb and Godey, *Coscinodiscus radiatus* Ehrneb., *Thalassiosira gravida* Cleve., *Planktoneilla* species, *Dytillum brightwelli* (West) Grun., *Asteroniella japonica* Cleve., *Nitzschia insignis* and *Rhoicosigma robustum* Grun. were showed total lack of growth at 1.0 ppm concentraton of iron, and at 1.5 ppm or above concentration they became dead.

Manganese (Mn) at 50 ppb concentration showed a fast growth of *Skeletonema costatum* (Grev) Cleve. In high concentration of Mn (100 ppb) showed growth of many more phytoplankton species viz; *Skeletonema costatum* (Grev) Cleve, *Melosira moniliformes* (Muller) Agardh, *Biddulphia aurita* (Lyngbye) Breb and Godey and *Oscillatoria* species. At 200 ppb of Mn concentration all the previously mentioned species were live and growing well but at this concentration the other species like *Biddulphia pulchella* Gray, *Coscinodiscus perforetus* Ehrneb, and *Synechococcus* species lacked their growth and were dead after a long exposure. A giant formation of *Nitzschia insignis* was observed at 200 ppb of manganese concentration.

Among different concentrations of Cadmium *Skeltonema costatum* (Grev) Cleve and *Synechococcus* species showed a preferencial growth at lower concentration 5 ppb. Four species of *Skeletonema costatum* (Grev) Cleve, *Grammatophora angulosa* Ehrneb., *Melosira moniliformes* (Muller) Agardh., And *Biddulphia aurita* (Lyngbye) Breb and Godey., showed a preferential growth at 10 ppb of Cd concentration. At higher concentration of 15 ppb, *Skeletonema costatum* (Grev) Cleve., *Melosira moniliformes* (Muller) Agardh, *Grammatophora angulosa* Ehrneb and *Melosira numuloides* grew well but *Biddulphia aurita* (Lyngbye) Breb and Godey., became dead.

Media containing different cobalt concentrations of 10, 25 and 50 ppb showed a preferential medium for growth *Skeletonema costatum* (Grev) Cleve and *Amphora costata*. Some sensitive species like *Biddulphia aurita* (Lyngbye) Breb and Godey, *Biddulphia pulchella* Gray,, and *Coscinodiscus perforatus* Ehrneb., remained live at 25 ppm but became dead at 50 ppb concentration of cobalt. *Synechococcus* species showed a fast growth at 10 ppb of Co concentration.

Two different concentrations of Cupper such as 25 and 50 ppb, also showed a preferential media for growth *Skeletonema costatum* (Grev) Cleve and *Melosira moliniformes* (Muller) Agardh. But at higher concentration like 100 ppb no species such as *Biddulphia aurita* (Lyngbye) Breb and Godey, *Coscinodiscus perforetus* Ehrneb and *Synechococcus* species could not survive except a few number of representative cells of *Skeletonema costatum* (Grev) and *Amphora costata* Wm. Sm.

In case of Zn only *Skeletonema costatum* (Grev) Cleve., *Biddulphia granulota* and *Synechococcus* species showed a remarkable growth at 100 ppb concentration and only *Skeletonema costatum* (Grev) Cleve and *Amphora costata*Wm. Sm. showed a dispersed growth (broken chain) at 150 ppb but other species like *Biddulphia aurita* (Lyngbye) Breb and Godey, *Biddulphia pulchella* Gray,, *Coscinodiscus perforatus* Ehrneb, *Coscinodiscus radiatus* Ehrneb., *Melosira moliniformes* (Muller) Agardh. and *Dytillum brightwelli* (West) Grun. were found dead even at 100 ppb concentration of Zn.

Media containing low concentration of Nickel of 10 and 20 ppb showed a preferential media for growth of *Skeletonema costatum* (Grev) Cleve., *Melosira moniliformes* (Muller) Agardh, *Melosira numuiloides,* and *Biddulphia aurita*(Lyngbye) Breb and Godey and only 10 ppb concetration was preferential for growth of *Biddulphia sinensis* but not 20 ppb. The higher concentration like 50 ppb was only preferred for growth by *Melosira moniliformes* (Muller) Agardh.

All the media containing Pb showed a preferential growth of *Skeletonema costatum* (Grev) Cleve, and *Melosira moniliformes* (Muller) Agardh. The other species like *Biddulphia pulchella* Gray*, Coscinodiscus radiatus* Ehrneb.*, Coscinodiscus perforetus* Ehrneb*, Biddulphia aurita* (Lyngbye) Breb and Godey, and *Dytillum brightwelli* (West) Grun, did not show any considerable growth at 10 and 50 ppb concentrations and became dead at higher cocentration like 100 ppb. *Amphora costata* Wm. Sm. showed a remarkable growth at 100 ppb.

In case of the media containing petroleum hydrocarbons *Skeletonema costatum* (Grev) Cleve, showed fast growth at 5 and 10 ppm but *Melosira moniliformes* (Muller) Agardh showed fast growth in 10 and 15 ppm of crude petroleum hydrocarbons concentration. Other diatoms like *Biddulphia pulchella* Gray*, Coscinodiscus radiatus* Ehrneb *, Coscinodiscus perforetus* Ehrneb*, Biddulphia aurita* (Lyngbye) Breb and Godey*, Dytillum brightwelli* (West) Grun. and *Planktoniella* species became dead at even 5 ppm of crude petroleum hydrocarbon. *Synechococcus* species and *Oscillatoria* species and *Amphora costata* Wm. Sm. showed 10 ppm as a preferential media for its growth (Plate XXV and XXVI).

As *Melosira moniliformes* (Muller) Agardh., grew in most of the metals containing artificial Alang seawater and it could tolerate crude petroleum hydrocarbons up to 15 ppm and grew well. Hence, it may be considered as the biomarker of the coastal seawater of the Alang ship breaking yard area. The excessive growth of *Melosira moniliformes* (Muller) Agardh was also observed in Alang during December 2002 subsequent accidental oil spillage during October 2002 at the coastal Seawater of the Alang ship breaking yard area. The other species namely *Skeletonema costatum* (Grev) Cleve, also emerged as a tolerant species of the pollutant seawater due to ship breaking activities at Alang. *Skeletonema costatum* (Grev) Cleve, is found to be more resistant to copper, as evidenced from the greater increase in cell number over the control and is higher in this species compared to *Nitzschia longissima* (Breb) Ralfs. (Subramanian, *et. al*. 1980). Erickson et al. Observed that *Skeletonima costatum* (Grev) Cleve, is slightly more resistant to copper than *Amphidinium carteri* and *Oscillatoria luteus*. (Erickson, *et. al*. 1970). Further it is also suggested that *Skeletonema costatum* (Grev) Cleve, and *Nitzschia longissima* (Breb) Ralfs could be used effectively in metal pollution monitoring studies. (Subramanian , *et al.*1980). But as the Alang seawater contains about 500 ppb and above of dissolved Fe concentration which might be a limiting factor for *Skeletonema costatum* (Grev) Cleve, as it was not observed to grow well in 0.5 ppm and above that of Fe concentration in laboratory experiment. The other species of diatoms may survive only at lower concentration of different metals in Alang seawater. In toxicity studies, it is suggested that, consideration should be given to the intra specific differences in nutrient uptake abilities of phytoplankton, and to the duration of exposure as well as to the specific effects of various metals. Some species like, *Biddulphia* species, and *Coscinodiscus* species showed shrinkage of protoplasmic materials inside the cell and this might be due to environmental stress condition caused by heavy metal concentration. In experiments with copper, even a slight increase in the metal concentration above the maximum tolerant limit resulted in broken and disintegrated cells in both the species (observed in light microscope). *Nitzschia longissima* (Breb) Ralfs. seemed to be more tolerant to zinc than *Skeletonema costatum* (Grev) cleve, (Subramanian, *et al.* 1980). Steeman Nielsen and Wium- Anderson (1971) observed loss of organic matter and a consequent shrinking of the cells in *Nitzschia palea*. The media containing mixture of all the metals showed a considerable growth for *Skeletonema costatum* (Grev) Cleve, and *Melosira moniliformes* (Muller) Agardh at lower concentration (Series-I) but did not show any remarkable growth at higher concentration (Series-II). Total lack of growth was observed for all species when the crude petroleum hydrocarbons were present even at lower concentration (5 ppm) in the presence of the metal concentration (Series-II). Braek *et al*.,(1976) reported that the combined action of heavy metals present in the zinc smelter effluents (Zinc, Manganese, Iron, Copper, Cadmium, Lead, Cobalt, Nickel and Chromium) might be responsible for the sub-lethal and lethal effects observed in *Skeletonema costatum* (Grev) Cleve, *Melosira moniliformis* (Muller) Agardh, *Stephanodiscus sp.* and *Navicula longa* (Greg) Ralfs.

Plate-XXV

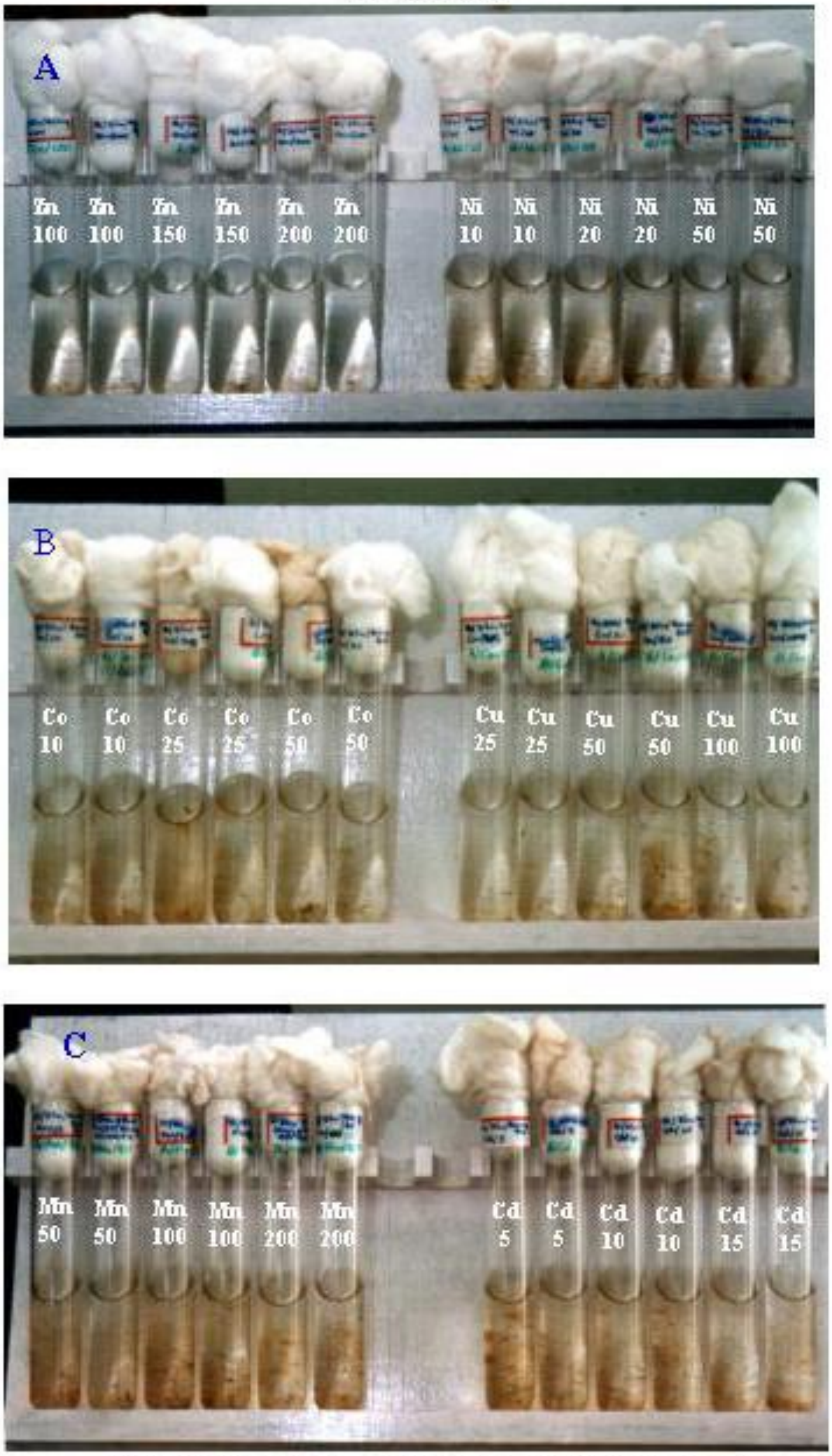


Fig A-C :Succession of Marine Phytoplankton Community composition was tested in different heavy metal composition.

Plate-XXVI

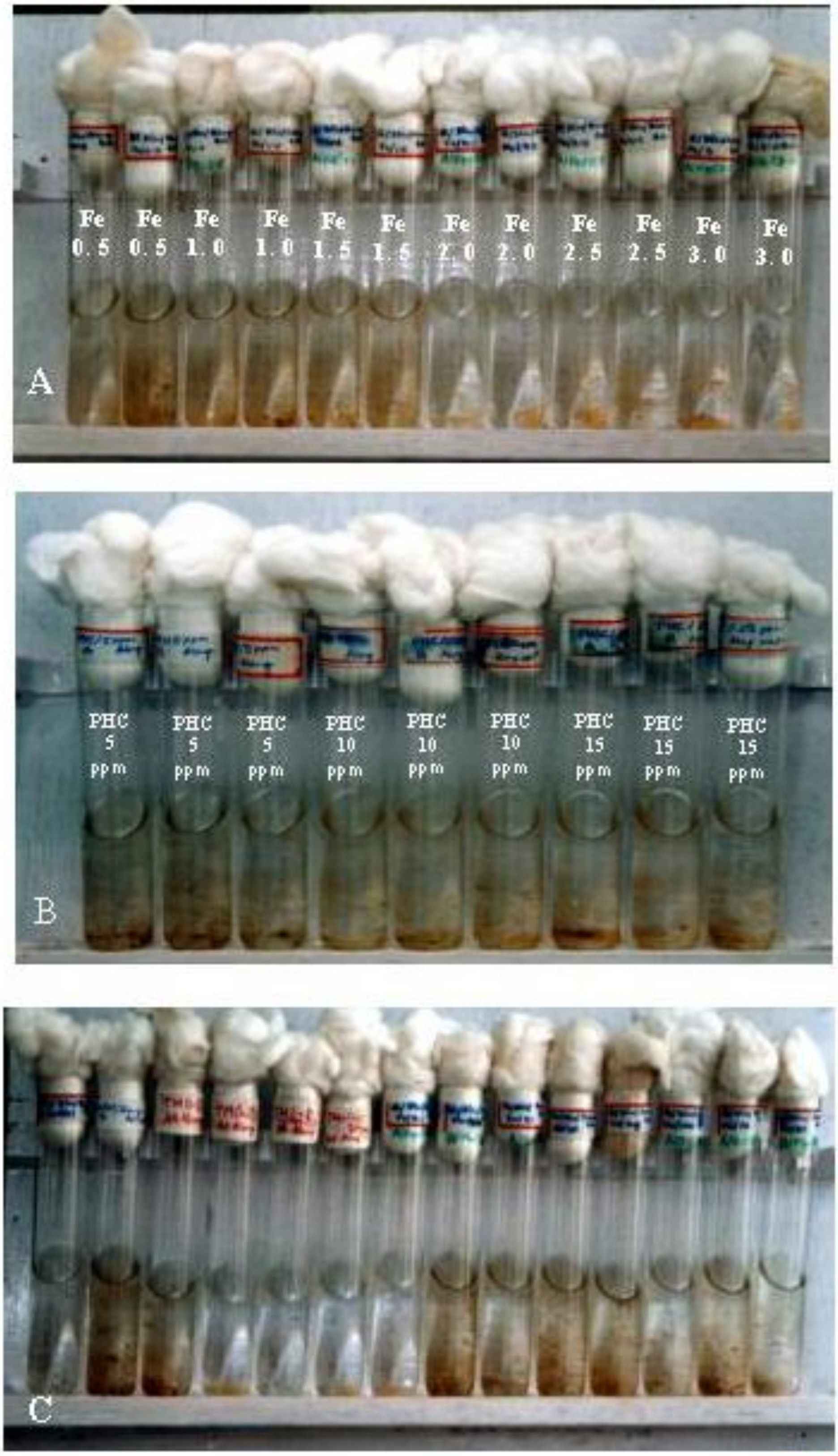
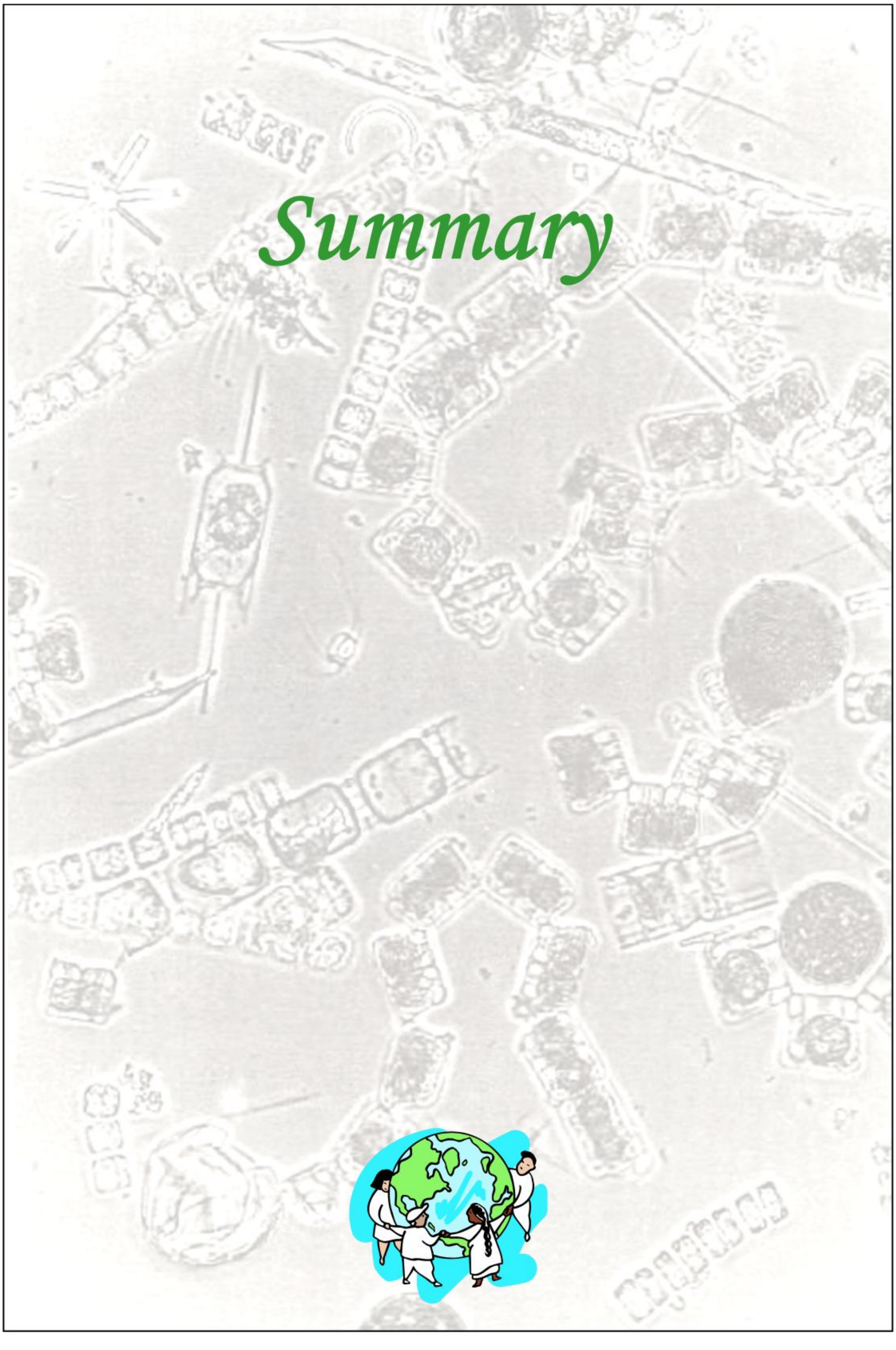


Fig A-C :Succession of Marine Phytoplankton Community composition was tested in Artificial Alang Seawater.

Summary



Summary

The present study of the "Studies on the effect of ship-scrapping Industry wastes on marine phytoplankton at Alang, Gujarat" envisages the investigation of various parameters in situ at Alang and also at Mahuva, the most distributed coastal area as a result of migration of the pollutants from Alang. The parameters include Air Temperature, Seawater Temperature, TSS, pH, salinity, DO, BOD, NO_2-N, NO3-N, NH_4-N, PO_4-P, Chlorophyll-a, Pheophytin, Gross and Net Primary Productivity. Among the 11 abiotic parameters (air temperature, seawater temperature, TSS, pH, salinity, DO, BOD, NO_2-N, NO3-N, NH_4-N and PO_4-P) studied at Alang and Mahuva, only total suspended solids (TSS) showed significant difference between two places. In this study, chlorophyll-a content showed a negative correlation with seawater temperature in both the places. Seawater temperature has an effect on the rate of production and growth of total population of phytoplankton and it might have affected the dominance of phytoplankton groups and has altered successions by inhibiting or killing of the more sensitive species. As the seawater temperature did not show any considerable difference between Alang and Mahuva, and both the places experienced a decrease in the number of genera and species during summer, the temperature may not be the principal variable for bringing differences in primary productivity and the community composition of marine phytoplankton between Alang and Mahuva as a whole. Seawater temperature might be the responsible factor for accelerating the effect of heavy metals and petroleum hydrocarbons on marine phytoplankton in different ways, thereby decreasing the dissolved oxygen into the water column by increasing the metabolic activity of marine organisms and degrading the organic loads faster in that region.

Chlorophyll-a and GPP showed significant differences between Alang and Mahuva with typical relation ships. Chlorophyll-a content showed higher value with lower productivity of the Alang region coinciding with the more number of genera and species and the total count of marine phytoplankton at Alang as compared to Mahuva. In Mahuva GPP and Chlorophyll-a concentration showed a better positive co-association than the one at Alang, indicating the environmental stress reducing the primary productivity in the coastal area of Alang.

GPP and Chlorophyll-a concentration did not show any strong association with nutrients, like NO_2-N, NO_3-N, NH_4-N and PO_4-P at both the places, Alang and Mahuva. So the nutrients like NO_2-N, NO_3-N, NH_4-N and PO_4-P might not have any significant role to bring the differences in Gross Primary Productivity, Chlorophyll-a content and community composition of Marine Phytoplankton in that region. Only Total Suspended Solids showed significant differences between Alang and Mahuva and it was more at Alang than Mahuva. These differences noticed might be due to the ship scrapping activities and man aided disturbances in the Alang coastal area and thereby the suspended particulate matters would not settle down to the sea bottom and would make the water column turbid. Therefore, it prevents penetration of light in that region and that might be causing the less productive zone.

Secondly, within the eight heavy metals, detected from seawater as dissolved, no metal showed any significant difference between Alang and Mahuva, but significant differences in Mn, Cu, and Ni concentrations were noticed in total suspended solids. So these three metals would obviously get dissolved very fast into the seawater and would take active participation in the biogeochemical cycle in the region at Alang and would not persist for a long time into the water column and might be the responsible for the environmental stress condition at Alang. The other five metals Fe, Cd, Co, Zn and Pb did not show any significant differences between Alang and Mahuva, and it appeared that these metals might be carried by the suspended solids as their concentrations remain nearly unchanged due to comparatively less uptake of marine phytoplankton at the Mahuva region. So, all five metals may be responsible for the environmental stress of the Mahuva region. Though GPP showed a positive co-association with Fe, Mn, Cu, Zn and Pb, at Alang, multiple regression analysis showed the cause and effect relationship with GPP that appeared to be less important. Co and Cd metals showed as important metals for Gross primary productivity and showed negative correlation with GPP, which might be responsible to control low primary productivity at Alang ship breaking yard area. Multiple regression analysis showed the cause and effect relationship of Co and Pb with Chlorophyll-a concentration with the other principal factors like; TSS, NH_4, and petroleum hydrocarbons, although, none of the eight metals showed any remarkable positive or negative correlation with chlorophyll-a concentration at Alang. So, the essential heavy metal Co and primary nutrients NH_4 might be the principal cause for higher value of Chlorophyll-a and influence the growth of cyanobacterial population like *Synechococcus* sp. at Alang. In Mahuva Co, Cu and Zn showed cause and effect relationship with GPP, although they did not show any remarkable correlation with GPP. The other principal factors showing the cause and effect relationship with GPP at Mahuva were found to be NO_2, PO_4 and petroleum hydrocarbons. Petroleum hydrocarbons showed the cause and effect relation ship with Gross primary productivity in both the places, as well as it showed statistical significant differences between Alang and Mahuva, which means the crude petroleum oil spillage of the ship breaking yard area causes lower primary productivity of that region. The toxicity of certain Poly Aromatic Hydrocarbons (PAHs) is greatly enhanced when it is exposed to sunlight. The mechanism of PAH phototoxicity includes absorbance of solar radiation by PAH which produces a free radical and this free radical in turn reacts with oxygen to produce reactive oxygen species, e.g. superoxide radical anion, that can damage DNA and other cellular molecules.

Number of genera and species and the total count of phytoplankton were also regulated by different independent variables at Alang and Mahuva in different ways. Number of genera showed a positive correlation with petroleum hydrocarbons at Alang, which means the petroleum hydrocarbons tolerant species are getting adapted with the environmental stress at Alang, whereas in Mahuva number of genera did not show the same type of relationship with the petroleum hydrocarbons. At both the places, Alang and Mahuva, number of species showed remarkable negative correlation with the heavy metal, Pb and petroleum hydrocarbons, which means the petroleum hydrocarbons and lead are the principal factors for regulating the phytoplankton succession of the coastal seawater of Alang and Mahuva. Total count showed positive correlation with Chlorophyll-a at Alang and showed no remarkable correlation at Mahuva. In general Fe and Mn never showed any negative correlation with any phytoplankton in both the areas, Alang and Mahuva. Fe and Mn showed exclusive positive correlation with 20 and 9 species respectively at Alang. Mainly some species of the genera *Amphora, Campylodiscus, Diploneis, Navicula, Pleurosigma, and Thalassiothrix* showed exclusive positive corellation with Fe at Alang. A few species of *Bacillaria, Biddulphia, Licmophora*, *Nitzschia, Pleurosigma* and *Surirella* showed exclusive positive corellation with Mn at Alang. Both the metals, Fe and Mn did not show any exclusive correlation at Mahuva. Fe and Mn showed a close association with respect to species abundance at Alang and Mahuha. So *Amphora, Campylodiscus, Diploneis, Navicula, Pleurosigma, and Thalassiothrix* might be Fe tolerant species and indicator species for Fe, whereas, *Bacillaria, Biddulphia, Licmophora, Nitzschia, Pleurosigma* and *Surirella* might be indicator species for Mn. Species from two genera viz; *Pleurosigma* and *Scoliopleura* showed a positive correlation and species of *Peridinium* and *Thalassiosira* showed a negative correlation exclusively with Co at Alang. There was only one species of *Pleurasigma* and one species of *Grammatophora* showed exclusive negative correlation with Zn and Pb respectively. Zn always showed positive or negative correlation in association with other metals, but it never showed any correlation individually. It showed positive correlation with the species where Mn showed positive correlation or it showed negative correlation with the species when either Co or Cd or Ni showed positive correlation. Abundance of some species of *Amphora, Asterionella, Biddulphia, Licmophora, Navicula, Nitzschia, Pleurosigma* and *Surirella* showed positive correlation with petroleum hydrocarbons at Alang, which means the derivatives generated from the petroleum hydrocarbons due to photo-oxidation might be preferred by the species of the above mentioned genera. In the same way some species of *Ceratium, Coscinodiscus*, and *Nitzschia* showed negative correlation with petroleum hydrocarbons, which might be more sensitive to the toxic effect of the petroleum hydrocarbons at Alang. At Mahuva, species of *Amphora, Bidduphia Chaetoceros, Coscinodiscus, Navicula, Nitzschia, Noctiluca, Pleurosigma, Surirella, Thalassiosira* and *Torpedoneis* showed positive correlation only and no species showed remarkable negative correlation with petroleum hydrocarbons. The crude petroleum oil spillage brings adverse effects on the intolerable species, as the costal area of Alang often experiences the oil spillage due to ship scrapping activities. Hence the prevailing community composition of marine phytoplankton will be preferentially petroleum hydrocarbons tolerant species. Some phytoplankton species might prefer to establish their population due to specific affinity to metal choice like Fe, Mn and Pb but the physiological activities of the primary producer might be influenced by the other heavy metals like; Co, Cd, Cu, Zn, and Ni at the coastal area of Alang.

In the Laboratory experiment, most of the phytoplankton species collected from Diu, free from all types of pollution, showed adverse effect in most of the metals treated with the same concentration as observed in coastal water at Alang. Zn showed the most adverse effect on the community composition in laboratory experiment. In case of other metals, most of the species like *Biddulphia, Coscinodiscus, Dytilum*, showed their intolerance in the highest concentration, which was also observed at Alang. Only *Skeletonema costatum* and *Melosira moniliformes* and *Synechococcus* sp showed some what fast growth and their tolerance in the artificially made Alang seawater. The laboratory experiment also showed the same situation as observed at Alang in case of *Melosira* *moniliformes* during December 2002 subsequent to oil spillage during October 2002. Total lack of growth for all species was observed in laboratory experiment when the crude petroleum hydrocarbons were present even at lower concentration in the presence of all metals at their highest concentration at a time. As there are fluctuations in the concentration heavy metals and Petroleum hydrocarbons in the Alang and Mahuva regions the community composition of marine phytoplankton however, maintain in that region. The expected variations in the Mahuva region were not observed which might be due to the adverse effect of organo-metalic complexes formed by petroleum derivatives and heavy metals, being carried by the total suspended solids. In Alang, the number of genera and species composition of marine phytoplankton were more than the ones at Mahuva and might be due to addition of exotic phytoplankton species in that area through the ballast water of dead ships. As the phytoplankton species of the ballast water could tolerate a certain concentration of heavy metals and petroleum hydrocarbons and would survive in that region and this would be specific for certain species of phytoplankton only. However, the primary productivity and the general diversity of marine phytoplankton were readily affected by the heavy metal and petroleum hydrocarbons pollution of that region and the generic composition of marine phytoplankton community might be altered due to ship scrapping activities at Alang.

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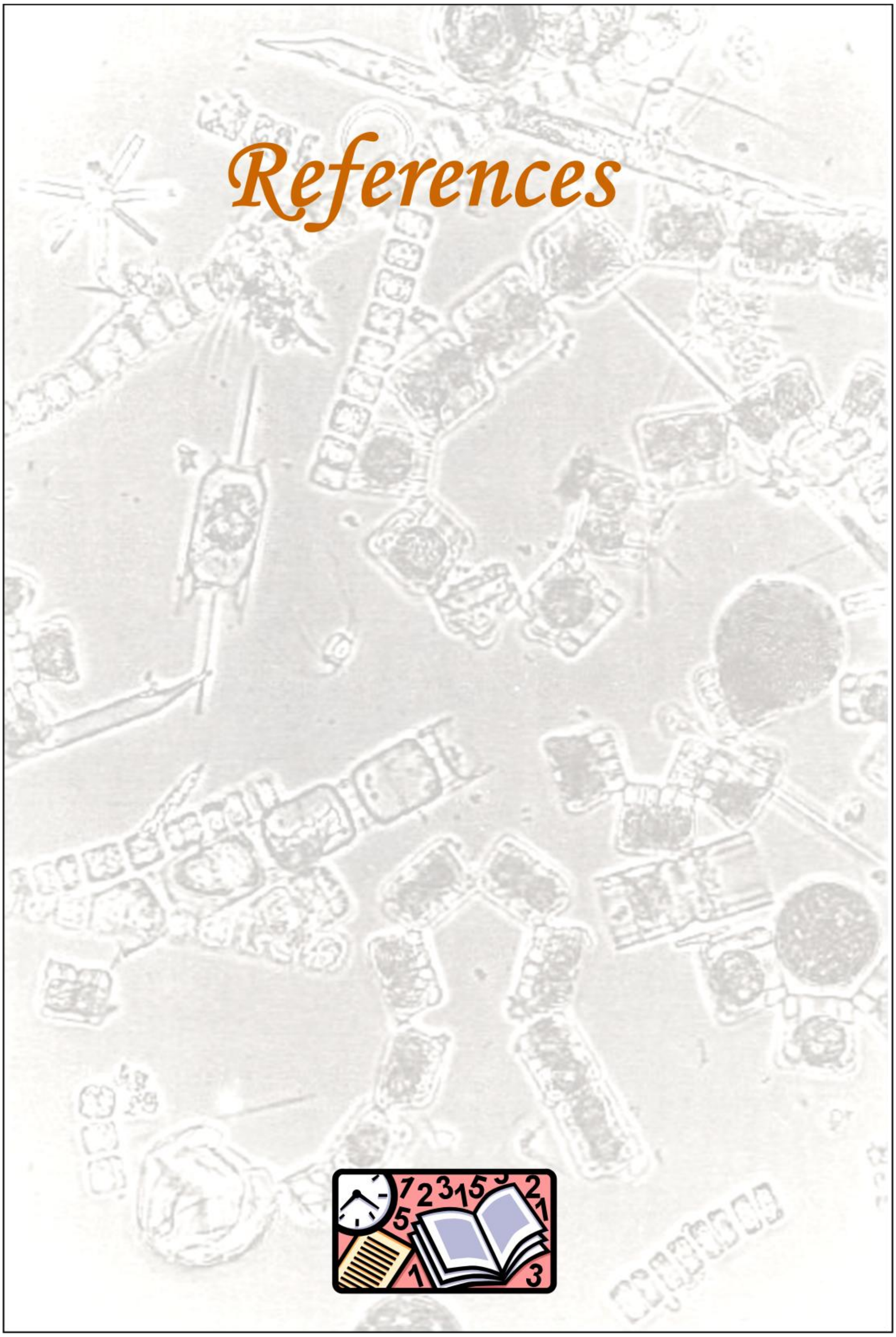

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