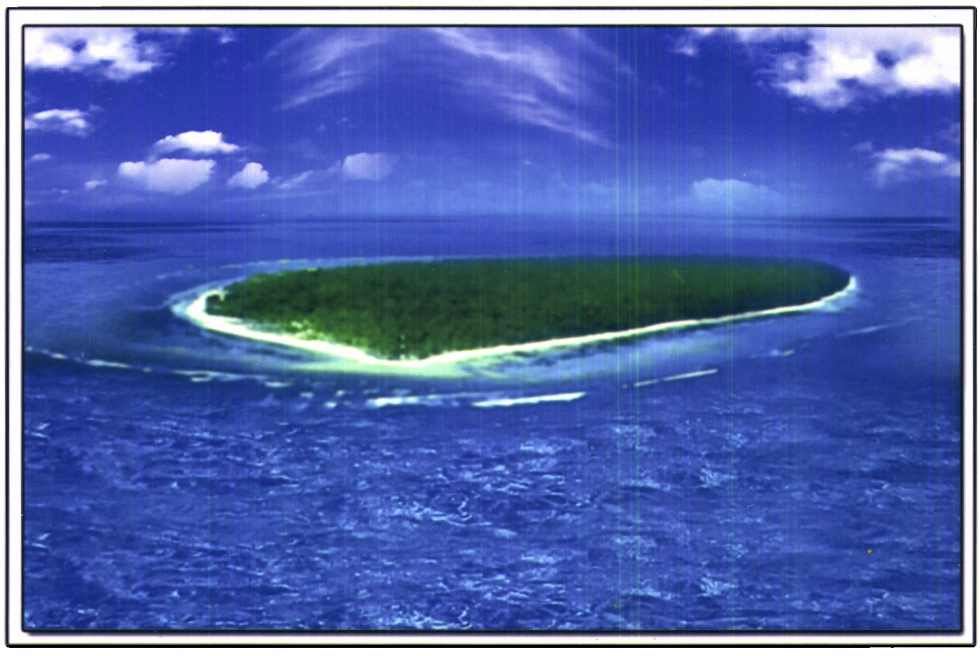
INTEGRATED COASTAL WATER QUALITY ASSESSMENT OF ANDROTT ISLAND, LAKSHADWEEP

Thesis submitted to the
COCHIN UNIVERSITY OF SCIENCE & TECHNOLOGY

For the award of the degree of
DOCTOR OF PHILOSOPHY

in

ENVIRONMENTAL SCIENCE
Under the School of Environmental Studies



By
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CENTRE FOR EARTH SCIENCE STUDIES
THIRUVANANTHAPURAM

July 2005

Dedicated to

my ever loving parents, Navami & Nandu

DECLARATION

I hereby declare that the thesis entitled "INTEGRATED COASTAL WATER QUALITY ASSESSMENT OF ANDROTT ISLAND, LAKSHADWEEP", is an authentic record of the research work carried out by me under the supervision and guidance of Dr.P.P.Ouseph, Head, Chemical Sciences Division, Centre for Earth Science Studies, Thiruvananthapuram, in partial fulfillment of the requirements for the award of the Ph.D. Degree of Cochin University of Science & Technology, under the Faculty of Environmental Science and no part thereof has been presented for the award of any degree in any University.

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CERTIFICATE

This is to certify that this thesis entitled **"INTEGRATED COASTAL WATER QUALITY ASSESSMENT OF ANDROTT ISLAND, LAKSHADWEEP"**, is an authentic record of the research work carried out by Mr. K. B. Bijumon, under my supervision and guidance, at Chemical Sciences Division, Centre for Earth Science Studies, Thiruvananthapuram, for the award of the Ph.D. Degree of Cochin University of Science & Technology, under the Faculty of Environmental Science and no part thereof has been presented for the award of any degree in any University.

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(K. B. BIJUMON)

CONTENTS

INTRODUCTION

1.1 Marine Water Quality Monitoring

Earth is the only planet in the solar system blessed with a liquid medium for life to evolve in and the man hold the oceans within him, both physically and mentally. So vast are the oceans that it covers almost 140 million square miles, out of roughly 200 million square miles of earth surface ie, 71% of the entire surface of the globe. In other words about seven tenths of earth s surface is covered with sea. It has an average depth of 12,230 feet (3730 m) and reaches the deepest point in the Mariana Trench of the Northwest Pacific Ocean, at 36,204 feet (11,038m) below sea level and hold over 285 million cubic miles of water (1185 million cu. km) This vast quantity of water arose from the Earth's interior as it cooled.

The oceans are the largest repositories of organisms on the planet, with representatives from all phyla from the obviously large whales the microscopic bacteria. Living organisms either live in water or have specific mechanisms to conserve it within their bodies Protoplasm is a complex colloidal mixture of sols and gels and the intercellular fluids are largely water Thus water makes up something like 70 %, or in some organisms like jelly fish more than 95 of the body weight and is the medium in which various chemical reactions take place, both inside and outside of their cells. Survival also requires energy input to drive these chemical reactions and environmental conditions suitable to maximize the efficiency of these reactions.

The marine and coastal areas harbour a variety of specialized ecosystems like mangroves, coral reefs, islands, salt lakes sand mud flats, which provide unique habitats for a myriad of flora and fauna Due to manifold usages of Seas and Oceans for harvesting resources, shipping and dumping of wastes the areas constantly face various environmental stresses and threats, which ultimately affect the biotic factors of the system Due to the rapid increase in global population and industrialization, the major source of marine pollution is from municipal and urban runoff and among them, industrialization contributes for 56 of the pollution load The industrial waste discharge is estimated to be 0.79 x 10^9 cu m as of 1994 (Subramanian, 1999), while microbial pollution is largely confined to nearshore waters, released/dumped chemicals are found even in the offshore waters

Water pollutants can be classified into categories such as non-degradable and biodegradable like sewage and other oxygen demanding wastes. Oxygen-demanding wastes lead to oxygen depletion, which affects aquatic life and produce annoying taste, odors and colour that impair water quality. The unlimited discharge of domestic and municipal wastes makes the self-purification ability of aquatic systems ineffective. Every year millions of fish are reported killed due to the municipal and industrial wastes that find their way to the ocean/water bodies.

India has a coastline of 8,129 kms with an Exclusive Economic Zone (EEZ) of 2.02 million sq. kms. Out of the 100 million population, 25 % live in coastal areas. The disposal of domestic sewage waste, mostly untreated, into the Indian coast has been estimated approximately 18,240 MLD (Million Litres per Day). Only primary treatment facilities are available in cities and towns with a population above 1, 00,000. This partial treatment allows the waste water retain its original features causing damage to the water quality.

Man generate significant adverse impact on the biology of the ocean, by altering its chemical composition by ways, including sewage and trash, storm drain and river run-off, and oil spills. Sewage and trash all over the world are dumped into the sea. Chemically, sewage acts like fertilizer and can be responsible for toxic plankton blooms and causes various water born diseases. At the same time, heavy metals and carcinogens in coastal waters are equally dangerous. Although the ocean is good at ridding itself of pollutants by chemical processing and dilution, as coastal populations grow, so do the human activity on the marine environment, which leads to continue the pollution constantly. Apart from this, storm drain and river run-off as non-point source pollution input large quantities of suspended solids, fertilizers, soap and organic wastes, that reduce oxygen dissolution, the same way sewage does. Debris like trash can entangle or be eaten by birds, fish and mammals, which can be very harmful and leads to mass mortality among them as the case of 'Ghost fishing' in trawl fishing activities all over the world. Oil floats on the surface of seawater and when spills occur, it tends to end up on the shore where it hurt marine life by matting down bird feathers, sticking to fish gills, disrupting breeding, and blocking the dissolution of oxygen.

Concentration of the gases dissolved in seawater is modified further by biological activity particularly by plants and certain bacteria. Dissolved oxygen in seawater plays a

very important role with respect to marine life and its amount in seawater is comparatively lower than that in fresh water or in atmosphere. The capacity of water to contain oxygen increases with decrease in temperature and salinity

Temperature is a very important physical parameter in the marine environment. It limits the distribution and ranges of ocean life by affecting the density, salinity, and concentration of dissolved gases, as well as influencing the metabolic rates and reproductive cycles of marine organisms.

When the physico-chemical characteristics of the seawater are affected by pollutants, the sensitive ecosystems are affected disrupting the existence of biotic factors at various strata. One among them is coral reef, which are self-prepared biogenic structures. In India, coral reef ecosystem extends over approximately 2300 sq. kms area as against a total 6 million sq. km area. The reefs are of fringing type in Andaman and Nicobar Islands, and in Gulf of Mannar. There is a 320 km long luxuriant barrier reef on the west coast of Andaman extending between $10^{o}26^{1}$ North to $13^{o}41^{1}$ North and a depth of 80 km. Atoll reefs are found in Lakshadweep. Reef formation is governed by some physico-chemical parameters such as temperature, depth, transparency, salinity and wave action. Reefs are well developed in areas where the annual mean temperatures are around 23^{o} to $25^{o}C$ with an optimum range of $29^{o}C$ and the salinity between 27 % and 40 %. A total of 200 species of corals from 71 genera are known from Indian Seas, of which 155 species from 50 genera are hermatypic.

Nutrients are inevitable parameters of a productive environment in the ocean. There is reclamation of nutrients in the form of nutrient cycles. A certain amount of nutrients utilized by phytoplankton is however regenerated by bacterial activity within the euphotic zone itself. But a good amount is lost from the euphotic zone as a result of the sinking of phytoplankton as well as through consumption by zooplankton inhabiting deeper levels during daytime. The nutrients that accumulate in the deeper levels are mostly returned to the surface waters by vertical mixing processes such as upwelling, eddy diffusion, vertical convection and wind mixing. In addition to this, land drainage and river influx also contributes to the replenishment of nutrients of the surface water at least of the coastal areas. The seasonal changes in environmental conditions drive the large-scale or global ocean-wide features while short-term variations are largely due to

inherent instabilities. Such phenomena are obvious in shallow waters and it will be difficult to predict long-term trends and this is one of the hardships of oceanographic studies.

Biological process exerts important influence in the composition of seawater through effects on the chemical forms that are present. At the same time, chemical characteristics have an important influence on biological activity, exemplified by the contrast in productivity between oligotrophic and eutrophic waters and life processes between oxic and anoxic waters. Those features of the present day composition of sea-water which show marked temporal and spatial variations are of particular interest from the marine biological standpoint, since they are often closely related to the cycles of organic production and decomposition and have immediate relevance in relation to productivity. In the marine environment, there is no community of organisms that is totally independent and many of these are intimately related. Thus, in order to understand the quality and various processes in the sea, the system has to be dealt with as an interrelated system between biotic and abiotic environment, rather than as discrete units.

During the past few decades, marine microbiology, like other disciplines of the biological sciences, has witnessed a rapid growth due to multidisciplinary approach and contribution of information based on ecology, physiology and biochemistry, which caused a marked change in this field of study. Recently, however, it has been appreciated that bacteria themselves have a very high demand for phosphates and nitrates, indeed, as high as the phytoplankton because bacterial cells contain as many or more phosphorous and nitrogen atoms for every carbon atom as do those of the photosynthetic algae. Bacteria may be a sink for nutrients along with zooplankton. The potentialities of an aquatic ecosystem such as nutrient dynamics, productivity, standing stock and energy transfer are vast and for the assessment of it, the study of physico-chemical characteristics incognizance with biological processes is inevitable. These parameters are interdependent and vary with seasons.

Fresh water pollution

Man's biological need for water is modest; only a few litres day and much of this is usually supplied by food. Man's desire for water, however, vastly exceeds his need. In most of the developing countries, 75% of the population lacks adequate sanitary facilities. Pathogenic bacteria, viruses and parasites make untreated human waste

towards the world's most dangerous environmental pollutant. Four out of every five common diseases in developing countries are linked to either infection from dirty water or lack of sanitation. Water-borne diseases cause an average of about 25,000 deaths a day (UNEP, 1987). Infectious bacterial agents are a hazardous constituent of wastewater from municipalities or sewage. Many of the diseases like cholera and typhoid whose epidemics recurrently decimate human populations are transmitted through water. From the epidemiological point of view, it is important to identify the potential pathogenic hazards in a potable water resource and formulate base line information. This information is vital in terms of designing proper management action plans.

In densely populated areas with varying geological setup, piped water supply cannot completely satisfy the drinking water requirement. Dependence on dug wells as drinking water sources, therefore, will continue indefinitely. One serious aspect of the high density of houses in small plots with dug wells and septic tanks/leach pits in close proximity is that the possibility of bacterial contamination of drinking water increases. A variety of water borne disease outbreaks are attributed to the consumption of contaminated water from poorly protected wells.

Water borne diseases and causative organisms

Waterborne Disease	Causative organisms	Source of organism in water	Symptoms
Gastroenteritis	Rota virus	Human feaces	Acute diarrhea or vomiting
Diarrhea	*Salmonella* (bacterium)	Animal or human feaces	Acute diarrhea or vomiting
Diarrhea	Enteropathogenic *E. coli* (bacterium)	Human feces	Acute diarrhea or vomiting
Typhoid	*Salmonella typhosa* (bacterium)	Human feaces	Inflamed intestine, enlarged spleen, High temperature; sometimes fatal
Dysentery	*Shigella* (bacterium)	Human feaces	Diarrhea – rarely fatal
Cholera	*Vibrio cholera* (bacterium)	Human feaces	Vomiting severe diarrhea, rapid dehydration mineral loss; high mortality
Infectious hepatitis	Hepatitis A (virus)	Human feaces, Shell fish grown in polluted waters	Yellowed skin, enlarged liver, abdominal pain; low mortality; lasts up to 4 months
Amoebic dysentery	*Entamoeba histolytica* (protozoan)	Animal or human feaces	Mild diarrhea chronic dysentery
Giardiasis	*Giardia lamblia* (protozoan)	Animal or human feaces	Diarrhea, cramps, nausea and general weakness; not fatal; lasts 1 week to 30 weeks
Cryptosporidiosis	*Cryptosporidium* (Protozoan)	Animal or human feaces	Diarrhea, stomach pain; lasts an average of 5 days

[Source: WHO, (1989). GEMS/Global database]

Historically, some of the most severe public health effects from contaminated drinking water were from diseases such as cholera and typhoid. Microbial contamination continues to be a national concern because contaminated drinking water systems can rapidly spread diseases (WHO & UNEP 1987). A variety of water borne disease outbreaks have been attributed to contaminated aquifers or poorly protected well sites containing pathogenic bacteria, viruses or eukaryotic organisms (ITRC, 1989, Chaudhari, 1985). Specific bacterial pathogens that have been isolated from well waters include entero-pathogenic *E coli*, *Vibrio cholera*, *Shigella flexneri*, *S.sonnei*, *Salmonella typhimurium* (Centre for Disease Control, 1980). Contaminated, untreated ground water was the source of 35.3 of water borne disease outbreaks in the USA over a 30 year period (Lippy & Waltrip, 1984). Even though 80% of water borne diseases and outbreaks are due to bacteriological contamination of water, most of the workers involved in water quality management are concerned more about the removal of chemical contaminants from water (Forsund,1986). Regular surveillance of water sources for quality and efforts to control bacteriological contamination is, therefore essential.

Any program of public health cannot be a success without the participation of local community. General public should be educated and public awareness created to prevent, reduce and eliminate ground water pollution through integrated and co-ordinate regulatory actions. In absolute numbers, most human sufferings and deaths in developing countries are due to water-associated diseases. Inadequate water supply, unsanitary excreta disposal and vector-infested water courses are held responsible for approximately half of the present child (< 5 years of age) diarrheal mortality of 4 millions per year in the third world. In the long run, water resource management must focus in prevention from point sources of waste discharge and diffuse penetration of storm water run off (Bartram and Balance, 1996). Thus, with respect to water borne diseases, only the improvement of the microbiological quality of drinking water, together with supporting measures in hygiene education, sanitation and food safety will cut by half the morbidity and mortality of water-related diseases (Hughes, 1993).

In terms of health impact assessment, water may be classified in three typical categories (Galal-Gorchev, 1986) as substances exerting acute and/or chronic toxicity (eg., metals, nitrates, cyanide etc.), genotoxic substances causing carcinogenicity, mutagenesis and

birth defects (synthetic organics, microorganisms, arsenic and some pesticides) and essential elements which are mandatory as dietary constituent (fluoride, iodine, selenium) New threats and contaminants have emerged today with such diverse water quality problems. Anthropogenic activities in one place are the cause of water quality deterioration and ecological disturbances elsewhere (Falkenmark, 1986).

Assessment of water quality now-a-days in global scenario implies the need for a reference point against which monitoring can be measured and weighed. Aquatic ecosystems as part of the natural environment are balanced both within themselves and with other environmental compartments and this equilibrium is subject to natural variations and evolutions as well as variations caused by human intervention. The present assessment is to identify, and possibly quantify, anthropogenic influences over time against a "natural" baseline situation. Water pollution problems have only recently been taken seriously in retrospect. Once damage occurred, it becomes immeasurable, and control action cannot be initiated.

The general occurrence and the natural variations of the constituents in ground water and their relation to the water use are of utmost significance in water quality management. Monitoring and assessment over a period of time are required to conduct the rational management The monitoring should cover standard measurements of water quality variables of chemical and biological components. To ensure safe recreational water and a continuous supply of potable water, frequent monitoring of both raw water sources and finished products for the presence of pathogens is very important. This procedure will establish baseline data against which microbiological quality can be compared during water bone epidemics or other unusual circumstances. Also, periodic examination will help to establish a system or protocol that can be activated, with our significant delay including sudden disease outbreaks More importantly, the detection of any enteric bacteria, even of low pathogenicity, in the aquatic environment may serve as a warning of unsafe recreational water or a breach in the integrity of disinfection or distribution system for potable water Thus for detecting the presence of these and other pathogens are respected to be carried out more often than before. Moreover, it is desirable to adopt relatively easy, sensitive, and highly specific methods for detecting every pathogen that could potentially present in

The enteric diseases caused by coliform bacteria are transmitted mainly by faecal contamination of water and food materials. Since, the faecal coliform predominantly of *Escherichia* are not usually long term occupants of aquatic ecosystems, their presence in water serves useful indicator of recent faecal contamination. The bacteria that have principally served as indices of such contamination are the faecal streptococci and *E coli*. Organisms like *Escherichia*, *Salmonella*, *Shigella*, *Proteus*, *Vibrio cholerae* and *V parahaemolyticus* belong to enteric group of organisms. *Salmonella* cause typhoid fever and Shigella cause bacterial dysentery whereas *V cholera* and *V parahaemolyticus* cause cholera and food poisoning. Some members of genera such as *Klebsiella* that have an extra intestinal prevalence and can cause disease by gaining entry into water from environmental sources and therefore should also be monitored.

Although microbial pathogens in water will be the main pollution problem for most developing countries for some time, chemical pollution has emerged as an equally serious threat in all countries, which have industrialization and chemically supported agriculture. The most immediate stress on human health from water pollution is through ingestion of contaminated water. Nitrates, for example, not only contribute to algal blooms in lakes and reservoirs but, when present in drinking water at high levels, can result in methaemoglobaenemia. The rapid increase in population density has generated human wastes, which have reached surface waters or percolated into the ground water with both immediate contamination and long-term deterioration of the aquatic environment. The limits of the waste assimilative capacity of the aquatic environment have been rapidly approached in the high-density agglomerations.

Chemical analysis gives a great deal of valuable information concerning the sanitary quality of water and many sources of pollution are detected by this method. Also, water, which on chemical analysis shows evidence of recent pollution, is at the time bacteriologically impure. Organic matter, admittedly, is food supply for bacteria and favours their multiplication, but large numbers of bacteria may be found in water of the highest standard of organic purity. As compared with chemical methods of analysis, bacteriology affords far greater delicacy and gives more exact information of the presence in water of excremental matter When chemical analysis affords valuable information of past or remote pollution, bacteriological examinations give less

information of the remote history of the water but, they disclose the immediate or near antecedents with and with greater reliability It is desirable that the chemical and bacteriological examinations always be correlated

1.3 Lakshadweep Archipelago –at a glance.

History

Local traditions attribute the first settlement Lakshadweep islands to the period of Cheraman Perumal, the king of Kerala advent of Islam dates back to the century around the year 1 Hijra Even after the conversion of the entire islands to Islam, sovereignty remained in the hands of the Hindu Rajah of Chirakkal for some years. From the hands of the Chirakkal Raja the administration of the island passed on to the Muslim house of Arakkal of Cannanore around the middle of 16th century Then the island's sovereignty came to be divided as five and fell under the rule of Tipu Sultan while, a part continued under the Arakkal house After the battle of Srirengapattanam in 1799, the islands were annexed to the British East India Company The British later brought the Lakshadweep Regulation 1912, which confers restriction to outsiders. The Union Territory was formed in 1956 and it was named Lakshadweep in 1973. This spectacular island groups is believed to have been discovered by shipwrecked sailors during the reign of Cheraman Perumal, the legendary king of Kerala in the 4th century AD.

Location, Area and Population

The tiniest Union territory of India, Lakshadweep is an archipelago consisting of 12 atolls, three reefs and five submerged banks (Fig. 1). It lies between 8^0 and 12^0 30^1 N latitudes and 71^0 and 74^0E longitudes. It is a uni-district Union Territory with an area of 32 Sq.Kms. and is composed of ten inhabited islands, 17 uninhabited islands attached islets, four newly formed islets and 5 submerged reefs. The inhabited islands are Kavaratti, Agatti, Amini, Kadamat, Kiltan, Chetlat, Bitra Androtl, Kalpeni and Minicoy They lie about 220 to 440 kms from the coast of Kochi. The atolls of the island rest on an underwater platform of about 100 fathom deep and 4,200 sq.kms.of lagoon , rich in marine wealth is spread over 36 islands. The islands have formed as a result of many thousand years of reef building activity.


MAP OF LAKSHADWEEP
MANGALORE
INDIA
CHETLAT
BITRA
KILTAN
CANNANORE
BANGARAM
KADMAT
ARABIAN SEA
KERALA
AMINI
AGATI
ANDROTT
CALICUT
KAVARATTI
KALPENI
COCHIN
MINICOY

Fig. 1.

According to 2001 Census, Lakshadweep has a population of 60,595. More than 93.4% of the population, who are indigenous, are Muslims and the majority of them belong to *Shafi* School of the *Sunni Sect*. The islands, ranging in area from 1 ha to nearly 440 ha, are little specks in the Indian Ocean. They are beautiful, idyllic and strategically located from the point of view of economic and defence considerations of India. Being oceanic islands, the continental shelf around them is limited to about 4,336 sq. km, but considering the lagoon area of about 4,200 sq. km., 20,000 sq. km of territorial waters and about 400000 sq. km of oceanic zone, Lakshdweep is one of the largest territories of our nation.

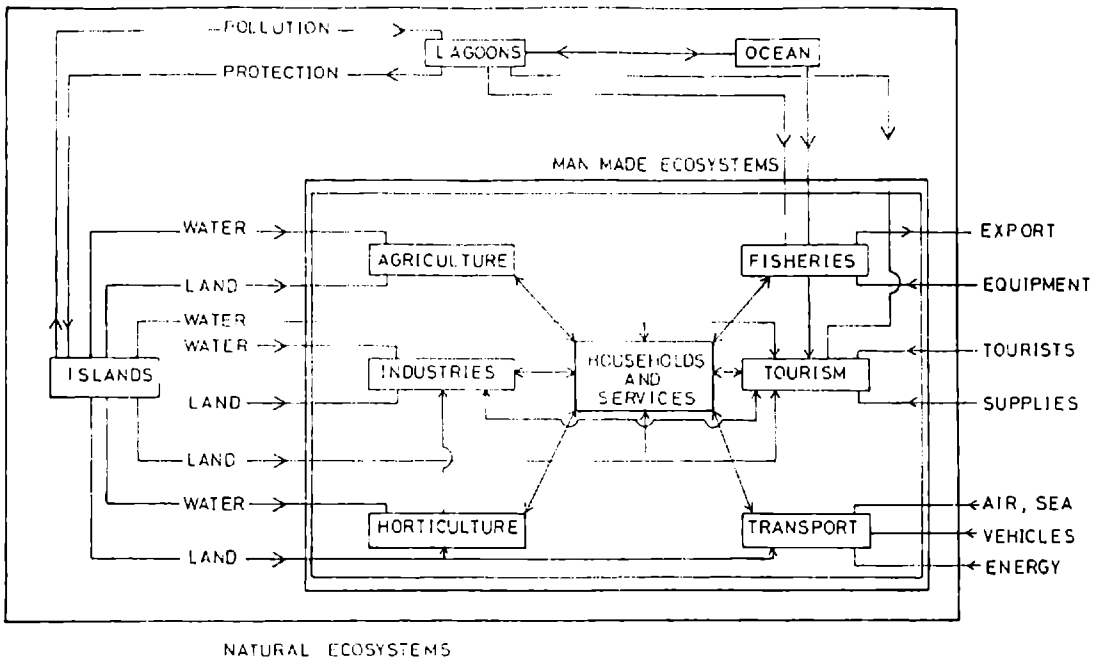
Administration

Prior to the formation of the Union Territory on 1st November 1956, these Islands formed a part of the erstwhile Madras State as one district which was divided into four Tahsils, each under the administrative control of a Tahsildar. In Minicoy, the post of Tahsildar was abolished and a Deputy Collector was appointed in August 1978. The Headquarters of the Administration was shifted from Calicut (Kerala State) to Kavaratti Island in March 1964 and new offices were created in 1972. The Administrator appointed under Article 239 of the Constitution of India is the head of this U.T. Panchayati Raj system came to existence under 73rd amendment of 1992. Ten inhabited Islands have the 10 Dweep Panchayats. The district Panchayat has its Headquarters at Kavaratti. There are 22 seats in the District Panchayat and of these 20 seats are reserved for Scheduled Tribes including 7 seats reserved for women belonging to STs.

Ecosystem linkage

The natural and man made ecosystem are closely linked together. The overexploitation or misuse of any one system has an impact on the other. Land is essential and limiting factor in the Island. The surface is needed for buildings, service and communication facilities. Sub surface rain water is the only source of potable water for the most Islands. However, an increasing population and accelerated developmental activities are using up more land simultaneously exhausting water more rapidly. The man, land, water and air are continuously interacting with each other and any imbalance in the quality of the system due to human interference leads to a drastic effect in the total ecosystem.

Eco System Linkages in Lakshadweep Island



Climate

The climate, more or less comparable to that of the coastal areas of Kerala, is warm and humid but bearable. The average rainfall is about 1640 mm for Minicoy and 1504 mm for Amini. The rainiest months are June to September with June receiving the maximum. Maximum temperature may range from 35^{0}C to 38^{0}C and minimum from 17^{0}C to 18^{0}C. Occasionally cyclonic storms occur, the oldest and the most serious recorded being the one that struck Kalpeni and Andrott on April 15, 1847 (Mannadiar, 1977).

Geology

Although theories on the formation of the island abounds, the most accepted one is attributed to Sir Charles Darwin, the renowned evolutionist. He opined that base of the islands below the reef is a volcanic layer over which corals settled and turned into atolls, over a period of time. The atolls consisting of the islands and lagoons are in various stages of development. The smaller lagoons are virtually filled with sediments while the larger ones are deeper in the range of 10-16 m. The enchanting aspect of these islands is due to the Coral Reef, biologically formed over many centuries. As of now, it extends along the coast, giving Lakshadweep its unique stature.

Soil is formed by the dead, disintegrated and weathered skeleton of corals. It is estimated to contain 95% calcium carbonate in the form of aragonite. The pH of the soil is neutral, index ranging from 6-8. Lakshadweep soils are rich in phosphorus and calcium.

Fresh Water

The Island situated 1-2 m above the sea level has a very thin lens of fresh water floating over the seawater. This is actually rain water collected and percolated through the porous calcareous soils of the Island. In some Islands, the depth of this lens may be 0.5 m whereas in others it could be 2 m. The quality and quantity of the fresh water lens also varies with the fluctuating tides.

Natural Resources

The most important flora and fauna of the islands are coconut trees and fishes, which form the mainstay of the economy of the islands. No cereal of any significant importance is grown in the islands. The flora of the islands consists mainly of Vazha (*Musa paradisiaca*), Chembu (*Colocasia antiquorum*), drumstick (*Moringa oleifera*), 'Chakka' (*Artocarpus incisa*) and wild almond (*Terminalia catappa*). Tapioca, Yam, fourds, legumes etc are also cultivated. A variety of wild herbs and shrubs grow and new plants occasionally introduced from the mainland. Two different varieties of sea grass *Thalassia hemprichin* and *Cymodocea isoetifolia* are seen adjacent to the beaches, which prevent sea erosion and movement of the beach sediments. Oceanic birds generally found are Tharathasi (*Sterna fuscata*) and Karifetu (*Anous solidus*) seen in one of the uninhabited islands, Pitti, which has been declared as a bird sanctuary. Molluscan forms, also important from the economic point of view of the islands are money cowrie (*Cypraea monita*), cypraca talpa and cyprea maculiffera. Among crabs, the hermit crab is the most common. Colourful coral fish such as parrot- fish (*Callyedon sordidus*), Butterfly fish (*Chaetodon auringa*). Surgeon fish (*Ancanthurus lineotus*) are also found in plenty. The Butterfly fish (*Chaaetodon auriga*) locally known as **Fakkikadia** is the animal, Sooty tern (*Anusolidus piletus*) locally known as **Karifettu,** the bird and bread-fruit (*Artocarpus Incise*) locally known as **Chakka** as the tree are the state symbols of Lakshadweep. Sea cucumber, a variety of shelled animals and hermit crabs are found on the shore line. Playful dolphins, turtles, rays and flying fishes are occasionally seen by keen observers.

Agro- horticulture and Industries

The most important agro-horticulture crop in the Islands is coconut which has traditionally been a non –irrigated crop. It is well suited to the agro-climatic and edaphic conditions prevailing in the Island. The land base economy of the territory revolves around the coconut palm. The husk is utilized for producing coir as well as for smoking tuna during the production 'mas' The coconut shell is a good fuel and is also used in handicrafts. The fronts serve as roof thatch. Together the haft and midrib, they also serve as fencing materials. The trunks of the fallen trees provide rafters and posts in house construction.

Though Lakshadweep is considered a no industry area, there are 7 coir fibre factories, six coir production units and fibre curling units employing more than 300 workers. The hosiery factory in Kalpeni is an innovative venture. There are boat building yards and work shop to cater the needs of the Islanders.

Animal husbandry

The lack of fodder is a hindrance to animal husbandry Cows are few and milk supply is inadequate.

Fisheries

The main occupation of the Islanders is fishing. The main fishery is tuna and then sharks. Oceanic species of tuna such as skipjack tuna *(Katsuwonus pelamis)* and yellow fin tuna (*Thunnus albacare*) contributes major tuna resources exploited by the Islanders by the pole and line fishery with live baits. Annual fish landings of 10,800 tonnes are contributed by approximately 496 mechanized fishing boats and 500 country crafts operating in the seas of Lakshadweep Minicoy possess rich fisheries for skipjack and yellow fin tuna. The skipjack is the most important fish of the Islands and has been filleted, boiled smoked and dried as "mas" The people of the Islands both in Minicoy and northern Islands have been seafarers. Fishing in the lagoon and open seas has been a hoary tradition. The reefs and lagoons are associated with most of the Islands yield fish for two different purposes (i) live bait fish and (2) ornamental fish.

Tourism

Tourism is another area where Lakshadweep is exploiting its potential. The society for promotion of recreation tourism and sports(SPORTS) is propagating the recreational activities in the Islands. The full fledged water sports institute opened in Kadamat attracts visitors. The Island administration has plans to open uninhabited Islands-Suheli (Cheriakara), Cheriyam and Tinnakara for foreign tourists.

1.4 Androtт Island - Study area

Androtт lies between 10^0-49^1 North latitude and 73^0-41^1 East longitude, located 293 kms from Cochin (Fig. 2). Androtт is the nearest Island to mainland and had an East-west orientation. It is the largest island in Lakshadweep having an area of 4.84 sq.kms and a perimeter of 10.59 kms. Thick vegetation, mainly coconut groves, add to the beauty of the Island The Island occupies the whole interior of the atoll. Except at the north-east extremity the reef flat is exposed at low tide. The corals have been blasted extensively (It was estimated that the Androtт has the dead coral percentage of 34.5% and live coral only 9.2 %) and a break water constructed here recently. In the absence of any lagoon, the coral growth on the reef flat is important. The reef consists mostly of *Acropora* species of non-branching type. The coral diversity is average and height of coral colonies is low and they are adapted to the strong surface current.

Fishing industry is well developed and coir and copra are the major products of the Island. Due to the lack of lagoon, there is sparse lagoon fishery in the Island. The Islanders have specialized in octopus and dolphin catching. As per 2001 census, 10720 people inhabit the island. It was the first Island to embrace Islam. Saint Ubaidullah, who is believed to have converted people of the island into Islam, died here and his tomb still remains in the Juma'ah Mosque.

Statement of problems relating to the ecosystem

The wild marine biodiversity of Lakshadweep faces many threats, which can be mitigated easily. The threats to the biodiversity of the Islands will be categorized as follows-

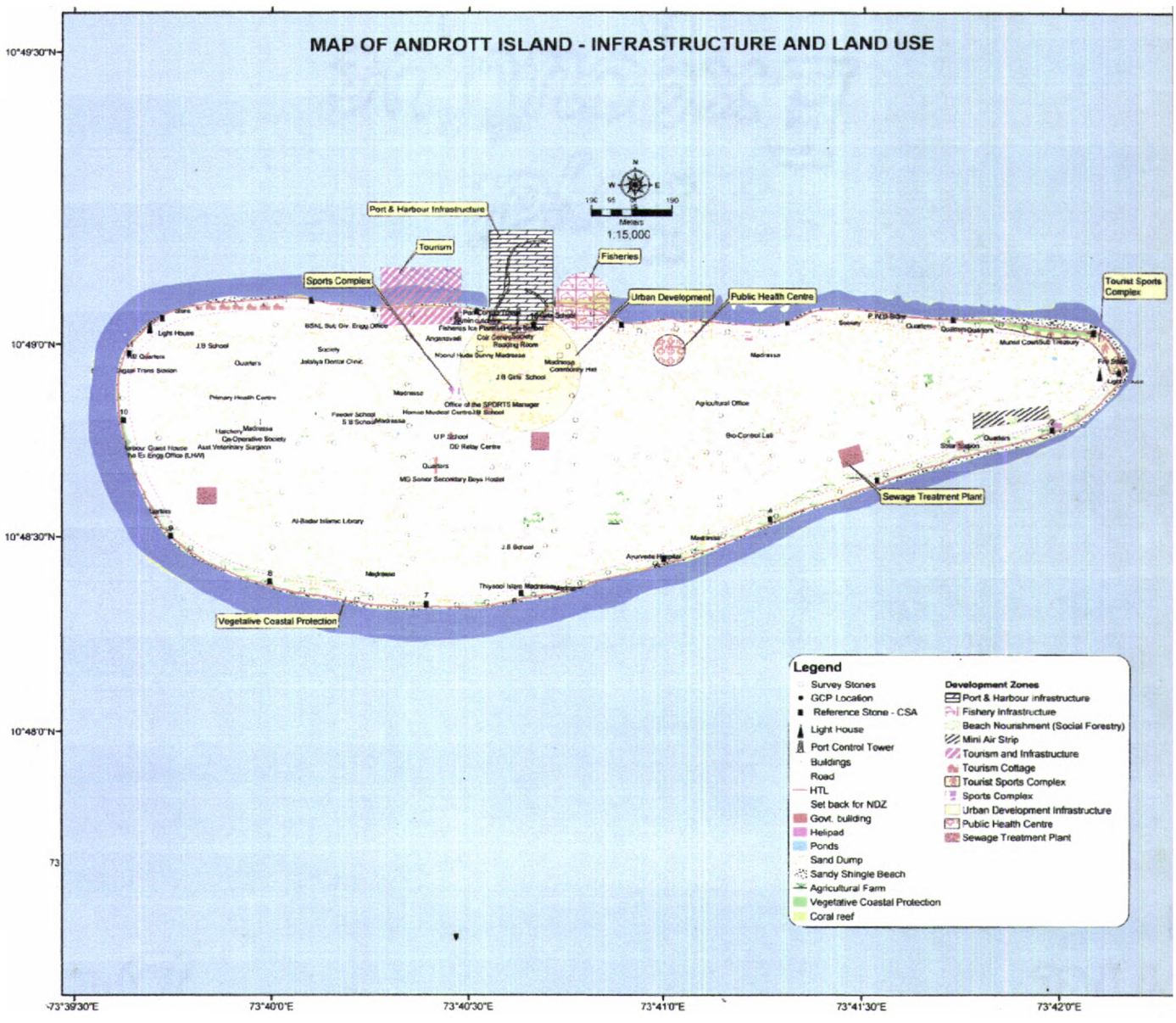

MAP OF ANDROTT ISLAND - INFRASTRUCTURE AND LAND USE
Port & Harbour Infrastructure
Tourism
Fisheries
Sports Complex
Urban Development
Public Health Centre
Tourist Sports Complex
Sewage Treatment Plant
Vegetative Coastal Protection
1:15,000
Legend
Survey Stones
GCP Location
Reference Stone - CSA
Light House
Port Control Tower
Buildings
Road
HTL
Set back for NDZ
Govt. building
Helipad
Ponds
Sand Dump
Sandy Shingle Beach
Agricultural Farm
Vegetative Coastal Protection
Coral reef
Development Zones
Port & Harbour infrastructure
Fishery Infrastructure
Beach Nourishment (Social Forestry)
Mini Air Strip
Tourism and Infrastructure
Tourism Cottage
Tourist Sports Complex
Sports Complex
Urban Development Infrastructure
Public Health Centre
Sewage Treatment Plant
10°49'30"N
10°49'0"N
10°48'30"N
10°48'0"N
73°39'30"E
73°40'0"E
73°40'30"E
73°41'0"E
73°41'30"E
73°42'0"E

Fig. 2.

I. The corals, the building blocks of the islands are deteriorating due to-

1. Global factors like climatic change ie. Coral bleaching
2. Break water construction activities.
3. Pollution due to oil spills, sewage, detergents, pesticides and fertilizers.
4. Over use of propeller boats and speed boats which cause turbidity.
5. Tourism related damages and thereby dumping of plastics and other wastes
6. Overexploitation of certain resources ie. Certain live bait fish.

II. Open Ocean

1. Over exploitation of resources
2. Pollution and habitat destruction
3. Poaching by foreign Vessels
4. Lack of scientific data regarding resources availability.

III. The Land

1. Collection of Jelly (coral sand/boulders) for construction.
2. Loss of natural vegetation which prevent erosion.
3. Use of pesticides and chemicals which cause toxicity of the soil and the fragile ground water.
4. Erosion of the beach

Simultaneously, the fresh water resources also facing multifarious problems

1. Non –regeneration of water lens
2. Highly extractive use of ground water with pumps and tanks.
3. Pollution with diesel from the electricity generating units.
4. Wastage of water and sewage mixing with fresh water.

Environmental Impact Assessment and Indicators

This measure is to make all developmental plans in the Islands ecologically compatible and avoiding ecological stress. The different environmental attributes, their ranking and impact indicators regarding the Island are given below.

No.	Environmental Attributes	Rank	Impact indicators
1.	Ground water lens	5	Change in quality or quantity
2.	Surface water quality	4	Change in sea/lagoon water quality
3.	Land use	5	Appropriateness of land use
4.	Soil characteristics	2	Change in sustainable productivity of soil
5.	Coastal zone	5	Erosion, accretion and stability
6.	Corals	5	Growth ,mortality etc.
7.	Aquatic ecosystem	4	Sustenance of fisheries, aquatic weeds, endangered species and species diversity.
8.	Air quality	2	Increase in dust and gaseous emission
9.	Noise level	1	Increase in ambient noise level
10.	Terrestrial flora & Fauna	3	Sustenance of flora, fauna, endangered species and species diversity
11.	Health	5	Disease sanitation and nutrition
12.	Amenities	5	Roads, buildings, transportation and other utilities
13.	Aesthetics	5	Landscape, beaches, lagoon, heritages, monuments, recreation etc.
14.	Economy	5	Change in crop & industrial production and land loss

1.5 Review of literature

Review of literature covered here includes the physico chemical status as well as biological productivity of the Laccadive Sea, Arabian Sea and similar studies conducted elsewhere. It also covered studies carried out for understanding the fresh water quality of dug wells and other drinking water sources.

Biological studies

The general features and considerations with respect to the fish information service of Lakshadweep islands were dealt by the following workers. Gardiner (1903, 1906) was among the pioneers who studied the fauna and geography of the Maldives and Laccadive Archipelago. When the general features of the islands were portrayed by Jones (1959) for the first time, Jayaraman *et al.*, (1960) described the hydrography of the Laccadive offshore waters. Jones (1968, 1969) also surveyed the fishery resources of the Laccadive Archipelago and made a catalogue of fishes. When Shah (1967, 1975) studied the diurnal changes in oceanographic features and its relation to one annual cycle of the primary standing crop in the Laccadive Sea off Cochin, Bhattathiri (1987) made a general discussion on the environmental characteristics of Laccadive Sea.

Primary productivity of the atolls of Lakshadweep was investigated by Nair and Pillai (1972), Qasim *et al.*, (1972) and Qasim (1973). The overall biological characteristics of the Laccadive Sea especially the distribution of photosynthetic pigments and column productivity was studied by Bhattathiri and Devassy (1979). Qasim and Bhattathiri (1971) specifically studied the primary productivity of sea grass bed on Kavaratti atoll and described the nutrient assimilative capacity of sea grass.

Bhattathiri (1984) made a comparative study on primary production and physico-chemical parameters of Laccadive and Andaman Sea. Saldanha (1989) had undertaken the environmental impact assessment of Andaman, Nicobar and Lakshadweep islands. Nair *et al.*, (1986a & b) investigated the environmental features and productivity of the Seas around Lakshadweep. Studies on the primary productivity and carbon assimilation patterns in tropical marine phytoplankton in the Lakshadweep Sea were carried out by Goes and Devassy (1986). Studies on productivity of the Arabian Sea along the Southwest coast of India was carried out by Rajagopalan *et al.*, (1992).

Seasonal primary production in different sectors of the EEZ of India was investigated by Sarupriya and Bhargava (1993).

Jayaraman (1972) studied on the occurrence of blooms of blue-green algae and the associated oceanographic conditions in the northern Indian Ocean. Qasim (1978) demonstrated that average surface chlorophyll *a* in Indian Ocean was moderate compared to that of Bay of Bengal and Arabian Sea.

Phytoplankton production in the Laccadive Seas was elaborately studied by Wafar (1977) and Pant (1979) described that average extracellular production at surface was higher than deeper layers within the euphotic zone. Studies of Matondkar *et al.*, (1992) established the role of bacterial sized phytoplankton in the Indian Ocean whereas works by Tiwari and Nair (1998) detailed the cell count, species diversity and phytoplankton pigments from Dharamtar creek, Bombay, West coast of India. Studies on phytoplankton composition and species diversity in Indian Seas were carried out by Santhanam *et al.*, (1987).

A comparative study of primary production, chlorophyll *a* and related hydrography of Kavaratti and Kalpeni islands was carried out by Bijumon *et al.*, (1999) which reported the Seas around Kalpeni atoll was biologically more productive. Walter *et al.*, (2001) also conducted studies on plankton and productivity along the coastal waters of Kavaratti island.

The effect of a factory effluent on the biological productivity of coastal marine system at Veli, Kerala coast was studied by Bijumon *et al.*, (2000) who emphasized that highly acidic factory effluents adversely affected the biomass and diversity of phytoplankton and zooplankton. Tiwari *et al.*, (2004) investigated the physico-chemical nature of highly turbid sea water and its effect on growth and species diversity of phytoplankton which portrayed a negative correlation between turbid sea water and the growth and multiplication of phytoplankton. Inter relationship between zooplankton and phytoplankton in tropical waters (Arabian Sea) was studied by Goes *et al.*, (1999) which demonstrated the coprophagic feeding habit of copepods and cladocera and the high assimilative and metabolic capacity of chlorophyll when it degraded in the digestive tract. The energy pathways in Laccadive Sea was demonstrated by Qasim *et al.*, (1979).

Zooplankton abundance, distribution and species diversity in Laccadive Seas and lagoons were investigated by Tranter and George (1972), Madhupratap *et al.*, (1977, 1991a & b) and Nasser et al., (1998). Similar studies by Goswamy (1973, 1979a & b) in Lakshadweep islands reported that copepods was the dominant group of zooplankton and calanoids were the prominent copepods. Studies by Achuthankutty *et al.*, (1989) in the Kalpeni and Agatti atolls also reported that copepods as the dominant groups among the zooplankton community. Rao *et al.*, (1987, 1992) investigated the distribution of foraminifera in the lagoons of certain Laccadive islands and submarine coral banks in southeast Arabian Sea and reported twenty five species of planktonic foraminifera. Studies on zooplankton standing stock and fishery resources in the Indian Seas demonstrated the linking of trophic levels among consumers was specifically carried by Goswamy *et al.*, (1992). Studies of Paulinose *et al.*, (1998) in the Gulf of Kachchh showed that larvae of *Metapeneus affinis* were dominant during monsoon and *Acetes indicus* during pre and post monsoon seasons and among fishes, larvae of clupeids dominated. Studies on the biochemical aspects of zooplankton from Laccadive Sea were conducted by Stephen *et al.*, (1979). Studies by Madhupratap *et al.*, (1996) looked into the seasonal and geographic variation of mesozooplankton biomass in the mixed water layers of Arabian Sea. Observations by Tiwari and Nair (1993) in Dharamtar creek, adjoining Bombay harbour described that copepods (71.6 %), decapods (11.4%) and chaetognaths (8.3 %) were the major share of zooplankton.

Aspects related to fishery resources of Lakshadweep were studied by various workers. Mathew and Gopakumar (1986) made studies on temperature in relation to surface tuna fishery of Minicoy island and found that spatial distribution of tunas was greatly influenced by Sea Surface Temperature(SST). Pillai and Mohan (1986) studied the ecological stress in Minicoy lagoon and its impact on tuna baits. Jones and Kumaran (1970, 1980) made new records of fishes from seas around India and described fishes of the Laccadive Archipelago.

Pillai (1986) investigated the status of coral reefs in Lakshadweep and Wafar (1992) put forwarded the management and conservation options for Indian coral reefs. Suresh and Mathew (1993, 1995) studied the coral reefs of Lakshadweep in general and the growth of Staghorn coral-*Acropora aspera* (Dana) in relation to environmental factors at Kavaratti atoll in particular. The studies pointed out that all conditions except the

amount of sediments in the seas seemed conducive for the growth of Acropora. The present status of coral erosion in Minicoy, Lakshadweep was documented by Navas and Mathew (1995). Untanwale (1983) studied the mangroves, coral reefs and island ecosystems along the Indian coast. Anon (1991) surveyed the fauna of Lakshadweep and described its richness and diversity and George *et al.*, (1986) studied ancillary marine living resources of Lakshadweep. James *et al.*, (1989) portrayed the overall picture of marine living resources of the Union Territory of Lakshadweep.

Physico-chemical studies

Physico chemical parameters hold a decisive role in the marine productivity. Hydrography of the Laccadive offshore waters was investigated by Nair *et al.*, (1960) and Patil and Ramamritham (1963). Sundararaman *et al.*, (1959) investigated the vertical distribution of dissolved oxygen in the Arabian Sea which reported a lower DO concentration in the deeper layers. Studies on the upwelling in the Minicoy region of the Arabian Sea was undertaken by Rao and Jayaraman (1966). Sankaranarayanan (1973) worked on the chemical characteristics of waters around Kavaratti atoll and reported that except pH, salinity and alkalinity, all other parameters showed high degree of variability. Three water masses in the Arabian Sea were identified from the physico-chemical characteristics and the high level of productivity in the Laccadive Sea was reported to be due to water movements (Sengupta *et al.*, 1975, 1979). A high salinity core in the Laccadive Sea (Lakshadweep) was recoded by Varkey *et al.*, (1979). Naqvi and Reddy (1979) studied the variation of calcium content in the waters of Laccadive Sea. Correlative study between nitrogenous nutrients and primary production in Laccadive Sea was undertaken by Wafar *et al.*, (1986) and the nitrogen cycle in the Arabian Sea, in general, was detailed by Hermann *et al.*, (2005). Sastry and D' Souza (1972) described the surface and column distribution of nutrients in the Arabian Sea which was found to be due to the upwelling and upward mixing. Nitrification in reef corals in Lakshadweep islands was studied by Wafar *et al.*, (1990). Studies on the isotopic evidence of past upwelling intensity in the Arabian Sea were carried out by Naidu (2004). Murthy (1989) studied the vertical distribution of phosphate, nitrite and nitrate of Lakshadweep waters in the Arabian Sea.

Studies related to trace metal analysis of Lakshadweep waters was carried out by various workers. Sanzgiri *et al.*, (1979) and Sanzgiri and Moraes (1979) reported that

though, the concentrations of trace metals varied depth wise, the values were within the permissible limit and the waters were free from trace metal pollution. George (1988) observed higher concentration of all trace metals inside the lagoon than the outside surface water and the same was the case of non-labile forms also. Nasnolkar *et al.*, (1997) opined that concentration of boron, calcium and magnesium were very much lower in lagoon water than that of surface water and the removal of calcium and magnesium in lagoon was attributed to their involvement in the biological precipitation of carbonates. Studies on the distribution of dissolved and particulate trace metals in Cochin estuarine waters reported that seasonal variation in the concentration of nickel and lead was negligible whereas cadmium showed high seasonal fluctuation (Ouseph, 1992). However, studies on the trace metal concentrations (Hg) in sediments of the same estuarine system showed considerable seasonal variation (Ouseph 1987, 1989). Specific programmes suitable for pollution monitoring of unique environments like coral islands were also devised. Goldberg (1975) formulated mussel watch as a first step tool in global marine pollution monitoring. National and global reviews regarding marine pollution were also made that could provide right direction to the research endeavors in the field (Subramanian, 1999).

Microbiological studies

Nair (1979) studied the microbial characteristics of the Lakshadweep Sea and reported moderate occurrence of total viable heterotrophic bacterial population that varied significantly with depth and station. Distribution, activity and biomass of heterotrophic bacteria in coral atolls of Lakshadweep Archipelago were investigated by Chandramohan and Ramaiah (1987) and Chandrika (1996). Lokabharathi *et al.*, (1986) reported high counts of *Vibrio parahaemolyticus* in the lagoonal systems during their investigation on the occurrence and distribution of these organisms in the Laccadive Sea. Pillai *et al.*, (2001) conducted investigations on the tidal influence of ground water quality of Kavaratti in terms of bacterial contamination.

Studies by Alavandi (1989) on heterotrophic bacteria in the coastal waters of Cochin revealed that bacterial counts were high during summer. Extremely low mineralization rates in the nearshore waters of Bombay evidenced from poor microbial heterotrophic activity and fewer bacterial groups suggesting environmental degradation was demonstrated by Ramaiah (1994). Ramaiah *et al.*, (1995) investigated the autotrophic

and heterotrophic characteristics in a polluted tropical estuarine complex at Cochin. Lokabharati *et al.*, (1990) studied the sulfate reducing bacteria in relation to the sulfur oxidising and heterotrophic bacterial population in the Arabian Sea. Pillai *et al.*, (1998) conducted studies on the indicator microbial population and pathogenic microbes in surface waters along southwest coast of India which indicated an alarming faecal contamination of water along the coast. Potential pathogens like *Salmonella*, *Shigella* and *Vibrio cholera* in the nearshore waters of Kerala coast throughout the year was reported by Alex *et al.*, (2001). Impact of coconut husk retting on bacterial counts in the Paravur estuary was demonstrated by Alex *et al.*, (2002).

Wright and Coffin (1983) studied the planktonic bacteria in estuarine coastal waters of northern Massachusetts and described their spatial and temporal distribution. Studies on the ecology, biomass, number and seasonal occurrence of heterotrophic bacteria in marine systems elsewhere were carried out by Ducklow (1984), Ducklow and Carlson (1972), Equra *et al.*, (1974) and Watson *et al.*, (1977). Heterotrophic marine bacteria ranging from 7.5×10^2 to 1.1×10^5 cfu/ml in water and 1.62×10^4 to 4.78×10^6 cfu/g in sediment in the intertidal zone of the yellow Sea near Kunsan, Korea was recorded by Lee and Lee (1991). Lee *et al.*, (1994) studied the distribution, bio-volume and extra-cellular activities of heterotrophic bacteria in the sea near Kunsan, Korea. Occurrence of faecal indicator bacteria in surface waters and subsurface aquifer in Key Largo was investigated by Paul *et al.*, (1995) which discussed the quantum of contamination of marine water by sewage disposal. Yaynor and Aristides (1995) conducted studies up to a depth of 10,500m in order to understand the occurrence and distribution of bacterial population in the deep Sea.

Ramaiah and Chandramohan (1992) studied the cellulases, alginate and pectin lyases of luminous and other heterotrophic bacteria associated with marine algae. Austin (1983) described the bacterial microflora associated with a coastal marine fish rearing unit and Delille and Razouls (1994) analysed the community structure of heterotrophic bacteria of copepod faecal pellets. Hoppe (1978) studied the relation between active bacteria and heterotrophic bacterial potential in the sea. Trollope *et al.*, (1984) studied the sewage derived bacteria monitored in a marine water column by means of captive mussels. Respiration corrections for bacterial uptake of dissolved organic compounds in natural waters were made by Hobbie and Crawford (1969). Removal of *Salmonella* from

multicell wastewater pond was experimented by Sandhya and Parhad (1998). Studies conducted by Lawrence and William (1993) revealed that the energy source for heterotrophic bacteria included not only the organic materials released by phytoplankton but also the dead phytoplankton and byproducts of zooplankton and protozoa.

Fresh water pollution

The geophysical and hydro geological aspects for the assessment of ground water potential in the Lakshadweep islands were studied by Varma *et al.*, (1988). Assessment of groundwater resource potential and management in Lakshwadweep atolls were conducted by Varma *et al.*, (1995); Varma and Ramachandran (1995) and Varma (1997) who described the resource potential, availability, usage of fresh water and causes of marine water infiltration. The hydrogeology of Vamanapuram, Ittikara and Kallada basins of Kerala was investigated by Najeeb (1988). Anon (1978) worked on water quality protection in Christina basin and Handa (1993) studied the potable water quality standards and consumers response. The quality of ground water in Gandheswari sub-basin, West Bengal was studied by Saha *et al.*, (1995). Galal-Gorchev (1986) recorded details on surveillance of drinking water quality in rural areas in which he classified chemicals in drinking water into three categories.

WHO (1989) has given an account of water borne pathogens in which fecal contamination has been cited as the major contributor to enteric diseases. Mwachiro and Durve (1997) studied the bacterial status of Lake Bari and bacterial enumeration has been used as an indicator of drinking water pollution. Faechem (1975) demonstrated an improved role for the ratio of faecal coliforms to faecal streptococci in differentiation between human and non human pollution sources. Jones (1972) studied the fresh water bacteria associated with algae and alkaline phosphate activity. An ITRC study (1989) described the bacteriological map of India in relation to the quality of drinking water in rural area as, many parts of the country having prevalence of water borne and water associated diseases.

A systematic study on the levels of various environmental factors in a system over a period of time is pre requisite for planning strategies in any developmental programmes. Basic research on the chemical and biological aspects will give an in depth picture about the life, stability and ecology of any living system. This has to be conducted

periodically at different stations in order to assess the spatial and temporal status of pollution in a particular area. This holds critical significance to the coral islands, as the corals are very sensitive organisms to even slight changes in the physico-chemical characteristics of the water body in which they grow. Since, Andrott is the largest island in area and population wise it attained special attention for the study. Moreover, it is the only island which is devoid of a lagoon system and protective reef barrier. The environmental strategy of the island has reached a stage where the ecological productivity was affected by human interference. In Andrott, leaching of corals and dead corals were observed during the study period, poses great threat to the island. This may be attributed to the anthropogenic interference, variation in environmental features such as temperature, salinity, DO, bacterial contamination or presence of high suspended solids. The ecological stress due to over construction activities, over mechanization, rapid urbanization may ultimately endanger this sensitive system and may pose threat to the very existence of the island. Overexploitation of resources due to overcapitalization is another threat to the system which may ultimately result in the decline of resources and ecological imbalance. Therefore, the natural resource utilization and management should be the thrust points to be noted and implemented according to action plan with minimum ecological stress. In Andrott, drinking water present in thin lens, which floats over the seawater, as the only source of drinking water, also faces damage due to seawater intrusion and sewage contamination. Due to mechanized withdrawal, the water layer, available, becomes characterized by the possibility of sudden intrusion of seawater. The absence of proper sewage system, the domestic sewage can get mixed with the fresh water resource and produce great catastrophe. This is particularly relevant in view that the dug wells are very shallow, and the depth of water level is generally 0.5 to 4.0 m below ground level. The septic tanks/leach pits are about 2.0 to 2.5 m deep with overflow provision at an average depth of 0.5 to 1.0 m below ground level ie, many of the dug wells are constructed to tap the aquifer into which these effluents are discharged. The population increase and the resultant over construction of houses without proper safety measures in this direction add to this problem. Monitoring of drinking water quality is hence very essential to alienate contamination from sewage and to prevent intrusion of saline water. Available data/ information on hydrological aspects in the island are limited, especially since groundwater is important not only from the point of view of the survival of humanity in the islands, but also from the point of view of ecology of the islands. An integrated

study comprising the microbiological, chemical and biological parameters in the seas around the island along with the drinking water quality is thus very essential in order to assess the environmental status of the island.

In the literature, it is found that piece meal studies at different interval have been made to assess the status of the island with regard to marine and fresh water pollution. It is therefore essential to have an integrated study incorporating all the environmental parameters of seas around the island and the drinking water sources. An attempt has been made to evaluate the integrated status of marine and fresh water system for a considerable period of two years. The thesis refers to the spatial and temporal variation in microbiological, physico-chemical and biological nature of the seawater as well as that of drinking water sources of Andrott island for the period from 1996-1998.

MATERIALS AND METHODS

2.1 Sample collection

2.1.1 Seawater samples: Surface water samples were collected from near shore, 2.5, 5.0 and 12.5 km stations across the transects such as Lighthouse, Helipad and Harbour during 1996 (post monsoon), 1997 (pre monsoon) and 1998 (pre and post monsoon) (Fig. 3).

2.1.2 Samples for microbiological analysis: Water samples for bacteriological analysis were collected in sterilised glass bottles with an overlapping rim of 300ml capacity. These samples were preserved in an icebox and analysed within three hours of collection.

2.1.3 Samples for physico-chemical analysis: Surface samples were collected using a clean plastic bucket. Separate sampling for DO and BOD was carried out and the DO was fixed by adding 0.5 to 1 ml of Winkler's A & B solutions and the bottles were kept in dark until analysis. Samples for the analysis of BOD were kept in an incubator for 5 days at 20^{o} C and then analysed. Samples for analysis of nutrients were collected in clean plastic bottles and acidified with 2 N HCl. All the glassware were cleaned by soaking in 6 N HCl and subsequently washed in double distilled water. Samples for Petroleum Hydro Carbon analysis were collected in 2.5 L amber coloured bottle (Strickland and Parsons, 1972; Grasshoff, 1983 & APHA, 1995).

2.1.4 Samples for Primary productivity and plankton: Samples for primary productivity measurement were collected in three BOD bottles of 300ml capacity of which two were light bottles and third one was dark bottle. Phytoplankton and zooplankton samples were collected in plastic bottles using standard plankton nets of mesh size 55µ and 180µ respectively. Ten liters of water was filtered through the plankton net and 100 ml aliquot was collected and preserved with 4 % formalin for phytoplankton analysis. One litre sample was collected in dark coloured plastic bottles for the estimation of chlorophyll pigment in order to analyse the phytoplankton standing crop. Zooplankton samples were collected by subsurface hauling of plankton net and kept in 250 ml plastic bottle and preserved in 4 % formalin.

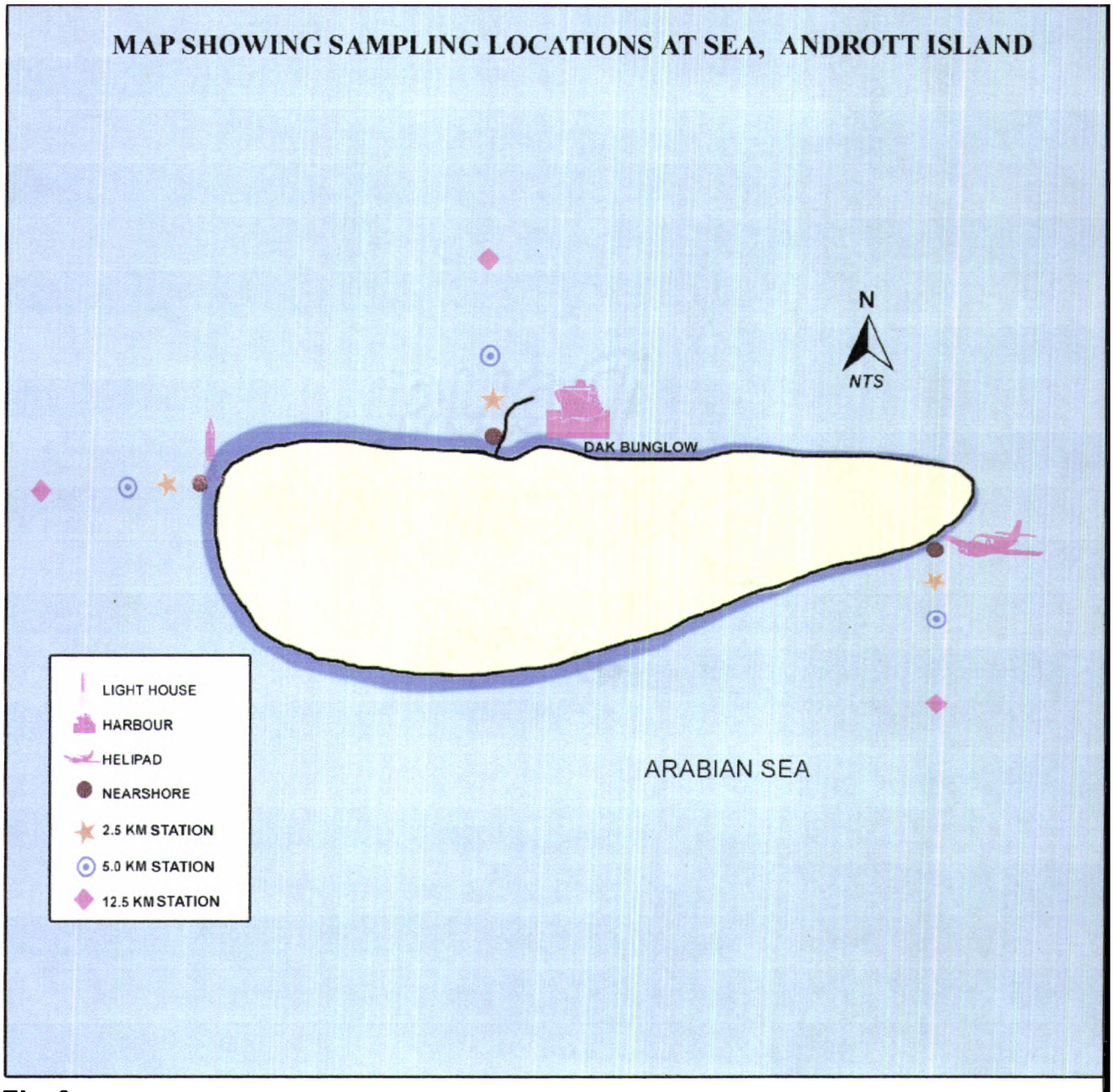

MAP SHOWING SAMPLING LOCATIONS AT SEA, ANDROTT ISLAND
N
NTS
DAK BUNGLOW
ARABIAN SEA
LIGHT HOUSE
HARBOUR
HELIPAD
NEARSHORE
2.5 KM STATION
5.0 KM STATION
12.5 KM STATION

Fig. 3.

2.2 Collection of dug well water samples

Water samples were collected from 10 dug wells from the relevant points of the entire Island (fig. 4). Samples for bacteriological analysis were collected using sterilised BOD bottles tied in a clean rope where as samples for physico-chemical analysis were collected using clean plastic bucket. The samples for bacteriological analysis were immediately brought to the Lakshadweep Science & Technology/ PWD laboratories for analysis. Depth, diameter etc. of the water column, presence/absence and proximity of leach pits/septic tanks to the dug wells were also noted. Possible pollution sources in the surroundings like the presence of sewage disposal, coconut husk retting centre etc. were also noted down.

2.3 Analytical techniques

2.3.1 Microbiological analysis

Both the sea water and dug well samples were analysed for Total Viable Count (TVC), Total coliforms (TC), Faecal coliforms (FC), Faecal streptococci (FS), *Salmonella* like organisms (SLO), *Shigella* like organisms (SHLO), *Proteus, Klebsiella* like organisms (PKLO), *Vibrio cholera* like organisms (VCLO) and *Vibrio parahaemolyticus* like organisms (VPLO). Analysis of seawater samples was carried out using spread plate technique in triplicate and the average value was taken. Bacteriological analysis of fresh water samples was carried by membrane filter method using 0.1 to 100ml sample (APHA, 1995).

i) Total Viable Count (TVC)

The enumeration of TVC was carried out on Nutrient Agar medium. Dehydrated medium (23g/1000 ml) (M/s Hi-Media Lab. Ltd., Bombay, India) was suspended in distilled water, boiled to dissolve completely, sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min and cooled to < 45°C. 12-15 ml of the cooled medium was poured over sterile Petri plates. Sample of 1 ml was spread over the solidified media and the plates were incubated at 37°C for 24 - 96 hrs. All the colonies in the range of 30 to 300 numbers were counted as TVC

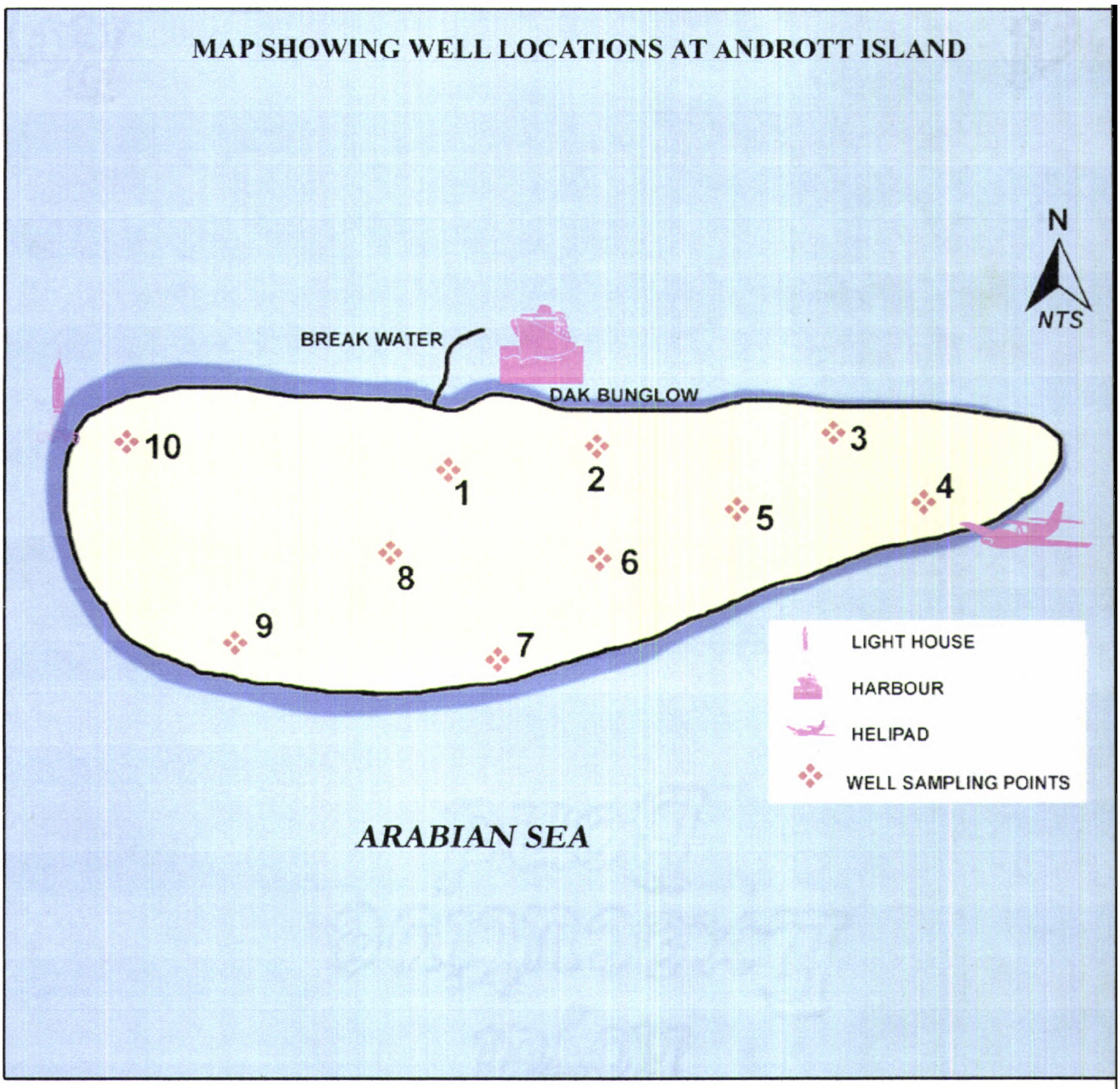

MAP SHOWING WELL LOCATIONS AT ANDROTT ISLAND
N
NTS
BREAK WATER
DAK BUNGLOW
10
1
2
3
4
5
6
7
8
9
LIGHT HOUSE
HARBOUR
HELIPAD
WELL SAMPLING POINTS
ARABIAN SEA

Fig. 4.

ii) Total coliforms (TC)

The enumeration of total coliforms was carried out using Mac Conkey's Agar. Dehydrated medium (M/s Hi-Media Lab. Ltd., Bombay, India) was suspended (55.1g/1000ml) in distilled water, boiled to dissolve completely, sterilized by autoclaving at 15 lbs pressure (121°C) for 15 min. Cooled to < 45°C and 12-15 ml of the cooled medium was poured on sterile Petri plates and sample of 1 ml was spread over the solidified media uniformly. The plates then incubated at 37°C for 24-48 hrs. Colonies having shades of pink to red colours were counted as TC. (APHA,1995).

iii) Faecal coliforms (FC)

FC were enumerated using M-FC agar using membrane filter technique (APHA, 1995). Dehydrated medium (M/s Hi-Media Lab. Ltd., Bombay, India) was suspended (23.2g/990 ml) in distilled water, heated to dissolve completely and 10 ml of rosolic acid was added, heated for 1 min. Cooled to < 45°C and 12-15 ml of the cooled medium was poured on sterile Petri plates and sample of 1 ml was spread uniformly over the solidified media. The plates were then incubated at 44.5°C for 24 hrs. Blue colonies formed on the agar were enumerated as FC (APHA,1995).

iv) *Salmonella* like organisms (SLO)

Salmonella like Organisms were screened using XLD (Xylose Lysine Deoxycholate) agar medium. Dehydrated medium (56.68g/1000 ml) was suspended in distilled water boiled to dissolve completely. Cooled to < 45°C and 12-15 ml of the cooled medium was poured on sterile Petri plates and sample of 1 ml was spread uniformly over the solidified media. The plates were incubated for a period of 24 - 48 hrs at 37°C. Red colonies with black centre were identified as SLO (APHA,1995).

v) *Shigella* like organisms (SHLO) and *Proteus* & *Klebsiella* like organisms (PKLO)

SHLO and PKLO were also screened using XLD (Xylose Lysine Deoxycholate) agar medium. Dehydrated medium (56.68g/1000 ml) was suspended in distilled water boiled to dissolve completely. Cooled to < 45°C and 12-15 ml of the cooled medium was poured

on sterile Petri plates and sample of 1 ml was spread uniformly over the solidified media. The plates were then incubated for a period of 24 48 hrs at 37°C. Red and yellow colonies were counted respectively as SHLO and PKLO, (APHA,1995).

vi) *Vibrio cholera* like organisms (VCLO) and *Vibrio parahaemolyticus* like organisms (VPLO)

Dehydrated TCBS (Thiosulphate Citrate Bile Salt Sucrose Agar) medium was suspended in distilled water (89.0g/1000 ml) and boiled to dissolve completely Cooled to < 45°C and 12-15 ml of the cooled medium was poured on sterile Petri plates. Sample of 1 ml was spread uniformly over the solidified media. The plates were incubated for 24 -48 hrs at 37°C. VCLO colonies look yellowish whereas VPLO forms greenish colonies (APHA,1995).

vii) Faecal streptococci (FS)

M-Enterococcus Agar medium was employed for enumerating FS. Dehydrated medium (41.5g/ 1000 ml) was suspended in distilled water and boiled to dissolve completely. Cooled to < 45°C and 12-15 ml of the cooled medium was poured on sterile Petri plates. Sample of 1 ml was spread uniformly over the solidified media and plates were then incubated. FS forms maroon coloured colonies after an incubation period of 24 -48 hrs at 37°C (APHA,1995).

2.3.2 Physico-chemical parameters

Measurements of temperature, pH and fixing of water samples for DO were done in-*situ* and analysis of other parameters was carried out in the laboratory. All the colorimetric estimations were done using double beam spectrophotometer (Shimadzu, UV 160 A). pH was measured using a portable pH meter, WTW Multiline P4, having a pH range of 0-14, possessing resolution of 0.01 and an accuracy of ± 0.05 pH. Conductivity of water samples was determined by a conductivity meter. Salinity was computed from chlorinity values using Knudsen hydrographic table. Chlorinity was estimated by the Argentometric (Mohr Knudsen) method. Winkler's method with azide modification was employed for the estimation of DO. Nitrite was estimated by colorimetric method after complexing

with α- naphthyl amine and sulphanilic acid. Nitrate was reduced to nitrite in a cadmium reduction column and estimated spectrophotometrically. For the determination of ammonia and phosphate, respectively phenate and molybdenum blue method were employed. For the estimation of total nitrogen, the sample was first oxidized with alkaline persulphate and estimated as nitrite after reduction.

i) Dissolved Oxygen (DO)

DO was determined by Winkler's method.

Water sample was fixed by adding 0.5ml of winkler A solution followed by 0.5ml of winkler B solution avoiding the entry of air bubble. Then the sample was shaken well and allowed to precipitate. The precipitate was dissolved completely by shaking after the addition of 1ml of 9N H_2SO_4. Clear solution (100ml) was transferred to a conical flask and titrated against 0.02N thiosulphate solution till a pale yellow colour appeared. Starch solution indicator was added and the titration continued until the blue colour disappeared. The titre value was noted.

Calculation

The amount of DO in 1L of sample was given by

$$DO\ (mg/l) = 8 \times N \times BR \times \frac{V}{V-1} \times \frac{1000}{a}$$

BR = Burette reading

V = Volume of the sampling bottle

a = Volume of the sample titrated

V/V-1 was included to correct the volume of reagents added to the sampling bottle.

ii) Biochemical Oxygen Demand (BOD)

Water samples were carefully filled in three BOD bottles avoiding air bubbles. One bottle was treated as initial DO bottle and analysis for the same was completed where as the remaining bottles were incubated in a BOD incubator for 5 at 20°C to find out the final DO. The difference between the initial and final DO was found out as a measure of BOD.

iii) Total suspended solids

a) Preparation of glass-fiber filter disk.

Filtration apparatus was inserted with a disk and vacuum was applied. The disk was washed with 3 successive 20 ml portions of distilled water. Suction was continued till all traces of water were removed. Filter paper was removed from the apparatus and transferred to an aluminum planchet as a support. It was dried in an oven at 103 –105°C for 1 hr, cooled in a dessicator and weighed.

Calculation

$$\text{Total solids(mg/l)} = \frac{(A - B) \times 1000}{V}$$

Where, A = weight of filter + dried residue

B = weight of filter

V= Volume of sample taken in ml

iv) Inorganic phosphate

Phosphate standard solution (5 ml) was transferred in a 500 ml volumetric flask and volume was made with distilled water. This solution contained 100 μ mol PO_4^{3} –P/l and the same was diluted 10 times to get 1.0 μ mol PO_4 –P/ 25 ml distilled water was taken in three test tubes for blank determination. Phosphate stock solution was measured out in25 ml portions in 3 test tubes and to each tube 0.5 ml of ascorbic acid was added and mixed well. In order to develop a blue complex, 0.5 ml of mixed reagent was added, mixed and kept for 10 min. Absorbance of blank[A(b)] and standard [A(st)] was measured by spectrophotometer at 882 nm using distilled water as reference.

Absorbance of samples was taken after treating 25 ml portions as described above. When the samples were turbid, the absorbance A(t) was measured separately on addition of 0.5 ml ascorbic acid.

Calculations

F = 1.0

A(st)-A(b) Where A (st) = Means absorbance of standards.

A(b) = Means absorbance of blanks.

PO_4^{-3} -P mol/l = F x (A (s) A (t) A (b) where A(s) Mean absorbance of sample.

A(t) = Mean absorbance of turbidity.

v) Silicate

To a 50ml sample taken in plastic tube, 2 ml of acid molybdate reagent was added, swirled and allowed to stand for 5 to 10 min. Two ml of oxalic acid was added followed immediately by 1 ml ascorbic acid and mixed gently between additions. Absorbance was measured in a spectrophotometer at 810 nm against distilled water as reference.

Calculation

Based on a standard curve prepared between 0.0 and 20mg/l of SiO_3 (at an interval of 2), by taking various dilutions of the silica solution (Na_2SiF_6) and using same quantity of reagents as for the sample, concentration of silicate was determined.

vi) Total phosphorus and Total nitrogen

Calibration and determination of blank

One ml of standard phosphate solution was diluted to 100 ml with ammonia free double distilled water (DDW). Similarly, 10 ml of the stock organic nitrogen solution was diluted to 100 ml. Ten ml of each solution was pippetted out into a volumetric flask of 250 ml capacity and diluted up to the mark with DDW This diluted combined standard solution contains 4 µ mol PO_4^{3} –P/l and 40 µmol organic N/l respectively. Fifty ml of double distilled water and 50 ml of combined standard solution were measured out in triplicate. Five ml oxidising agent was added to all the six flasks and autoclaved for 30 min. cooled it to room temp and taken out from autoclave, swirled to dissolve any

precipitate left. Twenty five ml of digested solution was transferred in glass tubes for calibration of total P and total N.

Sample analysis: Fifty ml of filtered sea water aliquot was taken in oxidation bottles and oxidising agent (5.0 ml) was added. Digestion procedure was followed as described above. Twenty five ml of the digested sample was transferred into clean graduated tubes and absorbance A(s) was found out at 882 nm.

Calibration factor (F) was calculated for total Nitrogen (µmol) following $F = \frac{4.0}{A(st) \quad A(b)}$

Where A (st) = mean absorbance of standard and A (b) = mean absorbance of blanks.

For total phosphorus calibration, 25 ml of the digested solution was measured in glass tubes and the calibration factor (F total P) was found out from the equation

$F \text{ total } P = \frac{4.0}{A(st) \quad A(b)}$

For sample analysis, 50 ml sample was digested with 5.0 ml oxidising agent as described above. For total nitrogen, 5 ml sample was diluted 10 times and digested. 25 ml of digested sample was transferred into clean graduated tubes and the absorbance A(s) was found out at 882 nm.

Calculation

Total N (µmol)/l = F total NO_3 x A (s) – A (b)

Total P (µmol)/l = F total P x A (s) – A (b); Where A (s) = mean absorbance of the sample and A (b) = mean absorbance of the blank.

vii) Ammonia-nitrogen (NH_3-N)

To 50ml of the sample, 2ml of phenol reagent, 1ml of citrate solution ad 2ml of hypochlorite reagent were added. The bottles were closed and put in a water bath for 30 min. at 37 ±1°C. The bottles were kept on a bench and allowed to cool for further 30 min. Absorbance was measured at 630 nm against a reference of acidified pure water (Grasshoff, 1999). Calibration factor was determined using standard stock solutions diluted with natural seawater low in ammonia, where F value was close to 6.0 with a 10 cm cell.

viii) Determination of Nitrite and Nitrate

Nitrite-Nitrogen (NO_2 - N)

A working standard of 2µmol NO_2-N/l was prepared from anhydrous sodium nitrite. 25 ml each of the working standard solution and distilled water was taken in three glass tubes and to each tube 0.5 ml of sulfanilamide was added, mixed and kept for 4 minutes. N-(1-naphthyl) – ethylene diamine dihydrochloride solution (0.5 ml) was added, mixed and allowed the reaction to proceed for 10 minutes. The absorbance of blanks and standards was measured in a 5.0 cm cell at 543nm against water as reference

Calculations

Factor (F) was calculated the from the relation,

$$F = \frac{\text{Conc. of standard solution}}{A\,(st) - A\,(b)}$$

Where, A (st) = Mean absorbance of standards and A (b) Mean absorbance of blanks

Concentration of nitrite-N was calculated from the relation;

Nitrite-N µmol/l = F [A(s) – A (b)]

Where, A(s) = Mean absorbance of the sample

ix) Nitrate-Nitrogen (NO_3-N)

Commercially available granulated cadmium (E Merck) was sieved and the fraction between 40 and 60 mesh was used. Iron particles, grease and oil were removed from the

cadmium filings with the help of a magnet and by washing with acetone respectively. In order to free the metal surface from oxides, 2N HCl was used with continuous stirring and the chloride ions were removed by washing with copious amounts of water. Cadmium is filled in a 125 ml stoppered glass bottle with copper sulphate solution taking care to avoid the air bubbles trapped inside. The bottle was rotated slowly for 2 min. and the copper sulphate solution was drained out completely with the help of distilled water. The copperised cadmium granules were kept under water.

After placing a plug of glass wool at the bottom end, the column and the reservoir was filled with distilled water. The copperised cadmium filings were then transferred into the column reservoir and allowed to fall freely into the column taking care that no air cavities were formed. Another piece of glass wool was placed on the top of the filings. The cadmium filings were always kept under water without getting dried.

Activator and buffer solutions, 50 ml each, were passed through the column at a rate of 50 ml in 8 min. discarding elute. The elution was repeated leaving water just above the filings in the column.

Preparation of blank and standard

A blank was prepared by passing 50ml each of water and buffer solutions through the column. The first 25ml portions were discarded and the next two 25ml portions were collected. The blank was kept in stoppered glass tubes and preserved.

A standard was also prepared similarly by replacing water with standard solution. Last two portions of 25ml were preserved. The elution was continued till the water level was just above the filings.

Sample analysis

Sample and buffer solutions were passed through the column as described above and the last two 25 ml portions preserved. The samples were preserved and the column was left with the buffer solution. Sulfanilamide (1ml) was added to each tube, kept for 4 min and 1 ml N-(1-napthyl) ethylene diamine dihydrochloride was added, mixed and waited for

another 10 min. Absorbance was measured using spectrophotometer at 540 nm in a 1 cm cell against distilled water

Calculations

Factor (F) was calculated from the formula described for nitrite and the concentration of nitrate-N + nitrite-N was calculated from the relation

C (NO_2+NO_3) µmol/l = F [A(s) – A (b)]

Where, A(s) = Mean absorbance of samples and A (b) is Mean absorbance of blanks. The values for nitrate was corrected using the relation

C (NO_3) µmol/l = C (NO_2+NO_3) – C (NO_2)

Where, the C (NO_2) is the concentration of nitrite in µmol/l.

x) Petroleum Hydrocarbon

Calibration and blank: The working standards were prepared by diluting 1ml of standard stock to 100ml with hexane (the solution contained 100µg oil/l). With hexane 0.1, 0.5, 1.0 and 2ml of the above working standards were diluted to 10 ml in volumetric flasks. These standards contained 1, 5, 10 and 20µg oil/l. The fluorescent intensities (excitation at 310nm and emission at 330nm) of the above standards were measured using double distilled hexane as blank.

Analysis of sample

Sample of 1.25L was measured out in a 2 L capacity separating funnel (1). Fifty ml of hexane was added and the contents were shaken for 5min retaining the hexane in funnel (1). The aqueous layer was transferred into another separating funnel (2) and 50ml hexane was added to funnel (2) and extracted for 5min and on retaining the hexane extract, the aqueous layer was discarded. Remaining 1.25L sample was transferred into the separating funnel (1) containing the hexane extract and extracted for 5min. The aqueous layer was transferred into the separating funnel (2), extracted for 5min and the aqueous layer was discarded. The hexane extract of both the funnels (1 and 2) was quantitatively transferred into a clean 250ml conical flask containing 2g anhydrous Na_2SO_4. The solution was decanted into a 100ml test tube leaving behind the Na_2SO_4

which was washed with hexane and the washings collected in the same test-tube. The extract was evaporated to nearly dryness under reduced pressure using water bath. With the help of dropper the sides of the tube was rinsed and shaken with hexane. The contents were transferred into a 10ml volumetric flask and the volume was made to the mark with hexane. The intensity of fluorescence was measured using spectrofluoro photometer (Grasshoff, 1999).

Calculations

Calibration curve was prepared by plotting fluorescent intensities against concentrations. Calculated the factor (F) from F= $\frac{\text{Concentration}}{\text{Fluorescent intensity}}$

Calculated the concentration of dissolved/dispersed total hydrocarbon in the sample from

PHC (µg/l) = $\frac{\text{Fx I(S)}}{2.5}$

Where I (S) =Fluorescence intensity of the sample

xi) Dissolved Trace metals

Cadmium (Cd) and Lead (Pb)

Calibration and determination of blank:

Metal free seawater was prepared as follows. Eight aliquots of 400 ml each of seawater was measured out in to pre-cleaned separating funnels. The pH of each solution was adjusted between 2 to 3 by adding 1N HCl (2ml). Ammonium pyrolidine dicarbomate (APDC) solution (10ml) was added and shaken for 30 sec. Fifteen ml of methyl isobutyl ketone (MIBK) solvent was added and vigorously shaken for 2 min. The MIBK layer was discarded and extracted again with 5ml APDC solution and 10ml MIBK solvent. The MIBK layer was discarded retaining the metal free seawater for blank determination and calibration.

The metal standard stock solution of lead and cadmium was diluted with aliquots of metal free seawater (400ml each) in pre-cleaned separating funnel. Duplicated the sample with 0.0 (blank), 0.5, 1.0 and 2 ppm of mixed working standard. The duplicate aliquot now

contained 0.0, 0.5, 1.0 and 2.0 µg of Pb and Cd. After treating with APDC and MIBK as described above, the solution was allowed to stand for 20 min for the phases to separate. The aqueous layer was collected in 500ml bottle and MIBK extract in 60ml capacity separating funnel. The aqueous layer was extracted once again with 5ml of APDC and 10ml of MIBK and the aqueous layer discarded and MIBK extract was added into the separating funnel which contained the first extract. The combined extract was washed with Milli-Q^R water and the aqueous layer discarded carefully

Concentrated HNO_3 (0.2ml) was added to the extract and shaken vigorously and allowed to stand for 20min for back extraction. Water sample of 19.8 ml was added shaken well and allowed the phases to separate. The aqueous layer was collected and stored in 50ml polyethylene bottle for analysis.

The absorbance of aqueous solutions of blanks and standards were measured on Flame Atomic Absorption Spectrophotometer at 283.3nm for Pb and 228.8m for Cd.

$$\text{Slope} = \frac{\text{Absorbance}}{\text{Concentration}}$$

$$F = 1/\text{Slope}$$

Sample analysis: Duplicate aliquots of 400ml sample (pH 2-3 with 1 N HCL) were measured out in separating funnel, extracted and absorbance (As) was measured as described above.

Calculation

µg/l metal = F x (As) x 2.5

xii) Mercury

Water sample of 100 ml was collected in specially cleaned, pretested, fluropolymer bottles. Samples were fixed using $K_2Cr_2O_7$ solution and kept in an ice box at a freezing condition. Five ml solution was pipetted out and 9ml 10 % HNO_3 and 2ml $SnCl_2$, were added and allowed to spike for 5 min. and the absorbance was noted. One ml of standard solution, 9 ml HNO_3 and 2 ml stannous chloride was used for checking the standard solution.

Analysis was proceeded in such a way that after the removal of the stopper, a suitable aliquot of the blank, standard or sample solution was taken in the reaction vessel. The small stirrer puddle was put in it and the required amount of 10% HNO_3 (to maintain a volume of 10ml) and 2ml of $SnCl_2$ solution (20% w/v in 10% HCl) were added and the stopper was replaced immediately The magnetic stirrer was switched on and vigorously stirred for about 5min. The '0' T and 100' T was adjusted and the filter rod was pulled out completely in the open position. The 'Hold' mode operation was switched on followed by 'Abs' mode (% T/Abs). Mercury free air was allowed to purge through the reaction vessel. Absorbance was noted using Mercury Analyzer within one minute and switched back to normal mode. Zero per cent and 100% T were adjusted before each measurement.

The measurements were repeated for standards 20, 40, 60, 90,100, 150 200 ng/l Hg and calibration graph was plotted with absorption vs. concentration of Hg. Two to three measurements were made for each sample for better precision. The absorbance value of 20ng of Hg was converted to % absorption.

$\frac{20ng}{\%\ absorption}$ ng for 1% absorption is the sensitivity

Standard preparation:

For the preparation of 100 ml of 1000 ppm Mercury standard (Stock) solution, 0.1354 g of $HgCl_2$ was measured out in 2 HNO_3 and 1 ml of 1 % K_2Cr_20- were added and made up to 100ml with 2% HNO_3. Standard solution (0.1ppm) was prepared by diluting the stock solution by maintaining HNO_3 (2 %) and $K_2 Cr_2 0_7$ (0.01 %)

xiii) Chloride

Ten times diluted sample (100 ml) in a pH range of 7 to 10 was directly used for titration. Two ml of K_2CrO_4 solution was used as the indicator and titrated against standard 0.025 N $AgN0_3$ solutions. Titration was continued when a colour change from

pinkish yellow to orange red as end point was noted. $AgNO_3$ titrant was standardized similarly to establish a reagent blank value.

Calculation

$$\text{Chlorides (mg/l)} = \frac{\text{ml of } AgNO_3 \times 1000 \times 35.5}{\text{ml of sample}}$$

xiv) Total Dissolved Solids

Preparation of evaporating dish

Clean dish was heated to 103 105 ^{O}C, for 1 hr and stored in a desiccator, then weighed.

Sample analysis

The sample was filtered through a filter paper (0.45 micron). A well-mixed 250ml sample was transferred to pre-weighed dish and evaporated to dryness in a drying oven for 1 hr at 103 - 105 ^{O}C. Cooled the dish in dessicator to balance the temperature and weighed.

Calculation

$$\text{TDS (mg/l)} = \frac{(A - B) \times 1000}{\text{Volume of sample in ml}}$$

Where, A = (weight of dried residue + dish)

B = (weight of dish).

xv) Total alkalinity

Hundred ml of filtered sample was taken in a conical flask and 2-3 drops of alcoholic phenolphthalein indicator was added. The sample was titrated with 0.02N H_2SO_4 until it became colourless. Few drops of aqueous methyl orange indicator was added, to the colourless solution and titrated similarly until yellow colour of solution turns orange colour as the end point.

Calculation

$$\text{Total alkalinity (mg/l)} = \frac{(\text{ml} \times N) \text{ of standard acid} \times 50}{\text{Volume of sample taken}}$$

xvi) Total Hardness

Fifty ml water sample was taken and its pH was maintained above 10 by the adding 1 to 2 ml of buffer solution. One to two drops of the Erichrome- Black -T indicator was added and slowly titrated against standard EDTA solution (0.01N) with continuous stirring. At the end point, the colour changed from wine red to blue.

Calculation

$$\text{Total hardness (mg/l)} = \frac{\text{ml of EDTA used} \times 1000}{\text{Vol. of sample used}}$$

xvii) Calcium hardness

Two ml of NaOH solution was added to 50ml water sample to increase the pH to 12 to 13. The solution was stirred well and a pinch of murexide indicator was added so that the colour became pink. EDTA solution was added slowly with continuous stirring until pink colour changed to purple. One to 2 drops of the titrant was added in excess to make sure that no further colour change occurred.

Calculation

$$\text{Ca (mg/l)} = \frac{A \times B \times 400.8}{\text{Vol. of sample in ml}}$$

$$\text{Calcium hardness as of } CaCO_3 \text{ (mg/l)} \quad \frac{A \times B \times 1000}{\text{Vol. of sample in ml}}$$

Where, A = Volume of EDTA in ml

B = mg of $CaCO_3$ equivalent to 1 ml of EDTA titrant at the Ca indicator end point.

xviii) Magnesium

Magnesium was estimated as the difference between total hardness and Calcium as $CaCO_3$.

Mg (mg/l) = [Total hardness (mg /l as $CaCO_3$) Calcium hardness (mg /l as $CaCO_3$)] x 0.243]

xxi) Fluoride

A standard curve was prepared using 0.0 to 4mg/l fluoride by diluting appropriate quantities of standard fluoride solutions to 50ml with distilled water Ten ml of mixed solution (5ml of SPANDS and 5 Zirconyl acid reagents) was added to 50ml standard, and mixed well. Absorbance was taken immediately of the bleached colour at 570nm using reference solution. Standard curve was plotted between concentration and absorbance.

For sample analysis, 50ml sample was treated similarly with 10ml mixed solution and the absorbance taken immediately at 570nm.

Calculation

$$F = mg/l = \frac{\text{mg F determined photometrically}}{\text{ml sample used}} \times 1000$$

xx) Sulphate

Fifty ml of water sample was taken in a flask and 10 ml of NaCl- HCl solution (reagent A), 10 ml of glycerol-ethanol solution (reagent B) and 0.15g of barium chloride (reagent c) was added. Sample was stirred well for an hour and measured the absorbance against distilled water as blank at 420 nm using spectrophotometer. Standard solutions of different strength in similar way were processed and d recorded the absorbance for each. Plotted a standard graph from these values putting strength (mg/l) on one axis and absorbance on the other.

Calculation

SO_4 (mg/l) = mg SO_4 x1000/ml of sample

2.3.3 Biological parameters

i) Primary Productivity

Productivity was measured by C^{14} experiment after 6 hrs. *in situ* incubation.

Before sunrise, water samples from specified depths were collected in the light, dark and control bottles. (An aliquot of 0.25 ml surface water and 0.25 ml ethanolamine was collected in a scintillation vial). Sodium bicarbonate (C^{14} -5 μ.C) was added to300ml bottles and incubated for 6 hrs by suspending them at the respective depth. Fifty ml from control bottle was filtered through a 0.25 mm GF/F, glass micro fiber filter maintaining a vacuum of less than 3.7mm Hg. Without rinsing, the filter was taken out and placed in a 20ml scintillation vial covered with 0.25ml 0.5N HCl and kept at room temperature until further processing. The light and dark bottles were also incubated for 6 hrs at the respective depths from where the samples were drawn.

After incubation, the water samples were filtered using a vacuum less than 70mm in a semi-darkened area. The filtrates were placed in scintillation vials wetted with 0.25 ml of 0.5 N HCl and stored without capping for 12 hrs. It was then capped for removing any inorganic carbonate. To the vials containing filtrates, 10ml of liquid scintillation cocktail-2.5ml water with 0.25 ml ethanolamine- was added.

Calculation

Rate of production ($mgCm^3$ hr) =

$$\frac{\text{Net activity (cpm bottle light- cpm bottle dark) x Total } CO_2 \text{ x } 1.06 \text{x} 1000 \text{x} 12/44}{\text{cpm of control bottle} \quad \text{x} \quad \text{hrs of incubation}}$$

Where, cpm = counts per minutes;

Total CO_2 is assumed to be constant in oceanic waters and the value is 90mg CO_2/L; 1.06, a correction factor for the isotope discrimination effect to be used as the C incorporation will be slow compared to C^{12}

1000 to convert the value for m^3

12/44 is a factor used to convert CO_2 to Carbon.

ii) Chlorophyll *a*

The water sample was filtered through Whatman GF/F filter paper (0.47μ) wetted with 1ml of $MgCO_3$ suspension to prevent the pigment degradation. Filtration was carried out with the help of vacuum pump. The paper was taken out with a clean forceps and ground in a mortar and pestle with 2-3ml acetone and washed to a test tube with 90% acetone to make up the final volume to 10 ml. The tube was covered with aluminum foil and kept in refrigerator at 4°C for 24 hrs to complete the extraction of the pigment. The extract was then centrifuged at 500rpm for 20 min. The supernatant was then transferred to a photometric cell and the absorbance measured with 664 nm and 750 nm. The extract was acidified with 0.1 ml, 0.1 N HCl, gently agitated and read at 665 nm and 750 nm after 90 seconds.

Calculation

Chlorophyll *a* (mg/m^3) = 26.7 (664b-665a) V_1 / V_2 x l

Where V_1 = volume of extract in litres

V_2 = volume of sample in m^3

l = light path length

Where, 26.7 is the absorbance correction and is equal to A x K

And A = absorbance coefficient for chlorophyll *a* at 664 nm = 11.0,

K = Ratio expressing correction for acidification

iii) Phytoplankton

Phytoplankton samples were collected using nylon net with 55μm pore size. The collected samples were preserved in 4% formalin and phytoplankton identification was carried out with biological microscope (Olympus CH 20). Cell density was expressed as cell/l and identified up to the species level with the help of standard keys (Santhanam *et al.*, (1987); Krishnapillai, (1986) and John (1967). Cell counts were made using concentrated samples with the help of Sedgewick – Rafter counting chamber. One ml of plankton sample was transferred to the counting chamber and the total number of phytoplankton/l sample was calculated.

Calculation

$$N = \frac{n \times v}{V}$$

Where, N total number of phytoplankton cells per litre of water filtered

n - Average number of phytoplankton cells in 1 ml of plankton sample taken for counting

v - Volume of plankton concentrates (ml)

V Volume of total water filtered (l)

iv) Zooplankton

Zooplankton samples were collected by using a standard zooplankton net with a mesh size 180µ. The filtered sample was preserved in 4% formalin. Zooplankton identification was carried out with the help of binocular stereo zoom microscope (Olympus SZ 60). Biomass was calculated by displacement volume measurement and expressed as ml/m^3 and the density was expressed as no/m^3 The identification of zooplankton was carried out using standard keys.

Correlation coefficients between phytoplankton and physico-chemical parameters were determined with SPSS 11.0 statistical package programme.

3. RESULTS AND DISCUSSION

3.1 Seawater analysis

The results are presented in tables 1-11 and charts 1-29

3.1.1 Biological parameters

Lighthouse transect

Primary productivity varied from 2.43 mgC/m^3/hr at near shore to 4.80 mgC/m^3/hr at 5.0 and 12.5 km stations during 1996, 1.68 mgC/m^3/hr at near shore to 3.95 mgC/m^3/hr at 12.5km station during 1997. 1.80 mgC/m^3/hr at 2.5 km to 4.20 mgC/m^3/hr at 12.5 km offshore during 1998 and 3.75 mgC/m /hr at 2.5km to 4.85 mgC/m^3/hr at 12.5 km station during post monsoon 1998.

Chlorophyll *a* varied from 0.24 mg/m^3 at near shore to 0.47 mg/m^3 at 5.0 km station during 1996, 0.23 mg/m^3 at 2.5 km to 0.39 mg/m^3 at 5.0 km during 1997, 0.32 mg/m^3 at the near shore to 0.68 mg/m^3 at 5.0 km station during 1998 and 0.37 mg/m^3 at near shore to 0.58 mg/m^3 at 12.5 km during post monsoon 1998.

Phytoplankton total count varied from 10.22 x 10^2 /l at near shore to 54.80 x 10^2/l at 12.5 km during 1996, 12.68 x 10^2 /l at the near shore to 39.30 x 10^2 /l at 5 km during 1997, 12.60 x 10^2 /l at 2.5 km to 42.10 x 10^2 /l at 5.0 km during 1998 and 29.44 x 10^2 /l at near shore to 51.20 x 10^2 /l at 5.0 km during post monsoon 1998.

Zooplankton biomass fluctuated from 0.16 ml/m^3 at near shore to 0.38 ml/m^3 at 12.5 km offshore during 1996, 0.21 ml/m^3 at near shore to 0.38 ml/m^3 at 12.5 km station during 1997, 0.23 ml/m^3 at near shore to 1.28 ml/m^3 at 2.5 km during 1998 and 0.19ml/m^3 at near shore to 0.68 ml/m^3 at 5.0 km station during post monsoon 1998. Zooplankton total count varied from 189/ /m^3 at near shore to 342 /m^3 at 12.5 km during 1996, 248 /m^3 at near shore to 416 /m^3 at 12.5km during 1997, 212 /m^3 at near shore to 898 /m^3 at 2.5 km during 1998 and 196 /m^3 at near shore and 5km offshore to 326 /m^3 at 12.5 km station during post monsoon 1998.

Helipad transect

Primary productivity varied from 3.20 mgC/m^3/hr at near shore to 4.60 mgC/m^3/hr at 2.5 km station during 1996, 2.20 mgC/m^3/hr at near shore to 3.90 mgC/m^3/hr at 5 km station during 1997, 2.35 mgC/m^3/hr at near shore to 3.85 mgC/m^3/hr at 5.0 km station during 1998 and 4.30 mgC/m^3/hr at 2.5 km to 5.65 mgC/m^3/hr at 5 km station during post monsoon1998. Chlorophyll *a* pigment varied from 0.18 mg/m^3 at near shore to 0.48 mg/m^3 at 12.5 km station during 1996, 0.28 mg/m^3 at near shore to 0.56 mg/m^3 at 12.5 km station during 1997, 0.31 mg/m^3 at the near shore to 0.63 mg/m^3 at 2.5 km station during 1998 and 0.29 mg/m^3 at near shore to 0.72 mg/m^3 at 2.5 km and 12.5 km stations during post monsoon 1998.

Phytoplankton total count varied from 23.26 x 10^2 /l at near shore to 49.38 x 10^2 /l at 12.5 km station during 1996, 10.32 x 10^2 /l at the near shore to 45.20 x 10^2 /l at 12.5 km during 1997, 38.18 x 10^2 /l at near shore to 45.24 x 10^2 /l at 5.0 km during 1998 and 38.18 x 10^2 /l at near shore to 54.60 x 10^2 /l at 5.0 km station during post monsoon 1998. Zooplankton biomass fluctuated from 0.23 ml/m^3 at 12.5 km to 0.34 ml/m^3 at 2.5 km offshore during 1996, 0.23 ml/m^3 at 5.km to 0.36 ml/m^3 at nearshore during 1997, 0.24 ml/m^3 at 2.5 km station to 0.51 ml/m^3 at 5.0 km during 1998 and 0.26 ml/m^3 at 2.5 km to 0.31 ml/m^3 at 12.5 km station during post monsoon 1998. Zooplankton total count varied from 189 /m^3 at 12.5 to 354 /m^3 at 5 km during 1996, 185 /m^3 at 5.km to 540 /m^3 at nearshore station during 1997, 312 /m^3 at 2.5 to 650 /m^3 at 5.0 km during 1998 and 154 /m^3 at 2.5 km to 256 /m^3 at 12.5 km station during post monsoon 1998.

Harbour transect

Primary productivity varied from 1.90 mgC/m^3/hr at near shore to 4.55 mgC/m^3/hr at 2.5 km station during 1996, 1.10 mgC/m^3/hr at near shore to 4.85 mgC/m^3/hr at 5.0 km station during 1997, 2.25 mgC/m^3/hr at near shore to 4.30 mgC/m^3/hr at 2.5 km offshore during 1998 and 3.45 mgC/m^3/hr at near shore to 4.85 mgC/m^3/hr at 2.5 km offshore during post monsoon 1998. Chlorophyll *a* pigment varied from 0.15 mg/m^3 at near shore to 0.63 mg/m^3 at 2.5 km station during 1996, 0.22 mg/m^3 at near shore to 0.52 mg/m^3 at 5.0 km during 1997, 0.28 mg/m^3 at the near shore to 0.72 mg/m^3 at 5.0 km station during 1998 and 0.17 mg/m^3 at near shore to 0.65 mg/m^3 at 5.0 km during post monsoon 1998. Phytoplankton

total count varied from 8.78 x 10^2 /l at near shore to 47.88 x 10^2 /l at 5 km during 1996, 12.40 x 10^2 /l at the nearshore to 35.28 x 10^2 /l at 5.0 km during 1997, 13.10 x 10^2 /l at near shore to 48.14 x 10^2 /l at 5.0 km during 1998 and 20.20 x 10^2 /l at near shore to 55.86 x 10^2 /l at 5.0 km during post monsoon 1998. Zooplankton biomass fluctuated from 0.12 ml/m^3 at near shore to 0.33 ml/m^3 at 5 km offshore during 1996, 0.21 ml/m^3 at 5 km to 0.56 ml/m^3 at 12.5 km station during 1997, 0.29 ml/m^3 at near shore to 0.39 ml/m^3 at 5 km during 1998 and 0.08 ml/m^3 at nearshore to 0.37 ml/m^3 at 2.5 km station during post monsoon 1998. Zooplankton total count varied from 132 /m^3 at near shore to 286 /m^3 at 5 km during 1996, 186 /m^3 at 5 km to 514 /m^3 at 12.5km during premonsoon 1997, 216/m^3 at near shore to 450 /m^3 at 5 km during 1998 and 86 /m^3 at near shore to 245/m^3 at 2.5km station during post monsoon 1998.

Discussion

The overall fluctuation in primary productivity was between 1.1 mgC/m^3/hr to 5.65mgC/m^3/hr. Irrespective of transects; offshore stations recorded the highest values compared to the nearshore waters. Seasonal variation in productivity values was marked and post-monsoon season showed higher values in all transects than in pre-monsoon. Similar trend was observed by Bhattathiri and Devassy (1979) that average primary productivity in Laccadive Sea during post-monsoon season (October-December) was higher than that in the pre-monsoon. The lowest production recorded from the nearshore waters of harbour transect might be attributed to the high turbulence caused by break water construction and extremely high tidal flow that reduced light intensity resulting in low plankton abundance. Significant levels of correlation by Chl *a* and nitrates with primary production was observed. The overall range of productivity recorded in the present study was higher than the reported values for Lakshadweep islands (0.144-3.023 mgC/m^3/hr by Bhattathiri and Devassy, 1979; 0.518-1.903 mgC/m^3/hr by Wafar, 1977). The high fluctuation in the production indicates that the areas adjacent to the atolls became occasionally oligotrophic while the offshore waters remain mostly eutrophic. However, the values obtained in the present study were lower than that (698mgC/m^2/day) reported for north eastern Arabian Sea (Radhakrishna *et al.*, 1978).

Chlorophyll, an indicator of phytoplankton biomass, varied temporally and spatially (0.15 mg/m^3 to 0.72 mg/m^3) High values were noted, in par with the primary production, from the offshore samples. The lowest value (0.15 mg/m^3) recorded from the nearshore of harbour transect, might be attributed to low phytoplankton biomass, as the area received considerable amount of suspended particles from the construction activities. Though, the values showed seasonal fluctuation among stations, higher concentrations were noticed during the post monsoon season. Earlier report (Bhattathiri and Devassy, 1979) from the Lakshadweep waters for premonsoon (0.01-0.2mg/m^3) and post monsoon (0.02-0.58 mg/m^3) and that (0.005-0.15 mg/m^3) for the EEZ of Mauritius (Devassy and Goes, 1991) showed that the values obtained during the present study were high. Average values reported by Qasim (1978) for Arabian Sea (0.244mg/m^3), Indian Ocean (0.158mg/m^3) and Bay of Bengal (0.224 mg/m^3) fell far below the present observations. However, high chlorophyll content (> 0.5 mg/m^3) similar to the present results was noted from western Indian Ocean region during the month of October and November (Yapa, 2000).

Significant correlation between phytoplankton abundance and chl *a* was observed in the present study (Chart -19). Similar results were reported from Dharamtar creek, West coast of India by Tiwari and Nair (1998) who had attributed to the phytoplankton production and zooplankton grazing as the major biological processes which influenced the spatial distribution of chlorophyll. The overall trend in productivity and chlorophyll indicated that Andrott waters are productive unlike the islands that possess lagoons. Lagoons by their high rate of bacterial decomposition were observed to have very low dissolved oxygen (Walter *et al.*, 2001)

Nutrients were found to be contributing substantially in controlling the distribution of chl *a* in the offshore area where a corresponding decrease in the concentration of nutrients were observed with high chl *a* content (Table-14a). This implies that availability of nutrients particularly NO_3-N control phytoplankton production. It has also been observed in the present study that the physical processes that control NO_3-N supply to the euphotic zone also control the magnitude of phytoplankton standing crop. Inverse relation observed

between chl *a* and nitrate nitrogen (r = -0.339) and phosphate (r = -0.244) indicates the effective utilization of nutrients by planktons (Table-14a).

The variation in phytoplankton abundance during the present study was between 8.78 x 10^2 cell l^{-1} to 54.80 x 10^2 cell l^{-1} Similar results in abundance (3.36x10^2cell l^{-1} to 572.4x10^2cell l^{-1}) and diversity were reported by Polat and Piner (2002) from northern Mediterranean coast. Though, phytoplankton count and diversity varied among stations and between seasons, maximum abundance was recorded during post monsoon at the lighthouse transect. This is in agreement with the earlier findings of maximum abundance noticed from Cochin coast during the post monsoon season (Gopinathan, 1972). Low count and diversity noted generally from the nearshore stations and particularly in the harbour transect may be attributed to the addition of wastes and lack of stabilization and disturbances of the water. The stirring up of the detritus and turbulence of the water restricts light penetration and as a result, the crop of phytoplankton never approaches the disturbed area though rich in nutrients.

Phytoplankton abundance and diversity agree with the observation (0.09 x 10^3 -6.8 x$10^3 l^{-1}$) made from the Indian Ocean around Mauritius (Devassy and Goes, 1991). *Coscinodiscus, Rhizosolenia and Chaetoceros* were the major groups of phytoplankton identified. Dinoflagellates (Peridinium and Porocentram) were poorly represented compared to diatoms. The increase in the number of the diatoms can be attributed to the increased nutrient concentration, especially nitrates and silicates. A positive correlation in the phytoplankton abundance and nutrient levels recorded from the offshore stations of lighthouse and helipad transects clearly indicates the influence of nutrients on plankton growth and multiplication.

Density and biomass of zooplankton varied respectively from 86/m^3 (harbour nearshore) to 898/m^3 (lighthouse transect) and 0.08 ml/m^3 (harbor nearshore) to 1.28 ml/m^3 (lighthouse), the maximum being in premonsoon. Generally, density and biomass showed wide fluctuation and tends to be increased towards the offshore. Abundance and biomass of zooplankton recorded in the present study are similar to those reported earlier (Tranter and George, 1972; Goswamy, 1972 and Wafar, 1977). Copepods, chaetognaths, decapod larvae,

Table No. 1 – Biological Parameters at Light House transect

Year	Distance from the shore	Primary productivity ($mgC/m^3/hr.$)	Chlorophyll *a* (mg/m^3)	Phytoplankton Total count (No/l)	Zooplankton Biomass (ml/m^3)	Zooplankton Density (No/m^3)
1996	Near shore	2.43	0.24	10.22×10^2	0.16	189
1997		1.68	0.25	12.68×10^2	0.21	248
1998		2.25	0.32	24.50×10^2	0.23	212
1998 (P)*		3.85	0.37	29.44×10^2	0.19	196
1996	2.5 KM	2.85	0.33	35.40×10^2	0.28	298
1997		3.50	0.23	23.16×10^2	0.24	262
1998		1.80	0.38	12.60×10^2	1.28	898
1998 (P)*		3.75	0.45	41.86×10^2	0.44	296
1996	5.0 KM	4.80	0.47	45.80×10^2	0	316
1997		3.15	0.39	39.30×10^2	0..	287
1998		3.85	0.68	42.10×10^2	0.39	314
1998 (P)*		4.60	0.57	51.20×10^2	0.68	196
1996	12.5 KM	4.80	0.42	54.80×10^2	0.38	342
1997		3.95	0.29	23.40×10^2	0.38	416
1998		4.20	0.36	32.60×10^2	0.34	323
1998 (P)*		4.85	0.58	45.20×10^2	0.48	326

* Post monsoon

Table No. 2 – Biological Parameters at Helipad transect

Year	Distance from the shore	Primary productivity ($mgC/m^3/hr.$)	Chlorophyll *a* (mg/m^3)	Phytoplankton Total count (No/l)	Zooplankton Biomass (ml/m^3)	Zooplankton Density (No/m^3)
1996	Near shore	3.20	0.18	23.26×10^2	0.24	246
1997		2.20	0.28	10.32×10^2	0.36	540
1998		2.35	0.31	26.12×10^2	0.42	485
1998 (P)*		4.80	0.29	38.18×10^2	0.29	196
1996	2.5 KM	4.60	0.32	31.10×10^2	0.34	248
1997		3.85	0.54	26.20×10^2	0.32	458
1998		3.15	0.63	42.00×10^2	0.24	312
1998 (P)*		4.30	0.72	48.62×10^2	0.26	154
1996	5.0 KM	4.15	0.34	36.14×10^2	0.32	354
1997		3.90	0.55	42.68×10^2	0.23	185
1998		3.85	0.43	45.24×10^2	0.51	650
1998 (P)*		5.65	0.48	54.60×10^2	0.29	246
1996	12.5 KM	3.60	0.48	49.38×10^2	0.23	189
1997		2.65	0.56	45.20×10^2	0.35	458
1998		2.45	0.62	42.10×10^2	0.28	380
1998 (P)*		4.40	0.72	54.18×10^2	0.31	256

* Post monsoon

Table No. 3– Biological Parameters at Harbour transect

Year	Distance from the shore	Primary productivity ($mgC/m^3/hr.$)	Chlorophyll *a* (mg/m^3)	Phytoplankton (No/l)	Zooplankton biomass (ml/m^3)	Zooplankton density (No/m^3)
1996	Near shore	1.90	0.15	8.78×10^2	0.12	132
1997		1.10	0.22	$12.40X\ 10^2$	0.27	205
1998		2.25	0.28	$13.10X\ 10^2$	0.29	216
1998 (P)*		3.45	0.17	$20.20X\ 10^2$	0.08	86
1996	2.5 KM	4.55	0.63	45.80×10^2	0.28	276
1997		3.45	0.34	$16.16X\ 10^2$	0.34	321
1998		4.30	0.38	32.26×10^2	0.34	318
1998 (P)*		4.85	0.34	42.10×10^2	0.37	245
1996	5.0 KM	3.30	0.29	47.88×10^2	0.33	286
1997		4.85	0.52	35.28×10^2	0.21	186
1998		4.15	0.72	48.14×10^2	0.39	450
1998 (P)*		4.35	0.65	55.86×10^2	0.21	163
1996	12.5 KM	4.15	0.46	$41\ 10 \times 10^2$	0.27	169
1997		3.80	0.24	13.48×10^2	0.56	514
1998		2.95	0.51	37.34×10^2	0.31	221
1998 (P)*		4.60	0.62	42.30×10^2	0.21	129

* Post monsoon

Table. 4 Phytoplankton species recorded during Post monsoon 1996

Name of species	Lighthouse	Helipad	Harbour
BACILLARIOPHYCEAE **Order: Centrales** **Family :Coscinodisceae**			
Stephanopyxis turris	+	+	+
Skeletonema costatum	+++	++ +	+++
Thalassiosira subtilis	++	+	+
Coscinodiscus eccentricus	+++	+++	+++
Planktoniella sol	++	+ +	+ +
Family: Soleniae			
Corethron hystrix	+	-	+
Schroederella delicatula	+	+	-
Leptocylindrus danicus	++		++
Guinardia flaccida	-	+	-
Rhizosolenia alata	++	++	++
Rhizosolenia robusta	+	+	+
Rhizosolenia stolterfothii	++	+	++
Rhizosolenia cylindrus	+	-	+
Family: Chaetocereae			
Chaetoceros lorenzianus	++	+	++
Chaetoceros affinis	+	-	+
Family: Biddulphieae			
Eucampia cornuta	-	+	+
Streptotheca indica	+	+	-
Biddulphia sinensis	++	++	++
Order: Pennales **Family: Fragilarioideae**			
Thalassionema nitzschioides	+ +	+ +	++
Thalassiothrix frauenfeldii	+	++	++
Family: Naviculoideae			
Gyrosigma balticum		+	-
Pleurosigma normanii	+	+	+
Pleurosigma elongatum	+	++	++
Nitzschia sigma	++	++	++
DINOFLAGELLATES **Order : Prorocentrales**			
Prorocentrum micans	+	-	
Order: Dinophysiales			
Dinophysis pedunculata	+	+	+
Ornithocercus steinii	+	+	+

(Continued..)

Order: Peridiniales			
Protoperidinium ovatum	+	+	+
Protoperidinium depressum	+	+	+
Ceratium furca	+	+	+
Ceratium tripos	+		+
Ceratium macroceros	+	+	
Ceratium trichoceros			+
CYANOPHYCEAE			
Trichodesmium erythraea	+++	+++	+++
HAPTOPHYCEAE			
Coccolithus sp.	+		
CHLOROPHYCEAE			
Chlorella marina	-	+	

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 5 - Phytoplankton species recorded during pre monsoon 1997

Name of species	Lighthouse	Helipad	Harbour
BACILLARIOPHYCEAE **Order: Centrales** **Family :Coscinodisceae**			
Stephanopyxis turris	-	+	-
Melosira sulcata	+	-	-
Thalassiosira subtilis	+	+	+
Coscinodiscus eccentricus	+++	+++	+++
Coscinodiscus radiatus	++	++	+
Planktoniella sol	+	+	+
Family: Actinodisceae			
Actinotychus undulatus	-	+	-
Family: Soleniae			
Corethron hystrix	-	+	+
Schroederella delicatula	++	++	++
Leptocylindrus danicus	++	++	++
Guinardia flaccida	+	-	+
Rhizosolenia alata	++	+++	++
Rhizosolenia robusta	+	+	+
Rhizosolenia cylindrus	+	-	+
Rhizosolenia imbricata	-	+	+
Family: Chaetocereae			
Bacteriastrum varians	+	+	-
Chaetoceros lorenzianus	++	++	++
Chaetoceros messanensis	+	+	+
Chaetoceros affinis	+	-	+
Family: Biddulphieae			
Eucampia cornuta	+	-	+
Streptotheca indica	+	+	-
Biddulphia sinensis	++	++	++
Order: Pennales **Family: Fragilarioideae**			
Thalassionema nitzschioides	+	+	+
Family: Naviculoideae			
Gyrosigma balticum	-	-	+
Pleurosigma normanii	++	+	++
Pleurosigma angulatum	+	-	+
Pleurosigma elongatum	++	+	+
Nitzschia sigma	+	+	+
Amphora lineolata	-	+	-

(Continued...)

DINOFLAGELLATES **Order: Prorocentrales**			
Prorocentrum micans	+	-	-
Order: Dinophysiales			
Dinophysis pedunculata	+	+	+
Ornithocercus steinii	+	-	+
Order: Peridiniales			
Protoperidinium ovatum	++	++	++
Protoperidinium crassipes	++	+	+
Protoperidinium depressum	++	++	++
Ceratium furca	+	+	+
Ceratium tripos	+	+	+
Ceratium macroceros	+	+	+
Ceratium inflatum	+	-	+
Ceratium trichoceros	+	-	+
CYANOPHYCEAE			
Trichodesmium erythraea	+++	+++	+++
CHLOROPHYCEAE			
Chlorella marina	+	-	-

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 6 - Phytoplankton species recorded during Pre monsoon 1998.

Name of species	Lighthouse	Helipad	Harbour
BACILLARIOPHYCEAE			
Order: Centrales			
Family :Coscinodisceae			
Stephanopyxis turris	-	+	+
Skeletonema costatum	+	+	+
Thalassiosira subtilis	+	+	+
Coscinodiscus eccentricus	+++	+++	+++
Planktoniella sol	+	+	+
Family: Soleniae			
Corethron hystrix	+	+	+
Schroederella delicatula	+	+	+
Leptocylindrus danicus	++	++	++
Guinardia flaccida	+	-	-
Rhizosolenia alata	+++	+++	+++
Rhizosolenia robusta	+	+	+
Rhizosolenia stolterfothii	+	+	+
Rhizosolenia cylindrus	+	+	+
Family: Chaetocereae			
Chaetoceros lorenzianus	+++	+++	+++
Chaetoceros affinis	+	+	+
Family: Biddulphieae			
Eucampia cornuta	+	-	+
Streptotheca indica	-	+	-
Biddulphia sinensis	+++	+++	+++
Order: Pennales			
Family: Fragilarioideae			
Thalassionema nitzschioides	+	+	+
Thalassiothrix frauenfeldii	+	+	+
Family: Naviculoideae			
Gyrosigma balticum	+	+	+
Pleurosigma normanii	+	+	+
Pleurosigma elongatum	++	++	++
Nitzschia sigma	++	++	++
DINOFLAGELLATES			
Order: Prorocentrales			
Prorocentrum micans	-	+	-
Order: Dinophysiales			
Dinophysis pedunculata	+	+	+

(Continued..)

Ornithocercus steinii	+	+	+
Order: Peridiniales			
Protoperidinium ovatum	+	+	+
Protoperidinium depressum	+	+	+
Ceratium furca	+	+	+
Ceratium tripos	+	-	+
Ceratium macroceros	+	+	-
Ceratium trichoceros	-	-	+
CYANOPHYCEAE			
Trichodesmium erythraea	+++	+++	+++
HAPTOPHYCEAE			
Coccolithus Sp.	+	-	-
CHLOROPHYCEAE			
Chlorella marina		+	

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 7 - Phytoplankton species recorded during Post monsoon 1998.

Name of species	Lighthouse	Helipad	Harbour
BACILLARIOPHYCEAE **Order: Centrales** **Family :Coscinodisceae**			
Stephanopyxis turris	+	+	-
Stephanopyxis Palmeriana	+	-	+
Skeletonema costatum	+++	+++	+++
Thalassiosira subtilis	+	+	+
Cyclotella striata	+	-	+
Coscinodiscus eccentricus	+++	+++	+++
Planktoniella sol	-	+	+
Family: Actinodisceae			
Actinotychus undulatus	-	+	-
Family: Solcniae			
Corethron hystrix	+	-	+
Schroederella delicatula	+	+	+
Leptocylindrus danicus	++	++	++
Guinardia flaccida	-	+	-
Rhizosolenia alata	++	++	++
Rhizosolenia robusta	+	+	+
Rhizosolenia stolterfothii	+	+	+
Rhizosolenia cylindrus	+	+	+
Rhizosolenia styliformis	+	+	+
Family: Chaetocereae			
Chaetoceros lorenzianus	+	+	+
Chaetoceros affinis	+	+	+
Chaetoceros curvisetus	+	-	+
Family: Biddulphieae			
Eucampia cornuta	+	+	+
Streptotheca indica	+	+	+
Biddulphia sinensis	++	++	++
Triceratium favus	++	++	++
Biddulphia mobiliensis	+	+	+
Order: Pennales **Family: Fragilarioideae**			
Asterionella japonica	++	++	++
Thalassionema nitzschioides	+	+	+
Thalassiothrix frauenfeldii	+	+	+
Family: Naviculoideae			
Gyrosigma balticum	-	+	-

(Continued...)

Pleurosigma normanii	+	+	+
Pleurosigma elongatum	+	+	+
Amphora lineolata	-	+	-
Nitzschia sigma	++	++	++
Nitzschia seriata			
DINOFLAGELLATES			
Order: Dinophysiales			
Dinophysis pedunculata	+	+	+
Dinophysis miles	+	-	+
Order: Peridiniales			
Protoperidinium ovatum	+	+	+
Protoperidinium oceanicum	+	+	+
Protoperidinium pedunculatum	+	+	+
Protoperidinium depressum	+	+	+
Ceratium breve	+	+	+
Ceratium tripos	+	+	+
Ceratium macroceros	+	-	+
Ceratium trichoceros	-	+	-
CYANOPHYCEAE			
Trichodesmium erythraea	+++	+++	+++
CHLOROPHYCEAE			
Chlorella marina	-	+	-

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 8 Zooplankton species recorded during Post monsoon1996.

Name of species	Lighthouse	Helipad	Harbour
FORAMINIFERA			
Globigerina sp.	+++	+++	+++
Textularia agglutinans	+	+	+
Bolivinita quadrilatera	+	+	+
Rosalina bertheloti	+	+	+
RADIOLARIA			
Thalassicolla sp.	+	-	+
HYDROZOA			
Obelia sp.	+	-	+
Lensia conoidea	+	+	+
CHAETOGNATHA			
Sagitta setosa	++	++	++
Sagitta elegans	+	+	+
CLADOCERA			
Evadne nordmanni	+	+	+
Podon leuckarti	+	+	+
COPEPODA			
a) CALONOIDA			
Calanus finmarchicus	+	++	+
Canthocalanus pauper	+	+	+
Undinnula vulgaris	+	+	+
Acrocalanus sp.	+++	+++	+++
Acartia amboinensis	++	++	+
Acartia danae	++	+	+
Labidocera detruncata	+	+	++
Pontella spinipes	+	+	+
Paracalanus parvus	+	+	+
Temora longicornis	+	+	+
Pseudocalanus elongatus	+	+	+
Eucalanus attenuatus	+	+	+
b) CYCLOPOIDA			
Oithona halgolandica	+	+	+
Cyclopina longicornis	+	+	+
Oithona brevicornis	+	+	+
Oithona plumifera	+	+	+
Oithona similes	+	+	+
c) HARPACTICOIDA			
Euterpina acutifrons	+	+	-
Microsetella norvegica	+	+	+

(Continued...)

AMPHIPODA			
Gammarus sp	+	+	-
DECAPODA			
Lucifer hansenii	+	+	+
PTEROPODA			
Creseis sp.	++	++	+
APPENDICULARIA			
Oikopleura sp.	++	++	++
MYSIDS			
Leptomysis gracilis	+	+	+
Hemimysis lamornae	+	+	+
LARVAE			
Copepod nauplii	+	+	+
Crustacea nauplii	+	+	+
Brachyurian crab Zoea	+	+	
Gastropod larvae	+++	+++	++
Bipinnaria larva	-	+	+
Polychaeta larva	+	+	
Lamellibranch larvae	+++	++	++
Cyphonautes larva	+	-	+
Mysis larvae	+	++	+
ICHTHIOPLANKTON			
Fish eggs	+	++	+
Fish larva	+	+	-

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 9 - Zooplankton species recorded during Pre monsoon1997.

Name of species	Lighthouse	Helipad	Harbour
FORAMINIFERA			
Globigerina sp.	+++	+++	+++
Bolivinita quadrilatera	+	+	++
Rosalina bertheloti	+	+	+
Spiriliina decorata	+	++	+
CIELIATA			
Tintinnopsis sp.	+	+	+
RADIOLARIANS			
Thalassicolla sp.	+	+ +	+
HYDROZOA			
Obelia sp.	-	+	-
Lensia conoidea	+	++	++
Cladonema radiatum	+++	+++	++
CHAETOGNATHA			
Sagitta setosa	++	+++	+++
CLADOCERA			
Evadne nordmanni	++	+++	+++
Podon leuckarti	++	+	++
COPEPODA **a) CALONOIDA**			
Calanus finmarchicus	++	++	++
Canthocalanus pauper	+	+	+
Undinnula vullgris	+	+	+
Acrocalanus sp.	+++	+++	+++
Acartia amboinensis	+++	++	++
Acartia danae	++	++	++
Labidocera acuta	+	++	+
Labidocera detruncata	+	+	+
Pontella spinipes	+	+	+
Paracalanus parvus	+	+	+
Temora longicornis	+	+	+
Pseudocalanus elongatus	+	+	+
Eucalanus attenuatus	+	+	+
b) CYCLOPOIDA			
Oithona halgolandica	+	++	+
Cyclopina longicornis	+	+	+
Oithona plumifera	+	+	+
Oithona similes	-	+	+

(Continued...)

c) HARPACTICOIDA			
Euterpina acutifrons	+	+	+
Microsetella norvegica	+	+	+
AMPHIPODA			
Gammarus sp.	+	+	+
DECAPODA			
Lucifer hansenii	++	+ +	+
APPENDICULARIA			
Oikopleura sp.	++	++	+ +
MYSIDS			
Leptomysis gracilis	+	+	+
LARVAE			
Copepod nauplii	++	+	++
Crustacea nauplii	+	+	+
Brachyurian crab Zoea	-	+	+
Gastropod larvae	++	++	++
Bipinnaria larva	+	+	+
Polychaeta larva	+	+	-
Lamellibranch larvae	+++	++	+ + +
Cyphonautes larva	-	+	-
Alima larva	+	-	-
Mysis larva	+	+	+
ICHTHIOPLANKTON			
Fish eggs	++	+ +	++
Fish larva	+	+	-

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 10 - Zooplankton species recorded during Pre monsoon1998.

Name of species	Lighthouse	Helipad	Harbour
FORAMINIFERA			
Globigerina sp.	+++	+++	++
Textularia agglutinans	+	++	+
Bolivinita quadrilatera	+	+	+
Rosalina bertheloti	+	+	+
RADIOLARIA			
Thalassicolla sp.	+	++	+
HYDROZOA			
Obelia sp.	-	-	-
Pleurobranchia pileus	+	+	+
Lensia conoidea	+	+	+
DOLIOLIDS			
Doliolum gegenbauri	++	+	+
CHAETOGNATHA			
Sagitta setosa	++	++	++
Sagitta elegans	+	+	+
CLADOCERA			
Evadne nordmanni	++	++	++
Podon leuckarti	-	+	+
COPEPODA			
a) CALONOIDA			
Calanus finmarchicus	++	++	+++
Canthocalanus pauper	++	++	+
Undinenula vulgaris	+	++	+
Acrocalanus sp.	+++	+++	+++
Acartia amboinensis	++	++	++
Acartia danae	++	++	+
Temora discaudata	++	+	+
Labidocera detruncata	++	+	+
Pontella spinipes	++	+	+
Paracalanus parvus	++	+	+
Temora longicornis	+	+	+
Pseudocalanus elongatus	+	+	+
Eucalanus attenuatus	++	++	+
b) CYCLOPOIDA			
Oithona halgolandica	+++	++	+
Cyclopina longicornis	++	+	+

(Continued...)

Oithona plumifera	+	++	+
Oithona similes	+	+	+
c) HARPACTICOIDA			
Euterpina acutifrons	+	+	+
Microsetella norvegica	+	+	+
CUMACEA			
Diastylis tumida	+	-	-
AMPHIPODA			
Gammarus sp.	+	+	+
DECAPODA			
Lucifer hansenii	++	++	++
PTEROPODA			
Creseis sp.	+	+	+
APPENDICULARIA			
Oikopleura sp.	++	++	++
MYSIDS			
Leptomysis gracilis	+	+	+
Hemimysis Lamornae	+	+	+
LARVAE			
Copepod nauplii	++	++	+++
Crustacea nauplii	+	+	-
Brachyurian crab Zoea	+	-	+
Gastropod larvae	+++	+++	+++
Bipinnaria larva	+	+	+
Polychaeta larva	+	-	+
Megalopa larva	+	+	+
Lamellibranch larvae	++	++	++
Cyphonautes larva	+	-	-
Mysis larva	+	+	++
ICHTHIOPLANKTON			
Fish eggs	+	+	+
Fish larva	+	-	+

+ Present, ++ Moderate, +++ Abundant, - Absent

Table. 11 - Zooplankton species recorded during Post monsoon1998.

Name of species	Lighthouse	Helipad	Harbour
FORAMINIFERA			
Globigerina sp.	+++	+++	++
Textularia agglutinans	+	+	+
Bolivinita quadrilatera	+	+	+
Rosalina bertheloti	+	+	+
RADIOLARIA			
Thalassicolla sp.	+	+	+
HYDROZOA			
Obelia sp.	-	+	+
Pleurobranchia pileus	+		
Lensia conoidea	+	+	-
DOLIOLIDS			
Doliolum gegenbauri	+	+	++
CHAETOGNATHA			
Sagitta setosa	++	+	++
Sagitta elegans	+	+	+
CLADOCERA			
Evadne nordmanni	+	+	+
Podon leucarti	+	+	+
COPEPODA **a) CALONOIDA**			
Calanus finmarchicus	++	++	+++
Canthocalanus pauper	+++	+	+
Undinenula vulgaris	+	++	+
Acrocalanus sp.	+++	+++	+++
Acartia amboinensis	+++	++	+
Acartia danae	+++	++	+++
Temora discaudata	+	+	+
Labidocera detruncata	+	+	+++
Pontella spinipes	+++	++	+++
Paracalanus parvus	++	+	+
Temora longicornis	+	++	+
Pseudocalanus elongatus	+++	++	++
Eucalanus attenuatus	+++	+++	+
b) CYCLOPOIDA			
Oithona halgolandica	+++	+	+

(Continued...)

Cyclopina longicornis	++	+	+
Oithona plumifera	++	+	+
Oithona similis	+		+
c) HARPACTICOIDA			
Euterpina acutifrons	++	++	+++
Microsetella norvegica	++	+	+
CUMACEA			
Diastylis tumida	+	+	+
AMPHIPOD			
Gammarus sp.	+	+	+
DECAPODA			
Lucifer hansenii	+	+	+
PTEROPODA			
Creseis sp.	+	+	+
APPENDICULARIA			
Oikopleura sp.	+	+	+
MYSIDS			
Leptomysis gracilis	+	+	+
Hemimysis Lamornae	+	+	+
LARVAE			
Copepod nauplii	++	++	+
Crustacea nauplii	+	+	+ +
Brachyurian crab Zoea	+	+	+
Gastropod larvae	++	+	+++
Bipinnaria larva	+	+	+
Polychaeta larva	+	+	-
Megalopa larva	+	-	+
Lamellibranch larvae	++	+++	++
Cyphonautes larva	+		
Mysis larvae	++	+	+
ICHTHIOPLANKTON			
Fish eggs	+	+	+
Fish larvae	++	+	+

+ Present, ++ Moderate, +++ Abundant, - Absent

Chart 1: Primary productivity at Lighthouse transect; 1996-1998

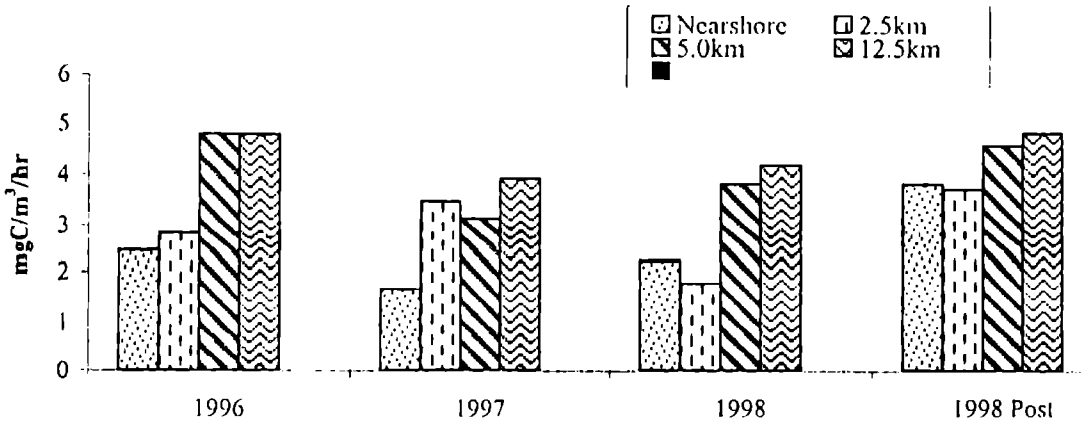


Chart 2: Primary productivity at Helipad, 1996-1998

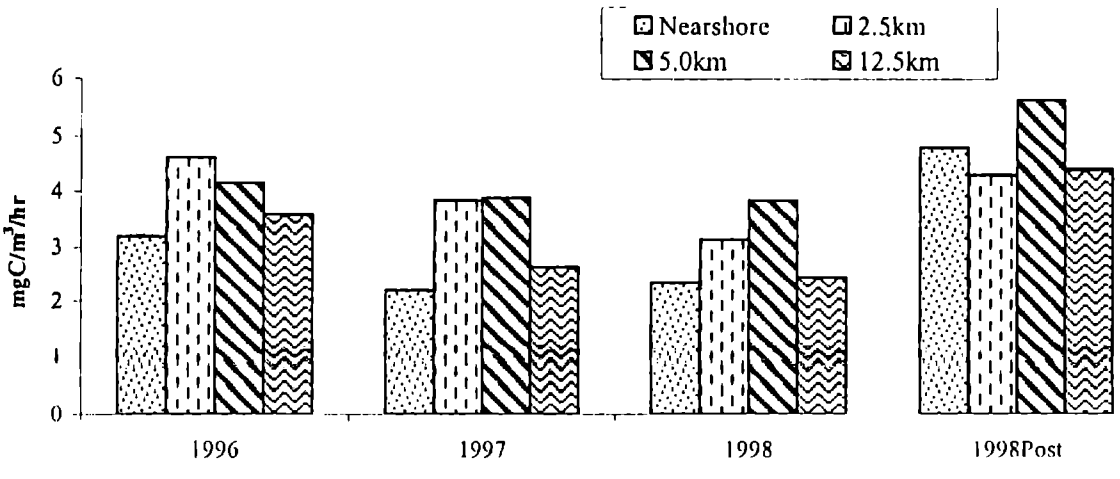


Chart 3: Primary productivity at Harbour, 1996-1998

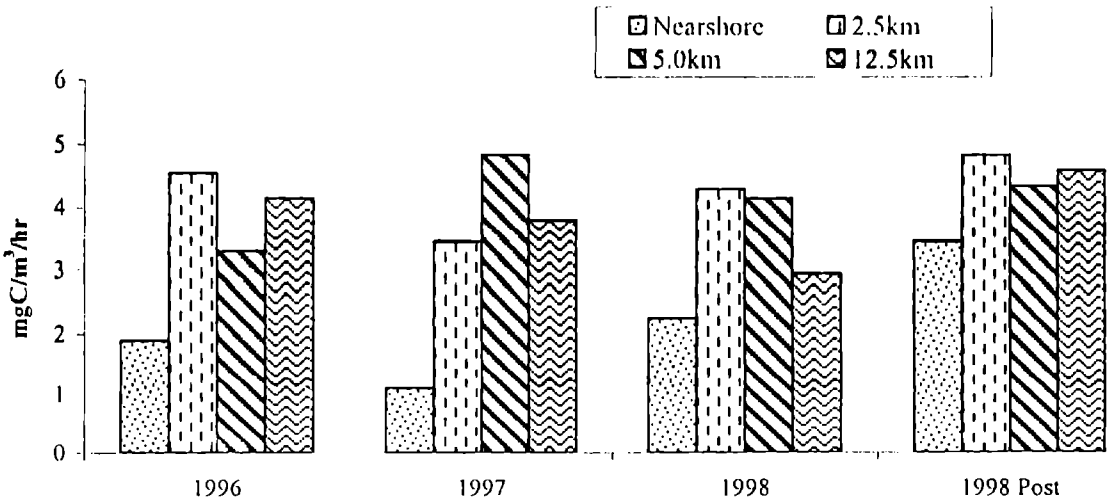


Chart 4: Chlorophyll *a* at Light house transect; 1996-1998

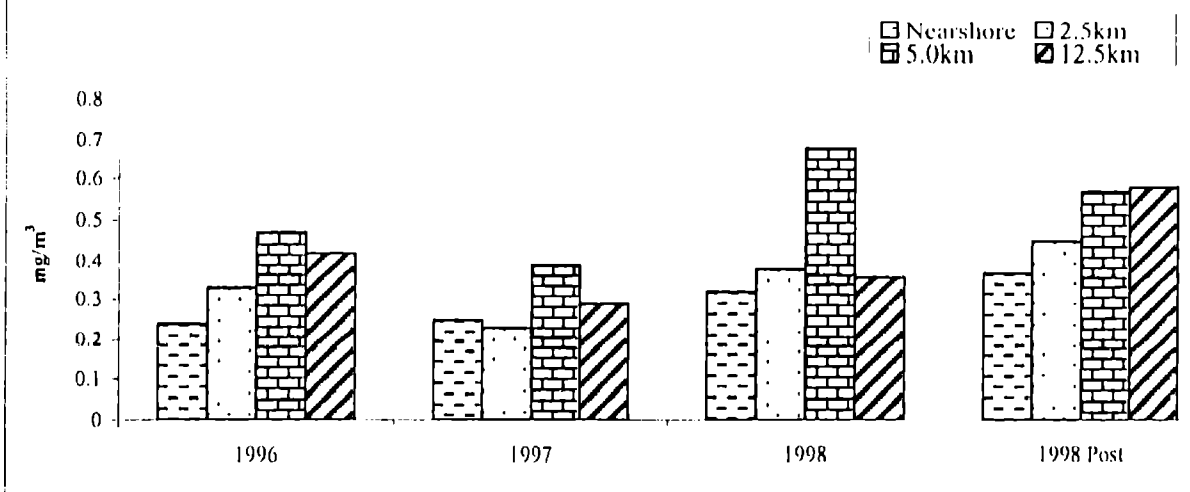


Chart 5: Chlorophyll *a* at Helipad transect; 1996-1998

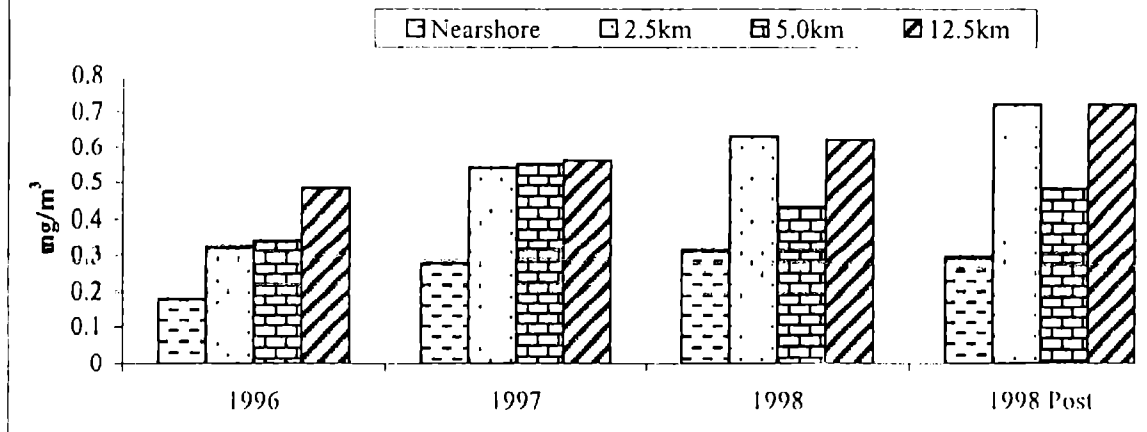


Chart 6: Chlorophyll *a* at Harbour transect; 1996-1998

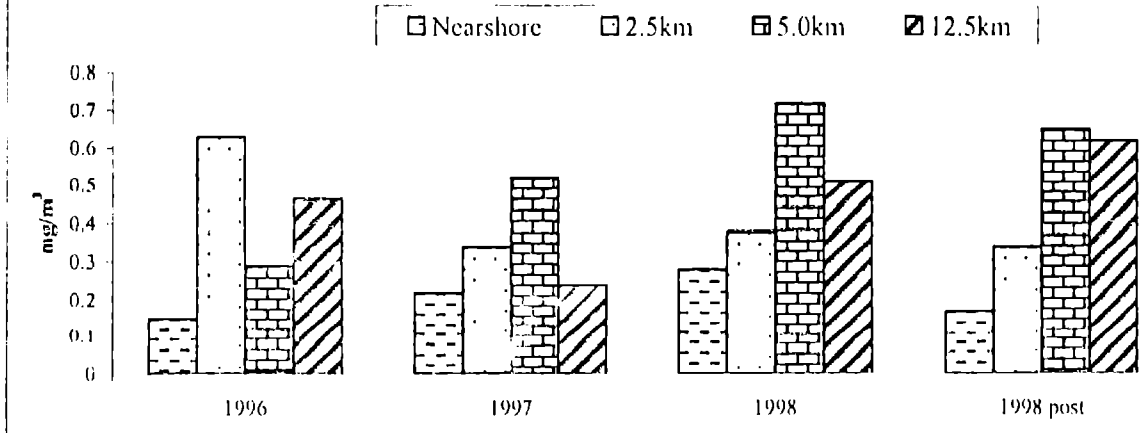


Chart 7: Phytoplankton count at Lighthouse transect; 1996-1998

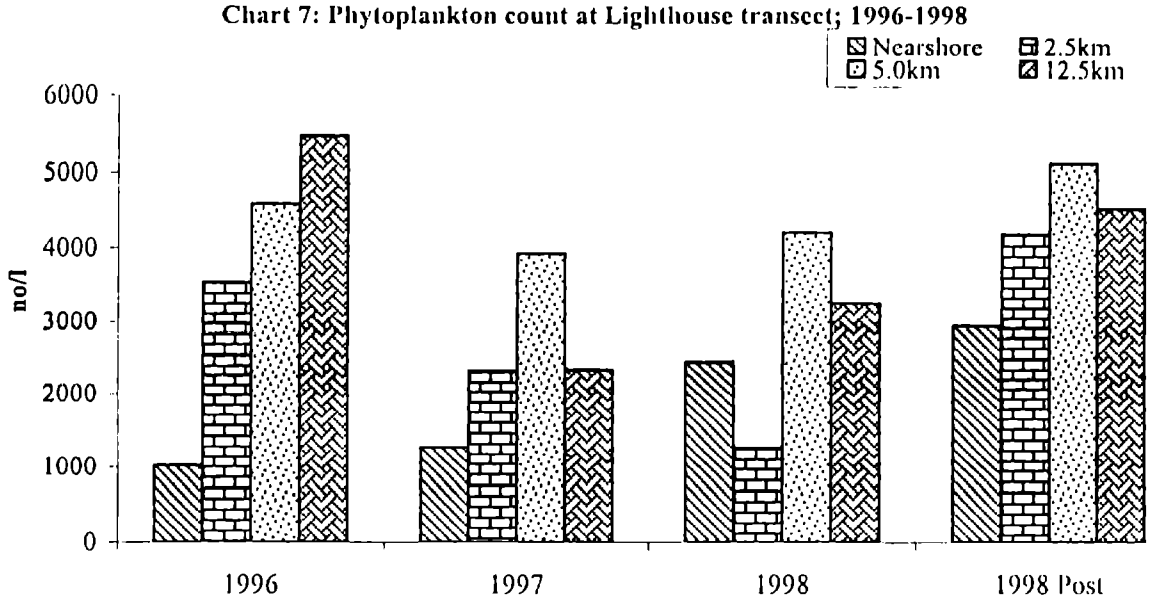


Chart 8: Phytoplankton count at Helipad transect; 1996-1998

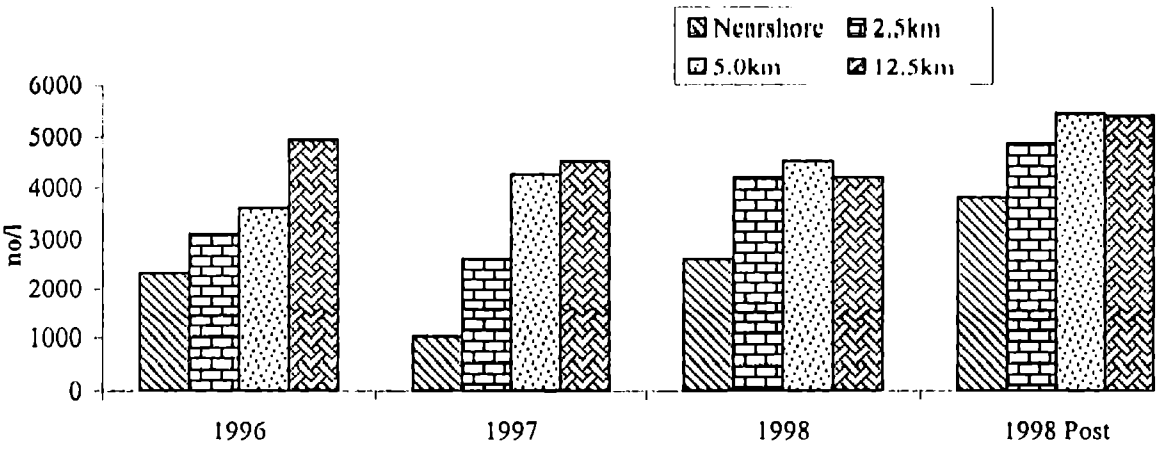


Chart 9: Phytoplankton count at Harbour transect; 1996-1998

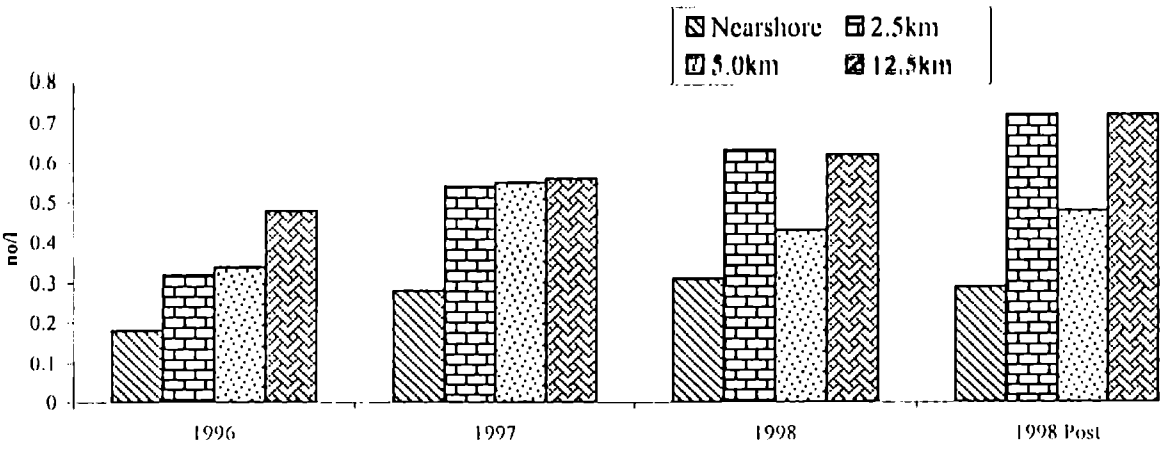


Chart 10: Zooplankton density at Lighthouse transect; 1996-1998

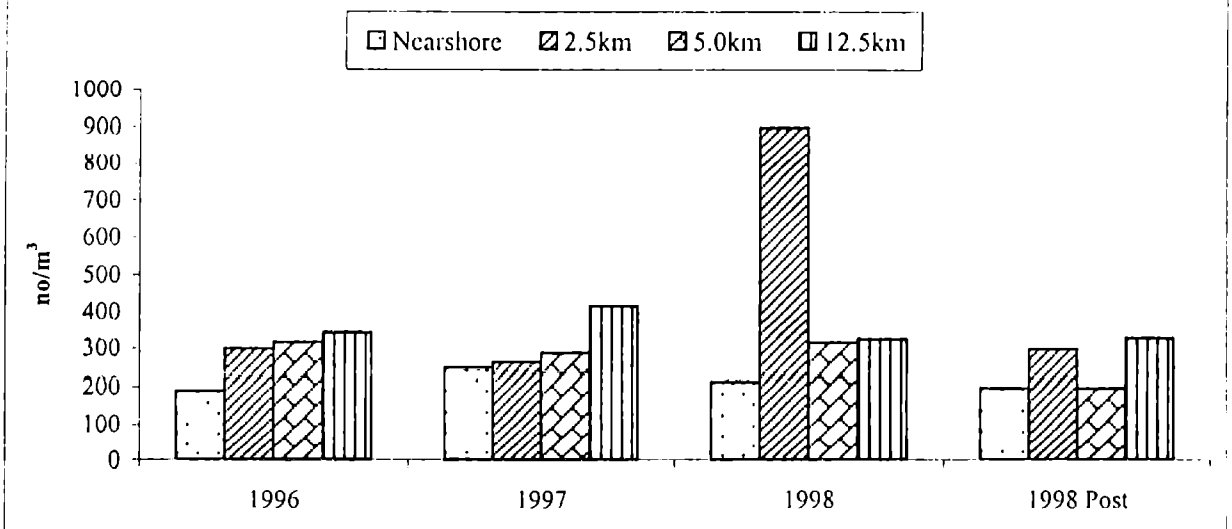


Chart 11: Zooplankton density at Helipad transect; 1996-1998

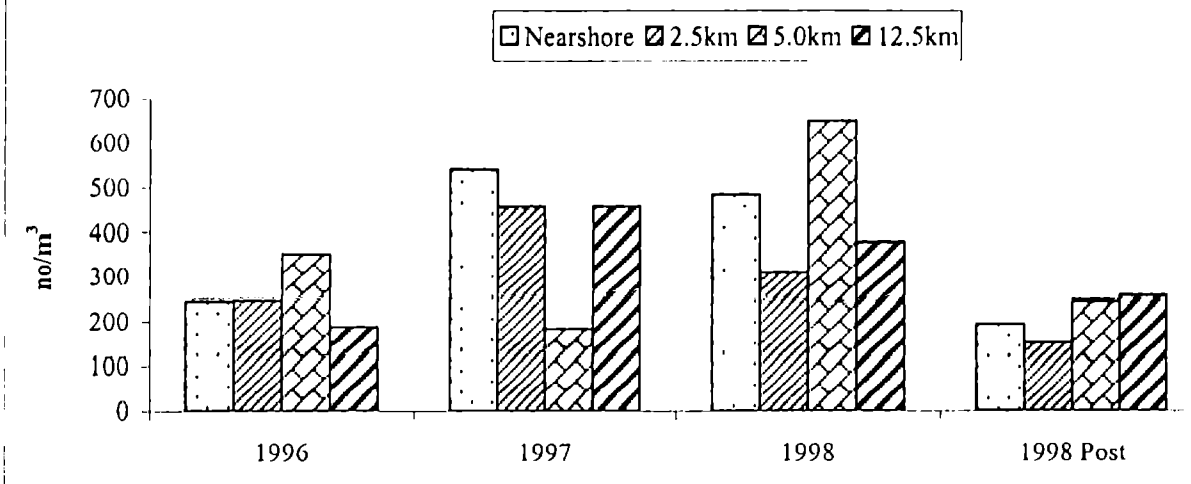


Chart 12: Zooplankton density at Harbour transect; 1996-1998

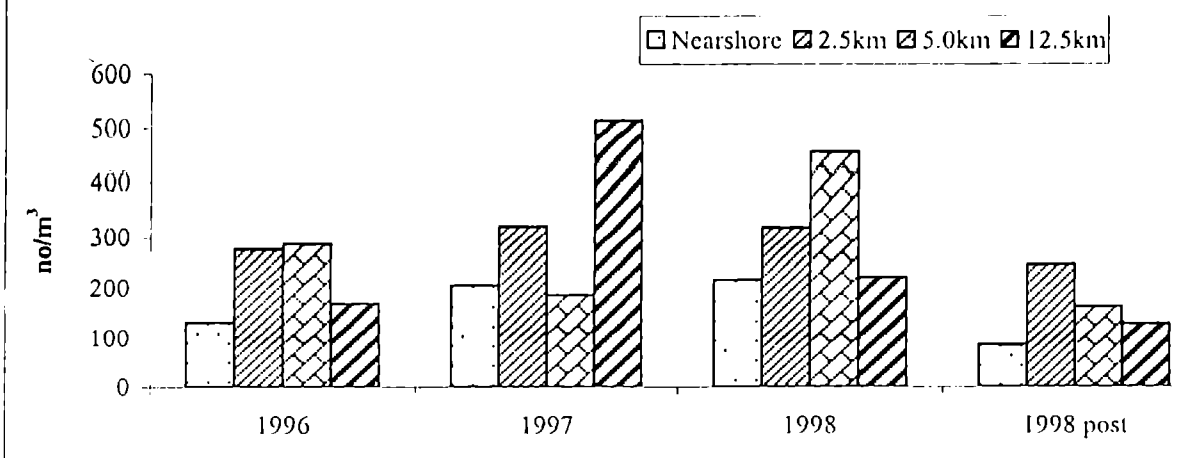


Chart 13: Zooplankton biomass at Lighthouse transect: 1996-1998

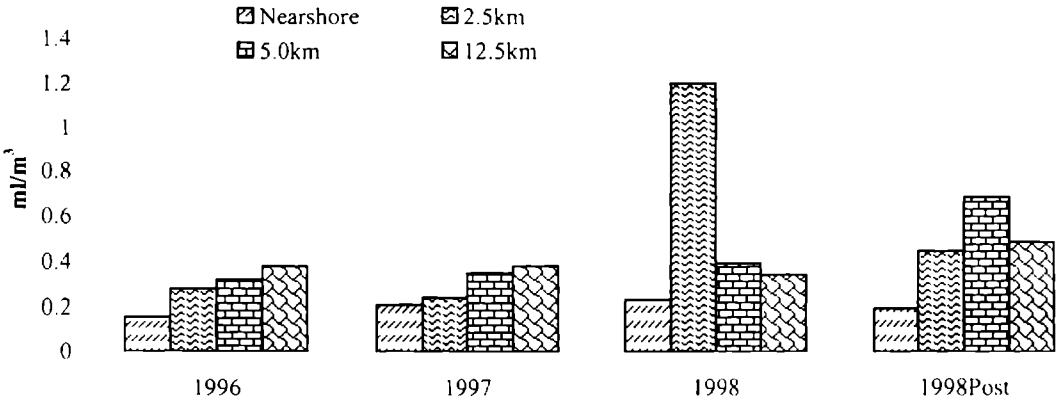


Chart 14: Zooplankton biomass at Helipad transect: 1997-2001

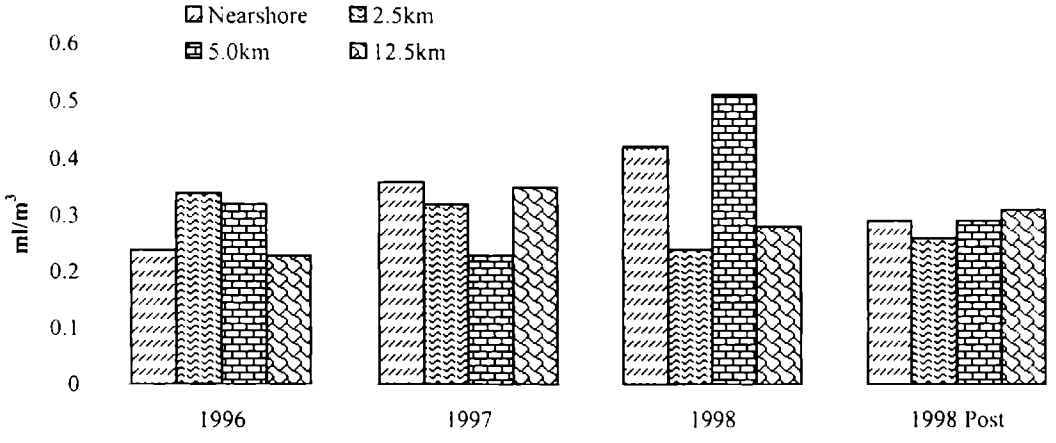


Chart 15: Zooplankton biomass at Harbour transect; 1997-2001

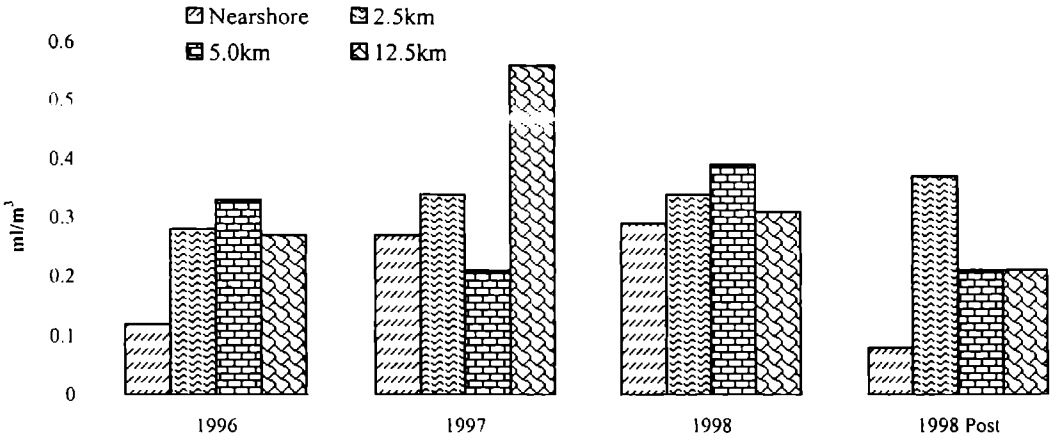


Chart 16: Zooploankton biomass and density at Light house transect, 1996-1998.

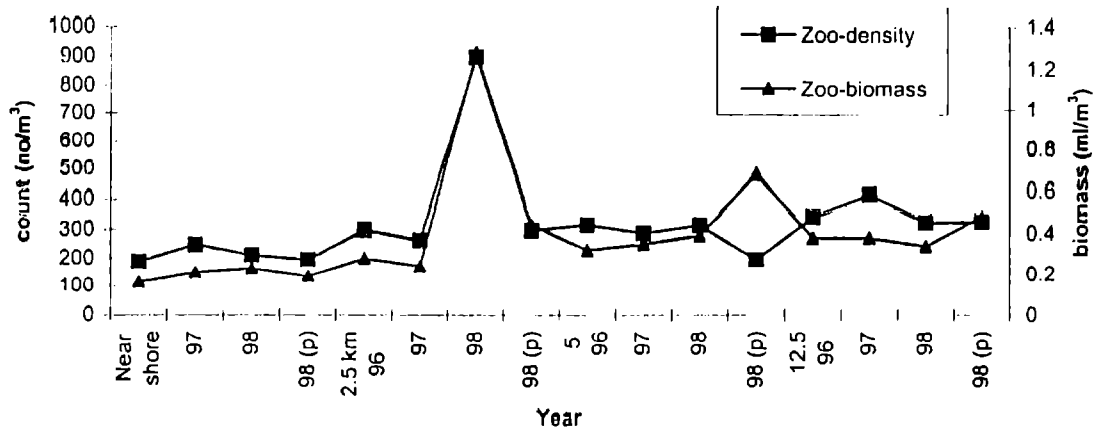


Chart 17: Zooploankton biomass and density at Helipad transect, 1996-1998.

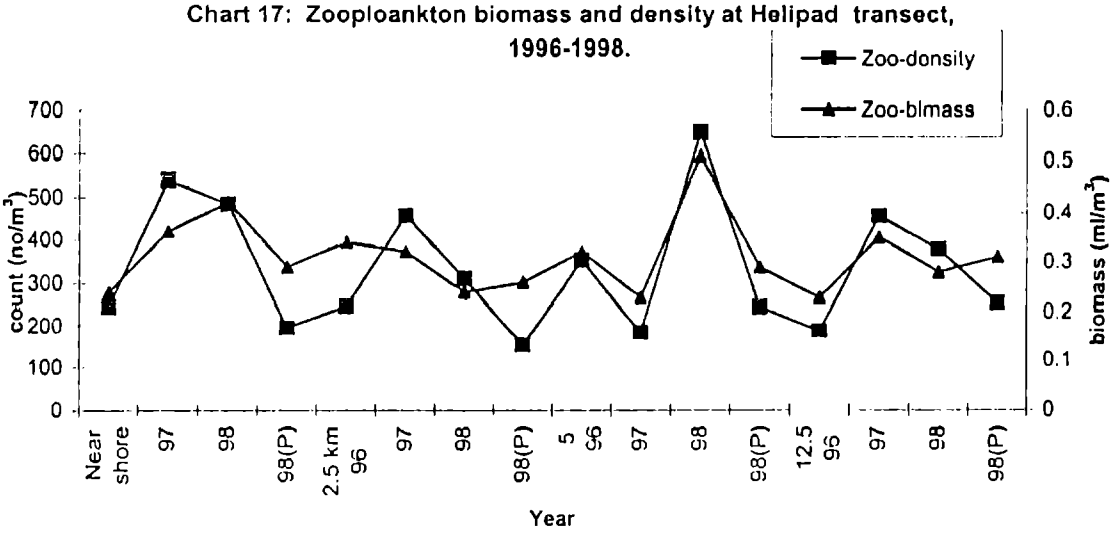


Chart 18: Zooploankton biomass and density at Harbour transect, 1996-1998.

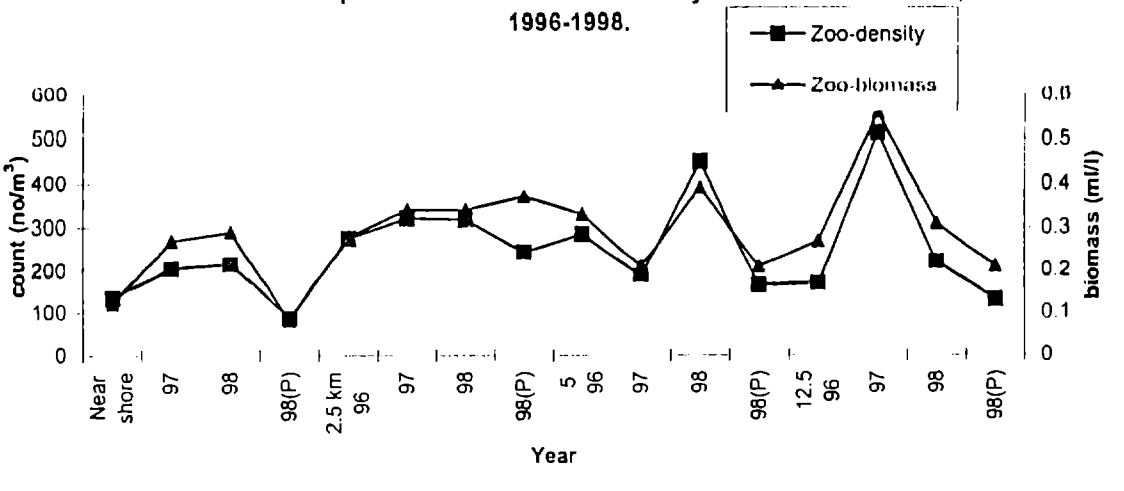


Chart 19: Phytoplankton count and Chlorophyll a at Light House transoct, 1996-1998.

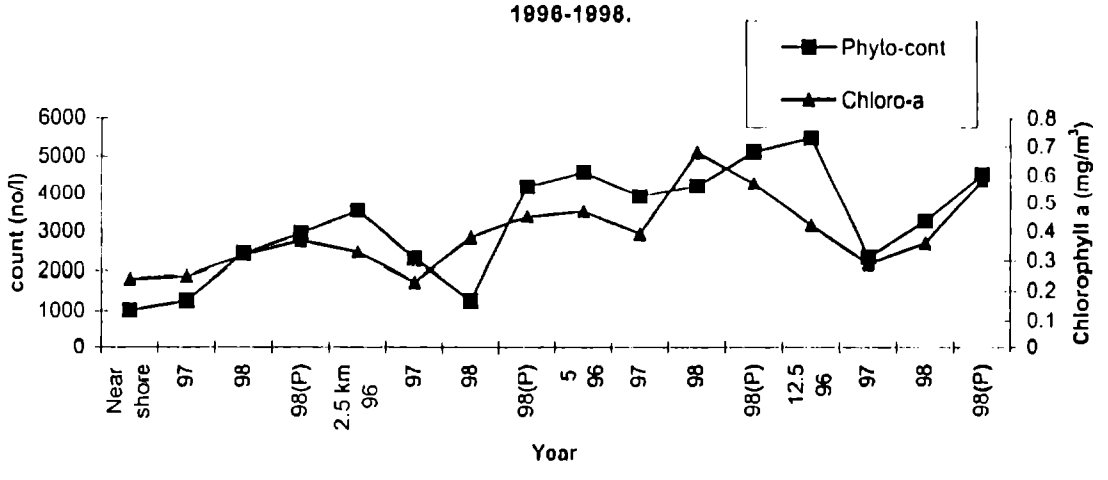


Chart 20: Phytoplankton count and Chlorophyll a at Hollpad transoct, 1996-1998.

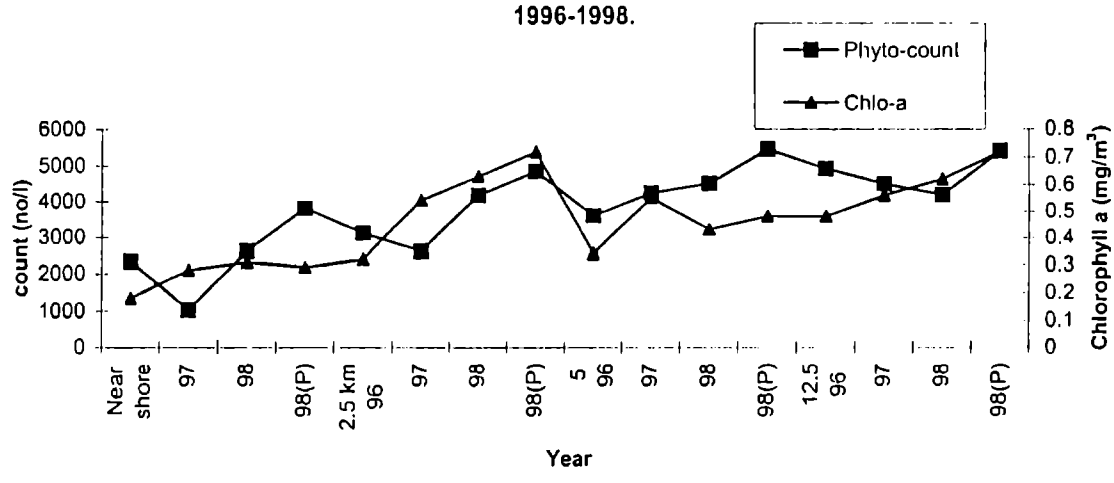


Chart 21: Phytoplankton count and Chlorophyll a at Harbour transoct, 1996-1998.

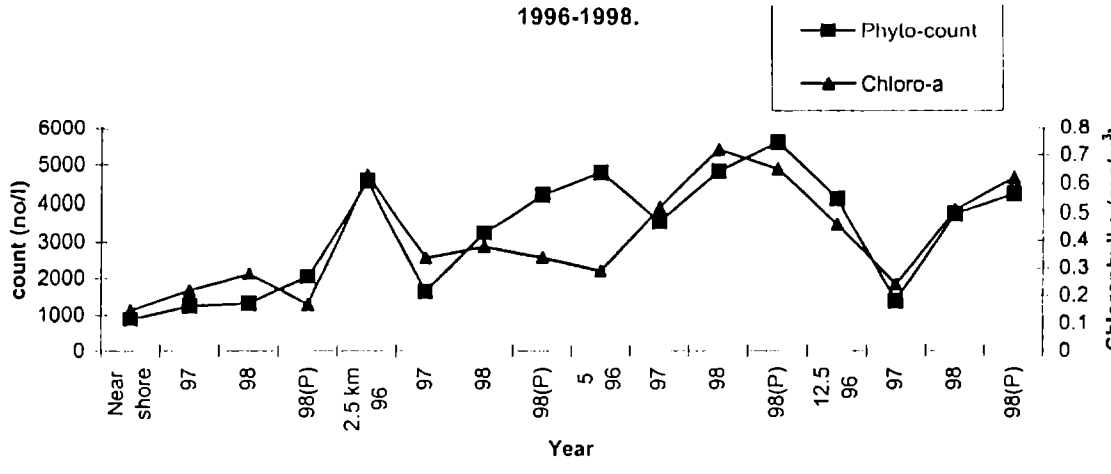


Chart 22: Chlorophyll *a* and Zooplankton density at Light house transect, 1996-1998.

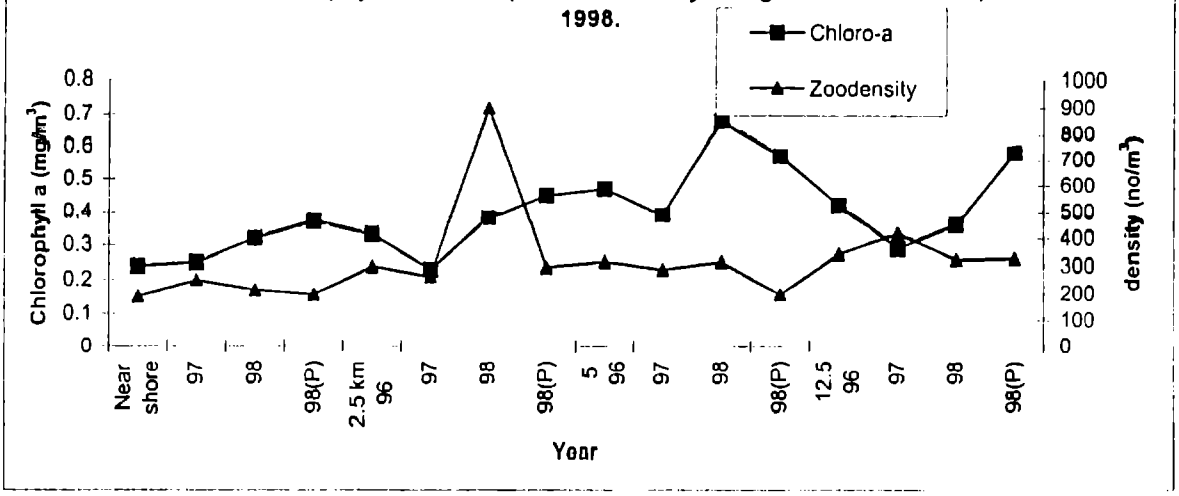


Chart 23: Chlorophyll *a* and Zooplankton at Helipad transect, 1996-1998.

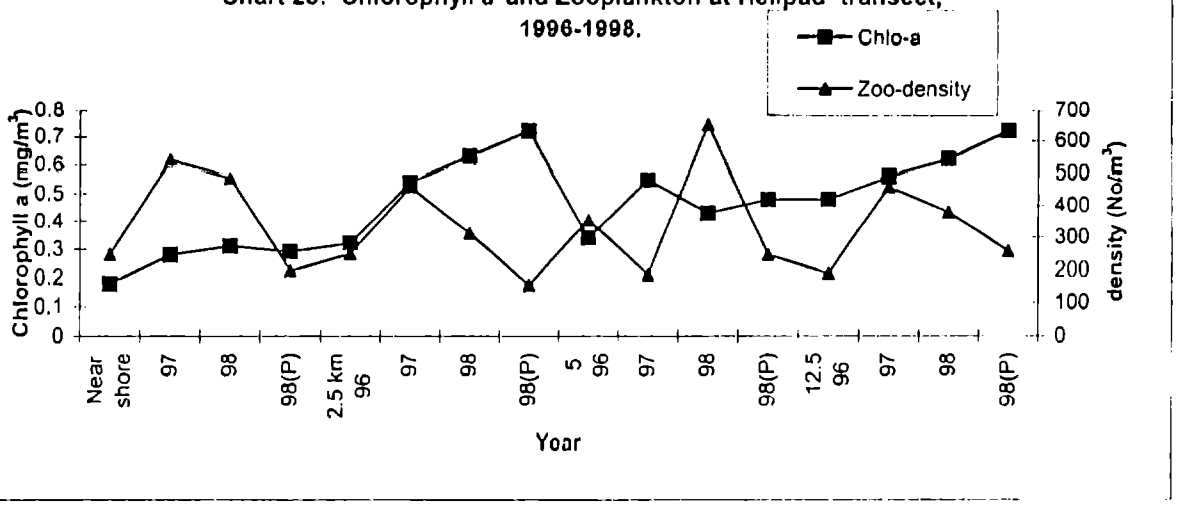


Chart 24: Chlorophyll *a* and Zooplankton density at Harbour transect, 1996-1998.

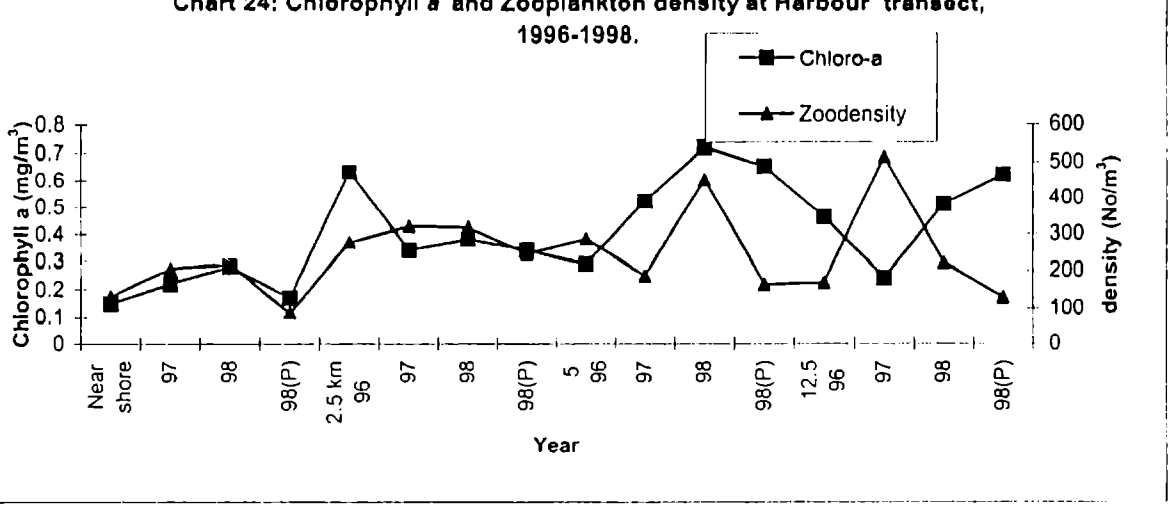


Chart 25: Variation of Primary Productivity between the transects

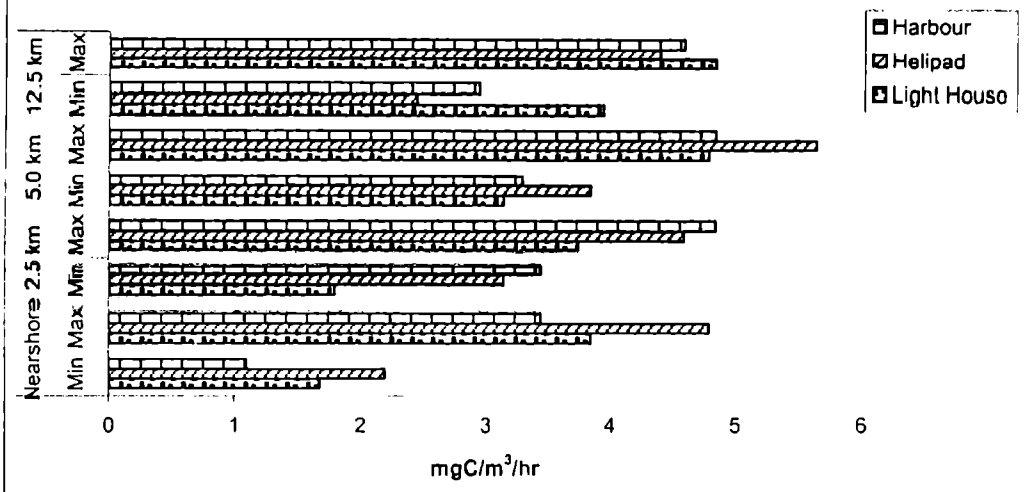


Chart 26: Variation of Cholrophyll a between the transects

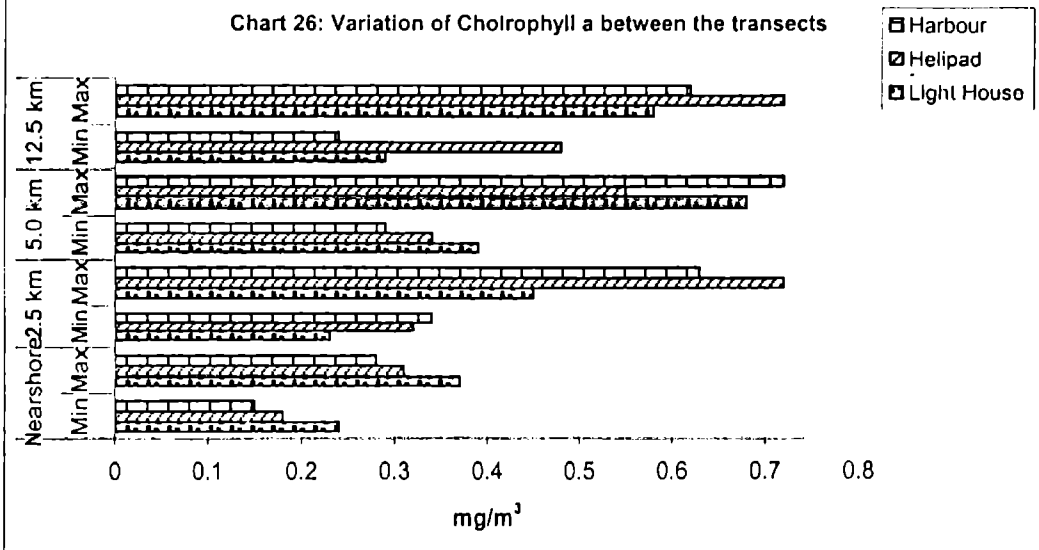
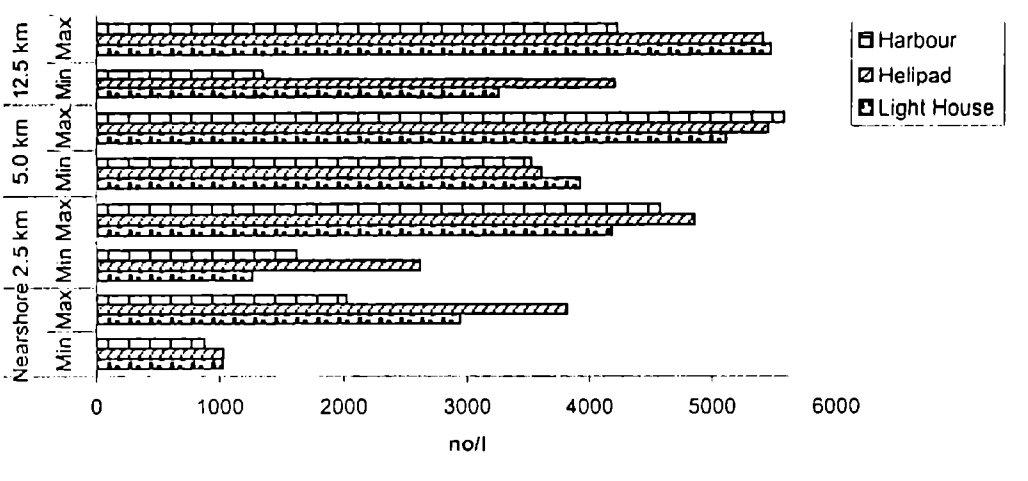


Chart 27: Variation of Phytoplankton Abundance between the transects



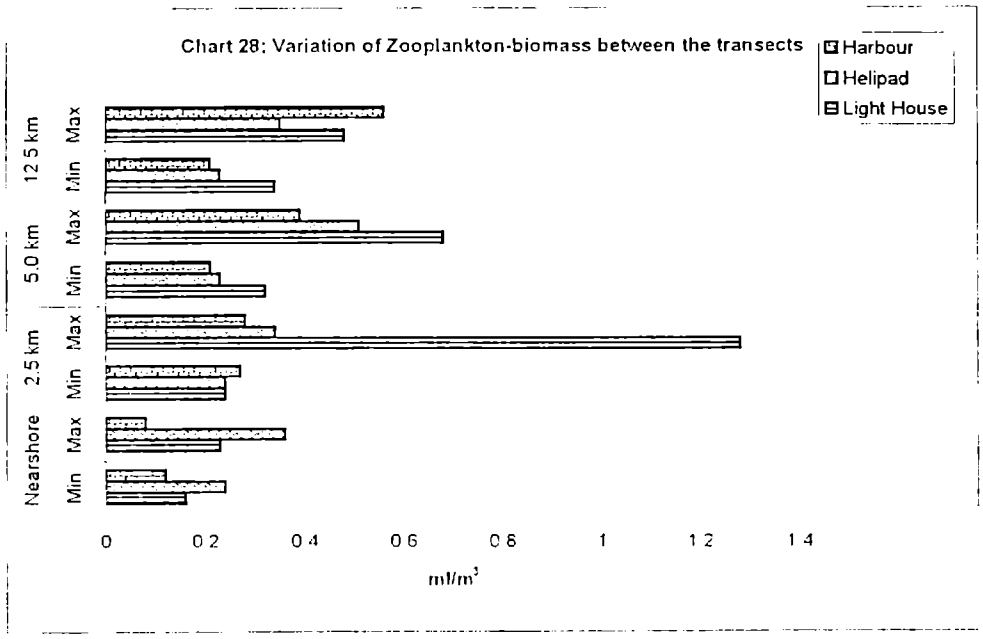
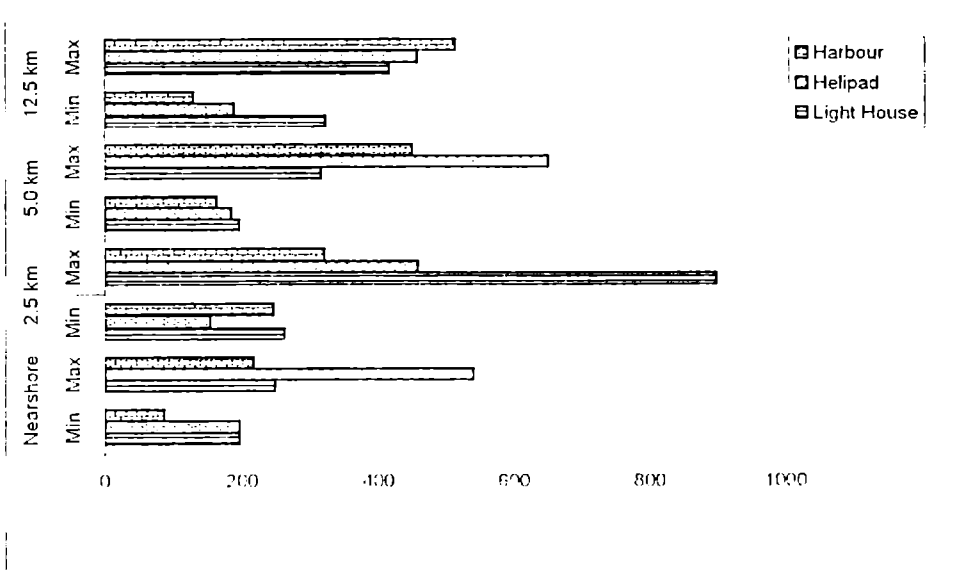


Chart 29: Variation of Zooplankton Density between the transects



fish eggs and fish larvae were the prominent zooplankton groups, though cladocera, amphipoda, appendicularia, doliolids and pteropoda were occasionally noticed. It was observed that, irrespective of seasons and stations, copepods were the dominant groups among the zooplankton community in which calanoid copepods contributed the maximum. Direct relationship was obtained between species diversity of copepods and zooplankton biomass. Similar observation was reported by Goswami, (1979) from Kavaratti atoll. Comparatively, high zooplankton biomass in correlation with density was noted during the gradual elevation of salinity regime (premonsoon) (Chart-16). The present study indicates minor variations in the distribution and biomass of planktonic groups in the Lakshadweep sea from February/March to October/November and the difference can be attributed to changes in physico-chemical characteristics such as salinity, temperature, DO, tides etc. However, high zooplankton count in near shore region of helipad with low phytoplankton abundance illustrates its coprophagic feeding habit. Goes *et al.*, (1999) observed such a phenomenon in a tropical marine system (Arabian Sea). This indicates that the zooplankton derive nutrition from sources other than phytoplankton. The alternative source identified might have been organic aggregates whose abundance in reef waters is of much ecological significance (Qasim and Sankaranarayanan, 1970).

Inter-relationship between primary producers and herbivores (Chart 22-24)

In the present study, interrelationship between primary producers and consumers in the system was observed. At helipad, during 1997 – 1998, a reciprocal relationship between phytoplankton standing stock and zooplankton count appeared which might have been due to rapid grazing behaviour of zooplankton. When, there was a rapid increase in the abundance of phytoplankton, count and biomass of zooplankton decreased and when the copepods and other members of zooplankton were reaching high densities, the phytoplankton tend to be decreased. However, as the crop of zooplankton declined, the plant population was found to rise again as during post monsoon 1998. However, at lighthouse, the general trend in relationship showed that, phytoplankton abundance always tend to be high, except during 1998, where high density of zooplankton reported, might have been due to the dominance of detritus feeding and carnivorous zooplankton. Similar

observation was made by Raymont (1967) in the behavioral and feeding habits of plant and animal planktons from the Indian Ocean.

3.1.2 Physico-chemical parameters (Table 12-14 & Chart 30-66)

Lighthouse transect

The water temperature varied from 28.2°C at 5 km to 29.9°C at 12.5 km during 1996, 28.8°C at 12.5 km to 29.8°C at near shore during 1997, 30.1°C at near shore to 31°C at 12.5 km during 1998 and 27.8°C at near shore and 12.5 to 28.1 °C at 5 km during post monsoon 1998. pH varied from 8.11 at nearshore to 8.32 at 5.0 km during 1996, 8.0 at 5.0 km to 8.4 at 12.5 and 12.5 km during 1997, 8.12 at 2.5 km to 8.31 at all other stations except 2.5 km during pre-monsoon 1998 and 8.2 at nearshore to 8.32 at 2.5 km stations during post monsoon 1998. Salinity fluctuated from 1 ppt at 12.5 km offshore to 35.4 ppt at 5.0 km during 1996, 35.12 ppt to 35.6 ppt during 1997, 35.12 ppt at 12.5 km offshore to 35.16 ppt at the nearshore and 5.0 km during 1998 and 34.8 ppt at 2.5 and 5.0 km to 35.4 ppt at nearshore during post monsoon 1998.

Lowest TSS concentration (3.8mg/l) was recorded at 12.5 km offshore whereas the highest value (4.5mg/l) was recorded at 2.5km station during 1996. During 1997, the minimum (3.3 mg/l) value was recorded from 2.5 km station and the maximum value (6.4mg/l) from the near shore. During pre monsoon 1998, it ranged from 3.5 mg/l at 12.5 km offshore station to 5.8mg/l at the near shore and 2.9 mg/l at 12.5 km to 10.8 mg/l at nearshore during post monsoon 1998. DO content broadly varied from 3.32mg/l at near shore during 1997 to 5.89mg/l in 12.5 km during 1996. Inorganic phosphate concentration ranged from 0.35µmol/l at 5.0km offshore to 0.98µmol/l at 2.5 km during 1996. During 1997, the offshore sample recorded minimum value (0.64µmol/l) and the 2.5km sample recorded the maximum value (0.72 µmol/l). During pre monsoon 1998, 2.5km station recorded the minimum value (0.58µmol/l) whereas the maximum value (0.98µmol/l) was recorded from the nearshore. During post monsoon 1998, it ranged from 0.53µmol/l at 5km offshore to 1.2µmol/l at the near shore. During 1996, the lowest silicate concentration (2.88µmol/l) was recorded from 5 km when the highest (5.82µmol/l) value was reported from the nearshore, 5.64µmol/l (12.5 km) to 6.84µmol/l (2.5 km) during 1997, 5.45µmol/l

(near shore) to 6.24μmol/l (2.5 km) during pre monsoon 1998 and 3.14μmol/l (5 km) to 8.24 μmol (near shore) during the post monsoon 1998. Total phosphorus concentration was maximum (1.64 μmol/l) at 12.5 km and minimum (1.14μmol/l) at near shore sample during 1996. During 1997 also, the highest value (1.64μmol/l) was at the near shore, but the minimum value (1.1μmol/l) at the 12.5 km offshore. During 1998, 2.5km station recorded the highest value (2.02μmol/l) while, the lowest concentration (1.21μmol/l) was at the near shore. During post monsoon also, 2.5km showed the highest value (2.02μmol/l) when 12.5 km offshore recorded the lowest (1.2μmol/l). Ammonia ranged from 0.021μmol/l at 12.5km to 0.084μmol/l at the near shore during 1996, 0.006μmol/l from 12.5km Station to 0.045μmol/l at near shore during 1997 0.008 μmol/l at 12.5 km offshore to 0.095 μmol/l at nearshore during pre monsoon 1998 and 0.022μmol/l at 2.5 km station to 0.094 μmol/l at 12.5km station during post monsoon 1998.

During 1996, Nitrite value fluctuated from 0.03μmol/l at the near shore to 0.21μmol/l at 2.5 km. During 1997, it varied from 0.012 at 5.0 km to 0.34μmol/l at 2.5 km. The minimum value (0.04μmol/l) was recorded from 5.0 km station and the maximum (0.28μmol/l) from near shore during 1998. During post monsoon 1998, the nearshore recorded the highest value (0.31μmol/l) when 5 km station recorded the lowest (0.03 μmol/l). During 1996, nitrate showed the minimum concentration (0.58 μmol/l) at 5km while the maximum value (1.8 μmol/l) was estimated from 2.5km station. During 1997, 2.5km reported the lowest value (0.54μmol/l) while 5.0 and 12.5km stations reported the highest value (2.3μmol/l). It varied from 1.14μmol/l at near shore to 2.5μmol/l at 5km and 12.5 km during 1998 and 0.52μmol/l at 12.5 km to 1.54μmol/l at near shore during post monsoon 1998. Total-N concentration fluctuated from 2.56μmol/l at 5.0 and 12.5 km offshore stations to 5.21μmol/l at near shore station during 1996, 2.3 at offshore to 5.19 μmol/l at 2.5km during 1997. The values ranged from 2.73 at offshore to 3.76μmol/l at near shore during pre monsoon 1998 and 1.92μmol/l at 5 km offshore to 4.64μmol/l at nearshore during post monsoon 1998.

BOD value fluctuated from 0.91mg/l at 5km offshore to 1.23mg/l at near shore during 1996, 0.68mg/l at 2.5km to 1 14mg/l at 12.5 km during 1997, from 0.84 mg/l (12.5 km) to 1.21mg/l (near shore) during pre monsoon 1998 and 0.82mg/l (2.5 km) to 1.32mg/l (near shore) during post monsoon 1998. PHC varied from 2.25µg/l at 5.0 km to 4.16 µg/l at 12.5 km. during 1996. It varied from 1.5 (5.0 km) to 4.53 µg/l (2.5 km) during 1997, 2.4 µg/l (5.0 km) to 6.49 µg/l (2.5 km) during 1998 and 3.29 µg/l (12.5 km) to 5.22 µg/l (2.5 km) during post monsoon 1998. Dissolved Cd value varied from 0.21 ppb at 12.5 km station and nearshore to 0.31 ppb at 5.0 km during 1996, 0.12 ppb at 12.5 km to 0.30 ppb at 2.5 km during 1997, 0.28 ppb at 2.5 km to 0. 4 ppb at 5.0 km station during 1998 and 0.23 ppb at 5.0 km to 0.34 ppb at nearshore station during post monsoon 1998. Concentration of Pb in sea water fluctuated from 1 15 ppb at 5.0 km to 1.67 ppb at nearshore during 1996, 1.16 ppb at 12.5 km to 1.83 ppb at nearshore during 1997, 1.05 ppb at 12.5 km to 1.31 ppb at nearshore during 1998 and 1.36 ppb at 2.5 km to 1.88 ppb at nearshore during post monsoon 1998. Dissolved Hg varied from 32 ng/l at all stations during 1996, 34 ng/l recorded at all stations except nearshore where the value was 35 ng/l at nearshore during 1997, 32 ng/l at 2.5 km to 38 ng/l at nearshore during 1998 and 31 ng/l at 2.5 km to 40 ng/l at 12.5 km during post monsoon 1998.

Helipad transect

Water temperature varied from 28.6°C at near shore to 29°C at 2.5 km during 1996, 29.8°C at 5 km offshore to 30.2°C at 2.5 km during 1997, 29.8°C at 2.5 km to 30.8°C at near shore during pre monsoon 1998 and 28.1°C at 2.5 km to 28.5°C at 5.0 km during post monsoon 1998. pH varied from 8.01 at 2.5 km to 8.5 at nearshore during 1996, 8.03 at 2.5 km to 8.40 at 5.0 km during 1997, 8.10 at 12.5 km to 8.36 at 5.0 km station during 1998 and 8.14 at 2.5 km and 12.5 km to 8.28 at 5.0 km station during post-monsoon 1998. Salinity varied from 35.1 ppt at the nearshore to 35.4 ppt at 12.5 km offshore during 1996, 35.2 ppt at 5.0 km to 35.89 ppt at 2.5 km during 1997, 35.3 ppt at 5.0 km to 36.1 ppt at 2.5 km during pre-monsoon 1998 and 35.1 ppt at 12.5 km offshore to 35.2 ppt at nearshore as well as 5.0 km station during post monsoon 1998. TSS varied from 3.78 at 12.5 km to 4. 8 mg/l at nearshore during 1996 when it varied from 2.9 mg/l at 12.5 km offshore to 4.1 mg/l

at 5.0 km station during 1997 During 1998, it varied from 3.8 mg/l at 2.5 km to 5.5 mg/l at the nearshore and 2.92 mg/l at 12.5 offshore to 6.4 mg/l at nearshore.

Dissolved Oxygen varied from 4.8 mg/l (nearshore) to 5.78 mg/l (12.5 km offshore) during 1996 and 4.32 mg/l (nearshore) to 5.11 mg/l (12.5 km) during 1997 During 1998, it varied from 4.3 mg/l at the nearshore to 4.92 mg/l at 12.5 km and from 4.6 mg/l at 5.0km to 5.12 mg/l at 12.5 km during post monsoon 1998. Inorganic phosphate varied from 0.5 µmol/l at 12.5 km to 1.02 µmol/l at the nearshore during 1996, 0.59 µmol/l at 12.5 km to 0.95 µmol/l at nearshore during 1997. 0.65 µmol/l at 12.5 km to 0.95 µmol/l at 2.5 km station during 1998 and 0.64 µmol/l at 12.5 km to 0.94 µmol/l at 5.0 km station during post monsoon 1998. Silicate value fluctuated from 3.87 µmol/l at 5.0 km to 6.25 µmol/l at nearshore during 1996, 5.69 µmol/l at 12.5 km to 6.8 µmol l at 2.5 km during 1997, 6.23 µmol/l at 5.0 km to 6.26 µmol/l at 2.5 km during 1998 and 3.56 µmol/l at the 12.5 km offshore to 6.52 µmol/l at the nearshore during post monsoon 1998. Total phosphorus ranged from 1.02 µmol/l at the 12.5 km offshore to 2.2 µmol/l at 2.5 km during 1996, 1.14 µmol/l at 12.5 km to 1.84 µmol/l at the nearshore during 1997, 1.54 µmol/l at near shore to 1.84 µmol/l at 2.5 km during 1998 and 1.64 µmol/l at 2.5 km to 1.68 µmol/l at 5.0 km station during post monsoon 1998. Ammonia concentration in sea water during 1996 ranged from 0.012 µmol/l at 2.5 km to 0.03 µmol/l at nearshore, 0.024 µmol/l at nearshore to 0.05 µmol/l at 5.0 km during 1997, 0.012 µmol/l at 12.5 km to 0.03 µmol/l at nearshore and 2.5 km during 1998 and 0.014 µmol/l at 2.5 km station to 0.04 µmol/l at near shore during post monsoon 1998.

Nitrite –N values varied from 0.10µmol/l at 12.5 km to 0.36µmol/l at nearshore during 1996 and during 1997, it ranged from nil at 12.5 km to 0.4µmol/l at nearshore. During 1998, it ranged from 0.06µmol/l at 5.0 km to 0.32µmol/l at near shore. During post monsoon 1998, value ranged from 0.14 µmol/l at near shore, 5.0 km and 12.5 km to 0.31 µmol/l at 2.5 km. Nitrate-N concentration in sea water varied from 0.98 µmol/l at 2.5 km station to 3.14 µmol/l at nearshore during 1996, 0.48 µmol/l at 5.0 km station to 2.65 µmol/l at nearshore during 1997, 0.69 µmol/l at 5.0 km to 2.36 µmol/l at 12.5 km offshore

during 1998 and 0.89 µmol/l at 12.5 km station to 3.12 µmol/l at nearshore during post monsoon 1998. Total nitrogen in sea water varied from 2.36 µmol/l at 5.0km to 4.12 µmol/l at near shore station during 1996, 2.65 µmol/l at 5.0 km to 4.23 µmol/l at 12.5 km during 1997, 2.25 µmol/l at 12.5 km station to 4.45 µmol/l at the nearshore during 1998 and from 1.45 µmol/l at 12.5 km to 4.12 µmol/l at near shore station during post monsoon 1998.

BOD fluctuated from 0.51 mg/l at near shore to 0.95 µmol/l at 2.5 km during 1996, 0.68 µmol/l near shore to 0.87 µmol/l at 12.5 km during 1997 0.68 µmol/l at 2.5 km and 5.0 km to 0.88 µmol/l at the nearshore during 1998 and 0.89 µmol/l at near shore during post monsoon 1998. PHC ranged from 2.56µg/l at 5.0 km station 3.65 µg/l at the 12.5km during 1996, 2.47µg/l at 5km to 3.41µg/l at near shore during 1997, 3.45µg/l at near shore and 5 km to 5.12 µg/l at 12.5km during pre monsoon 1998 and 3.24µg/l at 5km to 5.42µg/l at 12.5 km during post monsoon 1998. The dissolved cadmium concentration varied from 0.12 ppb at near shore to 0.18ppb at 5 km during 1996, 0.14 at 2.5km to 0.24 ppb at near shore and 5km during 1997, 0.13 at near shore to 0.16ppb at 2.5km during pre monsoon 1998 and 0.14ppb at near shore to 0.26 ppb at 12.5km during post monsoon 1998. The dissolved lead concentration varied from 0.87 ppb at 5 km to 1.47ppb at 12.5km during 1996, 1.14ppb at 5 km to 1.4ppb at 5.0 km during 1997, 0.96 ppb at near shore to 1.98ppb at 12.5 km during pre monsoon 1998 and 1.1ppb at 2.5km to 1.23ppb at 5 km during post monsoon 1998.

Harbour transect

Water temperature ranged from 28.7°C at the 5.0 km to 29.3°C at nearshore during 1996, 29.9°C at 5km to 30.2°C at nearshore during 1997, 30.1°C at nearshore to 30.2°C at other stations during pre monsoon 1998 and 28.3°C at the nearshore and 5.0 km to 28.5°C at 2.5km during post monsoon 1998. pH varied from 8.12 at 12.5 km offshore to 8.21 at 5 km during 1996, 8.2 at nearshore to 8.30 at 5 km during 1997, 8.18 at 2.5 km to 8.35 at 5.0 km during pre-monsoon 1998 and 7.8 at nearshore to 8.24 at 12.5 km offshore during post monsoon 1998. Salinity fluctuated from 34.5 ppt at nearshore and 35.6 ppt at 12.5 km during 1996, 35.1 ppt at 2.5 km to 35.4 ppt at nearshore during 1997, 35.1 ppt at nearshore

to 35.4 ppt at 2.5 and 5.0 km during 1998 and 3.1 8 ppt at the nearshore to 35.3 ppt at 5.0 km station during post monsoon 1998. TSS ranged from 3.2mg/l at 12.5km the near shore to 8.7mg/l at near shore during 1996. 2.8mg/l at the 12.5km Station to 12.5mg/l at the near shore during 1997, from 2.4mg/l at the 12.5km to 14.5mg/l at the nearshore during pre monsoon 1998 and 2.1mg/l at the nearshore to 18.7mg/l at the near shore during post monsoon 1998.

DO varied from 3.1mg/l at the nearshore to 5.24mg/l at 12.5km during 1996, 2.98mg/l at near shore to 5.5mg/l at 12.5km during 1997, 3.8 mg/l at near shore to 5.2mg/l during pre monsoon 1998 and 2.8mg/l at the nearshore to 4.82mg/l at 5.0km during post monsoon 1998. Inorganic phosphate concentration in water samples varied from 0.63µmol/l at 12.5km to 1.85µmol/l at nearshore during 1996. from 0.48µmol/l at 12.5km to 2.58µmol/l at the nearshore during 1997 0.62µmol/l at the nearshore to 3.05µmol/l at the near shore during pre monsoon 1998 and 0.54µmol/l at offshore to 4.26µmol/l at the near shore during post monsoon 1998. Total phosphorus varied from 0.98µmol/l at 5km to 1.88µmol/l at the near shore during 1996, 1.12µmol/l at the 12.5km Station to 2.98µmol/l at the near shore during 1997, 1.42 µmol/l at 5km to 3.41µmol/l at near shore station during pre monsoon 1998 and 0.99µmol/l at the 12.5 km to 4.65 µmol/l at the near shore during post monsoon 1998. Silicate values varied from 4.23 µmol/l at 12.5km to 6.22 µmol/l at 2.5km during 1996, 6.02 µmol/l at 2.5km to 6.45 µmol/l at 12.5km Station during 1997, 5.1 µmol/l at 2.5km to 7.2µmol/l at 5km during pre monsoon 1998 and 4.11µmol/l at 5km to 7.22µmol/l at the nearshore during post monsoon 1998. Nitrite nitrogen varied from 0.23µmol/l at the nearshore to 0.62 µmol/l at 12.5km during 1996, from 0.3 µmol/l at nearshore to 0.7 µmol/l at the 5km during 1997, 0.07µmol/l at off shore to 0.6 µmol/l at near shore during pre monsoon 1998 and 0.08 at 12.5km to 1.2 µmol/l at near shore during post monsoon 1998. Nitrate nitrogen varied from 0.95µmol/l at the 12.5km to 2.17µmol/l at near shore during 1996, 1.2 µmol/l at 12.5km to 3.41µmol/l at the 5km offshore during 1997, 2.1µmol/l at 12.5km to 3.52µmol/l at the near shore during pre monsoon 1998 and 1.1 at 2.5km to 3.42µmol/l at the near shore during post monsoon 1998. Ammonia nitrogen showed a fluctuation of 0.024µmol/l at the 12.5km to 0.11µmol/l at near shore during 1996,

0.022 µmol/l at 5km and 12.5km station to 0.098µmol/l at near shore during 1997, 0.024 µmol/l at 5km and 12.5km Station stations to 0.21µmol/l at near shore during pre monsoon 1998 and 0.032 µmol/l at 2.5km and 5km to 0.21 µmol/l at near shore during post monsoon 1998. Total nitrogen concentration varied from 2.54µmol/l at 5km to 4.28µmol/l at 2.5km during 1996, 2.11µmol/l at 12.5km to 4.32µmol/l at 5km during 1997, 2.25 µmol/l at 12.5km to 4.51µmol/l at the near shore during pre monsoon 1998 and 2.11µmol/l at 5km to 4.2 µmol/l at the near shore during post monsoon 1998. BOD values ranged from 0.64µmol/l at 12.5km to 1.22mg/l at the near shore during 1996, 0.61mg/l at 12.5km to 1.31mg/l at the nearshore during 1997, 0.89mg/l at 12.5km Station to 1.25 mg/l at nearshore during pre monsoon 1998 and 0.58mg/l at 12.5km to 1.32mg/l at near shore during post monsoon 1998. Petroleum hydrocarbon varied from 3.09µg/l at near shore to 4.52µg/l at 12.5km during 1996, 2.65 µg/l at 5km to 4.64 µg/l near shore during 1997, 2.82 µg/l at 5km offshore to 5.54 µg/l at 12.5 km during pre monsoon 1998 and 3.63 µg/l at 5km to 7.5 µg/l at the 12.5km station during post monsoon 1998. Dissolved concentration of Cadmium varied from 0.12 ppb at 12.5km to 0.24 ppb at 2.5km during 1996, 0.12 ppb at nearshore to 0.29ppb at 12.5km Station during 1997, 0.14ppb at 2.5km to 0.31ppb at 12.5km during pre monsoon 1998 and 0.16ppb at 12.5km to 0.35ppb at 2.5km during post monsoon 1998. Dissolved Pb varied from 1.15ppb at 5km to 1.3ppb at 2.5km during 1996, 1.25ppb at 2.5km to 1.57 ppb at 5km during 1997, 1.42ppb at near shore to 1.67 ppb at 12.5km during pre monsoon 1998 and 1.58 ppb at nearshore to 2.85 ppb at near shore during post monsoon 1998. Dissolved Hg varied from 25ng/l at 2.5km to 35ng/l at the near shore in 1996, 26ng/l at 12.5km to 32ng/l at the near shore during 1997, 24ng/l at 12.5km station to 32ng/l at near shore during pre monsoon 1998 and 27ng/l at near shore to 32ng/l at 2.5km during post monsoon 1998.

Discussion

Water temperature broadly varied from 27.8°C (light house near and offshore) during post monsoon 1998 to 31.2°C (12.5km off shore of harbour transect) during pre monsoon 1998. This indicates that seawater temperature becomes slightly high during pre-monsoon period though the variation is insignificant. Mathew and Gopakumar (1986) also noticed the

surface temperature in the range of 28-31°C at Minicoy island. The high temperature recorded may be attributed to high atmospheric heat and poor inflow of oceanic waters from outside causing maximum saturation with the water. Bhattathiri (1987) found that surface temperature in the Laccadive Sea during October, December and March had a narrow range. Girijavallabhavan *et al.* (1987) also reported high temperature during March from the Kavaratti lagoon area. The trend showed that there was a narrow increase in surface water temperature from 1996 to pre monsoon 1998 and the pattern showed that there was not much variation between transects and seasons. Generally, there was a slight increase in water temperature from nearshore to offshore region (up to 12.5 km) in all transects. Variation in pH (8.03 to 8.4) showed that there was no significant difference in pH values observed between stations and transects. This may be attributed to the absence of a point source of fresh water in the island.

Salinity ranged between 34.5 ppt during post monsoon and 36.1 ppt during premonsoon and did not show much spatial or temporal variation. Comparative high values during premonsoon might be due to evaporation and vertical mixing of surface waters with subsurface high saline waters whereas mixing with south west monsoon might have been caused low salinity during post monsoon. Studies conducted by Sankaranarayanan (1973) also reported similar observation and that the range of diurnal changes in the salinity values was within 0.16.

Total suspended solids varied broadly from 2.1mg/l at helipad transect (12.5km) during post monsoon 1998 to 18.7mg/l at nearshore of harbour transect during post monsoon 1998 indicating a sharp increase over the years. Correlation coefficient (Table-14a) interpreted that TSS inversely correlated with DO ($r = -0.671$). The sharp increase at harbour transect might be due to the break water construction activities carried out during the period. Barring this observation, TSS at all other stations did not exhibit any variability.

DO was in the order of 2.8 mg/l at near shore of harbour transect during post monsoon 1998 to 5.89mg/l at 12.5 station during post monsoon 1996 at light house transect. A low DO (2.8 ml/l) over the period of study was observed at harbour near shore. Break water construction at harbour area over the period might have been loaded high suspended solids.

Change in the concentrations of DO was due to water movements, circulation and mixing and effect of active photosynthesis by phytoplankton, seaweeds and sea grass. Girijavallabhan *et al.*, (1987) reported similar trend in DO (2ml to 6ml/l) from Kavaratti island. BOD values in the present study showed little variation except an occasional increase in the near shore waters of helipad and harbour transects, which might be due to the disposal of untreated domestic wastes. Inverse correlation (r 0.605) between BOD and DO demonstrates the rapid consumption of dissolved oxygen by aerobic bacterial population (Table -14a). Low oxygen values and the associated high nutrient levels at the nearshore are indicative of active regeneration processes leading to consumption of oxygen.

The significance of nutrients in the sea, especially of nitrates, phosphates and silicates was well recognized in understanding the diversity exhibited in the distribution of marine population in space and time and also in characterizing the water masses and their movements in conjunction with other physical oceanographic parameters. The degree of enrichments of nutrients varied from year to year and station to station. The nutrient concentrations in the near shore stations were relatively less affected by different seasons as compared with the offshore waters. These concentrations were generally high, possibly due to the rapid regeneration of nutrients by the bacterial oxidation and chemical decomposition. Further, at offshore there was a marked variation in the nutrient levels seasonally. The observed low nutrient levels in the offshore region as compared with near shore region might be due to the fact that consumption exceeds regeneration and lack of active replenishment of nutrients (Reddy and Sankaranarayanan, 1968). However, in near shore region the contrary is true. The ratio between nutrients such as silicate, NO_3 and PO_4 in the present study was highly variable. This variation may presumably be due to the differential and rapid rates of regeneration and consumption of the nutrients.

Significant variation in inorganic phosphate (0.35µmol/l to 4.26µmol/l) at harbour nearshore was observed and in general, high values were recorded during premonsoon season irrespective of transects. From the nearshore stations, the concentration was found to be decreasing towards offshore. Low phosphate in light house and helipad transects might possibly be due to low input, run off and active consumption by benthic algae. Similar

observation in Lakshadweep was made by Sankaranarayanan (1973). Mc Roy and Barsdate (1970) also reported the absorption of phosphate by Eel grass (*Zostera marina*). The inorganic phosphorus and the total phosphorus content of these waters showed that much of the phosphors present were organically bound (65- 98 %). The lower concentration of inorganic phosphate may possibly be due to active uptake by the macrophytes and phytoplankton in the system. The distribution of total phosphorus in waters showed that much of the phosphate was organically bound. Broadly, it varied from 0.98 µmol/l at helipad during 1996 to 4.65µmol/l in harbour near shore during 1998 post monsoon.

The silicate concentration in water varied from 2.88µmol^{-1} at 5.0km station (Light house) during 1996 to 8.24 µmol/l in the nearshore waters of light house during post monsoon 1998. Low value in surface waters may be attributed to the effective utilization of nutrients by diatoms. An inverse correlation (r 0.162) of chl-*a* with silicate was reported at the study area agrees with the inference (Table- 14a). Sengupta *et al.*, (1979) reported silicate values between 0 and 35 µg/l in Lakshadweep waters.

Nitrite nitrogen varied broadly from 0.012µmol/l at light house (1997) to 1.2µmol/l at harbour nearshore (1998). Seasonal variation showed that the concentration was high during pre monsoon seasons of 1997 and 1998 compared to post monsoon season. Correlation coefficient of physicochemical parameters (Table-14a) demonstrated high positive loading of NO_2-N and moderate negative loading of pH, DO and NH_4-N indicating oxidation of ammonia to nitrite or formation of nitrite in the process of remineralisation of organically bound material. Values of ammonia varied from 0.006 µmol/l (lighthouse 12.5km) during 1997 to 0.21µmol/l (harbour nearshore) during 1998. Though, low concentration was noticed at offshore waters, presence of excess ammonia in harbour nearshore indicated high anthropogenic input. However, in general, moderate concentrations were observed along the nearshore except that at harbour. Correlation factor accounts for high to moderate negative loading of DO, BOD, pH and NH_4-N. This factor depicts remineralisation sources of nitrite and can be identified as oxidation factor (Table-14a). Sengupta *et al.*, (1975) reported that ammonia was normally low at Arabian Sea, but

occasional high values due to precipitation or fixation of nitrogen by blue green algae may be noticed.

Nitrate-nitrogen fluctuated from 0.48µmol/l from 5km station of helipad transect during pre monsoon, 1997 to 3.52µmol/l at near shore of harbour transect during premonsoon, 1998. The concentration was low at offshore waters and high at nearshore stations (especially at harbour and helipad transects). The nutrient utilization by plankton and sea grass at harbour nearshore might be compensated with high input of organic waste or the decomposition of organisms itself. Present study showed that harbour waters are characterized by high proportions of inorganic nutrients due to inputs of more biodegradable waste materials as a symptom of urbanization. Correlation coefficient (Table-14a) of physicochemical parameters demonstrated that high positive loading of NO_3-N, NH_4-N and PO_4-P among themselves reported at the nearshore waters indicated their common sources of occurrence and high input of biodegradable wastes. However, the low values in the offshore areas indicated the effective utilization of nutrients by the producers. Seasonal distribution showed high values during premonsoon season and comparatively, low values during post monsoon season attributed to the mixing and dilution and effective uptake and rapid proliferation of plant planktons. Sengupta *et al* (1979) reported nitrate nitrogen values up to 4.21 µg/l in Lakshadweep waters. Wafar *et al* (1986) conducted similar studies relating the nitrogenous nutrients and primary production in tropical oceanic Lakshadweep waters and reported that inorganic nitrogen counted for less than 10% when dissolved organic nitrogen (DON) for more than 90% of the total nitrogen in the euphotic zone. They have shown that addition of nitrate, ammonia and urea as nitrogen source stimulated carbon fixation at all depths and this together with ambient concentration of inorganic nitrogen compounds, demonstrated that phytoplankton in these waters are nitrogen limited. Nitrates disappeared totally from the surface layers while phosphate was present always in a measurable quantity. So, nitrate was found to have a stronger influence than phosphate regulating primary productivity. Sastry and D' Souza (1972) also reported that the surface layer in the Arabian Sea was nutrient depleted during south-west monsoon season. In the present study, the nitrate concentration at surface waters fluctuated seasonally and the decrease observed at offshore stations of helipad and lighthouse transects reciprocally

Table 12 - Physico-chemical characteristics of surface waters at Lighthouse transect; 1996 -1998

Parameters	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)
	NEARSHORE				2.5KM				5.0KM				12.5KM			
Water temp (°C)	28.3	29.8	30.1	27.8	28.2	29.7	30.5	27.9	28.5	29.5	30.9	28.1	29.9	28.8	31	27.8
pH	8.11	8.12	8.31	8.23	8.24	8.24	8.12	8.32	8.32	8.16	8.31	8.26	8.21	8.24	8.31	8.21
Salinity (ppt)	35.12	35.24	35.16	35.4	35.24	35.12	35.14	34.8	35.4	35.17	35.16	34.8	35.1	35.6	35.12	35.0
TSS (mg/l)	4.2	6.4	5.8	10.8	4.5	3.3	5.6	6.9	4.2	3.6	5.5	4.8	3.8	3.4	3.5	2.9
DO (mg/l)	3.45	3.32	3.62	3.34	4.4	4.6	4.7	4.85	5.42	5.12	5.8	4.8	5.89	4.88	5.2	5.1
In. PO_4 (µmol/l)	0.58	0.71	0.98	1.2	0.98	0.72	0.58	0.54	0.35	0.65	0.85	0.53	0.39	0.64	0.85	0.54
Silicate (µmol l)	5.82	6.25	5.45	8.24	5.8	6.84	6.24	4.64	2.88	6.24	6.2	3.14	4.98	5.64	6.20	4.68
Total Phosphorus (µmol/l)	1.14	1.64	1.21	1.54	1.46	1.24	2.02	2.02	1.32	1.24	1.64	1.66	1.64	1.1	1.52	1.2
Ammonia (µmol l)	0.084	0.045	0.095	0.054	0.042	0.022	0.026	0.022	0.022	0.021	0.021	0.042	0.021	0.006	0.008	0.094
Nitrite-N (µmol l)	0.03	0.32	0. 28	0.31	0.21	0.34	0.25	0.06	0.05	0.012	0.04	0.03	0.12	0.12	0.2	0.4
Nitrate-N (µmol l)	1.62	1.35	1.14	1.54	1.8	0.54	1.4	1.4	0.58	2..3	2..5	0.87	0.85	2.3	2..5	0.52
Total -N (µmol l)	5.21	2.52	3.76	4.64	3.16	5.19	3.82	2.54	2.56	2.3	2.94	1.92	2.56	3.4	2.73	2.4
BOD (mg/l)	1.23	1.11	1.21	1.32	1.0	0.68	0.94	0.82	0.91	0.85	0.96	0.87	0.93	1.14	0.84	0.96
PHC (µg/l)	3.56	3.25	3.74	4.71	3.17	4.53	6.49	5.22	2.25	1.5	2.4	3.5	4.16	3.1	3.63	3.29
Dissolved Cd (ppb)	0.21	0.24	0.31	0.34	0.24	0.3	0.28	0.31	0.31	0.27	0.4	0.23	0.21	0.12	0.3	0.24
Dissolved Pb(ppb)	1.67	1.83	1.31	1.88	1.26	1.61	1.17	1.36	1.15	1.34	1.17	1.43	1.5	1.16	1.05	1.65
Dissolved Hg (ng l)	32	35	38	35	32	34	32	31	32.	34	35	36	32	34	36	40

Table 13 - Physico-chemical characteristics of surface waters at Helipad transect; 1996 -1998

Parameters	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)
	NEARSHORE				2.5KM				5.0KM				12.5KM			
Water temp (°C)	28.6	30.1	30.8	28.3	29	30.2	29.8	28.1	28.8	29.8	30	28.5	28.7	29.9	30.2	28.3
pH	8.24	8.26	8.12	8.21	8.13	8.03	8.18	8.14	8.15	8.40	8.36	8.28	8.35	8.11	8.10	8.14
Salinity (ppt)	35.1	35.8	35.86	35.2	35.2	35.89	36.1	35.12	35.12	35.2	35...	35.2	35.4	35.86	35.87	35.1
TSS (mg/l)	4.8	3.9	5.5	6.4	3.8	3.6	3.8	5.1	4.08	4.1	4.2	3.09	3.78	2.9	4.1	2.92
DO (mg/l)	4.8	4.32	4.3	4.8	5.16	4.58	4.46	4.98	5.23	4.6	4.89	4.6	5.78	5.11	4.92	5.12
In. PO_4 (µmol/l)	1.02	0.95	0.92	0.85	0.64	0.68	0.95	0.85	0.68	0.67	0.82	0.94	0.5	0.59	0.65	0.64
Silicate (µmol/l)	6.25	5.98	6.24	6.52	6.24	6.8	6.26	4.78	3.87	5.98	6.2...	5.68	4.51	5.69	6.24	3.56
Total Phosphorus (µmol/l)	1.55	1.84	1.54	1.66	2.2	1.62	1.84	1.64	1.64	1.24	1.54	1.68	1.02	1.14	1.68	1.65
Ammonia (µmol/l)	0.03	0.024	0.03	0.04	0.012	0.032	0.03	0.014	0.023	0.05	0.021	0.021	0.025	0.032	0.012	0.023
Nitrite-N (µmol/l)	0.36	0.4	0.32	0.14	0.3	0.12	0.25	0.31	0.12	0.2	0.06	0.14	0.10	ND	0.21	0.14
Nitrate-N (µmol/l)	3.14	2.65	2.0	3.12	1.8	2.01	2.3	1.54	0.98	0.48	0.69	1.04	1.36	2.23	2.36	0.89
Total -N (µmol/l)	4.12	3.58	4.45	4.12	2.85	2.69	3.14	2.58	2.36	2.65	2.47	3.14	2.58	4.23	2.25	1.45
BOD (mg/l)	0.51	0.68	0.88	0.89	0.95	0.84	0.68	0.65	0.94	0.84	0.68	0.68	0.78	0.87	0.72	0.65
PHC (µg/l)	3.24	3.36	3.45	3..34	3.47	2.58	4.21	3.58	2.56	2.47	3.45	3.24	3.65	3.41	5.12	5.42
Dissolved Cd (ppb)	0.12	0.24	0.13	0.17	0.16	0.14	0.16	0.15	0.18	0.24	0.13	0.14	0.16	0.15	0.14	0.26
Dissolved Pb(ppb)	1.26	1.35	0.96	1.13	1.23	1.14	1.63	1.1	0.87	1.4	1.10	1.23	1.47	1.26	1.98	1.20
Dissolved Hg (ng/l)	26	30	28	30	27	40	38	32	27	35	34	38	36	40	36	32

Table 14 - Physico-chemical characteristics of surface waters at Harbour Transect; 1996 -1998

Parameters	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)	1996	1997	1998	1998 (post)
	NEARSHORE				2.5KM				5.0KM				12.5KM			
Water temp (°C)	29.3	30.2	30.1	28.3	29.1	30.1	30.2	28.5	28.7	29.9	30.2	28.3	28.9	30.1	31.2	28.4
pH	8.16	8.2	8.26	8.18	8.2	8.22	8.18	8.2	8.21	8.3	8.35	8.24	8..12	8.26	8.22	8.24
Salinity	34.5	35.4	35.1	34.8	35.4	35.1	35.4	35.2	35.12	35.12	35.4	35.3	35.6	35.14	35.24	35.12
TSS (mg/l)	8.7	12.5	14.5	18.7	5.3	10.5	12.3	14.1	3.65	3.7	4.7	5.8	3.2	2.8	2.4	2.1
DO (mg/l)	3.1	2.98	3.8	2.8	4.8	4.9	4.7	3.1	5.2	5.2	4.38	4.82	5.24	5.5	5.2	4.58
In. PO_4 (µmol/l)	1.85	2.58	3.05	4.26	1.24	1.12	1.15	1.52	0.64	0.78	0.83	0.68	0.63	0.48	0.62	0.54
Silicate (µmol/l)	6.21	6.22	6.28	7.22	6.22	6.02	5.1	6.54	4.8	6.33	7.2	4.11	4.23	6.45	6.82	6.42
Total Phosphorus (µmol/l)	1.88	2.98	3.41	4.65	1.02	2.02	2.02	2.41	0.98	1.25	1.42	1.2	0.99	1.12	1.54	0.99
Ammonia (µmol/l)	0.11	0.098	0.21	0.21	0.042	0.064	0.042	0.032	0.027	0.022	0.024	0.032	0.024	0.022	0.024	0.09
Nitrite-N (µmol/l)	0.23	0.3	0.6	1.2	0.25	0.5	0.4	0.6	0.4	0.7	0.2	0.18	0.62	0.31	0.07	0.08
Nitrate-N (µmol/l)	2.17	3.11	3.52	3.42	1.2	2.81	2.43	1.1	1.21	3.41	2.11	1.11	0.95	1.2	2.1	1.2
Total -N (µmol/l)	3.42	3.65	4.51	4.2	4.28	2.4	2.51	2.45	2.54	4.32	3.12	2.11	3.1	2.11	2.25	3.11
BOD (mg/l)	1.22	1.31	1.25	1.32	0.95	0.91	1.13	0.93	0.98	0.88	0.93	0.88	0.64	0.61	0.89	0.58
PHC (µg/l)	3..32	4.64	4.48	5.75	3.74	3.89	3.54	3.82	3.09	2.65	2.82	3.63	4.52	3.64	5.54	7.5
Dissolved Cd (ppb)	0.13	0.26	0.18	0.23	0.24	0.29	0.14	0.35	0.16	0.12	0.21	0.33	0.12	0.31	0.29	0.16
Dissolved Pb(ppb)	1.22	1..38	1.42	2.85	1.36	1.25	1.43	2.68	1.15	1.57	1.44	1.58	1.34	1.56	1.67	1.71
Dissolved Hg (ng/l)	35	32	31	32	25	28	26	35	34	27	26	31	28.	26	24	27

Table No. 14a – Pearson Correlation coefficients of Physicochemical and biological parameters of the sea water samples of Andrott

	T	pH	Salinity	TSS	DO	Silicate	NH_3	Ino. PO_4	T PO_4	Nitrite	Nitrate	TN	BOD	PHC	Cd^	Pb^	Hg^	Chl a	Zoobio
T	1	.054	355*	.068	121	.348*	117	.001	.022	.001	.299*	.037	.043	.035	.022	.197	.231	.020	187
pH	-.054	1	104	-.281	.281	-.127	-.327*	-.369**	-.396**	-.300*	-.233	.019	-.270	-.240	-.035	-.250	120	.180	-.092
Salinity	.355*	104	1	-.240	116	.137	-.349*	-.212	-.213	134	124	.096	-.216	-.095	-.266	-.099	-.246	-.101	-.036
TSS	-.068	-.281	-.240	1	-.671**	.278	.681**	.851**	.824**	.630**	.436**	.229	.635**	.206	192	.511**	-.005	-.105	-.047
DO	.121	.281	116	-.671**	1	-.440**	-.628**	-.665**	-.534**	-.409**	-.239	-.436**	-.605**	-.208	-.081	-.494**	148	.345*	153
Silicate	.348*	127	137	.278	-.440**	1	.212	.358*	.253	.264	.466**	.503**	194	160	.039	.344*	119	-.162	101
NH_3	117	-.327*	-.349*	.681**	-.628**	.212	1	.817**	.656**	.528**	.335*	.366*	.587**	.300*	.010	.409**	.048	-.211	-.044
Ino. PO_4	-.001	-.369**	-.212	.851**	-.665**	.358*	.817**	1	.868**	.684**	.543**	.359*	.545**	.232	.008	.450**	-.006	-.244	-.091
T PO_4	.022	-.396**	-.213	.824**	-.534**	.253	.656**	.868**	1	.598**	.505**	.142	.436**	.309*	.071	.436**	.005	-.085	.090
Nitrite	.001	-.300*	134	.630**	-.409**	.264	.528**	.684**	.598**	1	.369**	.275	.252	196	-.062	.541**	.089	-.085	137
Nitrate	.299*	-.233	124	.436**	-.239	.466**	.335*	.543**	.505**	.369**	1	.364*	.269	-.007	-.205	.075	-.089	-.339*	111
TN	.037	.019	.096	.229	-.436**	.503**	.366*	.359*	.142	.275	.364*	1	.340*	105	139	.084**	.102	-.580**	-.082
BOD	-.043	-.270	-.216	.635**	-.605**	.194	.587**	.545**	.436**	.252	.269	.340*	1	-.056	179	.223	.216	-.304*	.022
PHC	-.035	-.240	-.095	.206	-.208	160	.300*	.232	.309*	196	-.007	.105	-.056	1	.083	.380	-.382**	154	.251
Cd^	.022	-.035	-.266	192	-.081	.039	.010	.008	.071	-.062	-.205	-.139	179	.083	1	.248	.077	178	.132
Pb^	197	-.250	-.099	.511**	-.494**	.344*	.409**	.450**	.436**	.541**	.075	.084	.223	.380*	.248	1	-.060	170	-.141
Hg^	-.231	120	-.246	-.005	148	119	.048	-.006	.005	.089	-.089	.102	.216	-.382**	.077	-.060	1	-.202	-.040
Chl a	.020	180	101	105	.345*	-.162	-.211	-.244	-.085	-.085	-.339*	-.580**	-.304*	154	178	170	-.202	1	.081
Zoobio	187	-.092	-.036	-.047	153	101	-.044	-.091	.090	137	111	-.082	.022	.251	132	141	-.040	.081	1

^ Dissolved metals

* Correlation is significant at the 0.05 level (2 - tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Chart 30: Fluctuation of water temperature in Seawater; 1996-1998

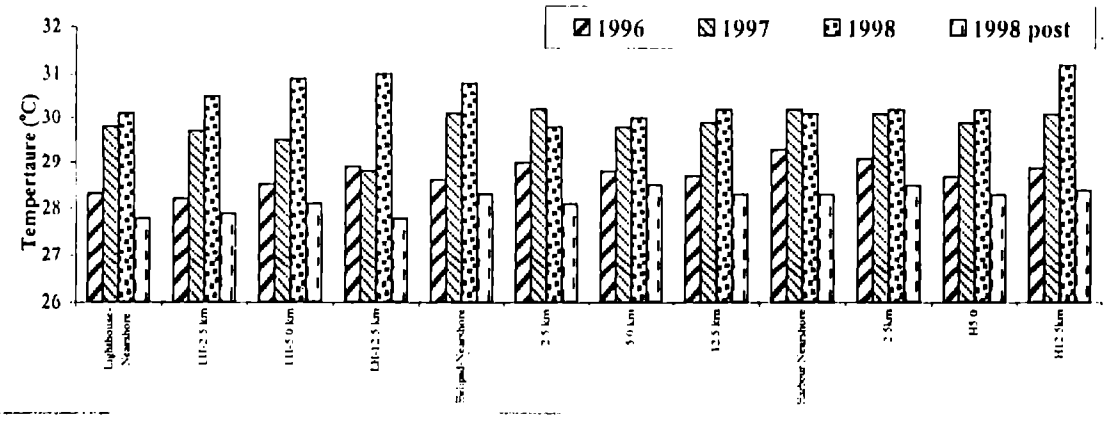


Chart 31: Fluctuation of pH in Sea water; 1996-1998

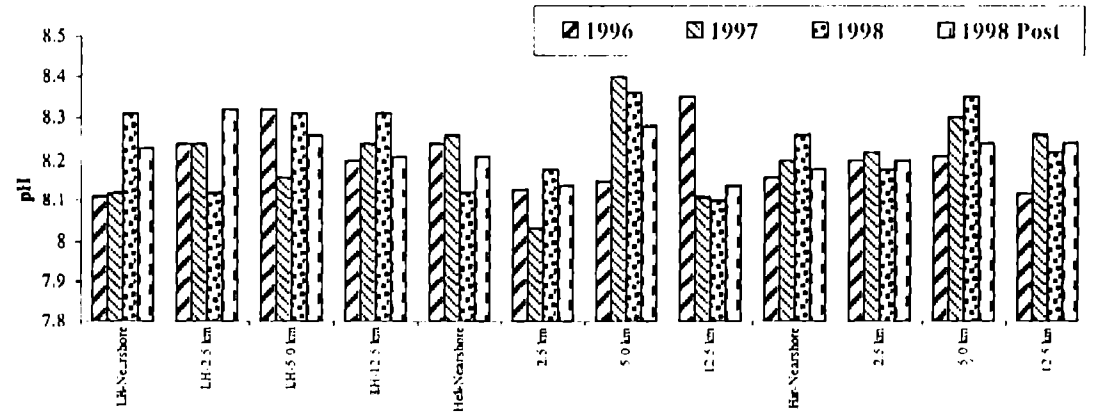
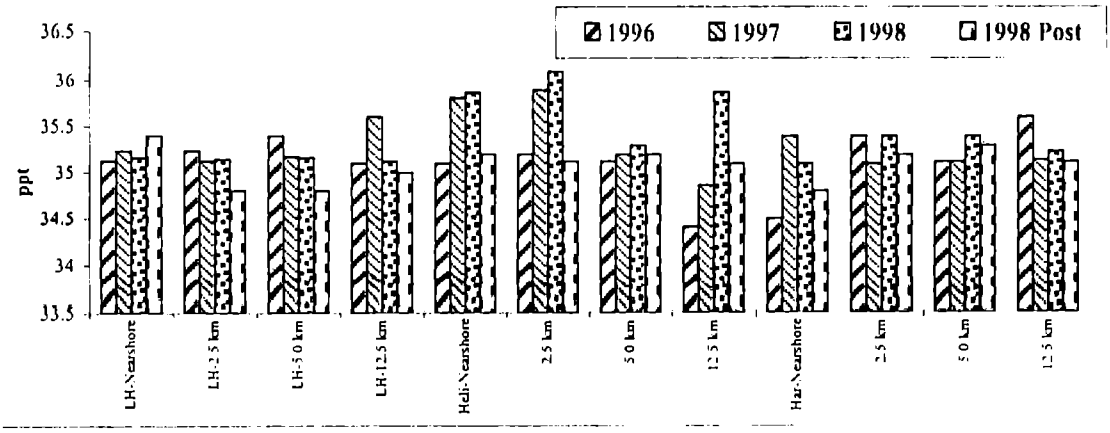


Chart 31a: Fluctuation of Salinity in Seawater; 1996-1998



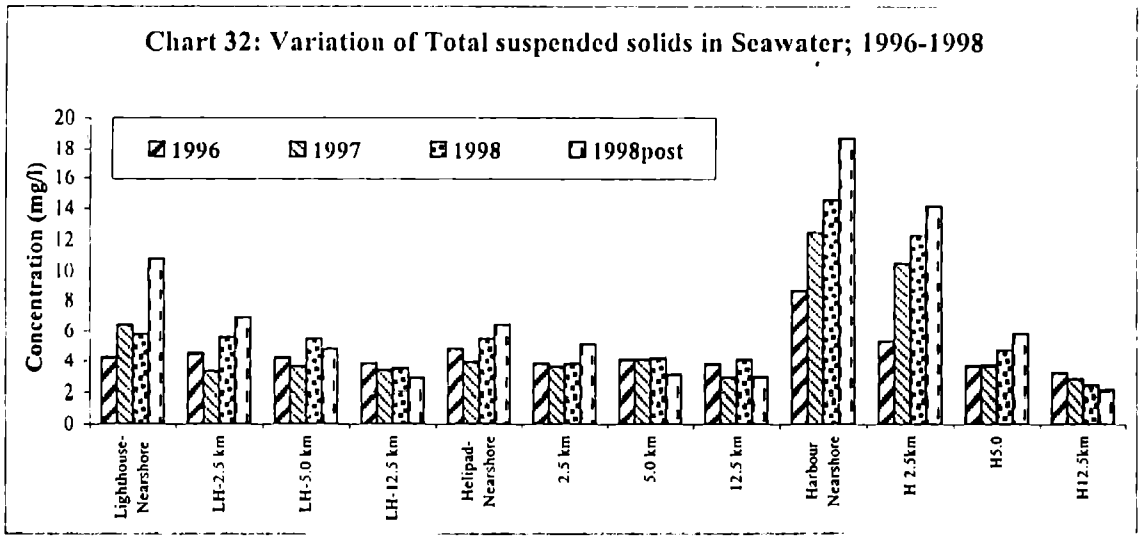


Chart 32: Variation of Total suspended solids in Seawater; 1996-1998
1996
1997
1998
1998post
Concentration (mg/l)
20
18
16
14
12
10
8
6
4
2
0
Lighthouse-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Helipad-Nearshore
2.5 km
5.0 km
12.5 km
Harbour Nearshore
H 2.5km
H5.0
H12.5km

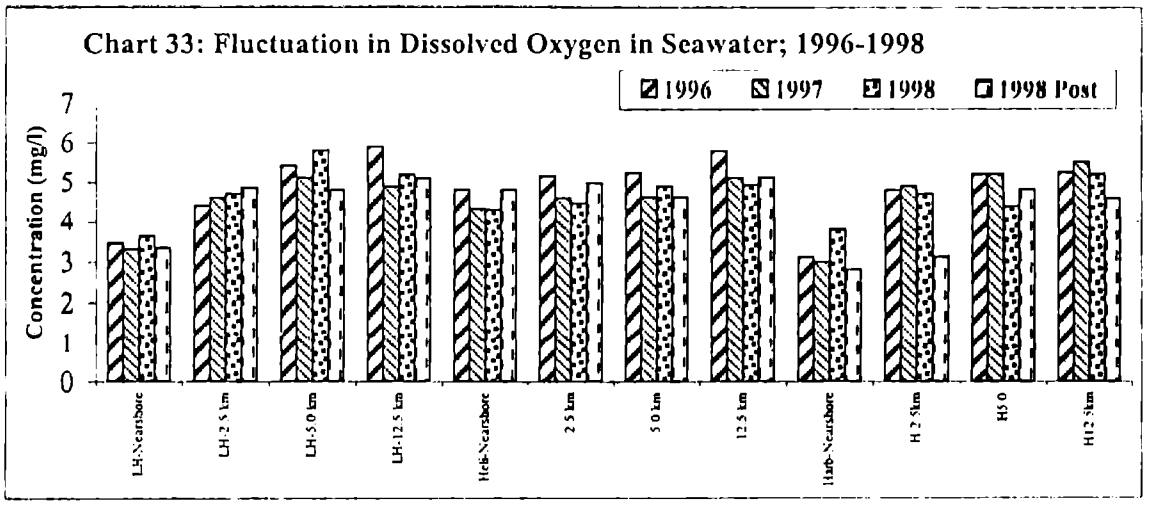


Chart 33: Fluctuation in Dissolved Oxygen in Seawater; 1996-1998
1996
1997
1998
1998 Post
Concentration (mg/l)
7
6
5
4
3
2
1
0
LH-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Heli-Nearshore
2.5 km
5.0 km
12.5 km
Harb-Nearshore
H 2.5km
H5.0
H12.5km

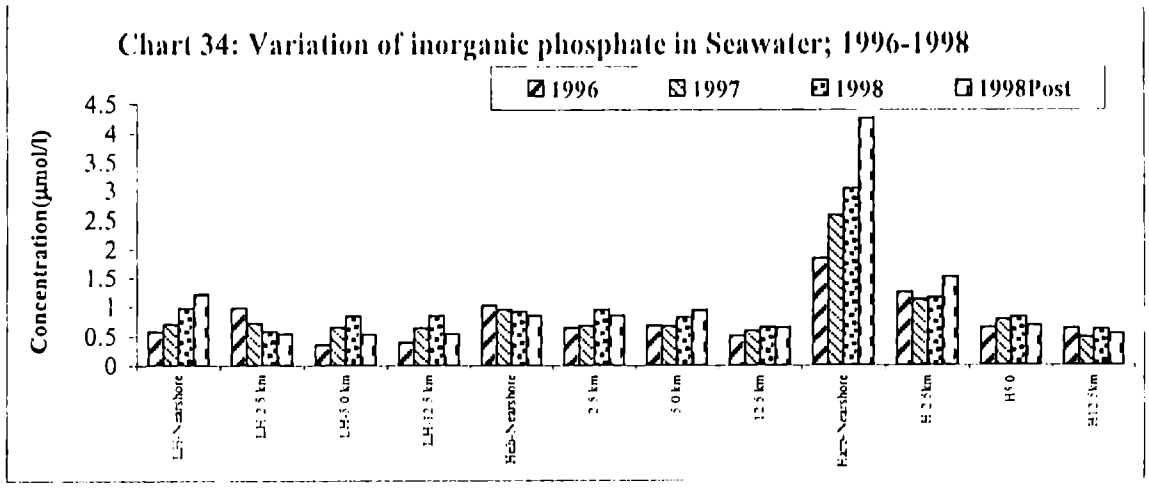


Chart 34: Variation of inorganic phosphate in Seawater; 1996-1998
1996
1997
1998
1998Post
Concentration(µmol/l)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
LH-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Heli-Nearshore
2.5 km
5.0 km
12.5 km
Harb-Nearshore
H 2.5km
H5.0
H12.5km

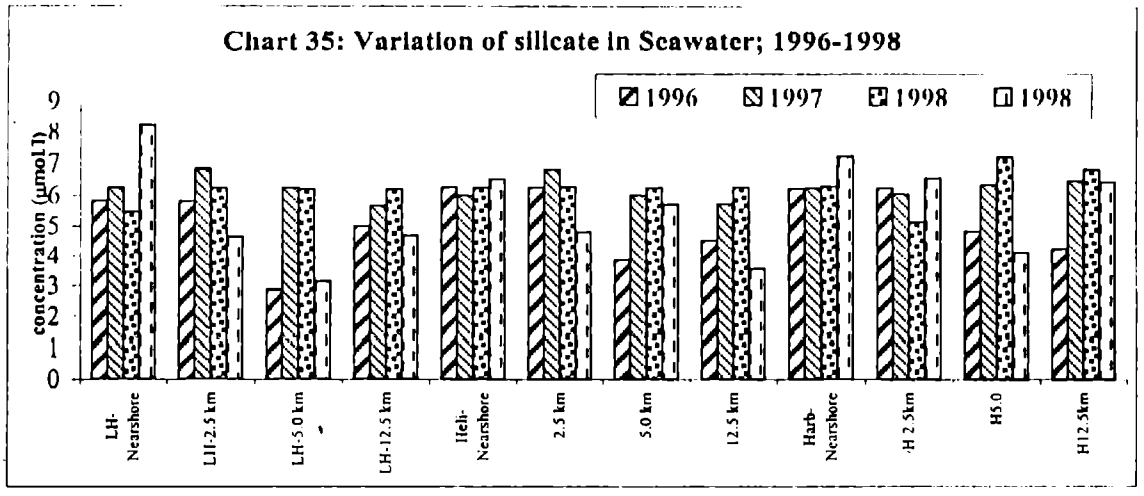


Chart 35: Variation of silicate in Seawater; 1996-1998
1996
1997
1998
1998
concentration (µmol/l)
0
1
2
3
4
5
6
7
8
9
LH-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Heli-Nearshore
2.5 km
5.0 km
12.5 km
Harb-Nearshore
H 2.5km
H5.0
H12.5km

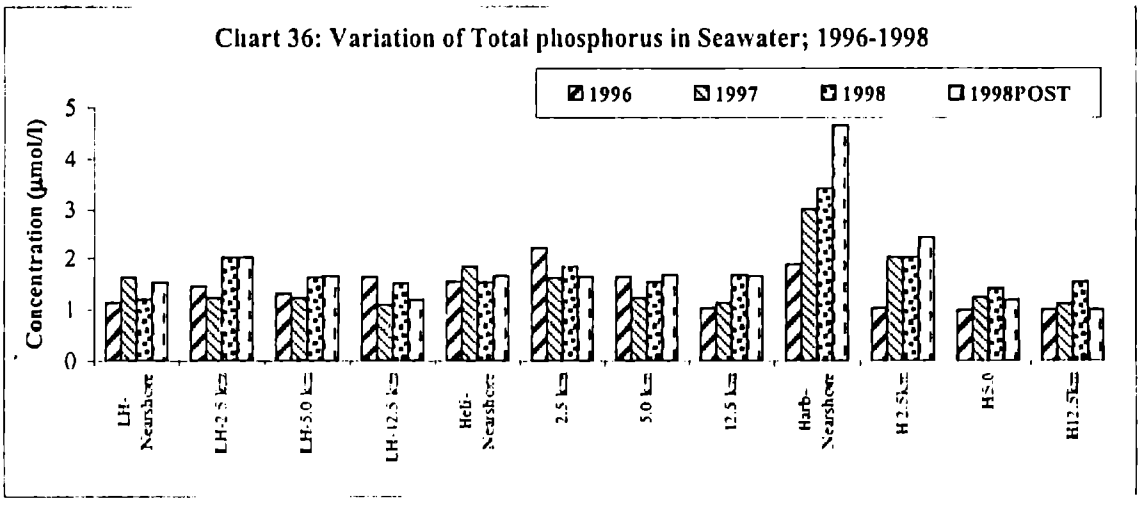


Chart 36: Variation of Total phosphorus in Seawater; 1996-1998
1996
1997
1998
1998POST
Concentration (µmol/l)
0
1
2
3
4
5
LH-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Heli-Nearshore
2.5 km
5.0 km
12.5 km
Harb-Nearshore
H12.5km
H5.0
H12.5km

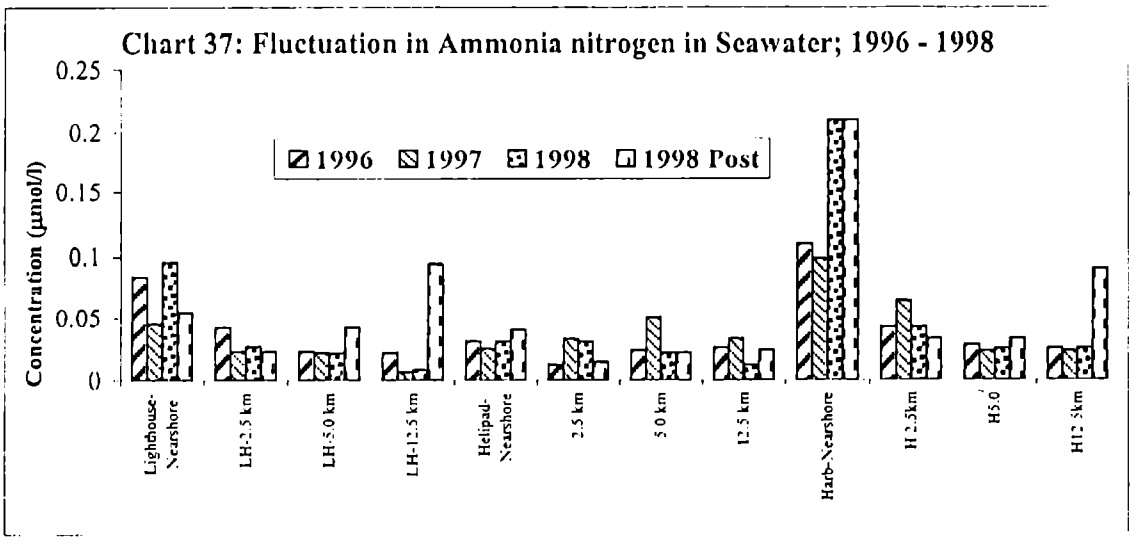


Chart 37: Fluctuation in Ammonia nitrogen in Seawater; 1996 - 1998
1996
1997
1998
1998 Post
Concentration (µmol/l)
0
0.05
0.1
0.15
0.2
0.25
Lighthouse-Nearshore
LH-2.5 km
LH-5.0 km
LH-12.5 km
Helipad-Nearshore
2.5 km
5.0 km
12.5 km
Harb-Nearshore
H 2.5km
H5.0
H12.5km

Chart 38: Variation of Nitrite nitrogen in seawater; 1996-1998

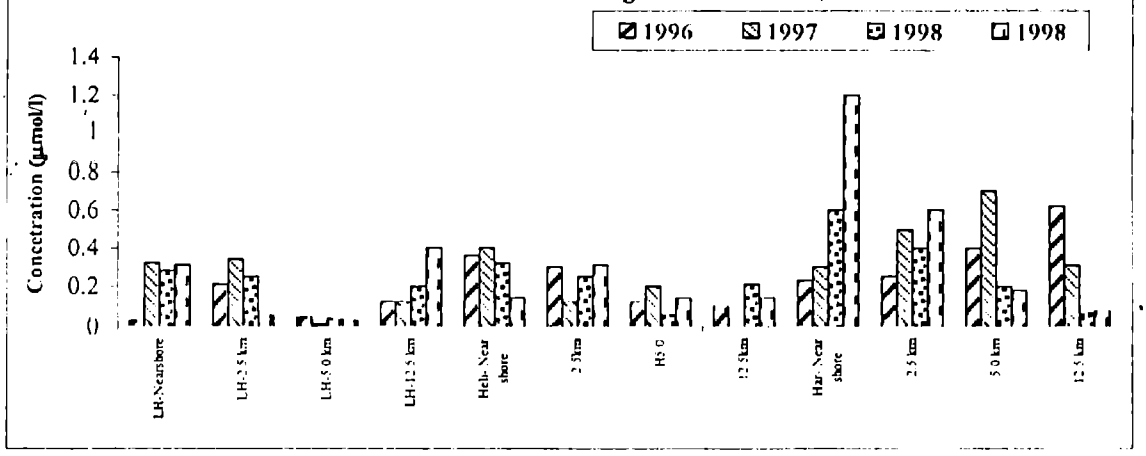


Chart 39: Variation of Nitrate nitrogen in Seawater; 1996-1998

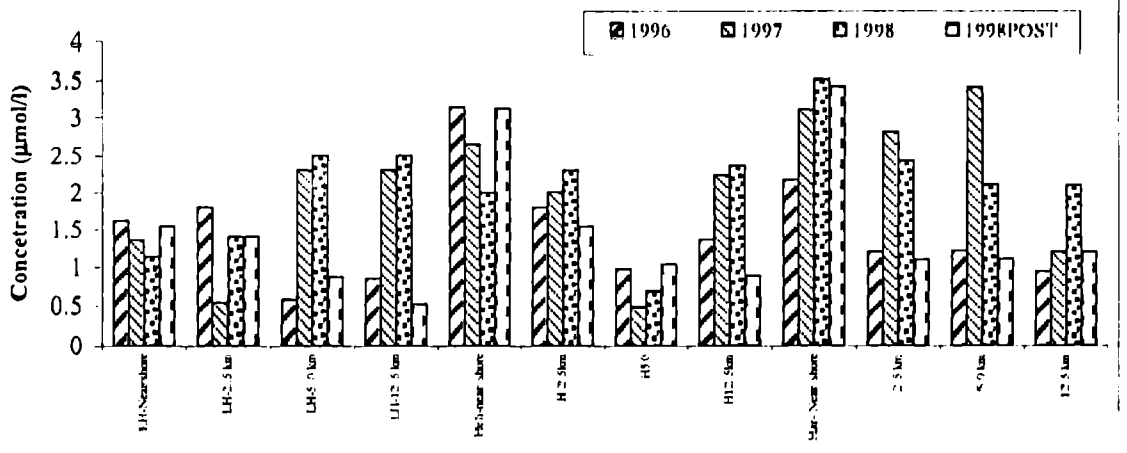


Chart 40: Variation of Total nitrogen in Seawater; 1996-1998

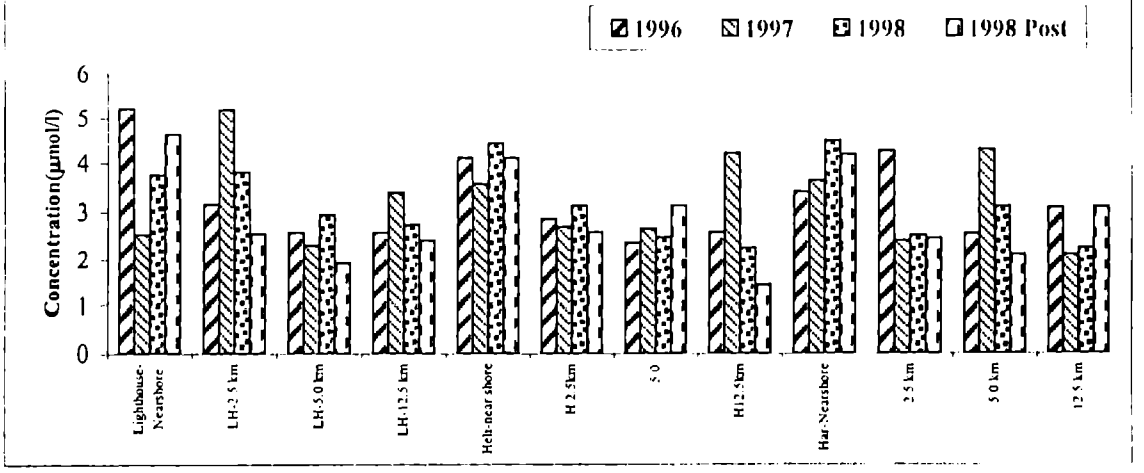


Chart 41: Variation of Biological Oxygen Demand in Seawater; 1996-1998

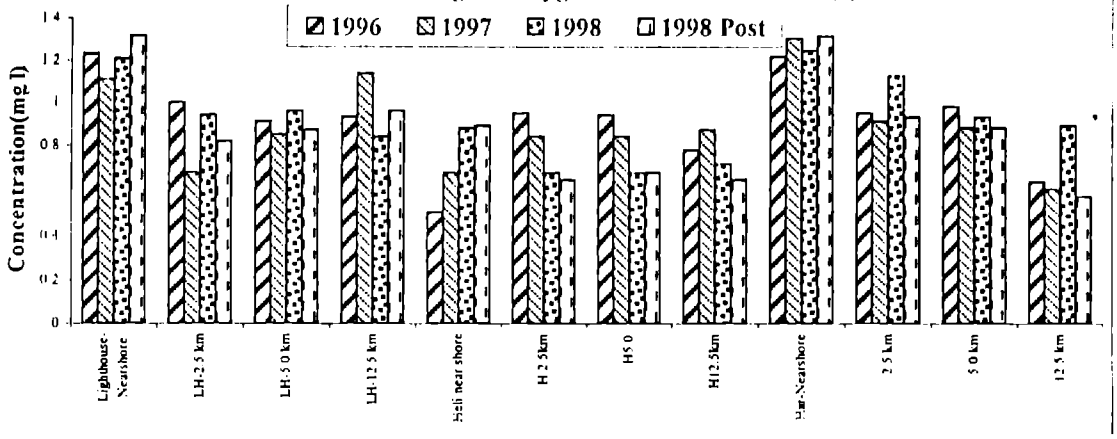


Chart 42: Variation of Petroleum Hydrocarbon in Seawater; 1996-199

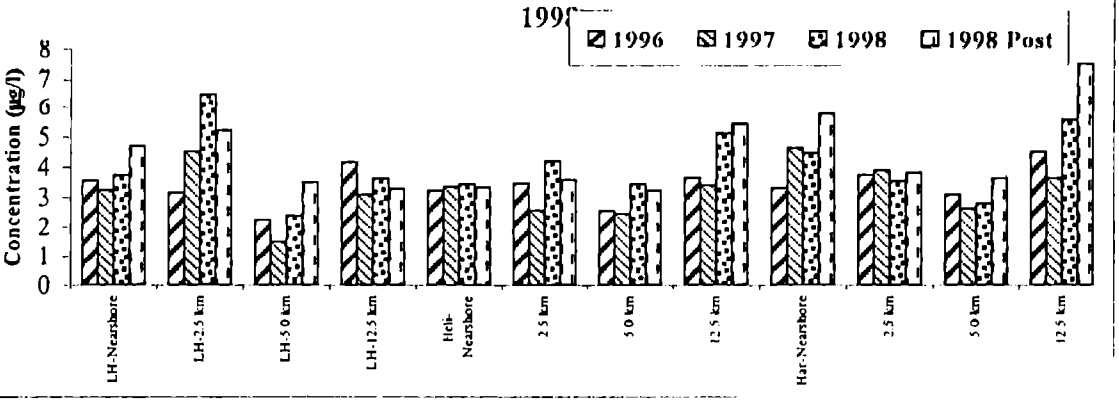
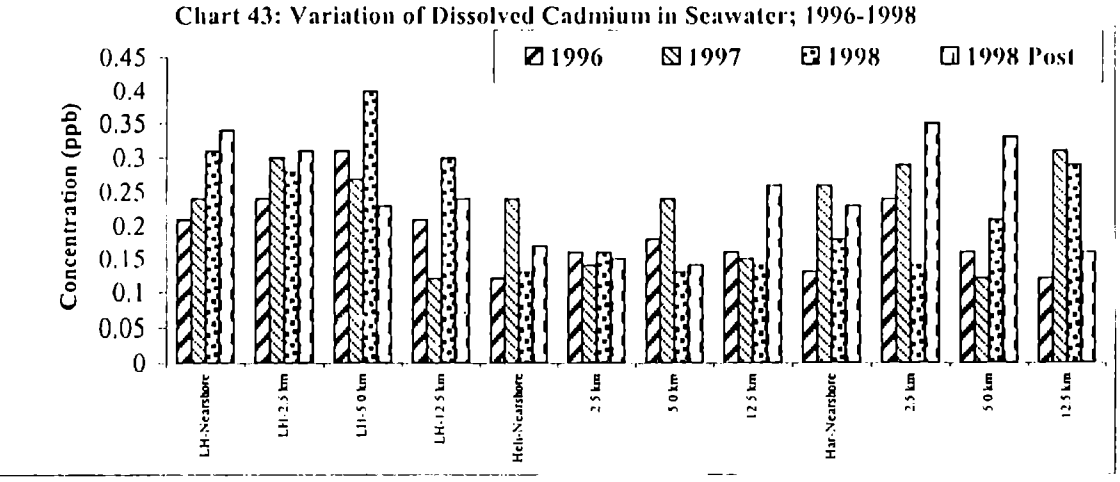


Chart 43: Variation of Dissolved Cadmium in Seawater; 1996-1998



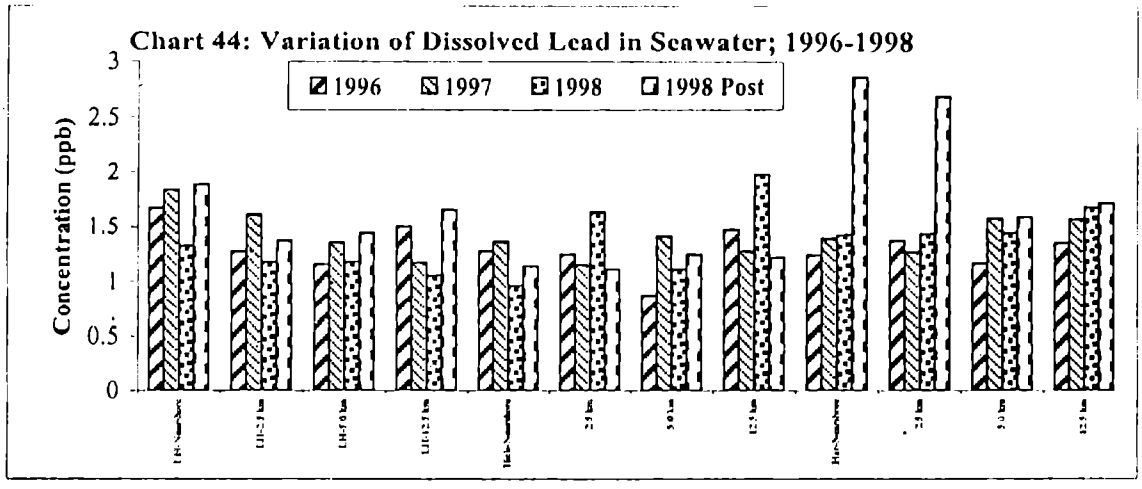


Chart 44: Variation of Dissolved Lead in Seawater; 1996-1998
1996
1997
1998
1998 Post
Concentration (ppb)
3
2.5
2
1.5
1
0.5
0

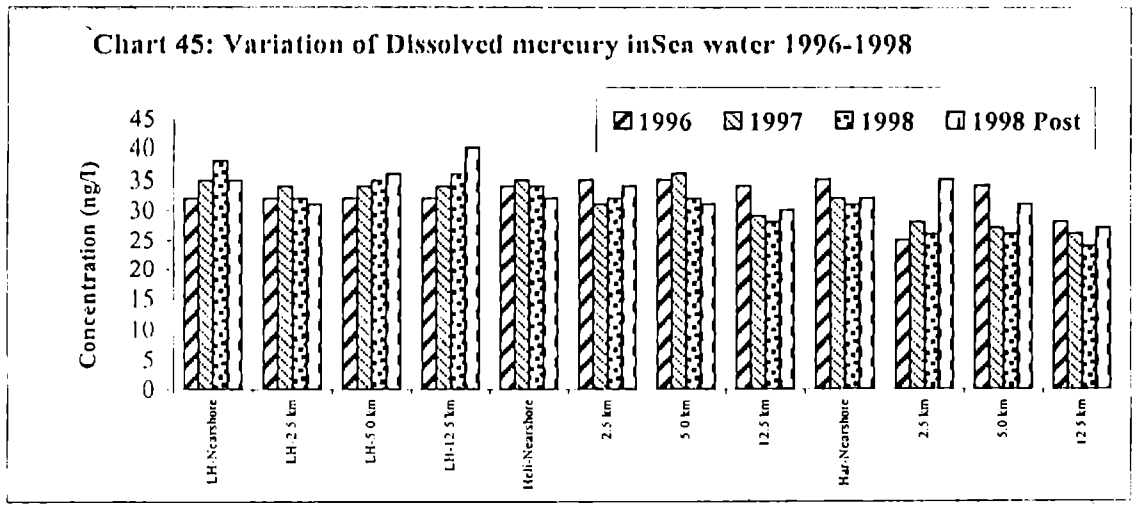


Chart 45: Variation of Dissolved mercury inSea water 1996-1998
1996
1997
1998
1998 Post
Concentration (ng/l)
45
40
35
30
25
20
15
10
5
0
LH-Nearshore
LH 2.5 km
LH-5.0 km
LH-12.5 km
Heli-Nearshore
2.5 km
5.0 km
12.5 km
Har-Nearshore
2.5 km
5.0 km
12.5 km

Chart 46: Seasonal Variation of Silicate at Lighthouse

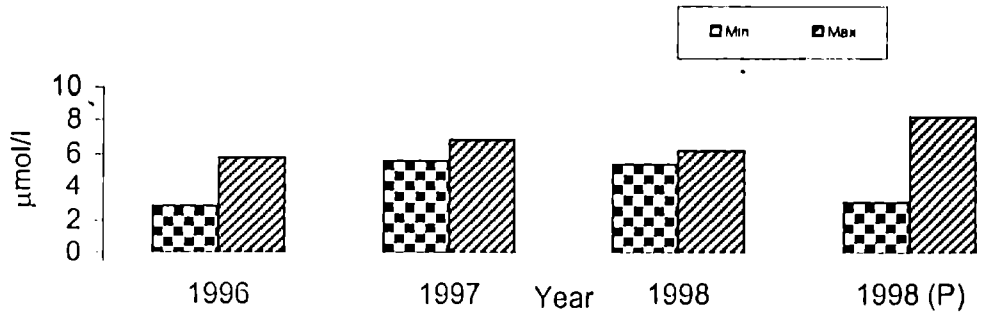


Chart 47: Seasonal Variation of Nitrate Nitrogen at Lighthouse

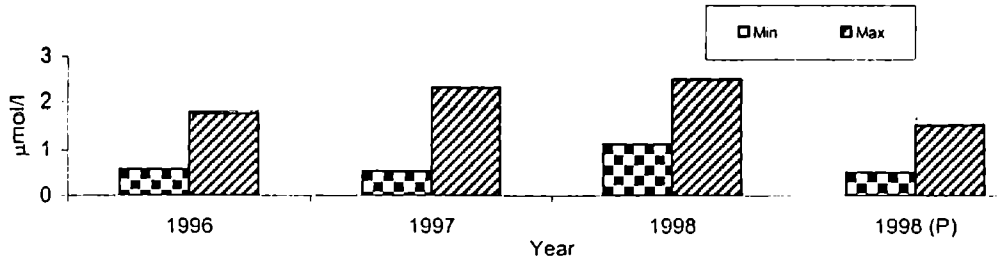


Chart 48: Seasonal Variation of Nitrite Nitrogen at Light house

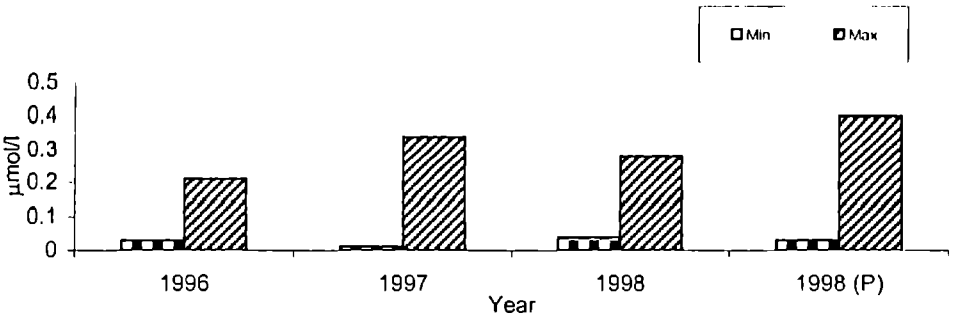


Chart 49: Seasonal Variation of Inorganic Phosphate at Lighthouse

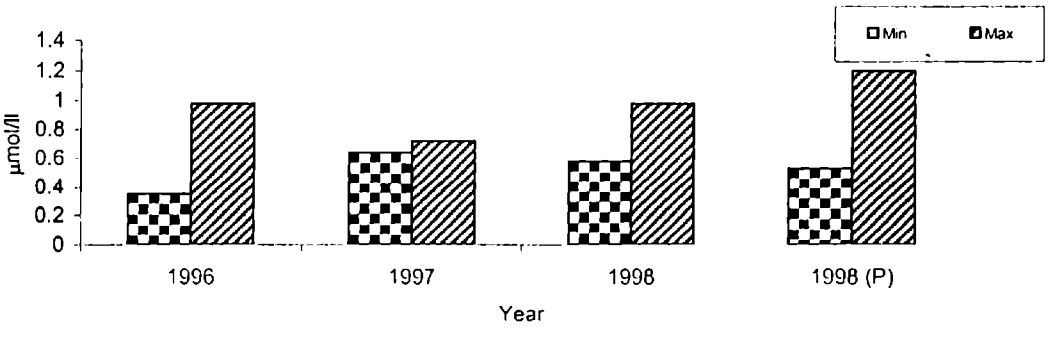


Chart 50: Seasonal Variation of Ammonia at Lighthouse

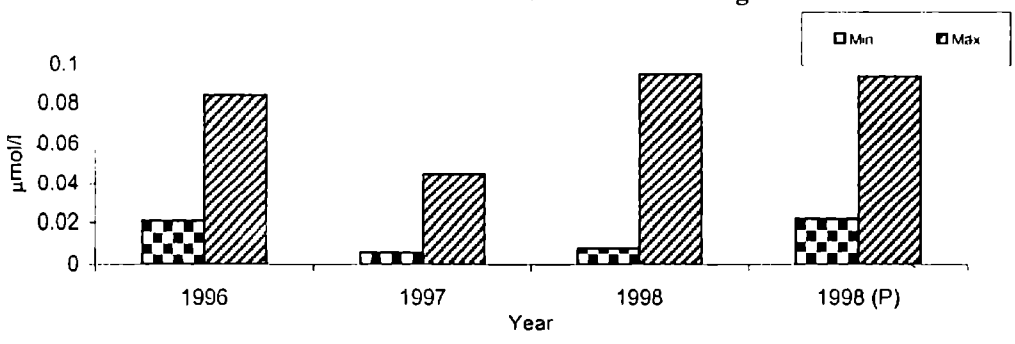


Chart 51: Seasonal Variation of Dissolved Oxygen at Lighthouse

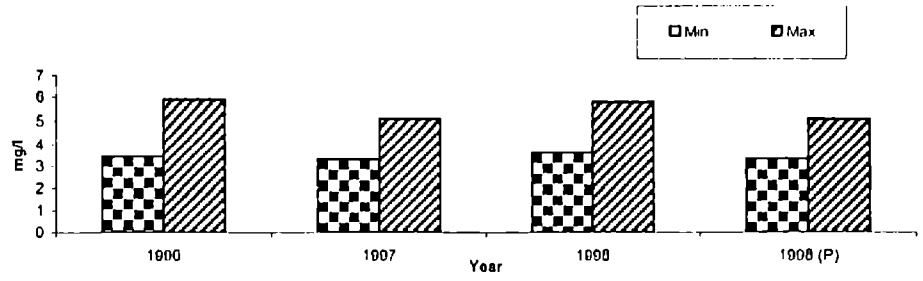


Chart 52: Seasonal Variation of Petroleum Hydrocarbons at Lighthouse

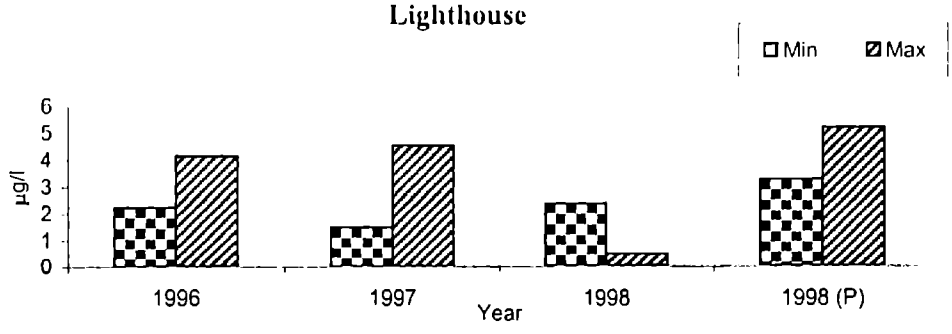


Chart 53: Seasonal Variation of Silicate at Helipad

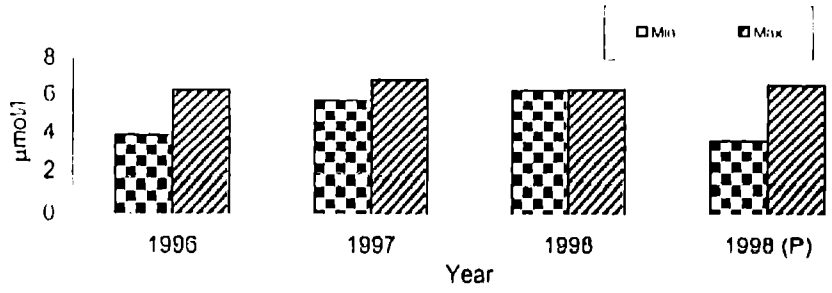


Chart 54: Seasonal Variation of Nitrate-Nitrogen at Helipad

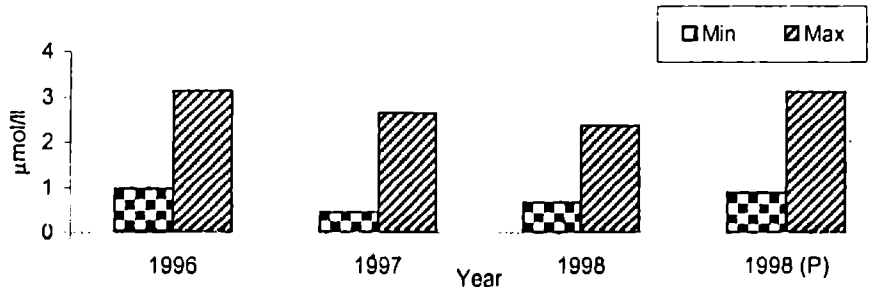


Chart 55: Seasonal Variation of Nitrite-Nitrogen at Helipad

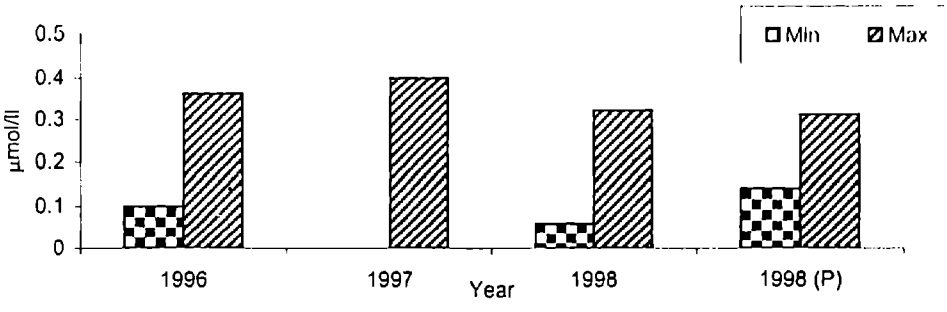


Chart 56: Seasonal Variation of Inorganic Phosphate at Helipad

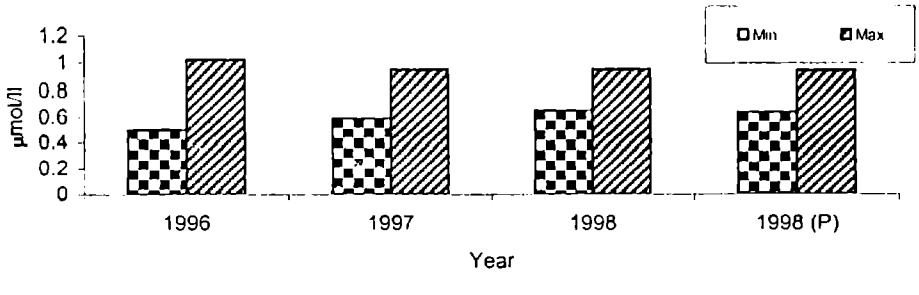


Chart 57: Seasonal Variation of Ammonia at Helipad

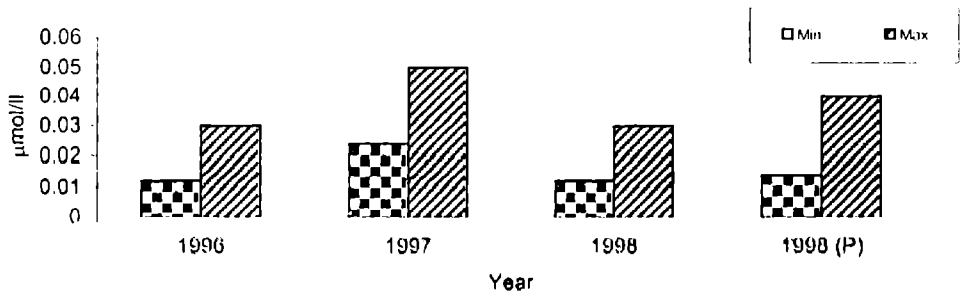


Chart 58: Seasonal Variation of Dissolved Oxygen at Helipad

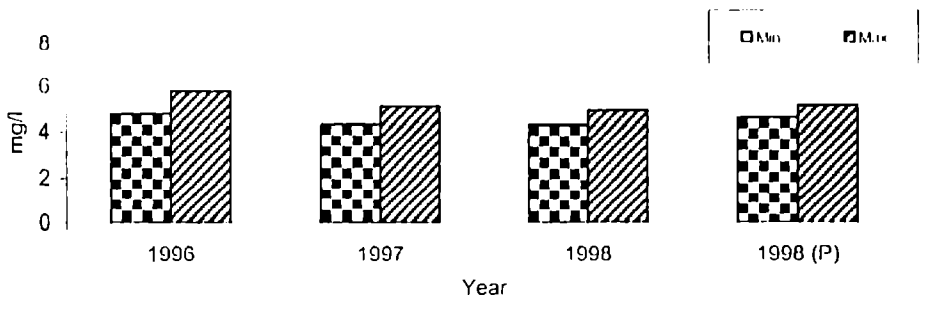


Chart 59: Seasonal Variation of Petroleum Hydro Carbons at Helipad

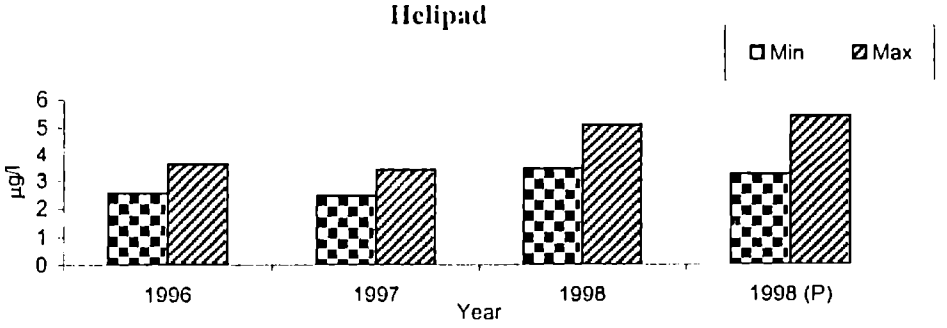


Chart 60: Seasonal Variation of Silicate at Harbour

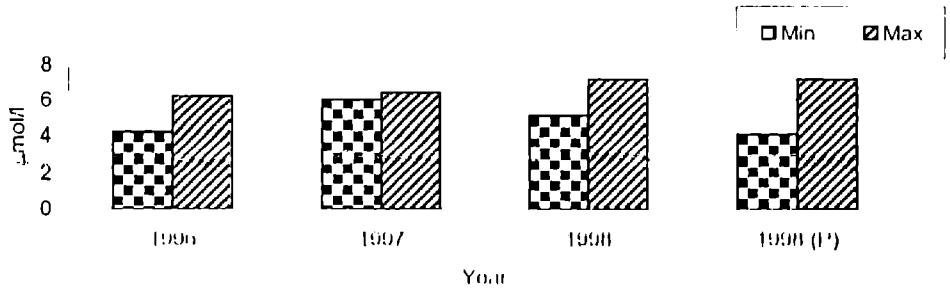


Chart 61: Seasonal Variation of Nitrate Nitrogen at Harbour

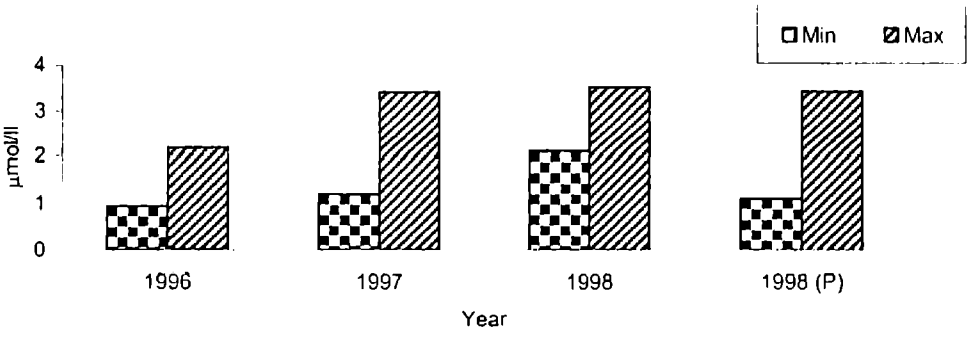


Chart 62: Seasonal Variation of Nitrite Nitrogen at Harbour

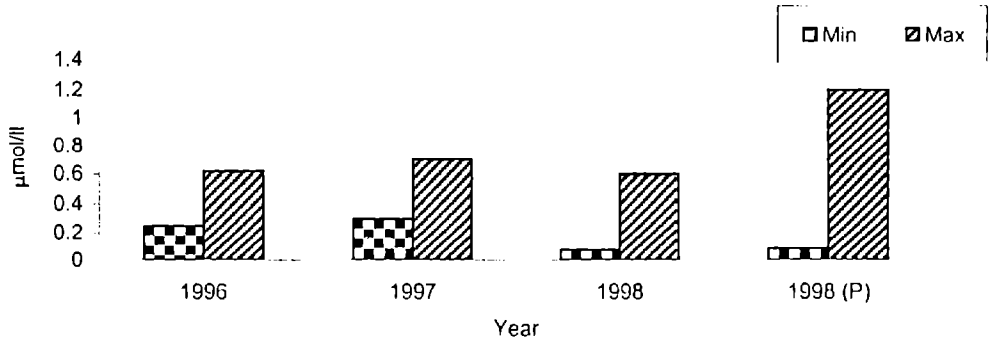


Chart 63: Seasonal Variation of Inorganic Phosphate at Harbour

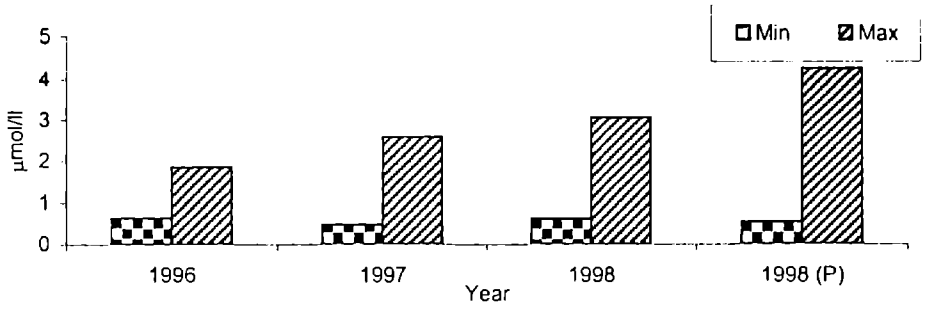


Chart 64: Seasonal Variation of Dissolved Oxygen at Harbour

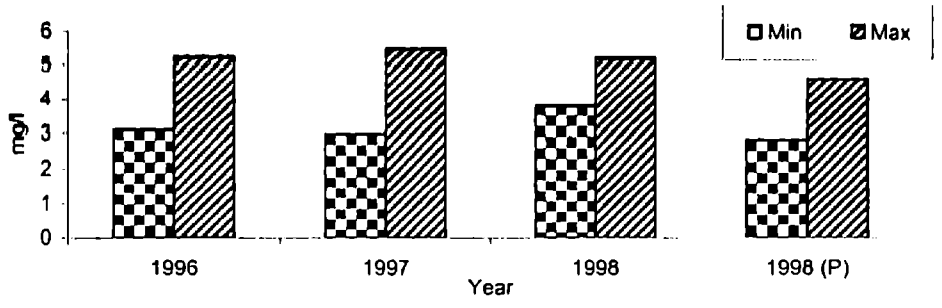


Chart 65: Seasonal Variation of Ammonia at Harbour

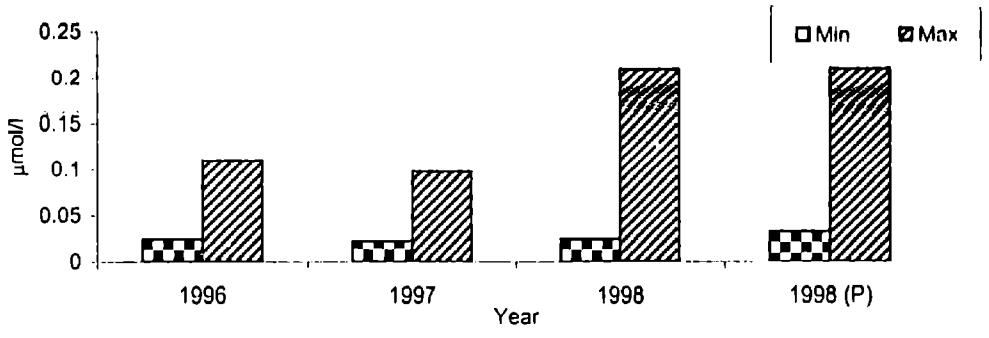
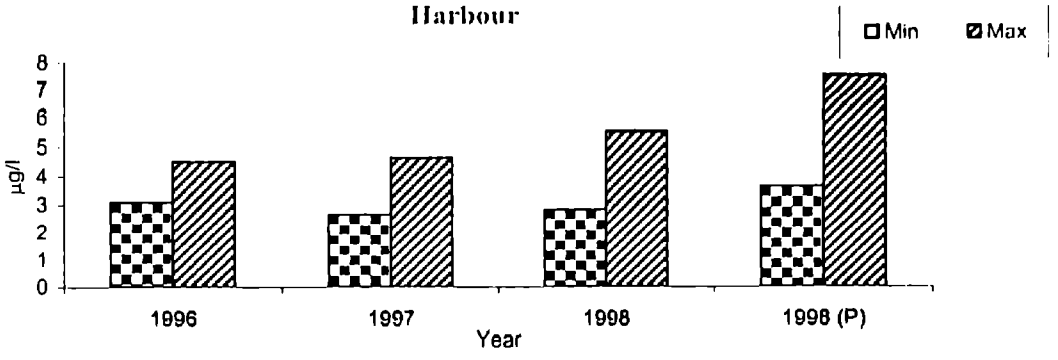


Chart 66: Seasonal Variation of Petroleum Hydro Carbons at Harbour



correlated with phytoplankton abundance. Correlation coefficient (Table-14a) of physicochemical and biological parameters showed significant negative correlation of chl-*a* with nitrate (r = 0.339) and inorganic phosphate (r 0.244) in surface waters also supported this inference. Singh *et al* (1989) reported lower concentration of nutrients at surface waters of Lakshadweep Sea while high concentrations were encountered at deeper depths with low values of dissolved oxygen.

Values of Mercury observed in the present study ranged between 24 ng/l and 40ng/l, which was found low and within the permissible limit compared to the results of studies conducted elsewhere. The average concentration of mercury reported earlier in the Lakshadweep Sea was 91ng/l (Sanzgiri *et al* 1979) and in the coastal waters of the Arabian Sea was 136ng/l. The reported values elsewhere were 0.5 225 ng/l in South west coast of India (Ouseph, 1987), 6-51 ng/l in the Seas around China and Japan (Chester *et al.*, 1973) and 0-221 ng/l in northern Indian Ocean (Singbal *et al.*,1978). Concentration of Pb obtained in the present study ranged between 0.12 – 1.88 ppb and that of cadmium between 0.12 – 0.4 ppb. Low values obtained might be due to the absence of a point source and lagoonal system in the island. However, variation in concentration was recorded over the period possibly due to increase in mechanized fishing and shipping activities. Results obtained in the present study were within the permissible limit.

The range of PHC concentrations (1.5-7.5µg/l) recorded over the study period was considerably low. Comparatively higher values were reported from the harbour transect especially from the offshore region. This might be attributed to the increased mechanized fishing and shipping activities over the period.

3.1.3 Microbiological parameters (Table 15-17 & Chart 67-90)

Lighthouse transect (Chart 67-74)

Total Viable Count (TVC) in water samples varied from 1.5 x 10^2 cfu/ml at 12.5 km offshore to 9.5 x10^2 cfu/ml at nearshore during 1996, 3.6 x10^2 cfu/ml at 12.5 km offshore to 1.24 x10^3 cfu/ml at the nearshore during 1997, 2.1 x10^2 cfu/ml at 12.5 km offshore to 1.1 x10^3 cfu/ml at nearshore during 1998 and 1.7 x10^2 cfu/ml at 12.5 km to 7.8 x10^2 cfu/ml at the nearshore during post monsoon 1998. Total Coliforms (TC) varied from nil at the 12.5km station to 60cfu/ml at the nearshore during 1996, 0 at 5.0 km and 12.5 km offshore

to 20cfu/ml at the near shore during 1997, 0 at 5.0 and 12.5 km stations to 15 cfu/ml at the near shore and 2.5km during 1998 and nil at 2.5 km and 12.5 km offshore to 25cfu/ml at the near shore during post monsoon 1998. *E.coli* like organisms (ECLO) ranged from nil at all stations except the near shore where 10cfu/ml was recorded during 1996. It ranged from nil at all other stations except near shore (25 cfu/ml) during 1997 nil at all stations except at near shore (20cfu/ml and 10cfu/ml respectively) during pre and post monsoon 1998. *Salmonella* like organisms (SLO) were generally not detected during any season except during 1996 from the near shore (5cfu/ml). *Shigella* like organisms (SHLO) varied from 5cfu/ml at 12.5 km to 25cfu/ml at near shore during 1996. It ranged from nil at 2.5 km and 5.0 km station to 35cfu/ml at the near shore during 1997, nil at 5km and 12.5km stations to 25cfu/ml in near shore during 1998 and nil at 5.0 km and 12.5 km offshore to 20cfu/ml at 2.5km during post monsoon 1998. *Proteus* and *Klebsiella* like organisms (PKLO) varied from 10cfu/ml at 2.5 km and to 25cfu/ml at 5.0km and 12.5km during 1996, nil at 5.0km and 12.5km stations to 30 cfu/ml at the near shore during 1997, nil at 5 km and 12.5km to 40cfu/ml 2.5km during 1998 and nil at 5.0 km and 12.5km to 25cfu/ml at 2.5km during post monsoon 1998.

Vibrio cholera like organisms (VCLO) ranged from 25cfu/ml at the 12.5km to 45cfu/ml at 5.0 km during 1996, 45cfu/ml at 12.5km to 70cfu/ml near shore during 1997, 15cfu/ml at 2.5km to 90cfu/ml at near shore station during 1998 and 15cfu/ml at near shore to 45cfu/ml at 12.5km during post monsoon 1998. *V parahaemolyticus* like organisms (VPLO) ranged from 10 cfu/ml at near shore to 35cfu/ml at 5 km offshore during 1996, 10cfu/ml at 12.5km to 45cfu/ml at near shore during 1997, 15cfu/ml at 2.5 km to 35cfu/ml at near shore during 1998 and 15cfu/ml at 2.5 km to 55cfu/ml at 12.5km Station during post monsoon 1998. *Streptococcus faecalis* like organisms (SFLO) were nil at 5km and 12.5km offshore stations during all seasons where as its maximum count (25cfu/ml) was recorded from near shore during 1996.

Helipad transect (Chart 75-82)

TVC in water samples varied from 3.8 $x10^2$ cfu/ml at near shore to 4.5 $x10^2$ cfu/ml at 12.5km during 1996, 5.4 $x10^2$ cfu/ml at 12.5 km offshore to 1.16 $x10^3$cfu/ml at the 2.5km

during1997, 6.8 $x10^2$ cfu/ml at near shore to 1.39 $x10^3$ cfu/ml at 2.5km during 1998 and 4.35 $x10^2$ cfu/ml at 5.0 km to 7.3 $x10^2$ cfu/ml at 12.5 km offshore during post monsoon 1998. T C varied from 0 at 5.0 km and 12.5 km stations to 45 cfu/ml at near shore during 1996 and nil at 12.5 km to 1.35 $x10^2$ cfu/ml at the near shore during1997, nil at 5.0km and 12.5 km stations to 1.2 $x10^2$ cfu/ml at the near shore station during pre monsoon 1998and nil at 5.0 km and 12.5 km stations to 55cfu/ml at the near shore during post monsoon 1998. *E.coli* like organisms were recorded from only from the near shore region where the maximum count (15cfu/ml) was recorded during 1997 *Salmonella* like organisms were not reported during any season from this transect. SHLO varied from nil at 5.0km and 12.5 km stations to 25cfu/ml at the near shore during 1996, 15cfu/ml at 2.5 km to 35cfu/ml at the near shore during 1997, nil at 5.0 km and 12.5 km stations to 40cfu/ml at the near shore during 1998 and nil at 5.0 and 12.5 km to 25 cfu/ml nearshore during post monsoon 1998. *Proteus* and *Klebsiella* like organisms ranged from nil at 2.5 km station to 25 cfu/ml at 5km during 1996, 15 cfu/ml at 2.5km and 12.5km to 25 cfu/ml at the near shore during 1997, 10 cfu/ml at 2.5km and 5.0 km to 15 cfu/ml at near shore during 1998 and nil at 12.5 km to 15 cfu/ml at the nearshore during post monsoon 1998. The count of *VCLO* like organisms varied from 45 cfu/ml at nearshore to 1.2 $x10^2$ cfu/ml at 5.0 km during 1996, 1.1 $x10^2$ at 12.5km station to 1.55 $x10^2$ cfu/ml at the 5km during 1997, 1.05 $x10^2$cfu/ml at near shore station to 1.4 $x10^2$cfu/ml at 5km during 1998 and 35 at nearshore and 5km to 55 cfu/ml at 12.5km Station during post monsoon 1998. VPLO ranged from 15 cfu/ml at 12.5 km to 1.1 $x10^2$ cfu/ml at 2.5 km station during 1996, 35 cfu/ml at 12.5 km to 1.75 $x10^2$ cfu/ml at the near shore during 1997, 25 cfu/ml at 12.5 km offshore to 1.15 $x10^2$ cfu/ml at the near shore during 1998 and 15 cfu/ml at 12.5 km station to 75cfu/ml at nearshore during post monsoon 1998. SFLO ranged from nil at all other stations to 15 cfu/ml at the near shore during 1996 and nil at 5.0 and 12.5 km to 15cfu/ml at the near shore during 1997, nil at 5.0 km onwards to 10cfu/ml at near shore and 2.5km during 1998. During post monsoon 1998, they were enumerated only from near shore (10cfu/ml).

Harbour transect (Chart 83-90)

TVC in water samples varied from 6.1x 10^2 cfu/ml at the 12.5km station to 1.64x10^3 cfu/ml at 2.5km during 1996, 8.41x 10^2 cfu/ml at 12.5km to 2.23 $x10^3$ cfu/ml at the near

shore during 1997, 11.05 x10^2 cfu/ml at 5km to 24.6 x10^2 cfu/ml at near shore during 1998 and 7.5x 10^2 cfu/ml at the 5km and 12.5km stations to 10.8 x10^2 cfu/ml at 2.5km during post monsoon 1998. TC count were nil at 5 and 12.5km during all seasons and the maximum counts were 1.75x 10^2 cfu/ml at near shore during 1996, 2.15x 10^2 cfu/ml at the near shore during 1997, 1.2 x 10^2 cfu/ml at near shore during 1998 and 50cfu/ml at near shore during post monsoon 1998. *E.coli* like organisms not detected at 5km and 12.5km stations from any season while the maximum count (40cfu/ml) was reported from the near shore during 1997 *Salmonella* sp. was reported only during 1997 and 1998 from the near shore (15 and 5cfu/ml respectively). SHLO varied from 10cfu/ml at 12.5km to 40cfu/ml at near shore during 1996, 10cfu/ml at 12.5km to 20cfu/ml at all other stations during 1997, 15 cfu/ml, at 5.0 and 12.5 km offshore to 60 cfu/ml at 2.5 km during post-monsoon 1998 and nil at 12.5 km offshore to 90cfu/ml at nearshore during post monsoon 1998. *Proteus* and *Klebsiella* like organisms ranged from 10cfu/ml at 5km to 40cfu/ml at 2.5km during 1996, 15cfu/ml at 5km to 145cfu/ml at the near shore during 1997, 15 cfu/ml at 5km to 30cfu/ml at 2.5km during 1998 and 10cfu ml at 5km to 85cfu/ml at near shore during post monsoon 1998. The count of VCLO varied from 50cfu/ml at 12.5km to 170cfu/ml at near shore during 1996, 70 cfu/ml at 12.5km to 175cfu/ml at 2.5km during 1997, 70cfu/ml at 5km to 145cfu/ml at 2.5km during 1998 and 40cfu/ml at 5km to 90cfu/ml at near shore during post monsoon 1998. VPLO ranged from 40cfu/ml at near shore and 12.5km to 90cfu/ml at 2.5km during 1996, 80cfu/ml at 12.5km to 105cfu/ml at 2.5km and 5km during 1997, 70cfu/ml at 12.5km to 1.65 x 10^2 cfu/ml at the near shore during 1998 and 15cfu/ml at 12.5km to 65cfu/ml at 2.5km. SFLO was mostly confined to the near shore stations, where a count of 2.2x 10^2 95, 40 and 25cfu/ml were reported for the consecutive years. SFLO represented during 1996 (5cfu/ml) and 1998 (10cfu/ml) at 2.5km station.

Discussion

The highest TVC noticed was 12.4 x10^2 cfu/ml at lighthouse transect during premonsoon 1997, 13.9 x10^2 cfu/ml at Helipad transect during pre monsoon 1998 and 24.6 x10^2 cfu/ml at Harbour transect during premonsoon 1998. Among transects, wide variation in heterotrophic population (TVC) was noticed. Nearshore samples recorded highest counts

in the harbour indicated the input of more assimilable organic matter into the region. Bacterial population reported earlier at subsurface waters of Kavaratti Island by Nair (1979) was lower (7 - 42cfu/ml). Similar trend was noticed at surface waters of Key largo, Florida (Paul *et al.*, 1995). However, higher bacterial density ($1x10^9$cfu/ml) was observed during inter-monsoon periods of September and April/May in Central and Eastern Arabian Sea by Ramaiah *et al.*, (1996) and found out higher TVC during inter-monsoon period compared to southwest monsoon period of July/August and winter monsoon period of February/March. Although primary production was low during April/May, bacterial production was higher during that period. However, Lee and Lee, (1991), in their studies on heterotrophic marine bacteria in the inter tidal zone of the Yellow sea near Kunsan, Korea reported a range of 7.5 x 10^2 to 1.1 x 10^5 CFU/ml in water. The studies by Alavandi (1989) in the coastal waters of Cochin also showed higher range (0.5 x 10^5 24.5 x 10^5 CFU/ml) of TVC. This showed that the heterotrophic activity in the Lakshadweep waters was much lower. The present study, however, highlights the fact that the heterotrophic bacterial population in coastal waters of Andrott has considerably increased over the years. The increase in heterotrophic bacterial activity can be attributed to the increased input of assimilable organic wastes into the coastal Seas. The study on bacterial population proved that over the years there is an increased anthropogenic contamination in the nearshore area of Andrott, which is a threat to the overall health of the coral Island including that of the inhabitants.

Total coliforms were also high during pre monsoon period of 1997 in the near shore waters of harbour transect. This may be attributed to the discharge of domestic and other waste into the sea near harbour. The 2.5 km offshore stations seldom showed the presence of coliforms. This was true in the case of faecal coliforms too, contamination of which was seen only in the immediate near shore waters. The bacterial standard recommended by the WHO for marine recreational waters is less than 350 faecal coliforms or 1000 total coliforms per 100 ml (Ferguson and Johannes, 1975). In Andrott, this limit was found seldom exceeded. Under normal conditions *E. coli* cannot multiply in marine environment (Enzinger and Cooper, 1976), except when seawater contains organic substances more than 100 mg/l. *Salmonella* can multiply in water outside the host animal, if the protein concentration in the water is high enough (Geldreich, 1972). *Shigella* like organisms

(SHLO) and *Proteus*, *Klebsiella* like organisms (PKLO) were also noticed in considerable numbers from the waters of Andrott. Presence of organisms like *Vibrio cholera* and *V parahaemolyticus* in high numbers can be seen as natural populations together with the anthropogenic contamination. *Streptococus faecalis* like organisms (SFLO), the rapid indicator of faecal contamination were enumerated from the nearshore waters irrespective of season. Their absence in the offshore samples indicates inability to survive in the seawater for longer periods. Potential pathogens such as *Salmonella* like organisms, though they were also noticed in near shore waters, can be attributed to the prevalence of open defecation in the seashore. For bathing, water sports and commercial fishing, the faecal coliform density fixed by pollution control board (CPCB, 1986) was $1x10^2$ cfu/100 ml with the average value not exceeding $2x10^2$ cfu/100 ml in 20 % of samples in a year and in three consecutive samples in monsoon months. Though, the faecal coliforms in the nearshore waters of seaside are high and replenish regularly by influx nearshore, counts were low or nil at offshore waters. This shows that bacterial pollution was found confined to the nearshore region and beyond five kilometers, their occurrence was rare or very few.

Table 15. Microbiological characteristics of surface waters of Lighthouse transect; 1996-1998

Unit: Colony Forming Units/ml (CFU/ml)

Year	Distance from the shore	TVC	TC	ECLO	SLO	SHLO	PKLO	VCLO	VPLO	SFLO
1996	NEARSHORE	950	60	10	5	25	15	40	10	25
1997		1240	20	25	ND	30	30	70	45	15
1998		1100	15	20	ND	25	30	90	35	15
1998 (post)		780	25	10	ND	20	20	15	30	15
1996	2.5KM	430	10	ND	ND	20	10	25	15	10
1997		560	10	ND	ND	ND	10	60	25	5
1998		420	15	ND	ND	10	40	15	15	10
1998 (post)		660	ND	ND	ND	20	25	25	15	ND
1996	5.0KM	220	5	ND	ND	10	25	45	35	ND
1997		440	ND	ND	ND	ND	ND	45	30	ND
1998		280	ND	ND	ND	ND	ND	80	25	ND
1998 (post)		420	5	ND	ND	ND	ND	15	20	ND
1996	12.5KM	150	ND	ND	ND	5	25	25	15	ND
1997		360	ND	ND	ND	5	ND	45	10	ND
1998		210	ND	ND	ND	ND	ND	35	20	ND
1998 (post)		170	ND	ND	ND	ND	ND	45	55	ND

TVC- Total Viable Count; TC- Total Coliforms; ECLO- *E.coli* like organisms; SLO- *Salmonella* like organisms; SHLO- *Shigella* like organisms; PKLO-*Proteus*, *Klebsiella* like organisms; VCLO- *Vibrio cholera* like organisms; VPLO- *V parahaemolyticus* like organisms; SFLO- *Streptococcus faecalis* like organisms

ND - Not detected at the time of enumeration.

Table 16 - Microbiological characteristics of surface waters at Helipad transect; 1996-1998
Unit: Colony Forming Units/ml (CFU/ml)

Year	Distance from the shore	TVC	TC	ECLO	SLO	SHLO	PKLO	VCLO	VPLO	SFLO
1996	NEARSHORE	380	45	10	ND	25	15	45	70	15
1997		850	135	15	ND	35	25	145	175	15
1998		680	120	15	ND	40	15	105	115	10
1998 (post)		550	55	5	ND	25	15	35	75	15
1996	2.5KM	420	5	ND	ND	20	ND	65	110	ND
1997		1160	15	ND	ND	15	15	135	55	5
1998		1390	5	ND	ND	25	10	115	65	10
1998 (post)		480	10	ND	ND	15	5	45	40	ND
1996	5.0KM	390	ND	ND	ND	ND	25	120	25	ND
1997		575	5	ND	ND	15	20	155	45	ND
1998		965	ND	ND	ND	ND	10	140	40	ND
1998 (post)		435	ND	ND	ND	ND	10	35	25	ND
1996	12.5KM	450	ND	ND	ND	ND	10	60	15	ND
1997		540	ND	ND	ND	15	15	110	35	ND
1998		875	ND	ND	ND	ND	15	125	25	ND
1998 (post)		730	ND	ND	ND	ND	ND	55	15	ND

TVC- Total Viable Count; TC- Total Coliforms; ECLO- *E.coli* like organisms; SLO- *Salmonella* like organisms; SHLO- *Shigella* like organisms; PKLO-*Proteus*, *Klebsiella* like organisms; VCLO- *Vibrio cholera* like organisms; VPLO- *V parahaemolyticus* like organisms; SFLO- *Streptococcus faecalis* like organisms ; ND - Not detected at the time of enumeration.

Table 17 - Microbiological characteristics of the Harbour waters; 1996-1998

Unit: Colony Forming Units/ml (CFU/ml)

Year	Distance from the shore	TVC	TC	ECLO	SLO	SHLO	PKLO	VCLO	VPLO	SFLO
1996	NEARSHORE	1480	175	15	ND	40	20	170	40	220
1997		2230	215	40	15	20	145	80	85	95
1998		2460	120	35	5	45	25	85	165	40
1998 (post)		1030	50	10	ND	90	85	90	45	25
1996	2.5km	1640	50	5	ND	30	40	110	90	5
1997		1810	20	ND	ND	20	100	175	105	ND
1998		1960	60	ND	ND	60	30	145	145	10
1998 (post)		1080	10	ND	ND	40	75	45	65	ND
1996	5.0km	980	ND	ND	ND	15	10	55	75	ND
1997		860	ND	ND	ND	20	15	85	105	ND
1998		1105	ND	ND	ND	15	15	70	140	ND
1998 (post)		750	ND	ND	ND	15	10	40	50	ND
1996	12.5km	610	ND	ND	ND	10	10	50	40	ND
1997		840	ND	ND	ND	10	15	70	80	ND
1998		1180	ND	ND	ND	15	25	85	70	ND
1998 (post)		750	ND	ND	ND	ND	15	45	15	ND

TVC- Total Viable Count; TC- Total Coliforms; ECLO- *E.coli* like organisms; SLO- *Salmonella* like organisms; SHLO- *Shigella* like organisms; PKLO-*Proteus*, *Klebsiella* like organisms; VCLO- *Vibrio cholera* like organisms; VPLO- *V parahaemolyticus* like organisms; SFLO- *Streptococcus faecalis* like organisms

ND - Not detected at the time of enumeration.

Chart 67: Total viable count in Seawater at Light house transect; 1996-1998

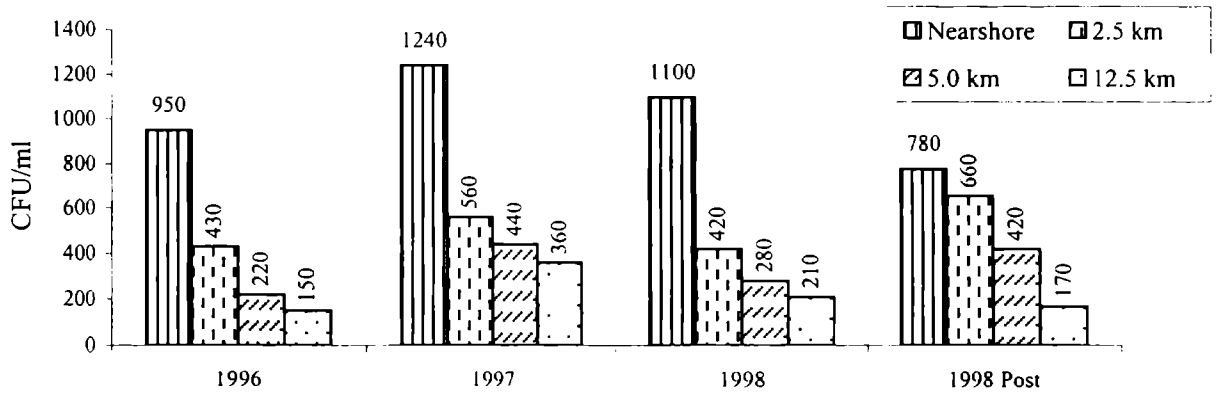


Chart 68: Total coliforms in Seawater at Light house transect; 1996-1998

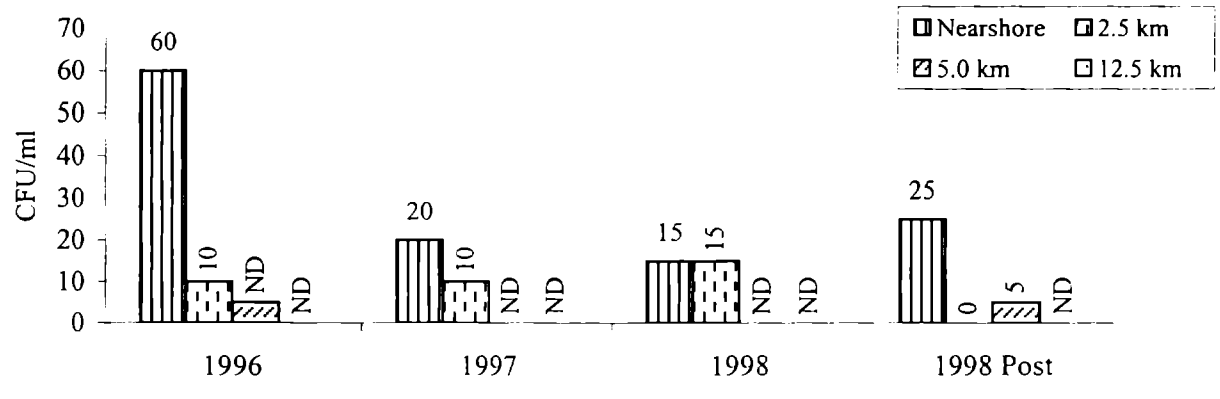


Chart 69: ECLO in Seawater at Light house transect; 1996-1998

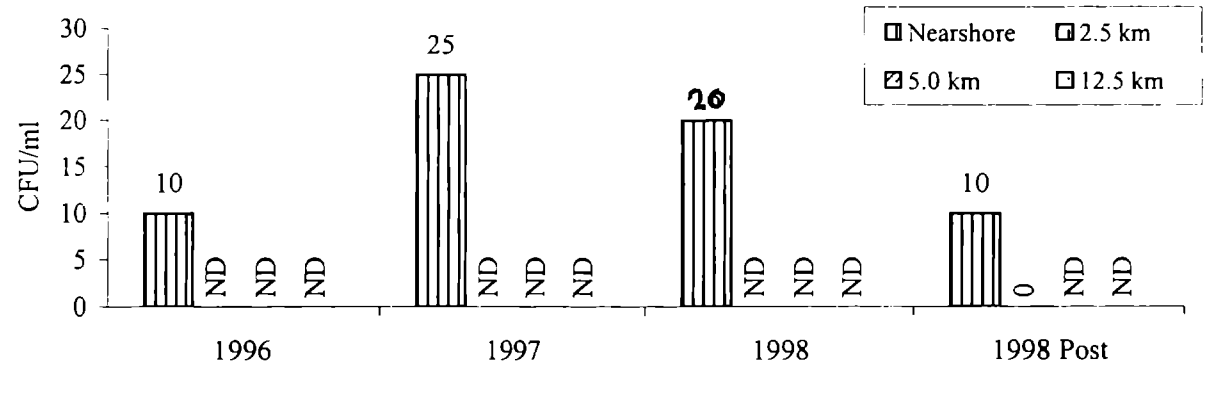


Chart 70: SHLO in Seawater at Light house transect; 1996-21998

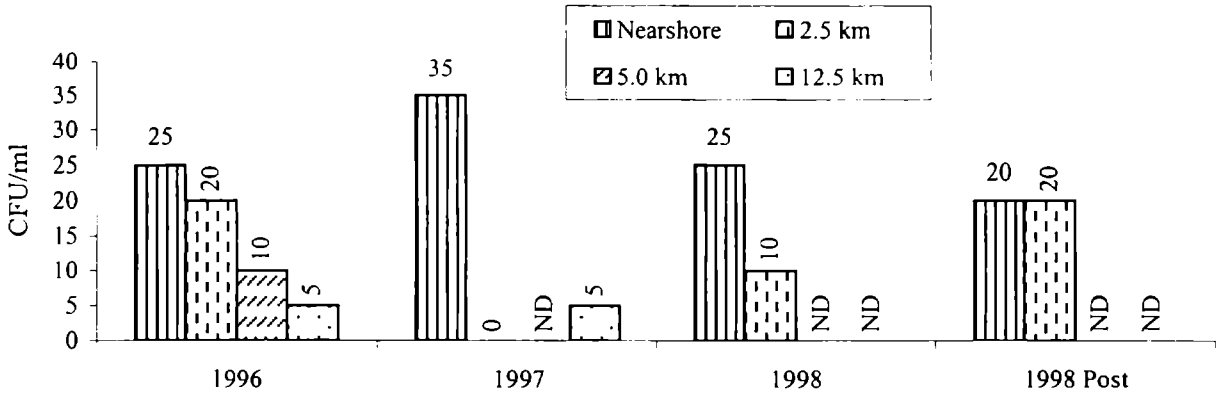


Chart 71: PKLO in Seawater at Light house transect; 1996-1998

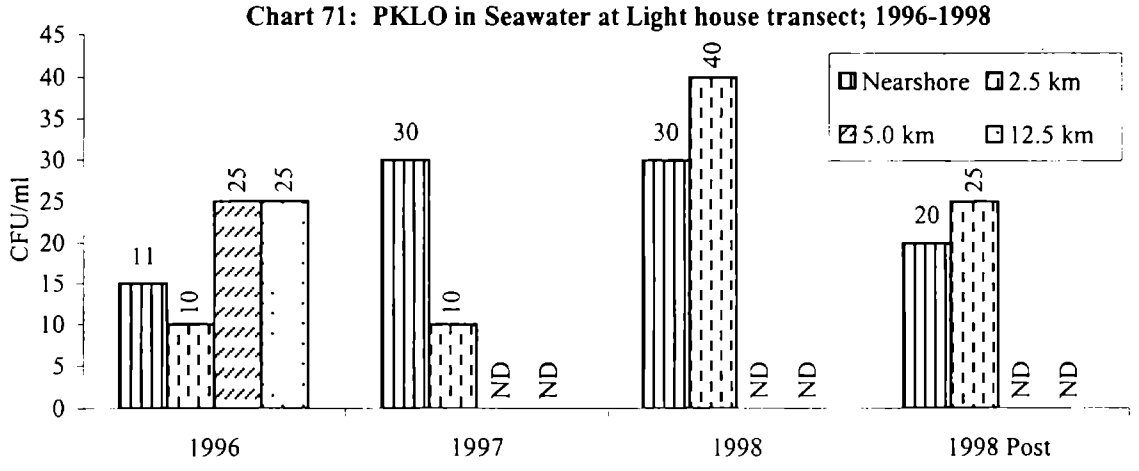


Chart 72: VCLO in Seawater at Light house transect; 1996-1998

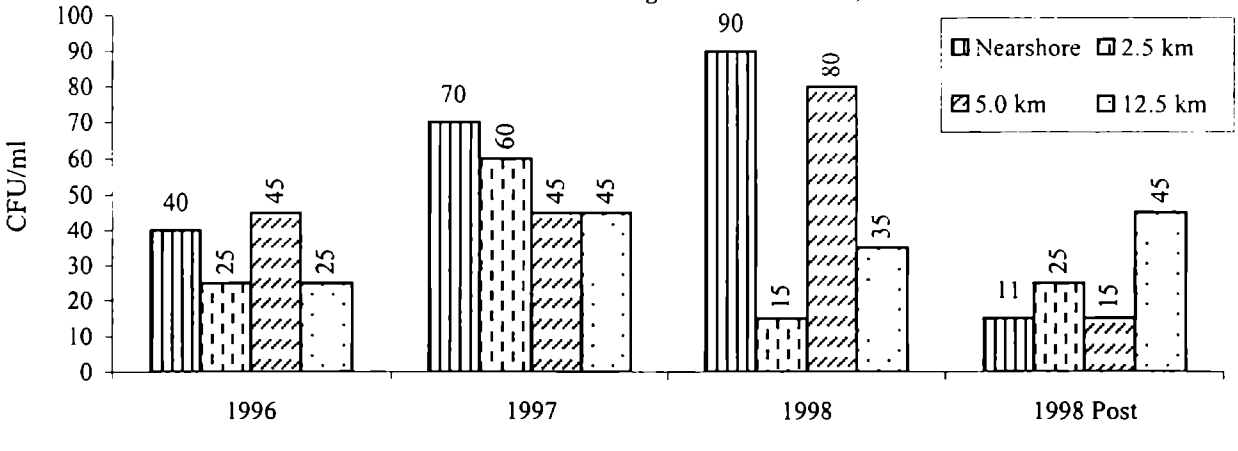


Chart 73: VPLO in Seawater at Light house transect; 1996-1998

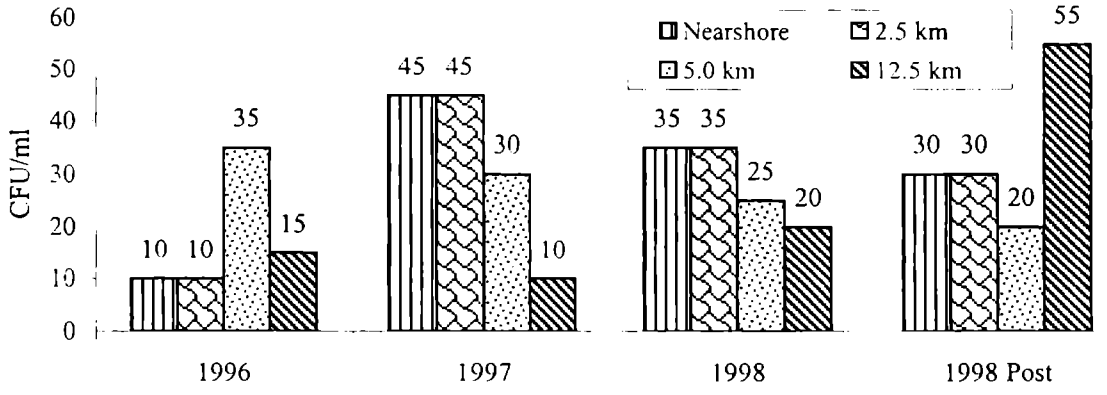


Chart 74: SFLO in Seawater at Light house transect; 1996-1998

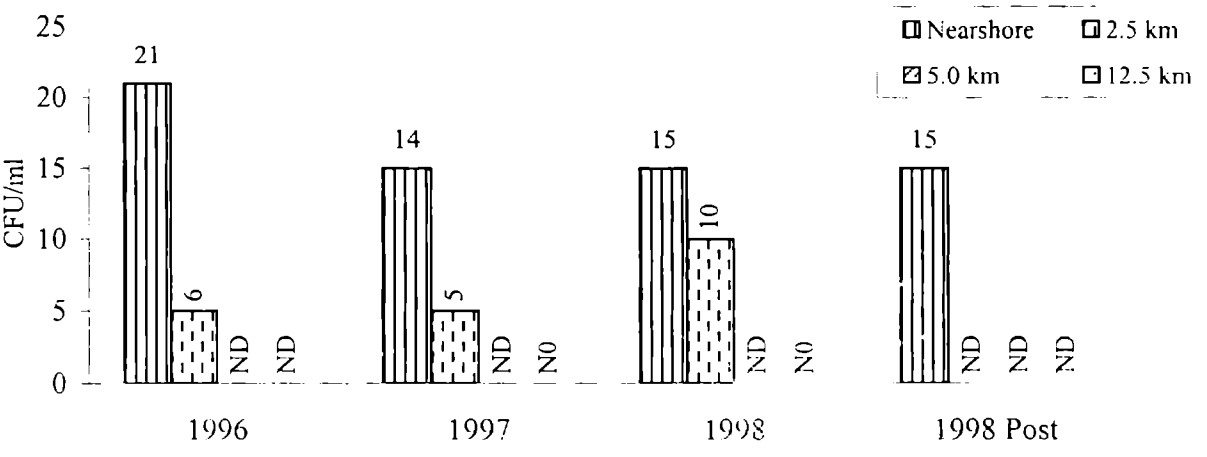


Chart 75: Total viable count in Seawater at Helipad transect; 1996-1998

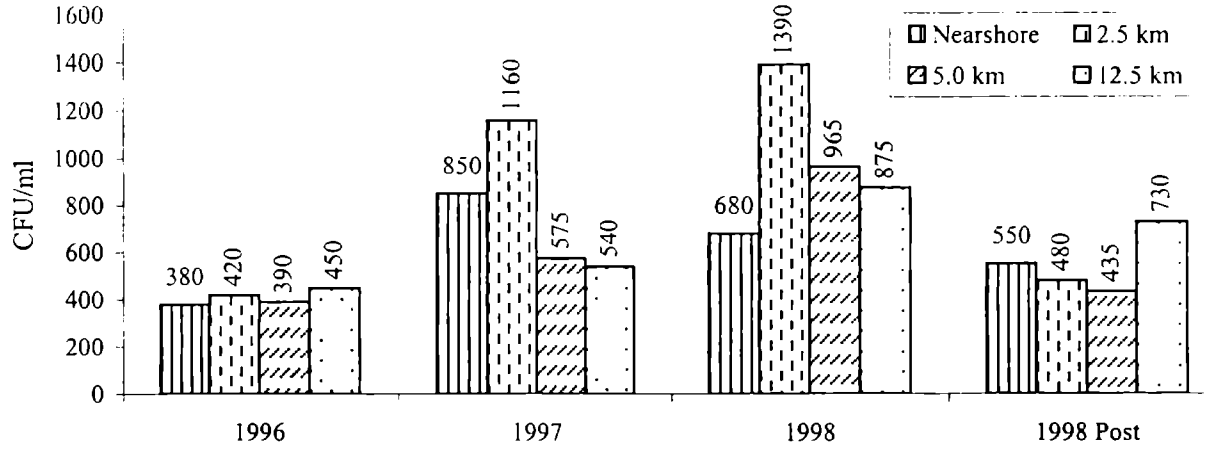


Chart 76: Total coliforms in Seawater at Helipad transect; 1996-1998

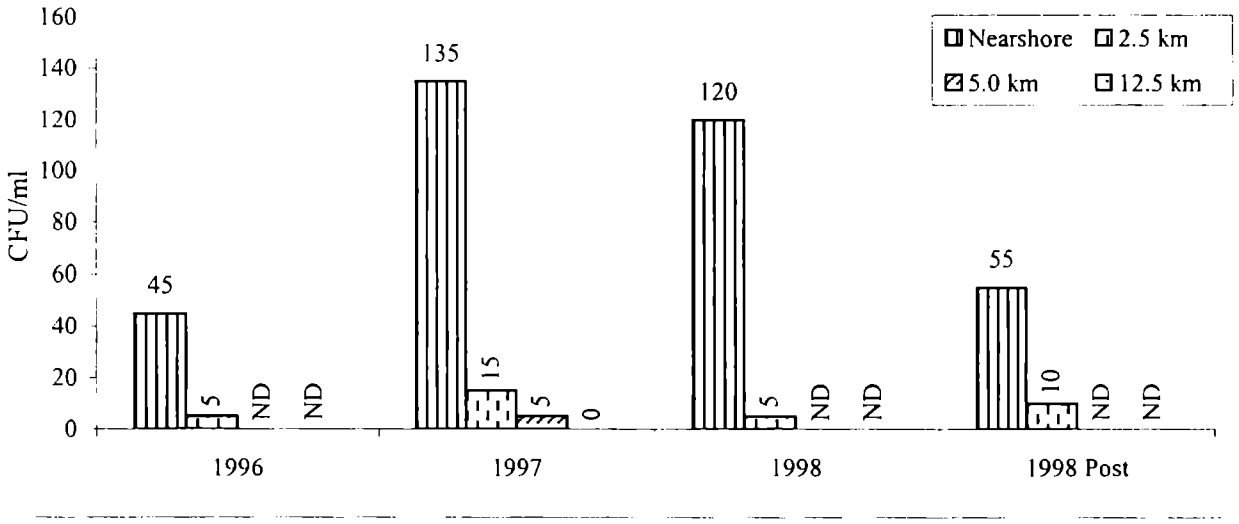


Chart 77: ECLO in Seawater at Helipad trasect; 1996-1998

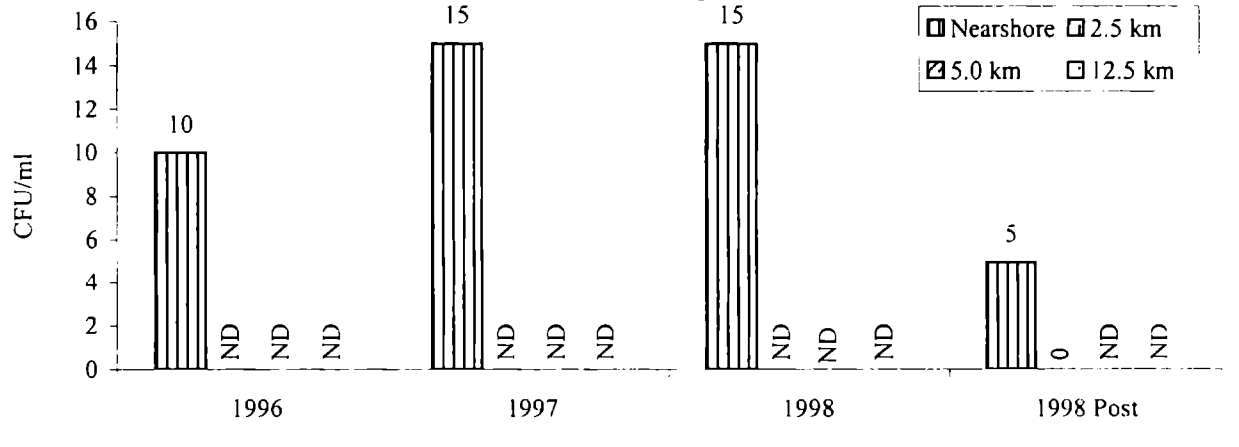


Chart 78: SHLO in Seawater at Helipad transect; 1996-1998

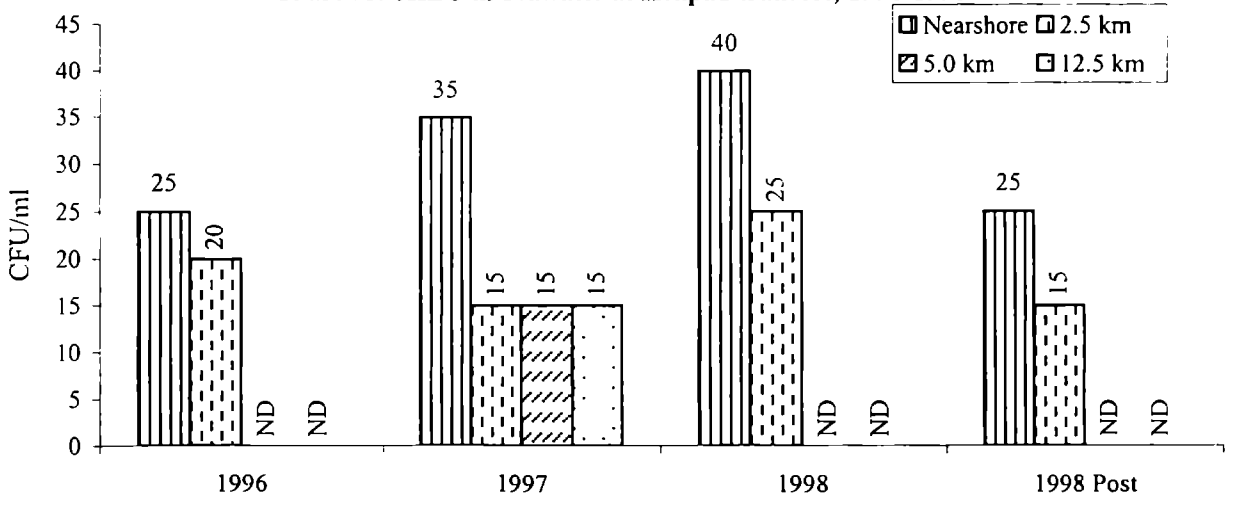


Chart 79: PKLO in Seawater at Helipad transect; 1996-1998

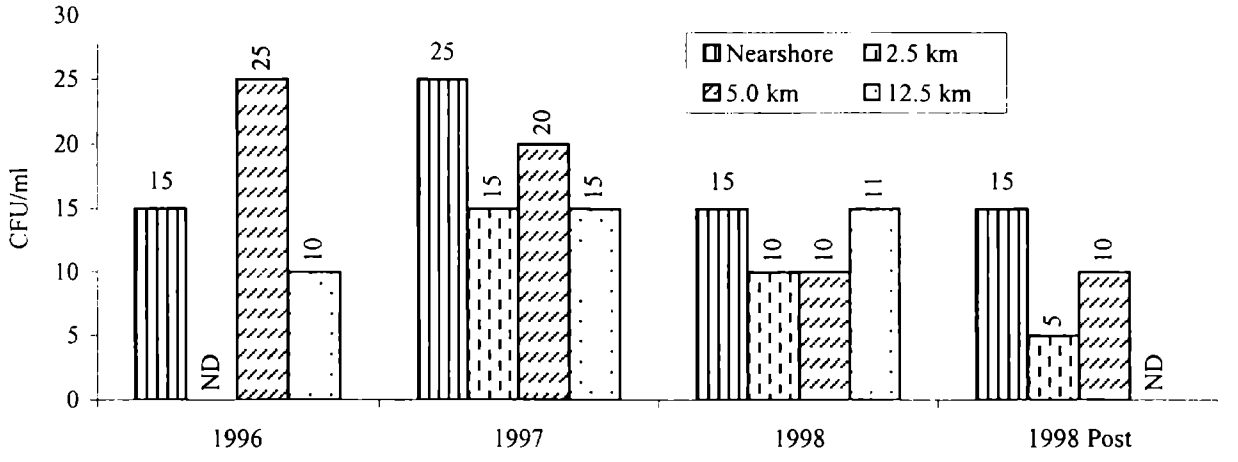


Chart 80: VCLO in Seawater at Helipad transect; 1996-1998

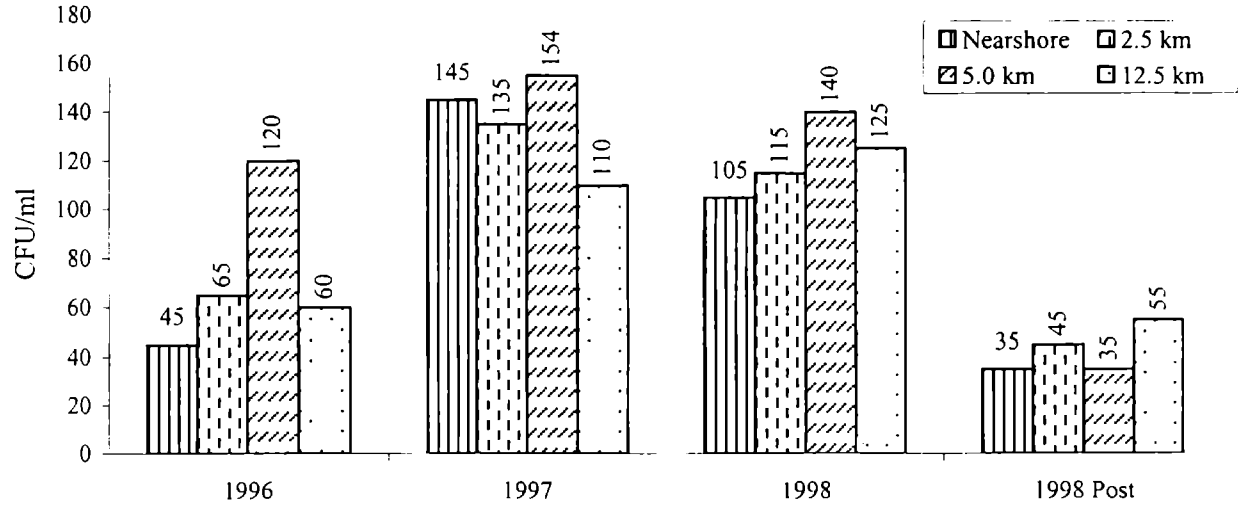


Chart 81: VPLO in Seawater at Helipad transect; 1996-1998

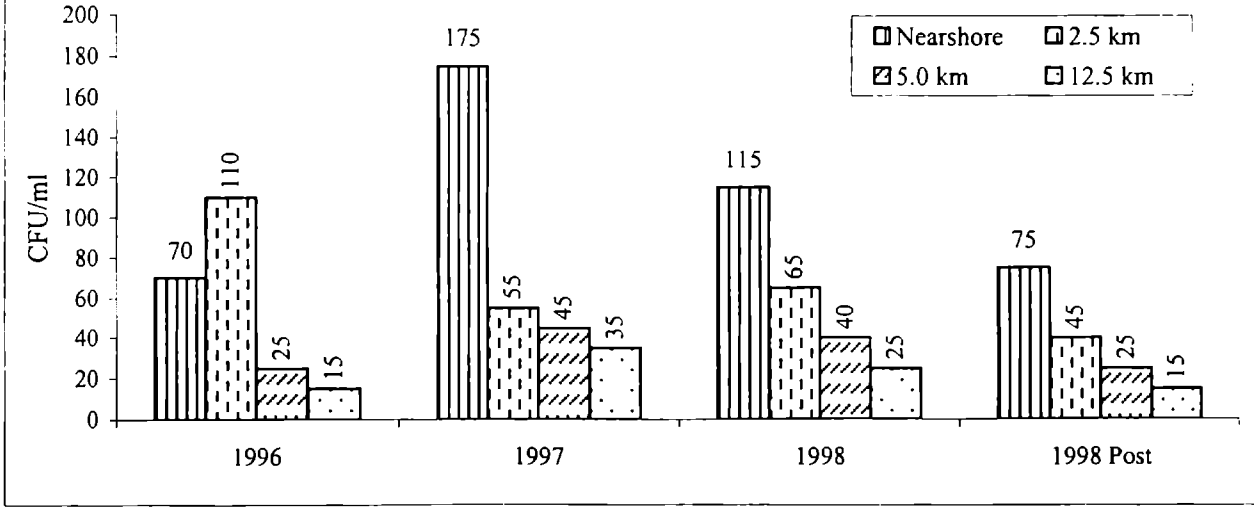


Chart 82: SFLO in Seawater at Helipad transect; 1996-1998

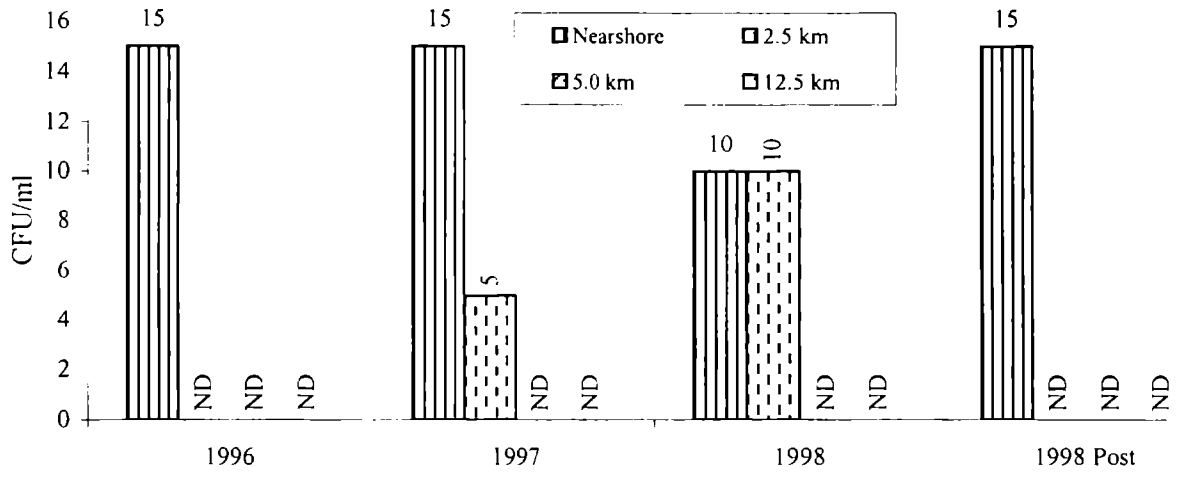


Chart 83: Total viable count at Harbour water:1996-1998

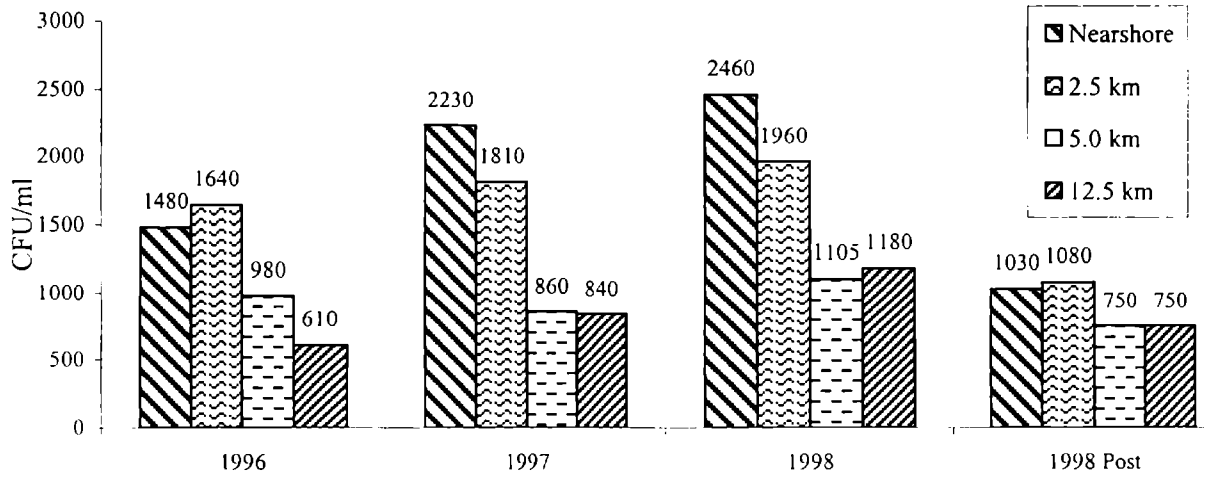


Chart 84: Total coliforms at Harbour water:1996-1998

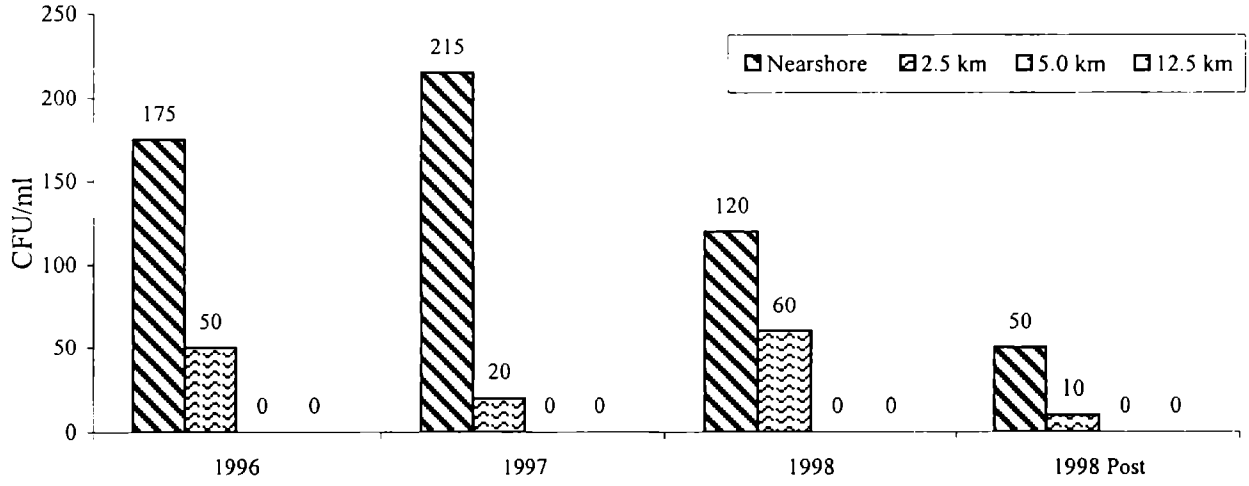


Chart 85: ECLO at Harbour water:1996-1998

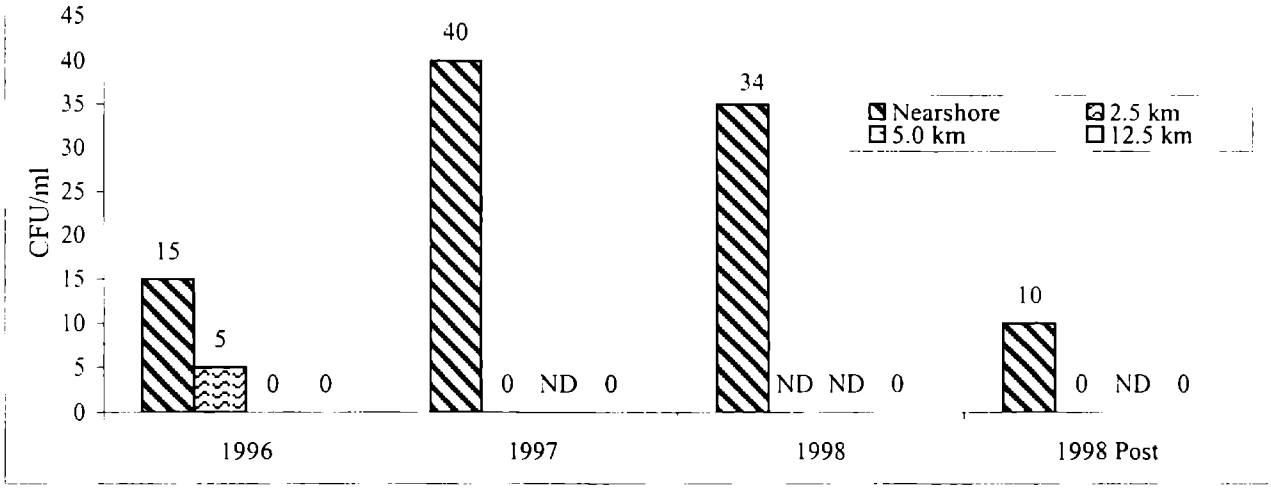


Chart 86: SHLO at Harbour water:1996-1998

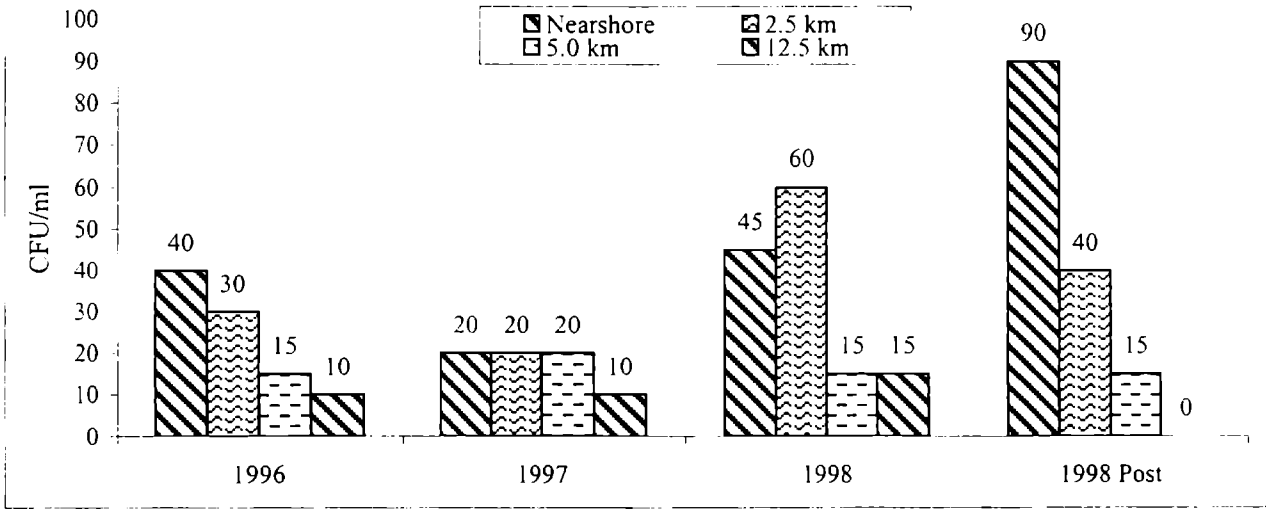


Chart 87: PKLO at Harbour water:1996-1998

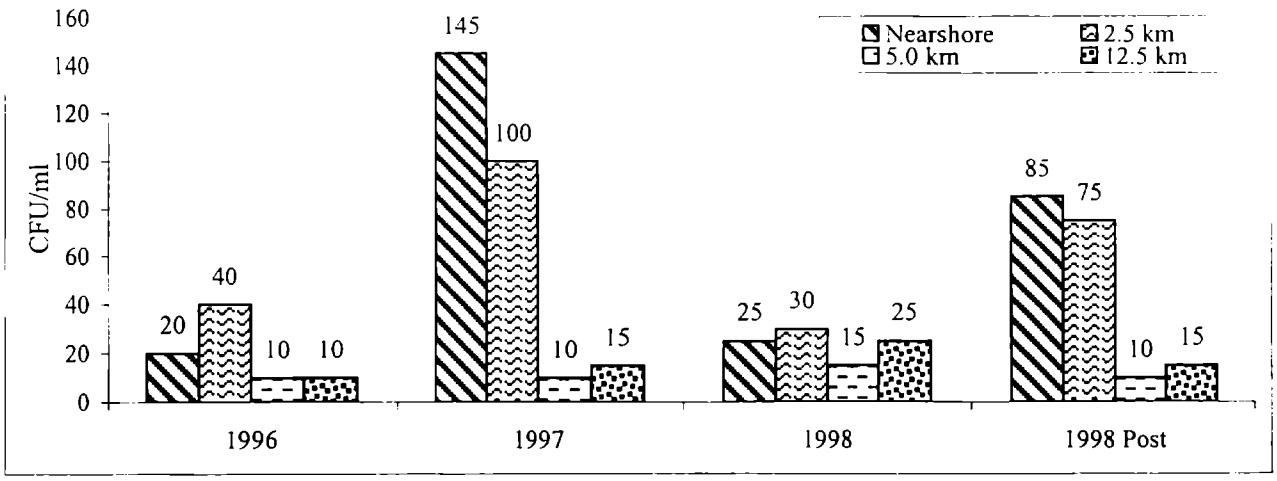


Chart 88: VCLO at Harbour water:1996-1998

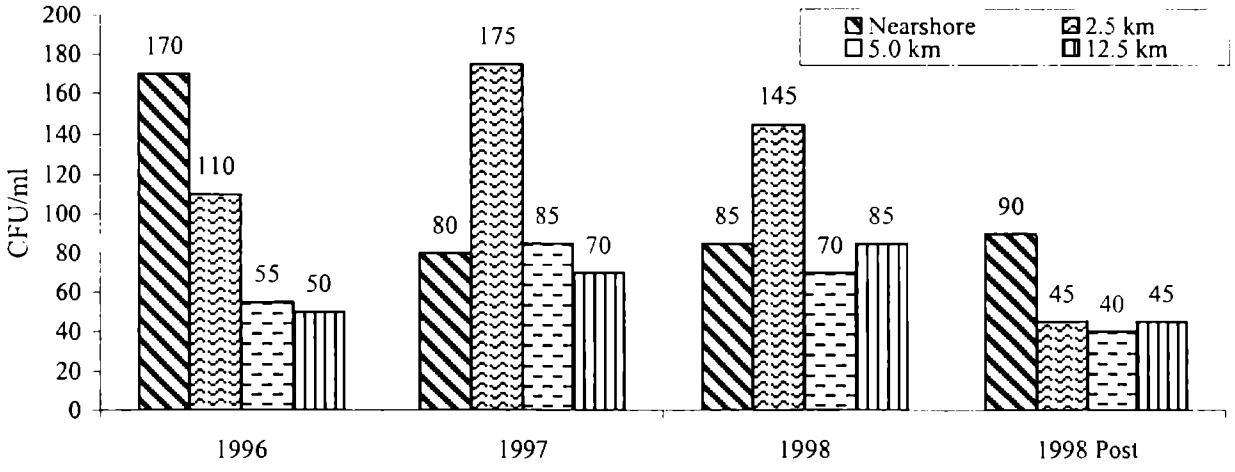


Chart 89: VPLO at Harbour water:1996-1998

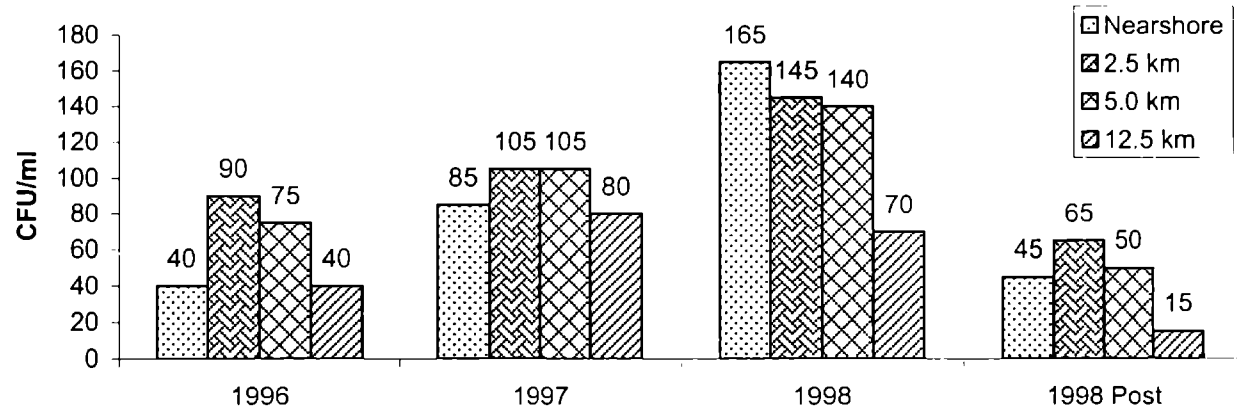
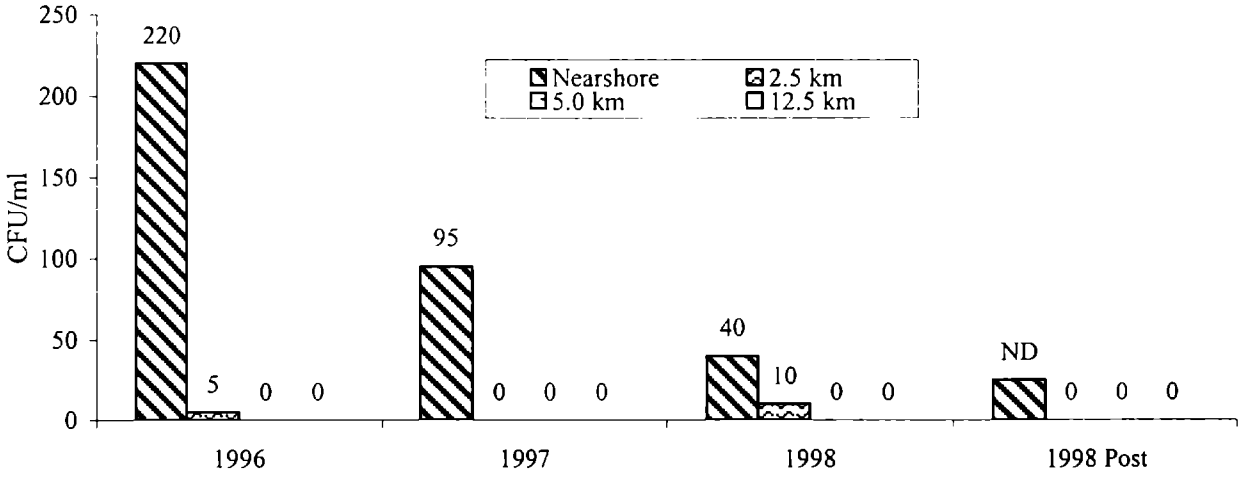


Chart 90: SFLO at Harbour water:1996-1998



3.2. Ground Water Analysis

The results are shown in table 18 to 25 and charts 91 to 186

3.2.1 Microbiological characteristics (Table 18 to 21 and charts 91 to 126)

Total viable count (TVC) (Chart 91 to 94)

TVC varied from 6.2 $x10^2$ cfu/100 ml in well 8 to 8.35x 10^3 in well 2 during 1996, 7.05 $x10^2$ cfu/100 ml in well 8 to 6.73 $x10^3$ cfu/100 ml in well 3 during 1997, 7.2 $x10^2$ cfu/100 ml in well 8 to 7.6 $x10^3$ cfu/100 ml in well 2 during pre monsoon 1998 and 4.6 $x10^2$ cfu/100 ml in well 8 to 6.1 $x10^3$ cfu/100 ml in well 2 during post monsoon 1998. In wells 2 and 3 recorded high TVC counts during 1996, 1997 and pre monsoon 1998 where as wells 7, 8 and 9 showed lower counts. This revealed that the distribution of heterotrophic population was highly fluctuating in the study period. In general, high counts were noticed during the pre-monsoon season, which might be due to organic matter accumulation in comparatively lower water volume during premonsoon that do not get diluted with rain water as in monsoon.

Total coliforms (TC) (Chart 95 to 98)

TC count ranged from 15 cfu/100 ml in well 8 to 1.06 $x10^3$ cfu/100 ml in well 6 during1996, 45cfu/100ml in well 8 to 1.45 $x10^3$ cfu/100 ml in well 4 during 1997, 35 cfu/100 ml in well 7 to $1.45x10^3$ cfu/100 ml in well 1 during pre monsoon 1998 and nil in wells 7 and 8 to 1.6 $x10^3$ cfu/100 ml in well 2 during post monsoon 1998.

Faecal coliforms (FC) (Chart 99 to 102)

FC was enumerated in 7 wells during 1996, the maximum count being $1.9x10^2$ cfu/100 ml in well 9. During 1997 and pre-monsoon 1998, they were enumerated from 9 out of 10 wells where the maximum count was 1.45x 10^2cfu/100 ml and $1.7x10^2$cfu/100 ml from well 1 respectively. During post monsoon, the count was generally lower and the maximum count was 30 cfu/100 ml from well 9. Faecal contamination noticed in wells irrespective of seasons clearly depicts that about 50 % or more of the well samples in Andrott are contaminated with enteropathogenic bacteria. The possible reason attributed to the increased faecal contamination was the seepage through un-plastered walls of the septic tanks/leach pits into the dug wells. Occurrence of entero-pathogenic *E.coli* in well water samples was an alarming case of drinking water pollution. This is particularly

significant in terms of the rate of population increase that may accelerate the chances of causing epidemics.

***Salmonella* like organisms (SLO) (103 to 106)**

SLO recorded their maximum count (5 cfu/100 ml) in wells 3, 7 and 9 during 1996, in well 2 (5 cfu/100 ml) during 1997, well 6 (15 cfu/100 ml) during pre-monsoon 1998 and in wells 2, 3, 6 and 8 (5 cfu/100 ml) during post monsoon 1998. Six wells duing 1996, 5 wells during 997, 5 wells during pre-monsoon 1998 and 4 wells during post monsoon 1998 recorded the presence of *Salmonella* like organisms. The presence of these organisms even in the absence of faecal coliforms may be due to their occurrence in water as natural inhabitants. However, the presence of the pathogens causative of typhoid fever, is an alarming case of drinking water contamination. *Salmonella typhosa* has been cited as one the major drinking water contaminants that cause diseases in human beings (WHO, 1989).

***Shigella* like organisms (SHLO) (Charts 107 to 110)**

SHLO varied from 10 in well 3 to 1.75 $x10^2$ cfu/100 ml in well 6 during 1996, 15 cfu/100ml in well 10 to 1.26 $x10^2$ cfu/100 ml in well 6 during 1997, 25 in well 10 to 1.55 $x10^2$ cfu/100 ml in well 6 during pre-monsoon 1998 and 25 cfu/100ml in well 1 to 1.28 $x10^2$ cfu/100 ml in well 6 during post monsoon 1998. These organisms were enumerated from most of the well waters irrespective of the seasons. *Shigella* is one of the chief contributors to dysentery in man that is waterborne. Presence of these organisms is also an indication of fecal contamination through septic tank leachate

***Proteus, Klebsiella* like organisms (PKLO) (Charts 111 to 114)**

PKLO count varied from 45cfu/100ml in well 5 to 1.8 $x10^2$ cfu/100ml in well 2 during 1996, 75 cfu/100ml in well 5 to 2.3 $x10^2$ cfu/100ml in well 1 during 1997, 45 cfu/100ml in well 7 to 2.14 $x10^2$ cfu/100ml in well 3 during pre-monsoon 1998 and 30cfu/100ml in well 5 to 1.4x10^2 cfu/100ml in well 1 during post monsoon 1998. The presence of PKLO was noticed in all wells during the entire study period. This indicated that PKLO is one of the natural inhabitants of fresh water.

***Vibrio cholera* like organisms (VCLO) (Charts 115 to 118)**

VCLO count varied from 0 in wells 5, 6, 8 to 2.4 $x10^2$ cfu/100 ml in well 2 during 1996, VCLO was not detected in wells 5, 6 and 8 during 1996. In wells 3, 4, 5, 8 and 10, VCLO was not detected during 1997. During 1998, these organisms were not detected in pre monsoon from wells 4, 5, 7, 9 and 10 whereas in post monsoon, they were not detected in wells 5, 6, 7, 8 and 9. Though, a majority of the species could be natural inhabitants in water, their high counts indicates the possible chances of cholera epidemics. Further analysis of the isolates by serological tests may help to identify the pathogenic species of *Vibrio*. Their distribution in the dug wells, however, warrants disinfection and careful management of sewage from contaminating the well waters. The dense and isolated population in the islands is also a serious factor to be considered. In case of epidemics like cholera a separate system that regularly monitors such components of environmental management should be there in the local level planning.

***Vibrio parahaemolyticus* like organisms (VPLO) (Charts 119 to 122)**

VPLO count varied from 65 cfu/100ml from well 10 to $2.15x10^2$ cfu/100ml in well 1 during 1996, 30 cfu/100ml in well 2 to $2.7x10^2$ cfu/100ml in well 1 during 1997, 40 cfu/100ml from well 2 to $7.4x10^2$ cfu/100ml in well 1 during pre-monsoon 1998 and 15 cfu/100ml from well 9 to $1.2x10^2$ cfu/100ml in well 1 during post monsoon 1998. The trend in the counts of these organisms showed that they were mostly present in pre-monsoon and a lowering in counts could be observed during post-monsoon. This showed that the pattern of their distribution was in tune with those of heterotrophic population and that VPLO could be a major component of TVC which prefer to exploit the organic rich premonsoon environment in the well waters.

Faecal streptococci (SFLO) (Charts 123 to 126)

SFLO varied from 5 in well 3 to 1.2 $x10^2$ in well 2 during 1996, 10 cfu/100ml from well 5 to 1.45 $x10^2$ cfu/100 ml in well 2 during 1997, 15 cfu/100ml from well 4 to 1.48 $x10^2$cfu/100ml from well 2 during pre-monsoon 1998 and 10 cfu/100ml from well 4 to 1.13 $x10^2$cfu/100ml from well 2 during post monsoon 1998. Faecal streptococci were present in almost all the wells during the entire study period. Widespread presence of these organisms was an indication of contamination from the un-plastered septic tanks/leach pits situated close to many wells. Their distribution clearly showed the continuous percolation

of leachate through the coral sand into the well water. The organisms such as fecal coliforms and streptococci have been considered indicators of water pollution because they are unable to grow in aquatic environment and consequently their presence indicates fecal contamination from warm blooded animals including man (WHO, 1984). The results of the present study showed that coliform contamination was nearly complete in the dug well waters covering all seasons. This revealed the severity of contamination from septic tank leachate through the sandy soil throughout the year.

Though the heterotrophic bacterial population (TVC) has not been generally considered under quality parameters, high concentration of such bacteria is not desirable in drinking water as it is an indirect indication of the organic load in the media. It is highly desirable that drinking water should be of the highest possible purity especially when one system serves large numbers of people. In order to prevent any possibility of water borne diseases, domestic water supply and its purification are of greatest public health importance. Water borne diseases can not only be transmitted through drinking water, but by various other faeco-oral routes also. These other routes are also facilitated by conditions of poor domestic hygiene and are therefore related to the availability of water for hygienic purposes rather than its quality.

Umar *et al.*, (2001), reported that 33 % of samples from hand pumps and 20 % from tube well samples in Aligarh city were found contaminated with coliforms and faecal coliforms. The possible reason attributed to this includes the physical environment around the well site, frequent broken state of platforms, accumulations of waste water and sources like sewage drainage, hospital discharge etc. Similar situations are also noted in case of the dug wells at Kavaratti where the bacteriological quality of dug well waters, open wells and surface water was studied by Nanoti (1989). In Lakshadweep islands, it is being reported that all these sources invariably contain coliforms. Out of a total of 126 samples from 9 islands, only 3 were free from coliform and these include 2 private hand pumps and an open well with pH 9.0. In the present study, the case of Andrott was far higher to this value.

Expanding human population worldwide exacerbates the degree and frequency of pathogens exposure. The hygiene related behaviour is also very important to interrupt the transmission of the enteric pathogens. One Guatemalan study showed that a hygiene

education programme among 106 mothers reduced the incidence of diarrhea in their children by 14 % and for the 4 months peak diarrhea season, the reduction was 32% (Ralph, 1992) and another study in Bangladesh showed that by providing free soap and water pitch along with awareness lecture reduced the incidence of secondary cases of Shigella dysentery by 84% (GEMS/DATABASE, 1989). The GEMS/DATABASE study reported that in India, out of the 3,119 cities only 217 have partial or full sewage treatment facilities. A study by Rai (1964) showed that the river Yamuna, which flows through New Delhi, enters the capital with 7.5 x 10^3 coliforms per 100 ml water after receiving an estimated 200 million litres of untreated sewage. Pathogens originated in human sewage may diffuse with rainwater and domestic wastewater through the sandy soil and reach the fresh water source. In case of Andrott, this might also be affected by the leach pit overflow as the pits are constructed near the dug wells. It is possible that during tidal influx, the wastewater from the pits could overflow and mix with the fresh water source. In this respect, the *Salmonella* species that cause typhoid fever and having numerous serotypes enumerated in low numbers from well waters of Andrott. In Lakshadweep, the water table is generally 0.5-4.0 m below ground level with an elevation between 0.5 m to 5.74 m above MSL. The septic tanks/leach pits are about 2-2.5m deep with overflow provision at an average depth of 0.5-1.0 m below ground level, ie, the dug wells are constructed to tap the same aquifer into which these effluents are discharged. Thus the septic tanks/leach pits, by design, allow entry of its effluents, into the water table. Rahman *et al.*, (2001) conducted studies in well waters from Ponnani and reported the total coliform range between 40 and 1.1 x10^3 per 100 ml. However, the mean values reported for faecal coliforms and faecal streptococci were lower compared to the results obtained from the main land.

Faecal streptococci are enteric bacteria found in the intestine of warm-blooded animals; including humans. *Streptococcus faecalis* is a representative of this group. Because faecal streptococci, particularly *S. faecalis* are abundantly present in the large intestines of humans, their occurrence in water is also indicative of faecal pollution. The most common water borne bacterial pathogens in contaminated drinking water supplies in the USA during 1961-1983 were *Shigella*, *Salmonella*, toxigenic *E.coli*, *Vibrio* and *Yersenia* (Mentzing, 1981).

High population densities with point source discharges of untreated domestic waste are the contributing factors that cross-contaminate the well waters rather than preventing contamination. Since the natural self-purification capacity of this receiving water is impaired, faecal contamination over base line water quality increases by 1 to 3 orders of magnitude. Here, the very low depth of wells also enhances the surface contamination of water sources from the accumulated wastes. The study shows that water quality management remains critical in Lakshadweep Islands since the ground water lens is continuously subjected to overdraft and bacterial contamination. The rise of water levels during high tide also found to be contributing to the increase of faecal bacteria of epidemiological significance in drinking water (Pillai *et al.*, 1998). The authors reported 2 to 100 fold increase in the count of faecal coliforms from the dug well waters taken during low and high tide period in Kavaratti. Similar results were also reported from Kadamat Island during 1997 which shows a drastic increase in the bacteriological and physico-chemical characteristics of the dug well waters.

Table 18: Bacterial distribution in dug wells during 1996

Date of Sampling: 29.10.1996 Date of Enumeration: 31.10.1996

Wells	1	2	3	4	5	6	7	8	9	10
TVC	4.75×10^3	8.35×10^3	6.3×10^3	6.54×10^3	2.26×10^3	2.46×10^3	1.23×10^3	6.2×10^2	7.6×10^2	2.26×10^3
TC	8.4×10^2	1.03×10^3	1.45×10^2	2.2×10^2	1.6×10^2	1.06×10^3	25	15	20	75
FC	1.15×10^2	85	ND	ND	5	40	5	ND	1.9×10^2	20
SLO	ND	5	5	ND	5	ND	5	ND	5	5
SHLO	45	50	10	25	25	1.75×10^2	25	50	85	25
PKLO	1.35×10^2	1.8×10^2	50	75	45	95	1.25×10^2	55	1.45×10^2	1.25×10^2
VCLO	1.25×10^2	5	20	55	ND	ND	1.15×10^2	ND	2.4×10^2	1.45×10^2
VPLO	2.15×10^2	70	1.15×10^2	75	90	1.75×10^2	1.5×10^2	1.45×10^2	80	65
SFLO	45	1.2×10^2	5	5	10	75	25	85	55	30

ND-Not detected at the time of enumeration. Unit Colony forming units/100 ml (CFU/100 ml)

Table 19: Bacterial distribution in dug wells during 1997

Date of Sampling: 20.02.1997 Date of Enumeration: 22.02.1997

	1	2	3	4	5	6	7	8	9	10
TVC	4.36×10^3	6.64×10^3	6.73×10^3	4.24×10^3	1.46×10^3	2.12×10^3	9.5×10^2	7.05×10^2	8.4×10^2	3.41×10^3
TC	1.1×10^3	1.26×10^3	4.2×10^2	1.45×10^3	2.4×10^2	1.1×10^3	55	45	1.1×10^2	65
FC	1.45×10^2	75	5	5	15	50	10	ND	85	15
SLO	ND	5	5	ND	ND	5	ND	ND	5	5
SHLO	50	20	40	35	45	1.25×10^2	15	75	1.05×10^2	15
PKLO	2.3×10^2	1.75×10^2	75	1.45×10^2	75	1.55×10^2	1.8×10^2	75	1.75×10^2	1.55×10^2
VCLO	80	75	ND	ND	ND	20	1.1×10^2	ND	185	ND
VPLO	2.7×10^2	30	45	45	1.2×10^2	85	65	1.55×10^2	1.25×10^2	55
SFLO	40	1.45×10^2	20	10	10	85	40	1.1×10^2	1.05×10^2	50

ND-Not detected at the time of enumeration; Unit: Colony forming units/100 ml (CFU/100 ml)

Table 20: Bacterial distribution in dug wells during 1998

Date of Sampling: 22.03.1998 Date of Enumeration: 24.03.1998

	1	2	3	4	5	6	7	8	9	10
TVC	5.84×10^3	7.6×10^3	7.27×10^3	2.43×10^3	1.26×10^3	2.26×10^3	7.6×10^2	7.2×10^2	1.2×10^3	3.6×10^3
TC	1.45×10^3	1.41×10^3	1.45×10^2	4.2×10^2	1.75×10^2	1.24×10^3	35	55	85	55
FC	1.7×10^2	65	10	10	20	35	15	ND	80	10
SLO	ND	15	10	ND	ND	15	ND	5	ND	5
SHLO	1.5×10^2	60	75	45	45	1.55×10^2	50	75	1.55×10^2	30
PKLO	1.5×10^2	1.85×10^2	2.15×10^2	1.75×10^2	50	1.8×10^2	45	1.55×10^2	1.45×10^2	85
VCLO	15	80	50	ND	ND	35	ND	75	ND	ND
VPLO	7.4×10^2	40	1.25×10^2	45	55	1.15×10^3	70	1.45×10^2	2.05×10^2	70
SFLO	35	1.5×10^2	25	15	20	1×10^2	45	1.45×10^2	1.1×10^2	55

ND-Not detected at the time of enumeration, Unit Colony forming units 10^2 ml (CFU 10^2 ml)

Table 21 Bacterial distribution in dug wells during post monsoon 1998

Date of Sampling . 20.11.1998 Date of Enumeration: 22.11.1998

	1	2	3	4	5	6	7	8	9	10
TVC	3.13×10^3	6.1×10^3	5.23×10^3	1.46×10^3	8.9×10^2	1.8×10^3	4.9×10^2	4.6×10^2	9.8×10^2	2.68×10^3
TC	1.4×10^3	1.6×10^3	85	75	55	4.85×10^2	ND	ND	20	45
FC	15	15	5	5	15	20	5	ND	30	5
SLO	ND	5	5	ND	ND	5	ND	5	ND	ND
SHLO	25	45	55	35	40	1.3×10^2	55	45	80	25
PKLO	1.4×10^2	1.15×10^2	1.2×10^2	75	30	1.1×10^2	45	1.05×10^2	1.05×10^2	70
VCLO	25	1×10^2	20	15	ND	ND	ND	ND	ND	10
VPLO	1.2×10^2	30	25	30	30	45	55	70	15	40
SFLO	30	1.15×10^2	20	10	20	75	15	1.05×10^2	80	30

ND-Not detected at the time of enumeration, Unit: Colony forming units/100 ml (CFU/100 ml)

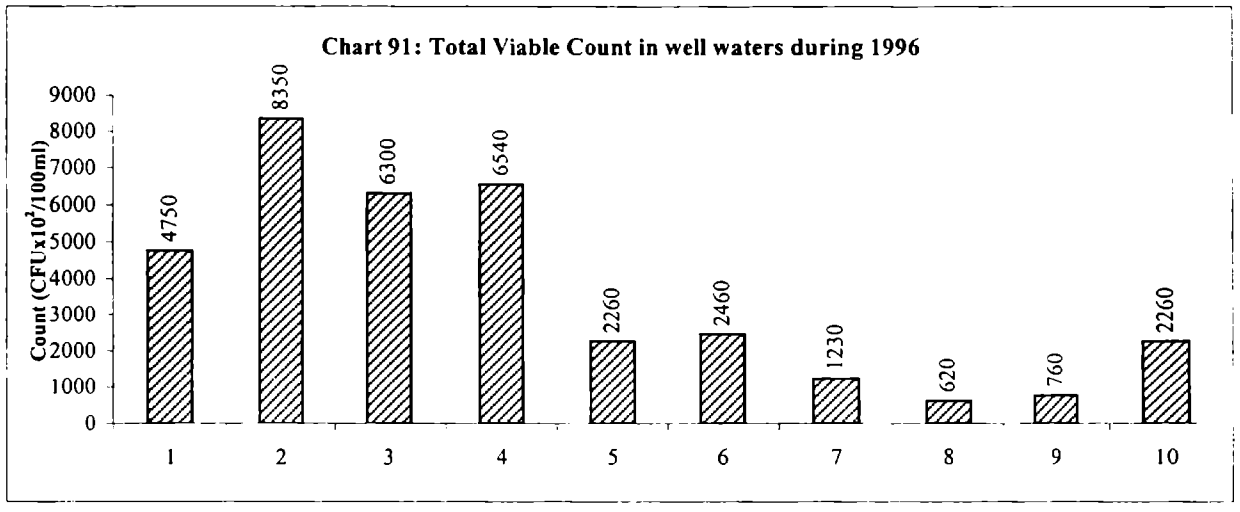


Chart 91: Total Viable Count in well waters during 1996
Count (CFUx10²/100ml)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
4750
8350
6300
6540
2260
2460
1230
620
760
2260
1
2
3
4
5
6
7
8
9
10

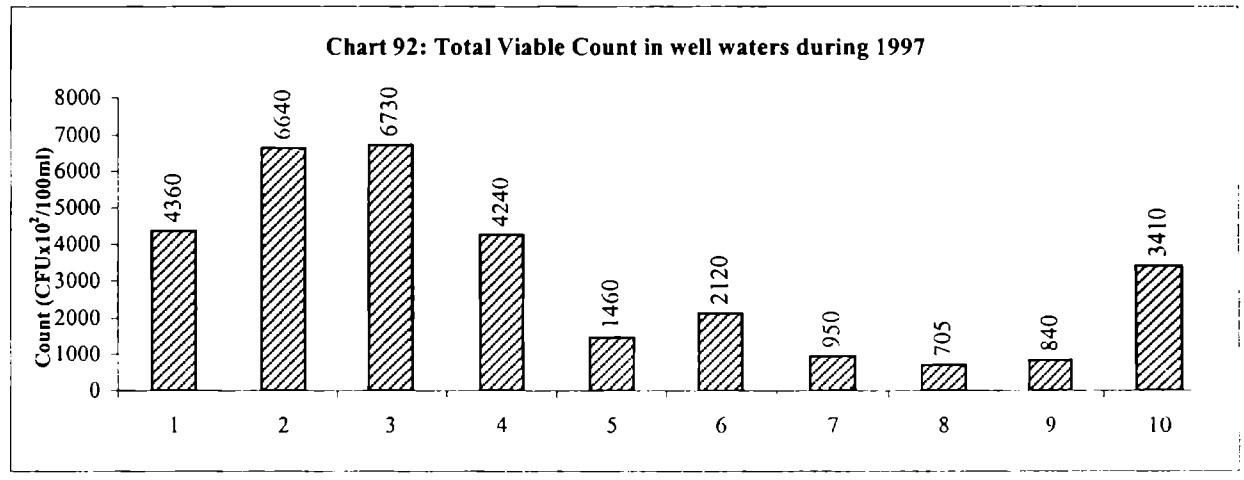


Chart 92: Total Viable Count in well waters during 1997
Count (CFUx10²/100ml)
8000
7000
6000
5000
4000
3000
2000
1000
0
4360
6640
6730
4240
1460
2120
950
705
840
3410
1
2
3
4
5
6
7
8
9
10

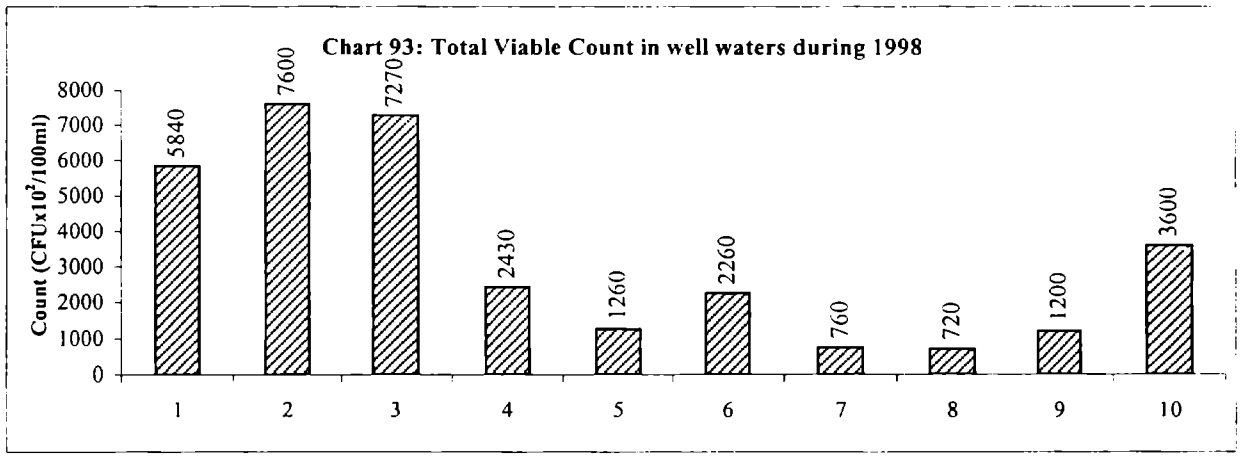


Chart 93: Total Viable Count in well waters during 1998
Count (CFUx10²/100ml)
8000
7000
6000
5000
4000
3000
2000
1000
0
5840
7600
7270
2430
1260
2260
760
720
1200
3600
1
2
3
4
5
6
7
8
9
10

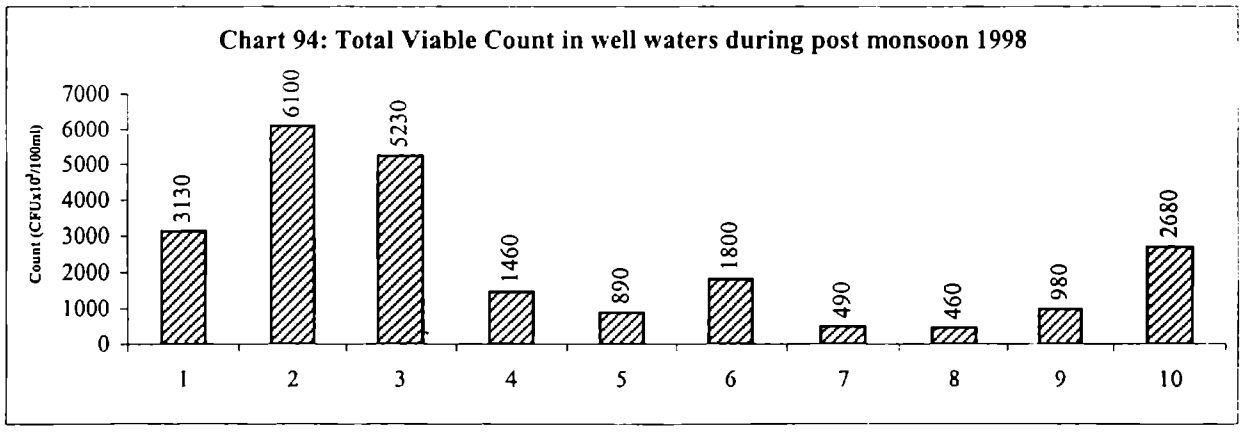


Chart 94: Total Viable Count in well waters during post monsoon 1998
Count (CFUx10²/100ml)
7000
6000
5000
4000
3000
2000
1000
0
3130
6100
5230
1460
890
1800
490
460
980
2680
1
2
3
4
5
6
7
8
9
10

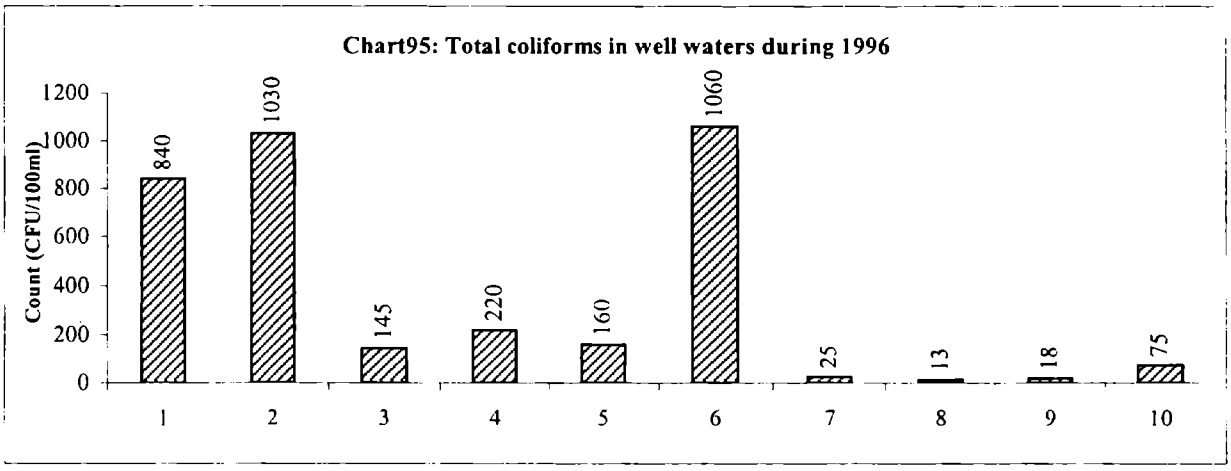


Chart95: Total coliforms in well waters during 1996
Count (CFU/100ml)
1200
1000
800
600
400
200
0
840
1030
145
220
160
1060
25
13
18
75
1
2
3
4
5
6
7
8
9
10

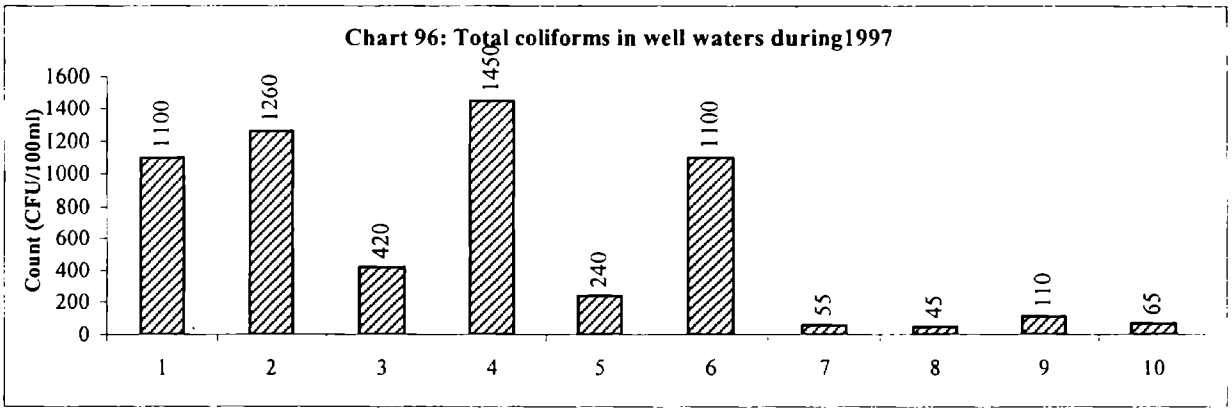


Chart 96: Total coliforms in well waters during1997
Count (CFU/100ml)
1600
1400
1200
1000
800
600
400
200
0
1100
1260
420
1450
240
1100
55
45
110
65
1
2
3
4
5
6
7
8
9
10

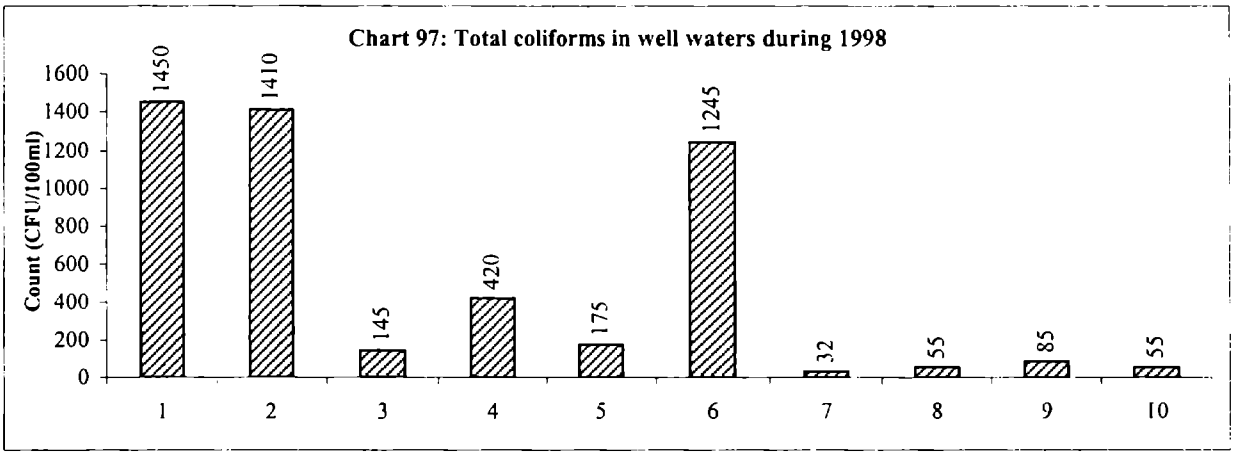


Chart 97: Total coliforms in well waters during 1998
Count (CFU/100ml)
1600
1400
1200
1000
800
600
400
200
0
1450
1410
145
420
175
1245
32
55
85
55
1
2
3
4
5
6
7
8
9
10

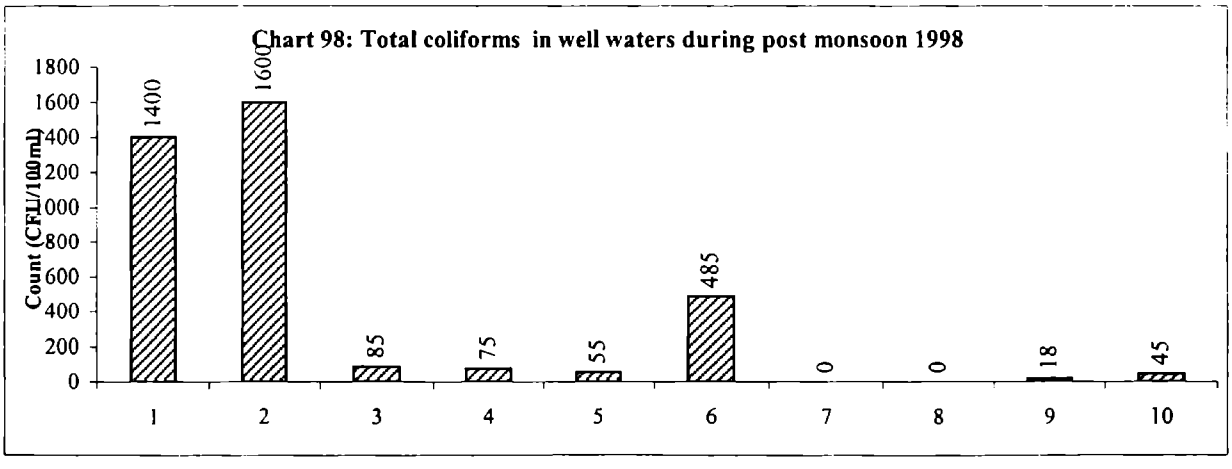


Chart 98: Total coliforms in well waters during post monsoon 1998
Count (CFU/100ml)
1800
1600
1400
1200
1000
800
600
400
200
0
1400
1600
85
75
55
485
0
0
18
45
1
2
3
4
5
6
7
8
9
10

Chart 99: Faecal coliforms in well waters during 1996

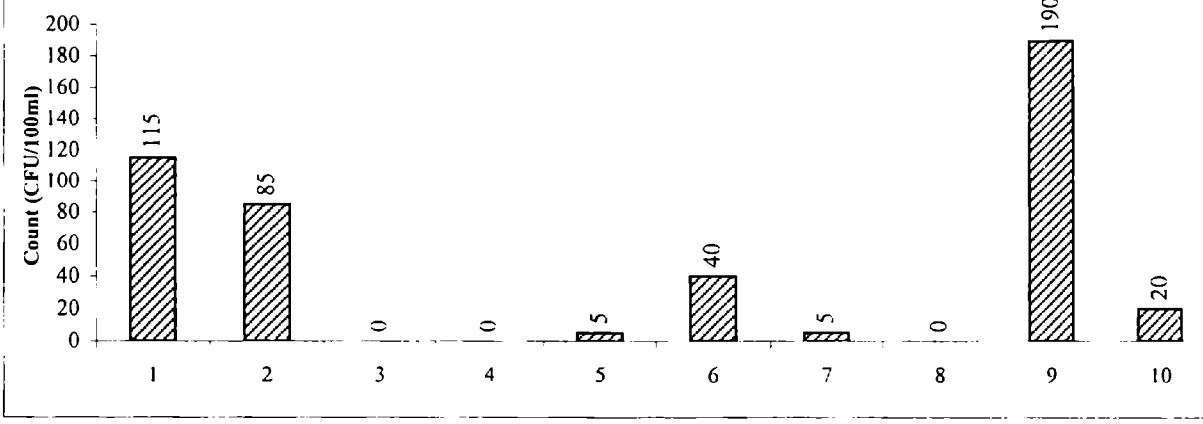


Chart 100: Faecal coliforms in well waters during 1997

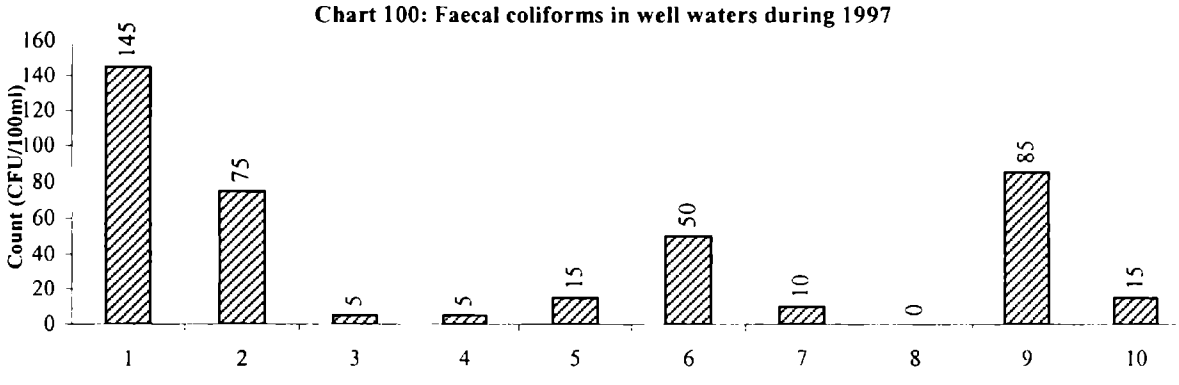


Chart 101: Faecal coliforms in well waters during 1998

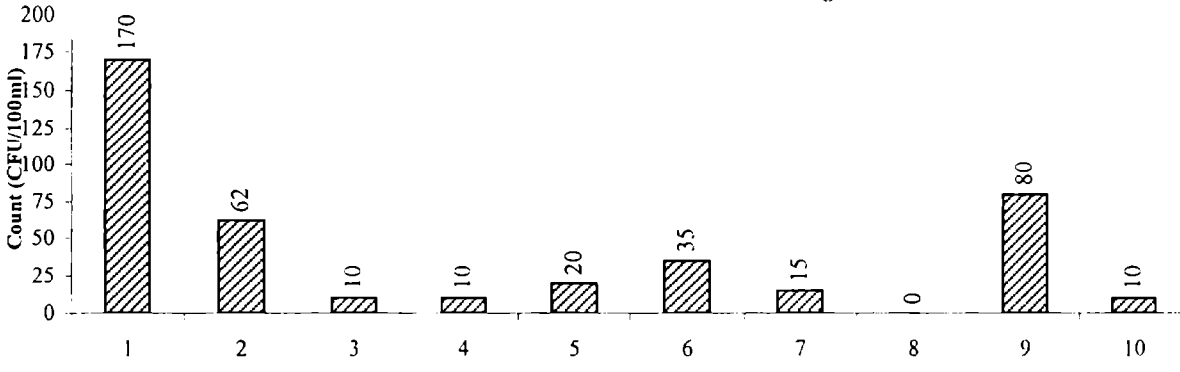


Chart 102: Faecal coliforms in well waters during post monsoon 1998

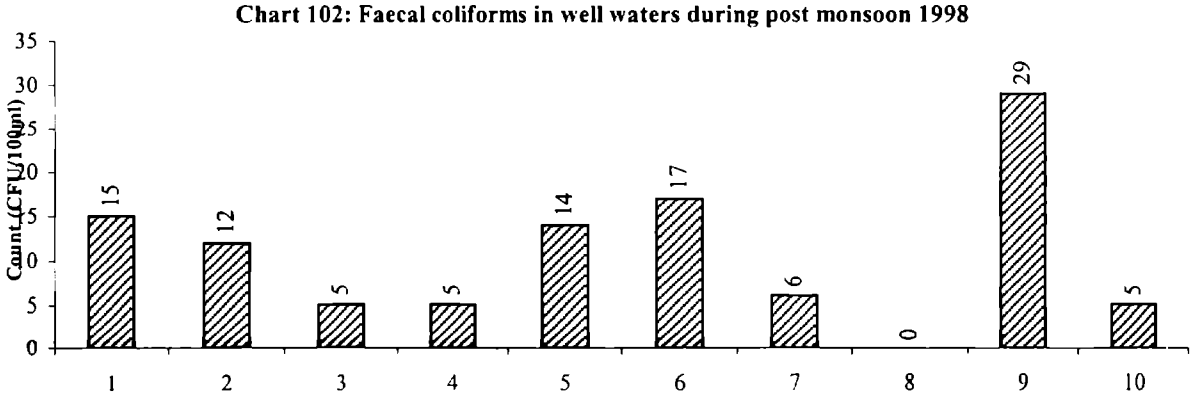


Chart 103: SLO in well waters during 1996

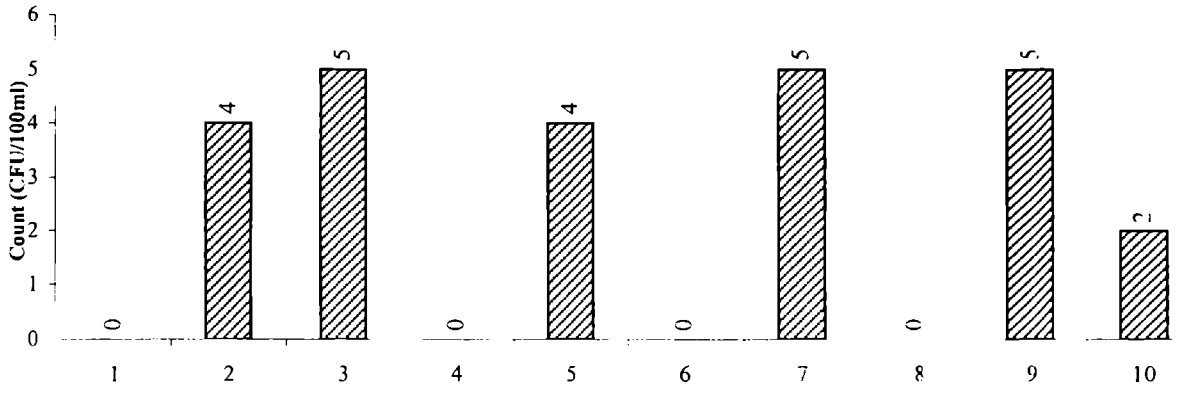


Chart 104: SLO in well waters during 1997

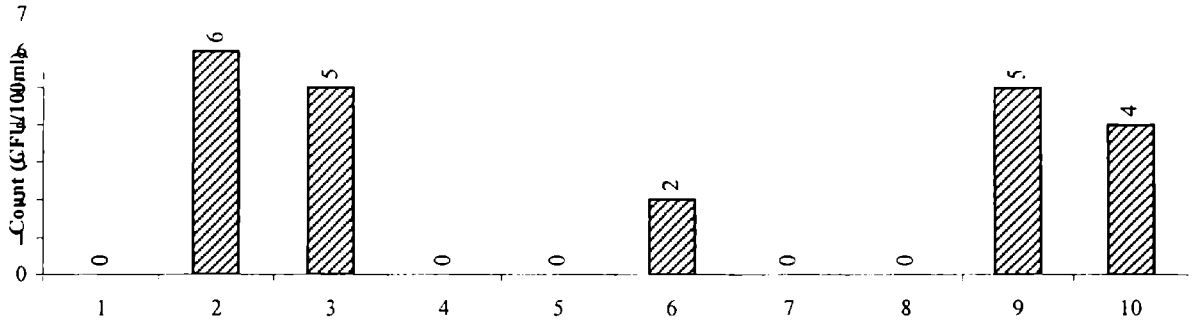


Chart 105: SLO in well waters during 1998

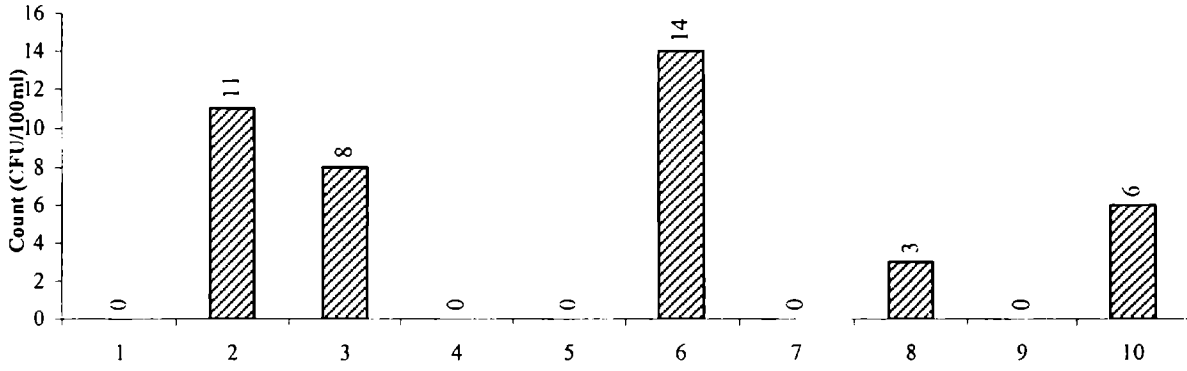
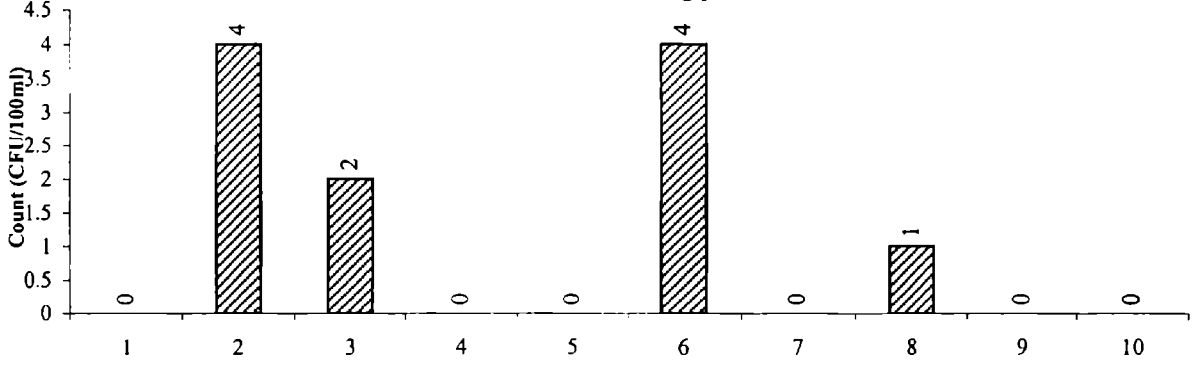


Chart 106: SLO in well waters during post monsoon 1998



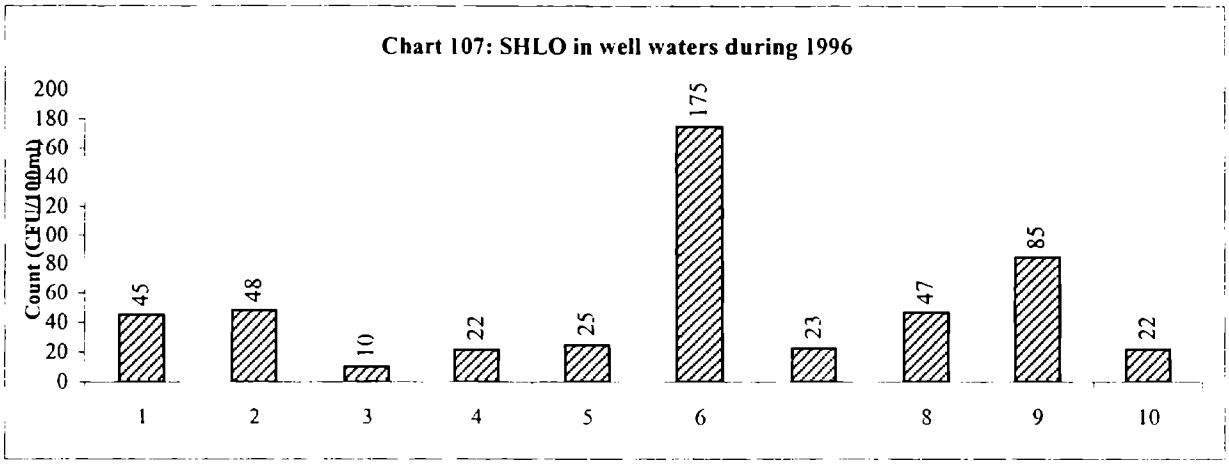


Chart 107: SHLO in well waters during 1996
Count (CFU/100ml)
200
180
160
140
120
100
80
60
40
20
0
45
48
10
22
25
175
23
47
85
22
1
2
3
4
5
6
8
9
10

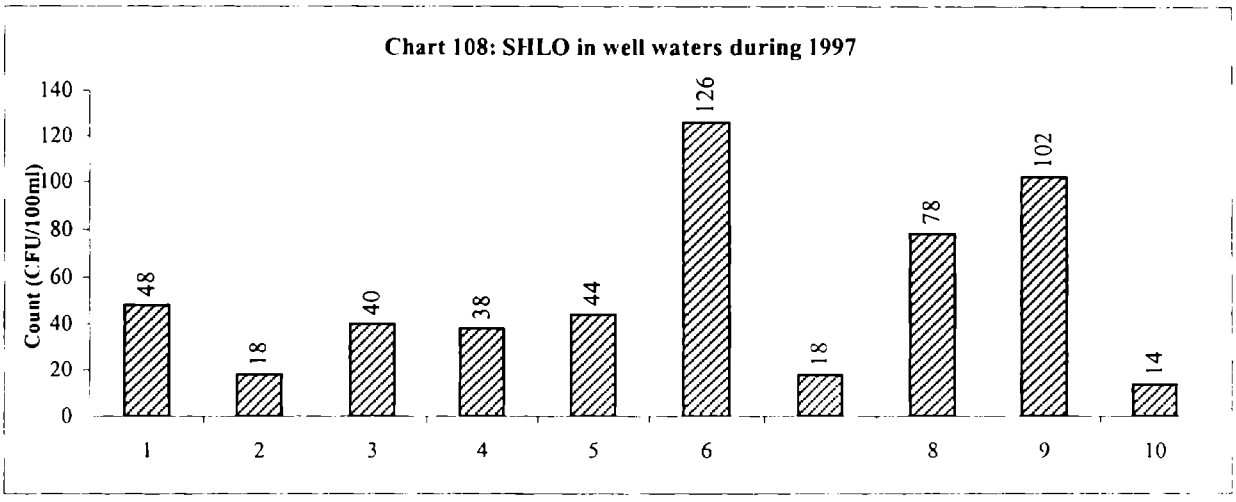


Chart 108: SHLO in well waters during 1997
Count (CFU/100ml)
140
120
100
80
60
40
20
0
48
18
40
38
44
126
18
78
102
14
1
2
3
4
5
6
8
9
10

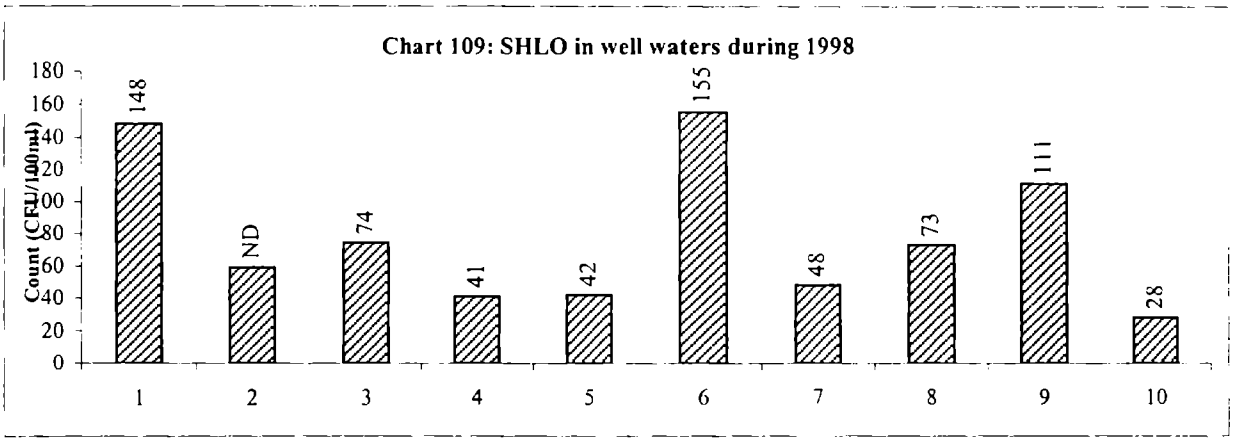


Chart 109: SHLO in well waters during 1998
Count (CFU/100ml)
180
160
140
120
100
80
60
40
20
0
148
ND
74
41
42
155
48
73
111
28
1
2
3
4
5
6
7
8
9
10

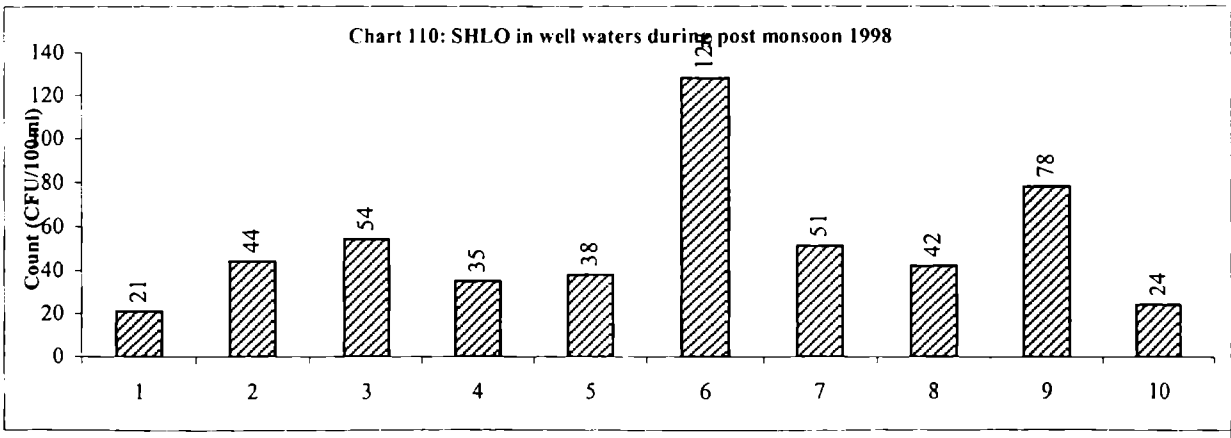


Chart 110: SHLO in well waters during post monsoon 1998
Count (CFU/100ml)
140
120
100
80
60
40
20
0
21
44
54
35
38
126
51
42
78
24
1
2
3
4
5
6
7
8
9
10

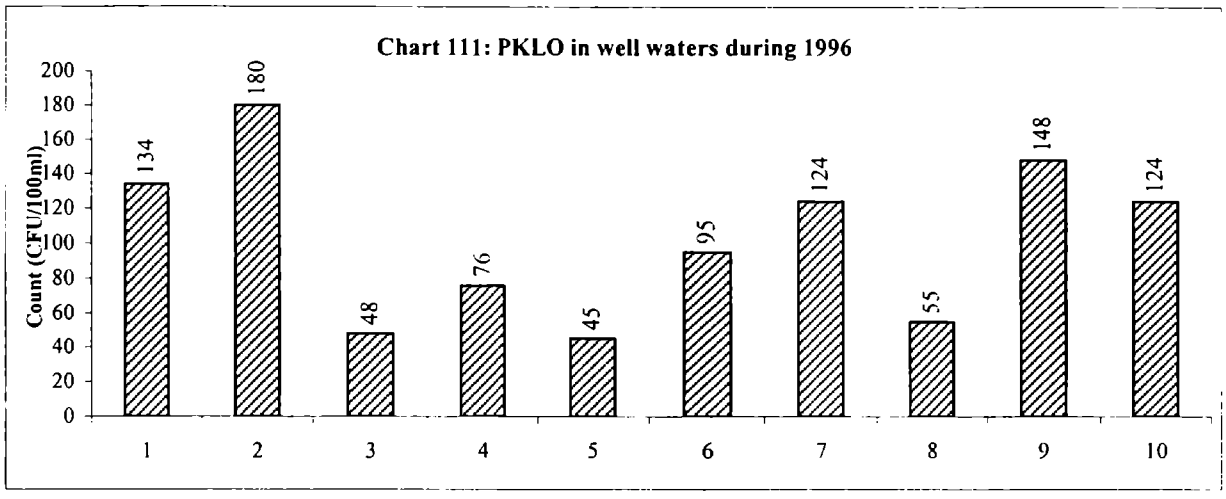


Chart 111: PKLO in well waters during 1996
Count (CFU/100ml)
200
180
160
140
120
100
80
60
40
20
0
134
180
48
76
45
95
124
55
148
124
1
2
3
4
5
6
7
8
9
10

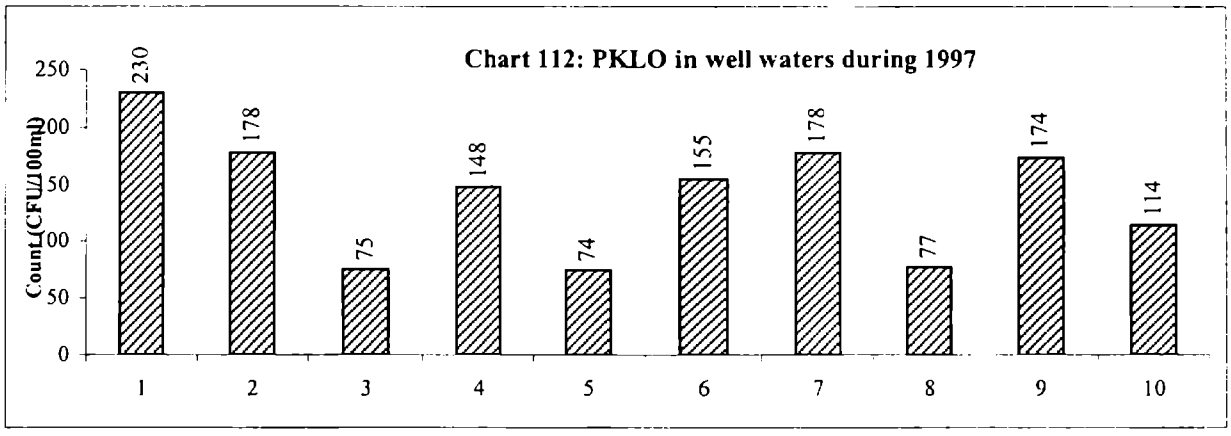


Chart 112: PKLO in well waters during 1997
Count (CFU/100ml)
250
200
150
100
50
0
230
178
75
148
74
155
178
77
174
114
1
2
3
4
5
6
7
8
9
10

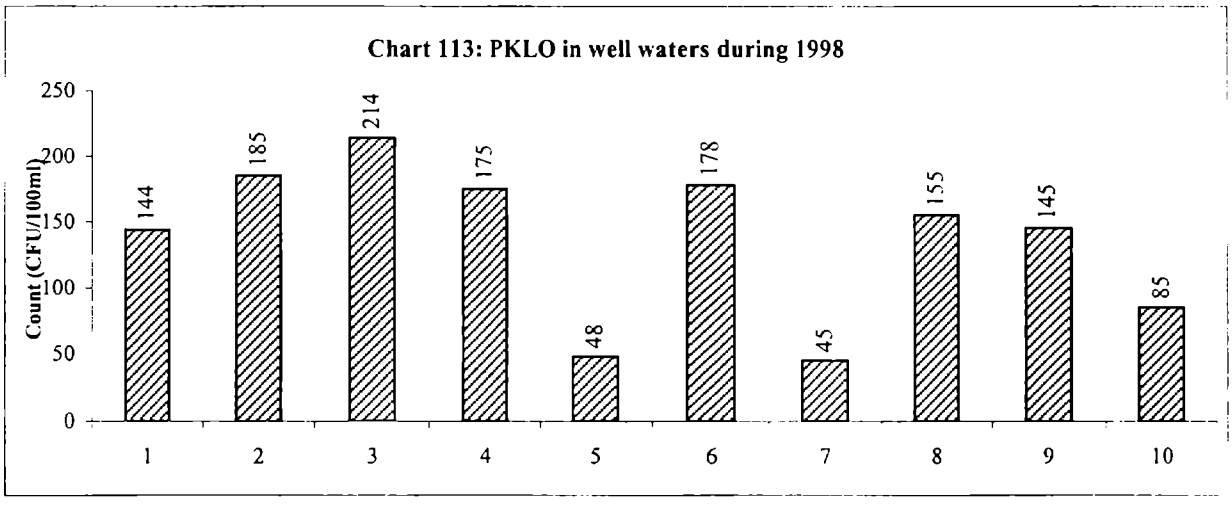


Chart 113: PKLO in well waters during 1998
Count (CFU/100ml)
250
200
150
100
50
0
144
185
214
175
48
178
45
155
145
85
1
2
3
4
5
6
7
8
9
10

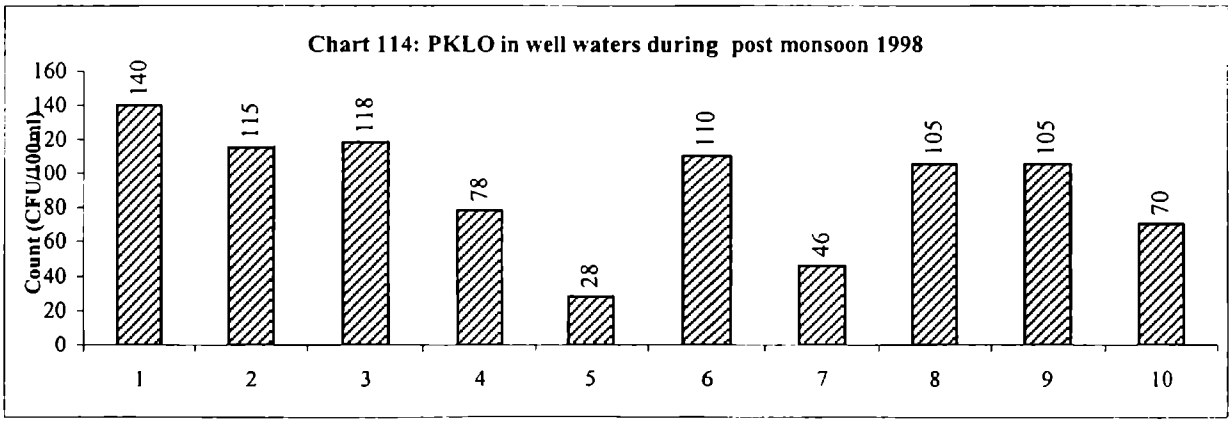


Chart 114: PKLO in well waters during post monsoon 1998
Count (CFU/100ml)
160
140
120
100
80
60
40
20
0
140
115
118
78
28
110
46
105
105
70
1
2
3
4
5
6
7
8
9
10

Chart 115: VCLO in well waters during 1996

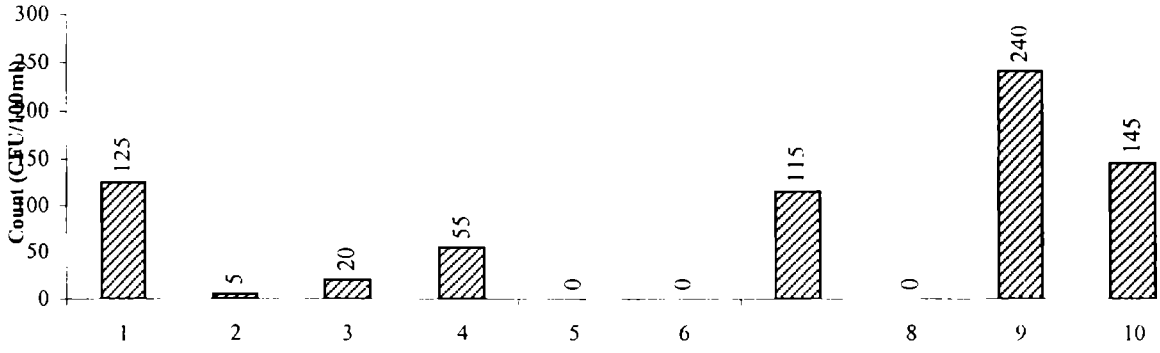


Chart 116: VCLO in well waters during 1997

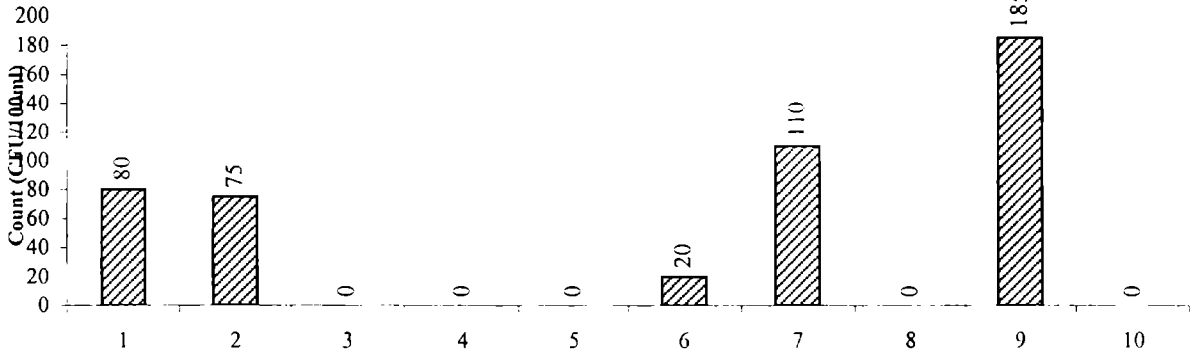


Chart 117: VCLO in well waters during post monsoon 1998

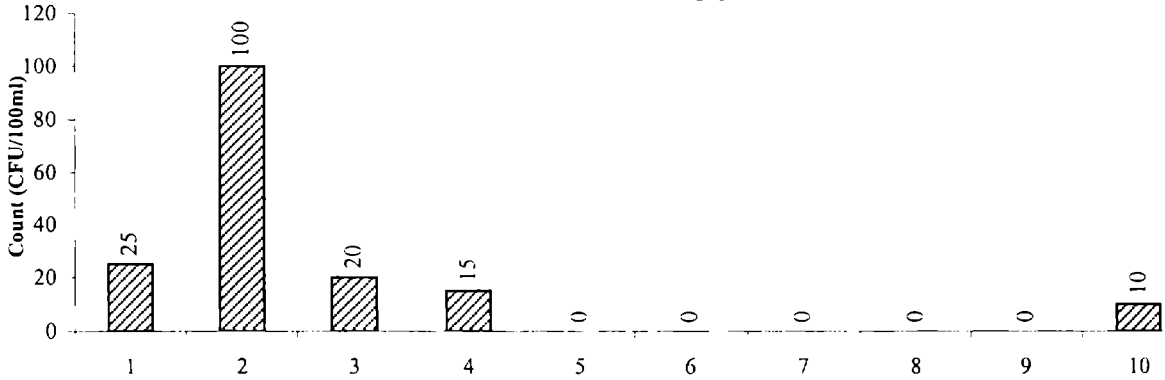
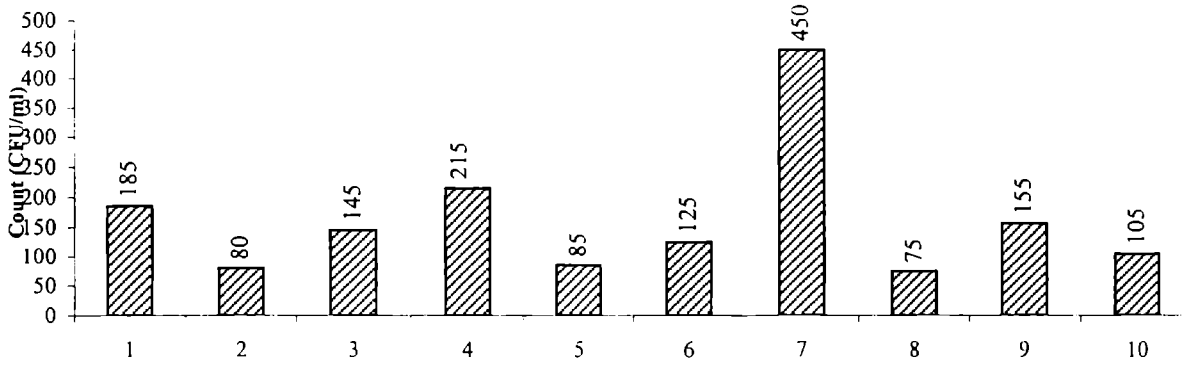


Chart 118: VCLO in well waters during 1998



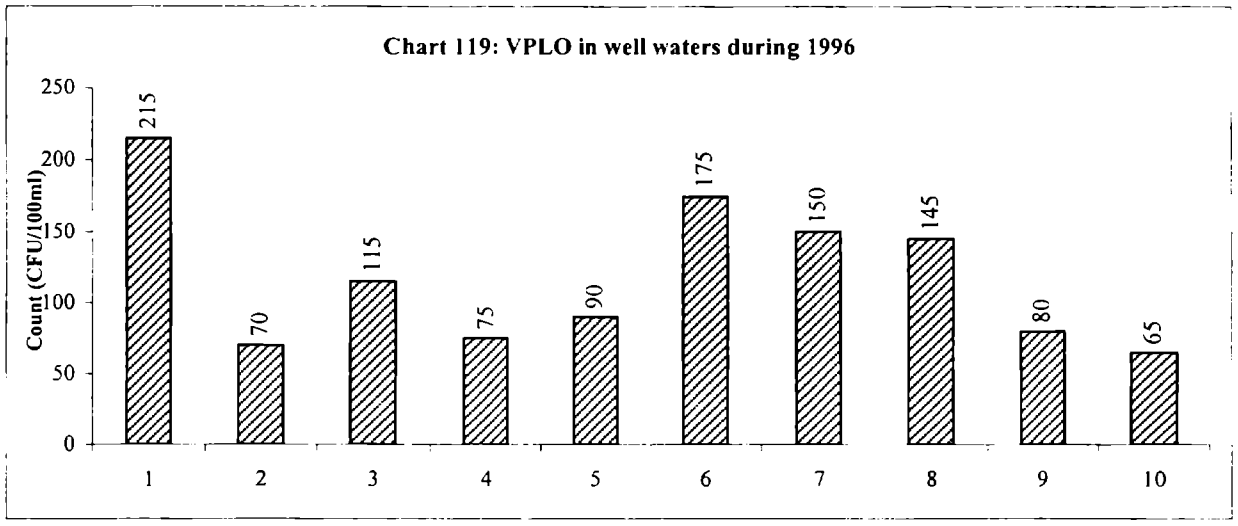


Chart 119: VPLO in well waters during 1996
Count (CFU/100ml)
250
200
150
100
50
0
215
70
115
75
90
175
150
145
80
65
1
2
3
4
5
6
7
8
9
10

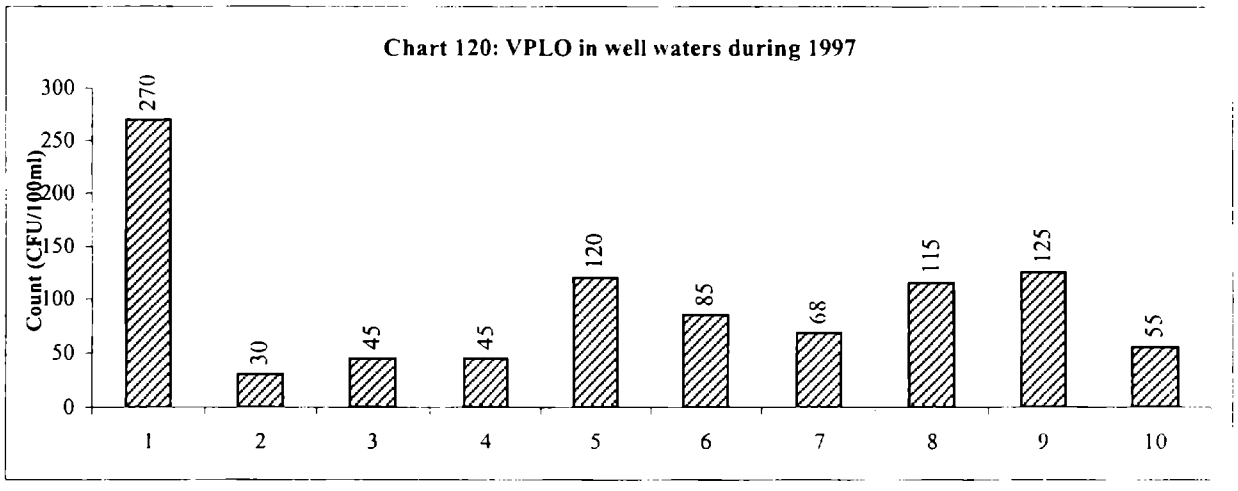


Chart 120: VPLO in well waters during 1997
Count (CFU/100ml)
300
250
200
150
100
50
0
270
30
45
45
120
85
68
115
125
55
1
2
3
4
5
6
7
8
9
10

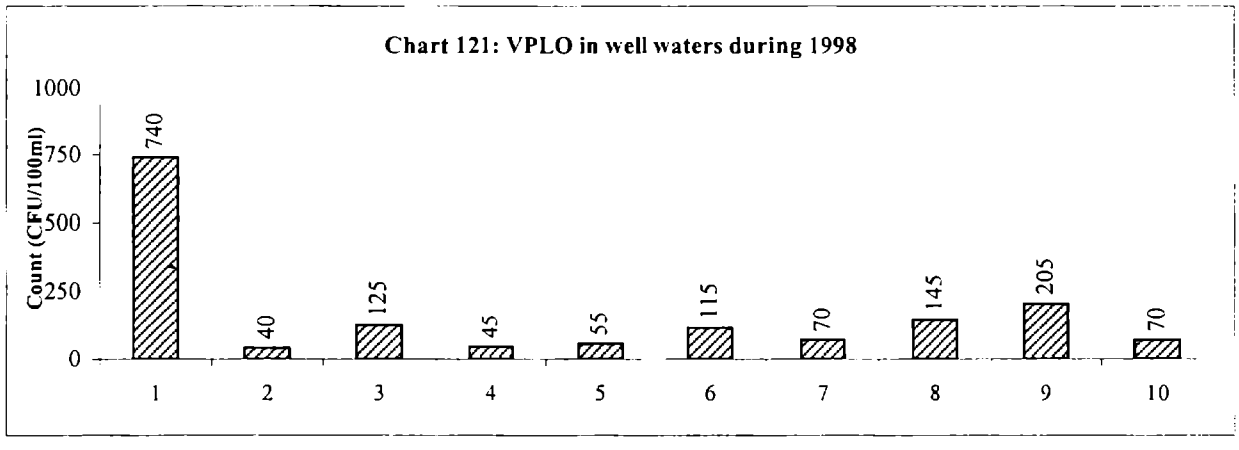


Chart 121: VPLO in well waters during 1998
Count (CFU/100ml)
1000
750
500
250
0
740
40
125
45
55
115
70
145
205
70
1
2
3
4
5
6
7
8
9
10

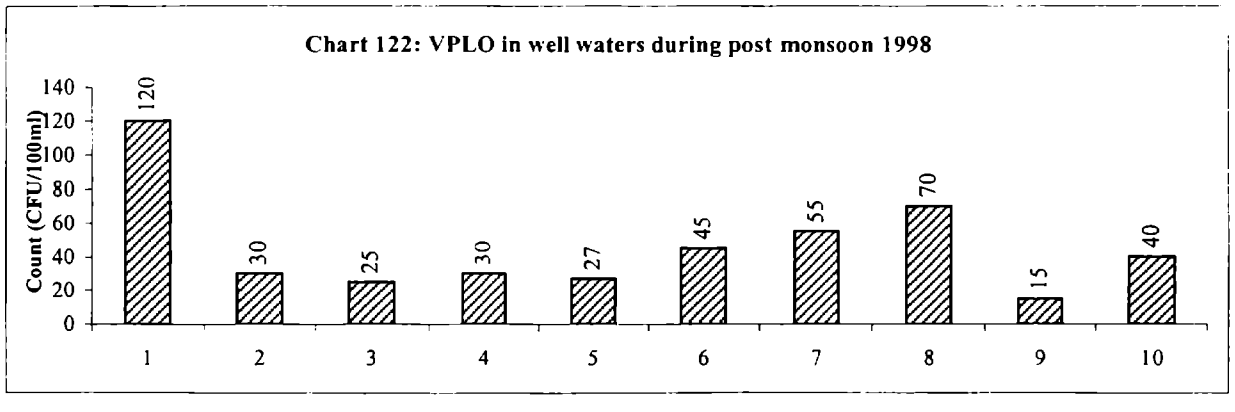


Chart 122: VPLO in well waters during post monsoon 1998
Count (CFU/100ml)
140
120
100
80
60
40
20
0
120
30
25
30
27
45
55
70
15
40
1
2
3
4
5
6
7
8
9
10

Chart 123: SFLO in well waters during 1996

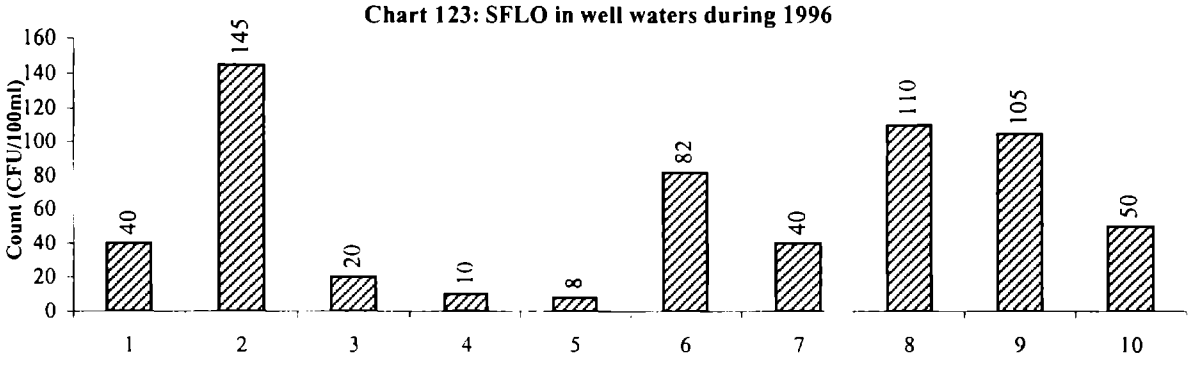


Chart 124: SFLO in well waters during 1997

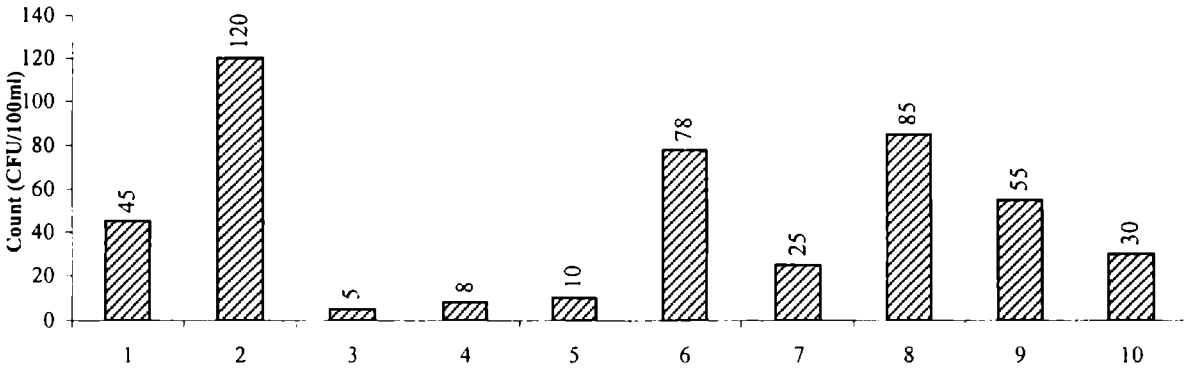


Chart 125: SFLO in well waters during 1998

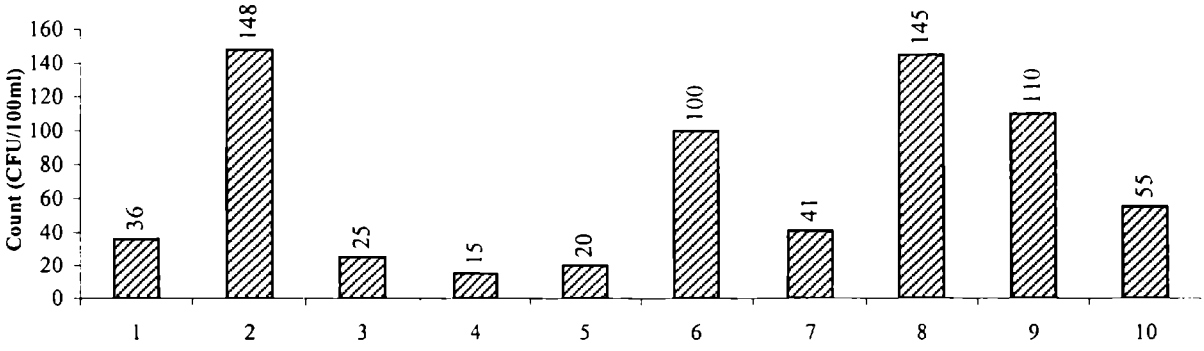
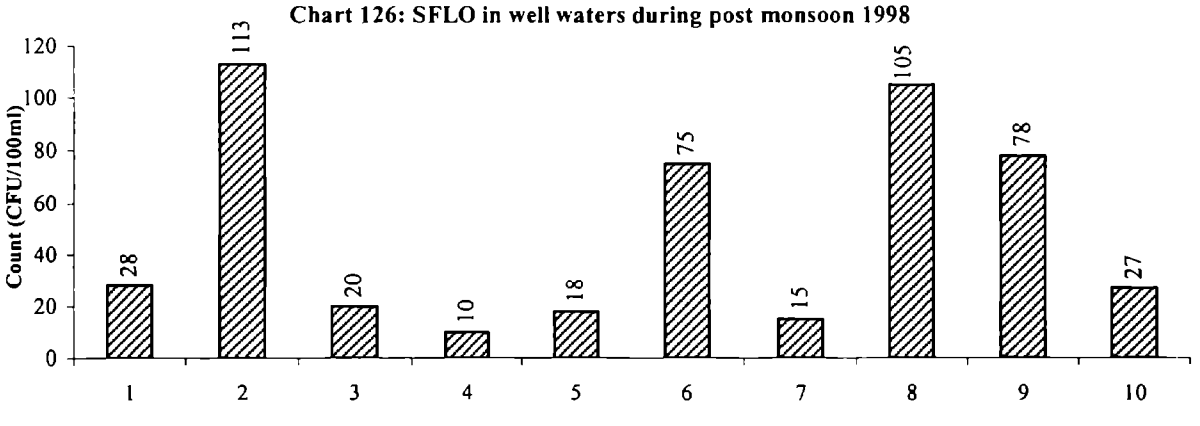


Chart 126: SFLO in well waters during post monsoon 1998



3.2.2 Physico-Chemical characteristics (Table 22-25 & Chart 127-186)

BIS standards for drinking water (1991)

Parameters	Desirable limit	Permissible limit in the absence of alternate source
pH	6.5-8.5	9.2
Conductivity (μmhos/cm)	1500	3000
Chloride (mg/l)	250	400
Total suspended solids (mg/l)	<100 (WHO)	
Total dissolved solids (mg/l)	500	
Total hardness (as mg/l)	300	600
Dissolved Oxygen (mg/l)	>6(WHO)	
Calcium hardness (mg/l)	75	200
Magnesium hardness (mg/l)	30	100
Total alkalinity (mg/l)	200	600
Nitrite (mg/l)	1.0 (WHO)	
Nitrate nitrogen (mg/l)	45	100
Fluoride (mg/l)	1.0	1.5
Sulphate (mg/l)	200	400

Water temperature (Charts 127- 130)

Water temperature varied from 27.2°C in well 1 to 28.6°C in well 10 during 1996, 27.2 °C in well 1 to 28.6 °C in well 10 during 1997, 26.5 °C in wells 3 and 6 to 28.2 °C in well 1 during pre-monsoon 1998 and 26.8°C in well 5 to 28.2°C in well 10 during post monsoon 1998. The results showed that temperature in well waters generally fluctuated between 26.5°C to 28.6 °C irrespective of the seasons.

pH (Charts 131-134)

The pH values in well waters ranged from 7.2 in well 1 to 7.6 in wells 2, 4 and 5 during 1996, 7.28 in well 1 to 7.98 in well 10 during 1997, 7.6 in well 2 to 7.95 in well 7 during pre-monsoon 1998 and 7.42 in well 8 to 8.0 in wells 4 and 10 during post monsoon 1998.The pH generally falls within the prescribed limit (6.5-8.5 as per BIS). The pH of the

well water falls in the range of 7.2 to 8.0, which is slightly alkaline in nature. This trend is expected in the atolls surrounded by sea. The pH range acceptable as per BIS and WHO is 6.5 - 8.5 and most of the samples studied fall under this range. Beyond this range, the water will affect the mucous membrane of the digestive system and also corrode the water distribution channels. The pH limit is categorized as essential; however, it may be relaxed up to 9.2 in absence of alternate sources. Out of the wells studied, no sample was found above this limit. The impact of season over pH has also been found negligible.

Conductivity (Charts 135 - 138)

During 1996, conductivity fluctuated from 1020 μmhos in well 7 to 3300 μmhos in well no.9 μmhos, 813 in well 5 to 1510μmhos in well 10 during 1997, 728 μmhos in well 7 to 3300 μmhos in well 1 during pre-monsoon 1998 and 618 μmhos in well 1 to 1312 μmhos in well 10. Out of 10 wells, no well in the conductivity range of 500 to 1000 μmhos when 7 wells fell between 1000 to 1500 μmhos and two well above 3000 μmhos. During 1997, 4wells fell below 1000μmhos when 5 wells showed the values between 1000-1500μmhos and one well above 1500μmhos. During pre-monsoon 1998, 2 wells were above 3000μmhos and 6wells between 1000-1500μmhos when 6 wells were below 1000μmhos and 4 wells between 1000-1500μmhos during post-monsoon 1998. The desirable conductivity value as per BIS is 1500 μmhos, though the permissible barrier has been placed up to 3000 μmhos in case of absence of alternative source. The wells that showed conductivity above elevated permissible limit could be the result of overdraft, which is being practiced recklessly in the island. The lowering of conductivity in certain wells may be due to dilution from rain water. However, lowering of conductivity is only partial and on completion of rain effect, the original situation is retained. Generally, there is a clear indication of overdraft prevalent in the island that affects the water quality

Chloride (Charts 139 - 142)

The chloride content varied from 36.3 mg/l in well 6 to 120.6mg/l in well 9 during 1996, 13.6mg/l in well 3 to 48.9mg/l in well 4 during 1997, 18.6mg/l in well 8 to 120.2 mg/l in well 2 during pre-monsoon 1998 and 14.9mg/l in well 4 to 38.2mg/l in well 10 during post monsoon 1998. This showed that the maximum values in the study period were within the desirable limit, but they were below the permissible limit (1000 mg/l) extended in the case

of absence of alternate source. Many times, there is an impact of overdraft in wells showing varying chloride.

Total suspended solids (Charts 143 - 146)

The total suspended solids varied from 5.3mg/l in well 4 to 16.9mg/l in well 10 during 1996, 5.9 mg/l in well 8 to 18.6 mg/l in well 9 during 1997, 6.2mg/l in well 8 to 17.8 mg/l in well 10 during pre-monsoon 1998 and 6.3 mg/l in well 2 to 18.6 mg/l in well 7 during post monsoon 1998. The results showed that the suspended solid concentration widely fluctuated and the sharp increase in certain wells was found to be due to poor protection of wells from contamination.

Total dissolved solids (TDS) (Chart 147 - 150)

During 1996, the total dissolved solids varied from 310 mg/l in well 7 to 436mg/l in well 10, 352mg/l in well 2 to 423mg/l in well 10 during 1997, 341mg/l in well 1 to 542mg/l in well 10 during pre monsoon 1998 and 350 mg/l in well 4 to 523mg/l in wells 3 and 6 during post monsoon 1998. Four wells during pre-monsoon 1998 and 3 wells during post monsoon 1998 exceeded the desirable limit. Beyond 500 mg/l, the palatability of water decreases and may cause gastro-intestinal irritation. This limit shows that total dissolved solids in the fresh water is on an increasing trend and many of the well waters have TDS above the desirable limit. This is an indication of seawater intrusion that increases the salinity of waters. However, most of the well waters were within the desirable limit of 500 mg/l. This observation is similar to the data recorded by Nanoti (1989). He has highlighted high values in the populated area on southeastern side of Kavaratti island. The dissolved solids in the fresh water clearly revealed that the water samples from some wells crossed the permissible limit in TDS, which was a clear indication of seawater intrusion. The results, thus, highlight the need for controlled exploitation of this fragile resource that would otherwise become a lens mixed with seawater. Though, this is expected from the soil nature of the island, the trend shows that over the years, alkalinity is increasing that could easily be traced as cases resulting from overdraft.

Water, with a high TDS indicates more ionic concentration, which is of inferior palatability and can induce an unfavourable physicochemical reaction in the consumers. Excess concentration of total hardness has no known adverse effect on health, but it prevents the formulation of lather with soap and increases the boiling point of the water. Na^+ restricted diet is recommended to patients suffering from hypertension or congenial heart disease. Intake of high Na^+ proves critical and for people not accustomed to high

concentrations of Cl^- in drinking water, the Cl^- may cause a laxative effect. High concentration of SO_4^{2-} has been found to have a cathartic action on human beings and can cause respiratory problems also (Subharao, 1993).

Total hardness (Charts 151 - 154)

Total hardness varied from 316mg/l in well 1 to 436 mg/l in well 9 during 1996, 236mg/l in well 3 to 616mg/l in well 1 during 1997, 216mg/l in well 6 to 387mg/l in well 9 during pre-monsoon 1998 and 216mg/l in well 6 to 610mg/l in well 1 during post monsoon 1998. All wells during 1996, 3 wells in 1997, 5 wells during pre-monsoon 1998 and 6 wells during post monsoon 1998 values showed values above the desirable limit (300mg/l).

Dissolved Oxygen (Charts 155 - 158)

DO values recorded were well above 4.0mg/l in almost all the wells, irrespective of seasons, but wide fluctuation was noticed from premonsoon to post monsoon period. High fluctuation in dissolved oxygen during pre-monsoon to post monsoon may be attributed to be oxidation process in groundwater during monsoon season. The accumulated organic load is assimilated in the impounding favourable conditions during monsoon because monsoon provides ample supply of air and nutrients. Nanoti (1989) reported DO values from Kavaratti in the range of 4.4–9.2 mg/l during premonsoon and 4.5-8.0 mg/l during post monsoon period in the wells adjacent to lagoon, 4.4-8.9 mg/l during premonsoon to 4.5-9 mg/l during post monsoon period in the centre region and 4.9-8.9 mg/l during premonsoon to 5.0-8.6 mg/l during post monsoon period in wells adjacent to the stormy beach.

Calcium hardness (Charts 159 - 162)

The calcium hardness in 1996 ranged from 31.2 in well 10 to 48 mg/l in well 9, during 1997 it ranged from 31 mg/l in well 2 to 42 mg/l in well 9, 34 mg/l in well 7 to 49.1 mg/l in well 6 during pre-monsoon 1998 and 30.1 mg/l in well 10 to 41.2 mg/l in well 3. Study showed that all the values of calcium during the period were within the desirable limit (75 mg/l).

Magnesium hardness (Charts 163 - 166)

In case of magnesium hardness, it fluctuated from 23.6 mg/l in well 1 to 38.4 mg/l in well 7, during 1996, 23.6 mg/l in well 3 to 39.1 mg/l in well 9 during 1997, 19.4 mg/l in well 6

to 43.1 mg/l in well 9 during pre-monsoon 1998 and 26.6 mg/l in well 10 to 43.7mg/l in well 3 during post monsoon 1998. Magnesium hardness showed values above the desirable limit (30 mg/l) in 7 wells during 1996, 6 wells during 1997 and 6 wells during pre monsoon and 9 wells during post monsoon 1998. However, no well showed value above the permissible limit (100 mg/l). This indicated that quality of dug well waters over the period has slightly deteriorated in terms of hardness.

Total alkalinity (Charts 167-170)

Total alkalinity varied from 125mg/l in well 6 to 360 mg/l in well 8 during 1996, 158 mg/l in well 5 to 287mg/l in well 9 during 1997, 214 mg/l in well 6 to 365 mg/l in well 9 during pre monsoon 1998 and 240 mg/l in well 4 and 6 to 540 mg/l in well 9 during post monsoon 1998. Alkalinity values showed that almost all the well waters are having alkalinity above the desirable limit (200 mg/l), however, below the permissible limit (600 mg/l) prescribed for the case without alternate source. Alkalinity values, as an indicator of seawater intrusion, are on the rise in Andrott island and can be enhanced by the continued overdraft.

Nitrite-Nitrogen (Charts 171 - 174)

Nitrite-nitrogen varied from 0 from wells 4 & 5 to 0.34 µmol/l in well 9 during 1996, 0 in well 6 and 7 to 0.67 in well 3 during 1997, 0.013 µmol/l in well 7 to 0.61 µmol/l in well 5 during pre-monsoon 1998 and 0.04 µmol/l in well 1 and 9 to 1.02 µmol/l in well 3 during post monsoon 1998. The nitrite content showed wide fluctuation. The sharp increase at certain wells (well 3) during post monsoon 1998 may be an indication of infiltration from the domestic sewage. Even then these figures are lower in most of the wells in comparison with internationally accepted levels (1.0 mg/l) (WHO, 1984).

Nitrate-nitrogen (Charts 175 - 178)

Nitrate-nitrogen fluctuated from 3.2 µmol/l in well 3 to 20.1 µmol/l in well 6 during 1996, 5.3.µmol/l in well 6 to 15.3 µmol/l in well 5 and 7 during 1997, 4.06 µmol/l in well 10 to 20.7 µmol/l in well 8 during pre-monsoon 1998 and 7.2 µmol/l in well 4 to 16.2 µmol/l in well 1 during post monsoon 1998. The nitrate values recorded during the study period were well below the desirable limit (45 mg/l). The values were only in µmol ranges.

Nanoti (1989) reported that 43 wells in Kavaratti Island in Lakshadweep showed values up to 45 mg/l and 13 wells between 46 to 100 mg/l. He concluded that high nitrate in water was caused by the usage of nitrogenous fertilizer. The present study shows that fertilizer usage in the island system is considerably reduced over the years. In view of the difficulty in establishing that any cases of methaemoglobinemia are caused by nitrate levels of less than 10 mg/l NO_3-N for drinking water, the WHO (1984) has set a recommended guideline value of 10mg/l No_3-N for drinking water. BIS has set the desirable and permissible level in case of absence of alternate source as 45 mg/l and 100mg/l respectively.

Fluoride (Charts 179 - 182)

Fluoride content in the water samples ranged from 0 (wells 2, 3,6,7,9 and 10) to 0.3 mg/l (well 3) during 1996, 0 (wells 1, 2, 5,7,8,9 and 10) to 0.3 mg/l (well 4) during 1997, 0 in 7 wells to 0.6 mg/l (well 5) during pre-monsoon 1998 and 0 in 7 wells to 0.21 mg/l (well 8) during post monsoon 1998. All values in the present survey were within the desirable limit. This indicated that fluoride contamination in well waters of Andrott is not severe that treatment in this direction, as of now, is not required. These values were below those reported by Nanoti (1989) from Kavaratti well waters in which, 2.6ppm fluoride was found in an open well. In Kerala state, fluoride content above 2.0 ppm was reported in deep wells of Palghat district where many cases of dental carries were reported.

Sulphate (Charts 183 - 186)

Sulphate concentrations ranged from 12.6 mg/l in well 1 to 32.6 mg/l in well 3 during 1996, 13.6 mg/l in well 9 to 34.8 mg/l in well 10 during 1997, 15.7 mg/l in well 6 to 43.3 mg/l in well 3 during pre-monsoon 1998 and 8.9 mg/l in well 9 and 36.8 mg/l in well 4 during post monsoon 1998. The results showed that the well waters are having sulphate values below desirable units (200 mg/l) irrespective of the seasons.

Table 22: Physico-chemical characteristics of dug well waters during 1996

Date of sampling: 29.10.1996

Well nos.	1	2	3	4	5	6	7	8	9	10
Water temp. (^{o}C)	27.2	27.8	28	28.1	27.6	27.9	28.1	27.9	28.2	28.6
pH	7.2	7.6	7.4	7.6	7.6	7.3	7.43	7.23	7.43	7.53
Conductivity (µmhos)	3100	1250	1120	1230	1092	1420	1020	1350	3300	1620
Chloride (mg/l)	110.3	108.5	47.5	58.9	46.4	36.3	38.9	45.6	120.6	42.3
TSS(mg/l)	9.1	14.3	12.6	5.3	7.9	13.5	9.3	15.3	14.5	16.9
TDS (mg/l)	410	415	325	325	412	326	310	351	415	436
Dis. oxygen (mg/l)	4.2	4.6	4.5	5.1	4.8	4.9	5.6	5.6	5.3	5.9
Total alkalinity (mg/l)	156	215	250	230	280	125	129	360	250	274
Total hardness (mg/l)	316	320	356	385	360	412	362	421	436	364
Calcium (mg/l)	45.2	34.6	43.5	34	35	37.2	34	42	48	31.2
Magnesium (mg/l)	23.6	31.1	28.2	23.7	34.6	35.3	38.4	36.9	37.2	32.4
Nitrite-Nitrogen(µmol/l)	0.02	0.03	0.1	0.12	0.13	0.07	0.02	0.08	0.34	0.05
Nitrate nitrogen (µmol/l)	15.6	13.1	3.2	6.2	5.7	20.1	13.1	12.1	12.1	32
Fluoride (mg/l)	0.02	ND	ND	0.1	0.3	ND	ND	0.2	ND	ND
Sulphate (mg/l)	12.6	23.1	32.6	18.9	21.4	20.1	17.8	14.9	22.5	16.9

Table 23: Physico-chemical characteristics of dug well waters during 1997

Date of sampling: 20.02.1997

Well nos.	1	2	3	4	5	6	7	8	9	10
Water temp. (°C)	27.2	27.6	28.1	27.6	27.8	27.5	28.2	27.9	28.1	28.6
pH	7.28	7.85	7.69	7.58	7.64	7.86	7.52	7.47	7.67	7.98
Conductivity(µmhos)	1130	1230	1120	916	813	828	1020	1060	987	1510
Chloride (mg/l)	31.2	30.2	13.6	48.9	28.2	21	21.6	24.1	30.4	32.6
TSS (mg/l)	12.7	6.2	8.1	7.6	13.2	14.9	17.6	5.9	18.6	14.8
TDS (mg/l)	361	352	369	421	385	378	410	369	412	423
DO (mg/l)	5.3	5.4	6.4	5.17	5.6	6.12	5.9	5.78	4.8	5.2
Total alkalinity (mg/l)	185	212	236	285	158	213	254	263	287	214
Total hardness (mg/l)	616	605	236	612	269	310	314	315	264	269
Calcium (mg/l)	35	31	34	32	32	34	37	39	42	40
Magnesium (mg/l)	32	36	23.6	28.6	31.7	26.4	27.2	38.2	39.1	35.6
Nitrite-Nitrogen (µmol/l)	0.02	0.026	0.067	0.06	0.12	ND	ND	0.03	0.04	0.012
Nitrate nitrogen (µmol/l)	10.1	8.2	7.1	6.3	15.3	5.3	15.3	11.2	6.2	12.8
Fluoride (mg/l)	ND	ND	0.2	0.3	ND	0.12	ND	ND	ND	ND
Sulphate (mg/l)	22.3	16.7	15.7	25.6	23.5	34.2	23.7	18.8	13.6	34.8

Table 24: Physico-chemical characteristics of dug well waters during 1998

Date of Sampling 22.03.1998

Well nos.	1	2	3	4	5	6	7	8	9	10
Water temp. (°C)	28.2	27.6	26.5	27.2	27.3	26.5	26.7	27.2	27.1	27.6
pH	7.69	7.60	7.87	7.87	7.77	7.86	7.95	7.86	7.76	7.94
Conductivity(μmhos)	3300	1216	1312	1098	3110	896	728	3200	1456	1246
Chloride (mg/l)	32.1	120.2	36.4	18.9	24.6	30.6	96.5	18.6	35.6	41.3
TSS (mg/l)	10.2	9.5	14.8	12.3	15.3	10.2	8.3	6.2	16.3	17.8
TDS (mg/l)	341	412	532	465	425	514	369	426	524	542
DO (mg/l)	4.9	5.2	5.6	5.12	5.6	5.24	6.2	5.47	5.2	5.8
Total alkalinity (mg/l)	253	265	298	312	345	214	236	326	365	325
Total hardness (mg/l)	610	290	608	286	263	216	218	369	387	316
Calcium (mg/l)	38.5	45.6	38.2	37.5	41.5	49.1	34	46.2	42.6	37.2
Magnesium (mg/l)	32.1	23.4	27.5	29.1	32.4	19.4	34.1	38.2	43.1	40.1
Nitrite-Nitrogen (μmol/l)	0.04	0.06	0.018	0.02	0.61	0.06	0.013	0.4	0.09	0.07
Nitrate nitrogen (μmol/l)	12.2	5.6	17.1	7.2	8.3	10.2	4.5	20.7	8.5	4.06
Fluoride (mg/l)	0.2	0.3	ND	ND	0.6	ND	ND	ND	ND	ND
Sulphate (mg/l)	26.3	32.5	43.3	32.6	23.7	15.7	18.8	32.9	34.8	23.1

Table 25: Physico-chemical characteristics of dug well waters during post monsoon 1998

Date of sampling: 20.11.1998

Well nos.	1	2	3	4	5	6	7	8	9	10
Water temp. (°C)	27.3	26.9	27.3	27.3	26.8	27.2	27.4	28.1	27.4	28.2
pH	7.86	7.92	7.5	8.0	7.79	7.58	7.62	7.42	7.65	8.0
Conductivity(μmhos)	618	928	1012	812	1018	814	716	928	1210	1312
Chloride (mg/l)	21.3	25.6	34.6	14.9	17.9	24.6	35.4	29.2	34.3	38.2
TSS (mg/l)	10.3	6.3	7.6	15.3	11.9	15.3	18.6	17.6	15.3	17.3
TDS (mg/l)	390	425	523	350	475	523	425	512	463	478
DO (mg/l)	5.31	4.58	6.23	4.36	5.12	5.43	4.8	5.24	5.31	5.34
Total alkalinity (mg/l)	610	310	605	240	270	240	275	620	540	265
Total hardness (mg/l)	310	289	275	315	298	256	324	369	346	298
Calcium (mg/l)	34.7	31.2	41.2	35.1	30.8	34.2	32.1	35.2	38.2	30.1
Magnesium (mg/l)	31.2	34.1	43.7	30.1	32.2	32.1	30	31	32	26.6
Nitrite-Nitrogen (μmol/l)	0.04	0.07	1.02	0.9	0.92	0.14	0.84	0.32	0.04	0.51
Nitrate nitrogen (μmol/l)	16.2	9.2	13.2	7.2	8.5	9.3	10.3	12.2	11.2	8.4
Fluoride (mg/l)	ND	ND	0.2	0.1	ND	ND	ND	0.21	ND	ND
Sulphate (mg/l)	32.5	25.6	34.5	36.8	35.7	34.3	31.2	24.3	8.9	17.6

Chart 127: Temperature in Well waters during 1996

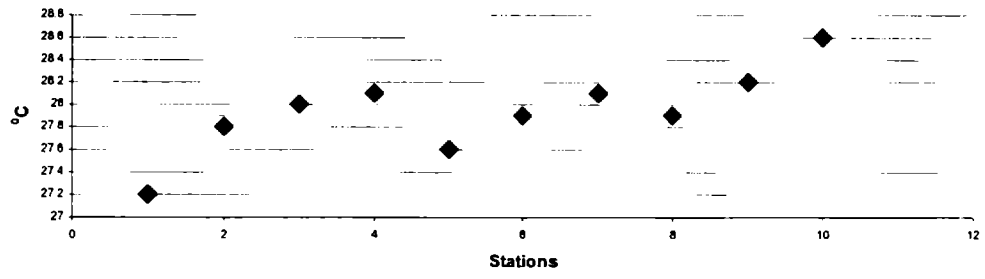


Chart 128: Temperature in Well waters during 1997

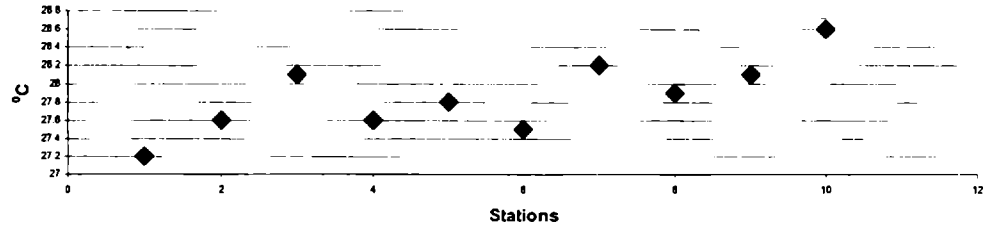


Chart 129: Temperature in Well waters during 1998

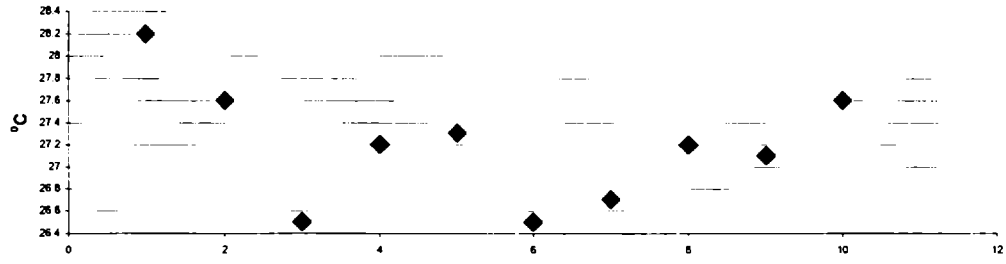
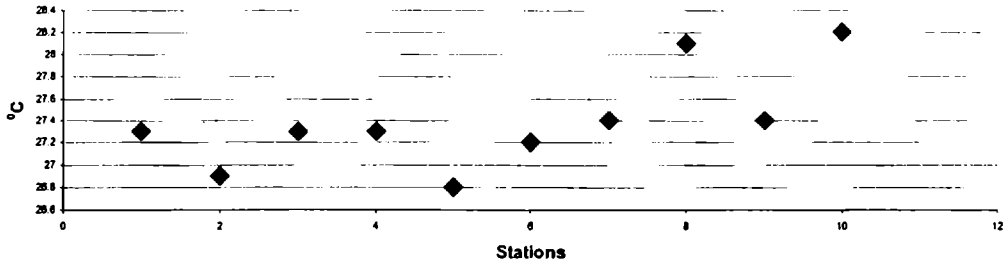


Chart 130: Temperature in Well waters during 1998 Post Monsoon



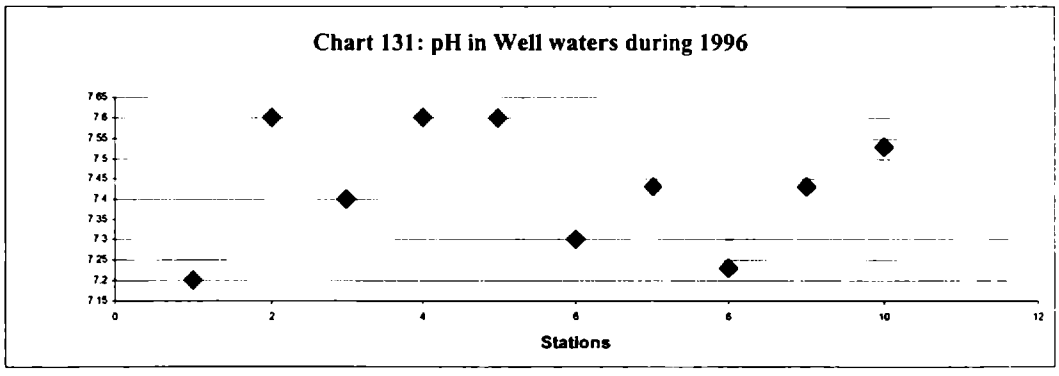


Chart 131: pH in Well waters during 1996
Stations

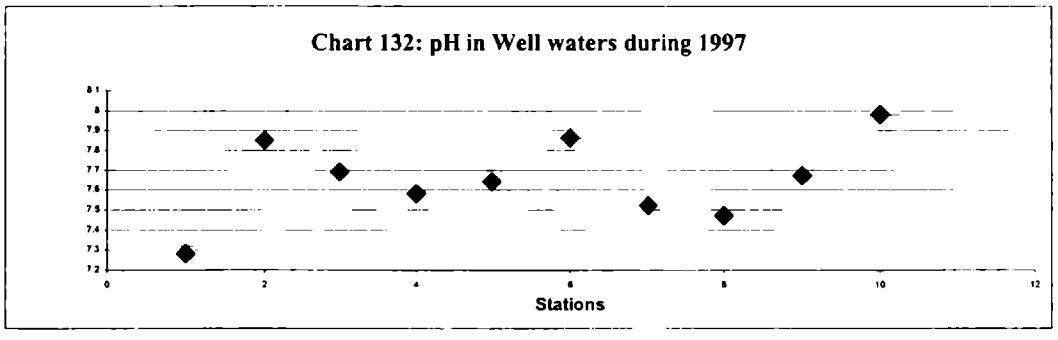


Chart 132: pH in Well waters during 1997
Stations

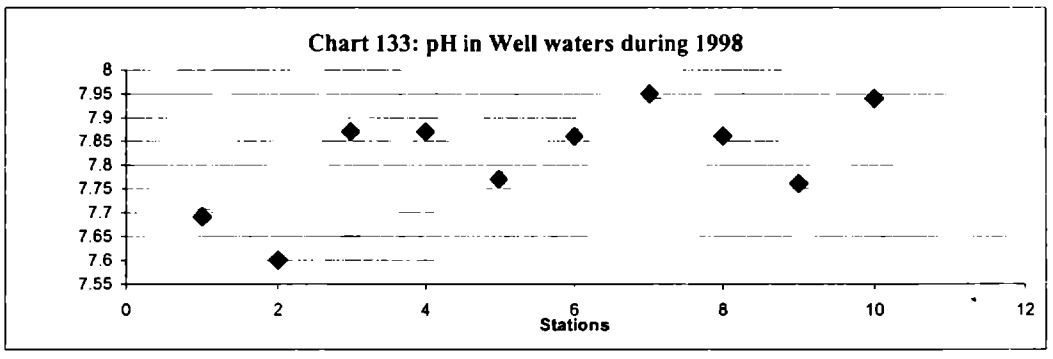


Chart 133: pH in Well waters during 1998
8
7.95
7.9
7.85
7.8
7.75
7.7
7.65
7.6
7.55
0
2
4
6
8
10
12
Stations

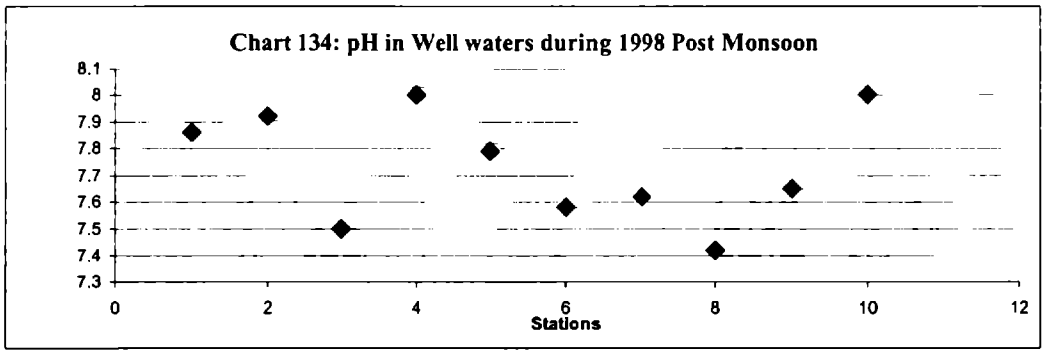


Chart 134: pH in Well waters during 1998 Post Monsoon
8.1
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
0
2
4
6
8
10
12
Stations

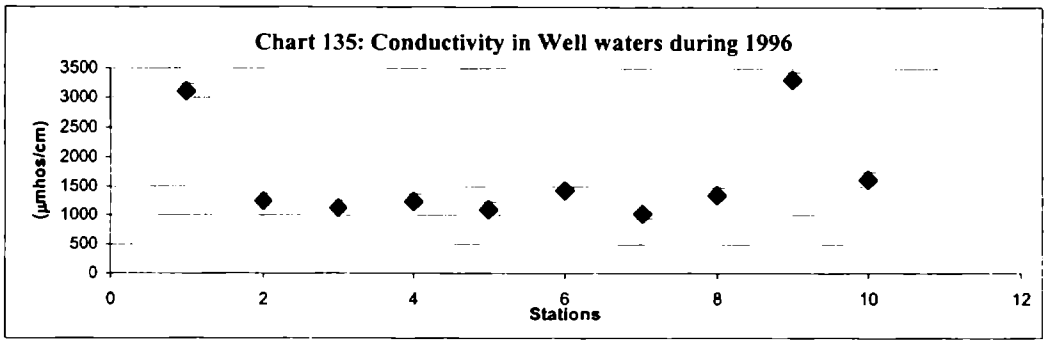


Chart 135: Conductivity in Well waters during 1996
(µmhos/cm)
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
Stations

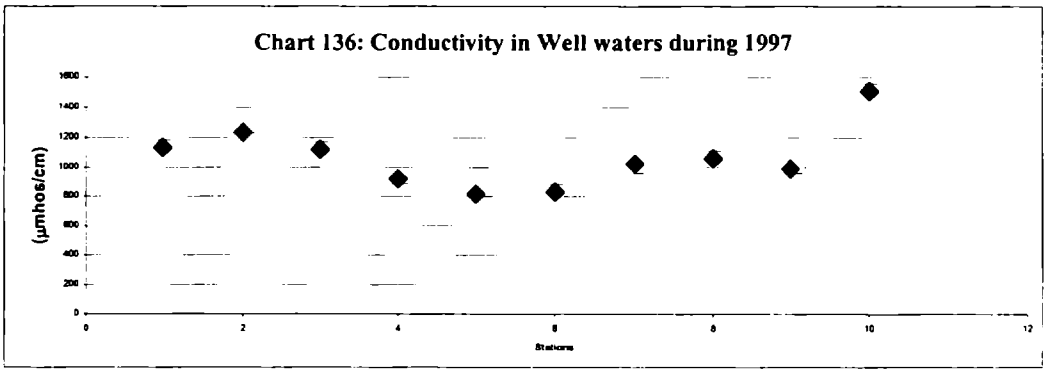


Chart 136: Conductivity in Well waters during 1997
(µmhos/cm)

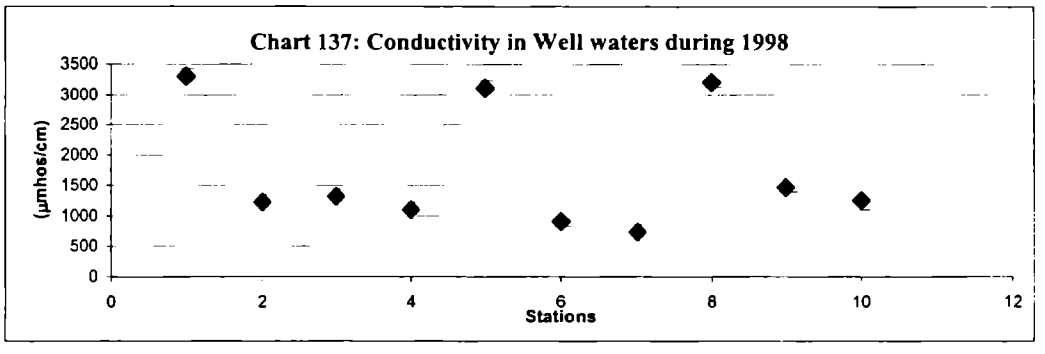


Chart 137: Conductivity in Well waters during 1998
(µmhos/cm)
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
Stations

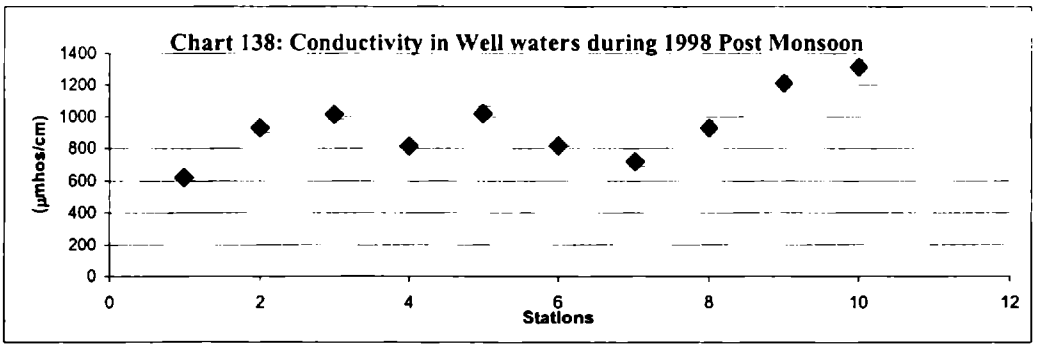


Chart 138: Conductivity in Well waters during 1998 Post Monsoon
(µmhos/cm)
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
10
12
Stations

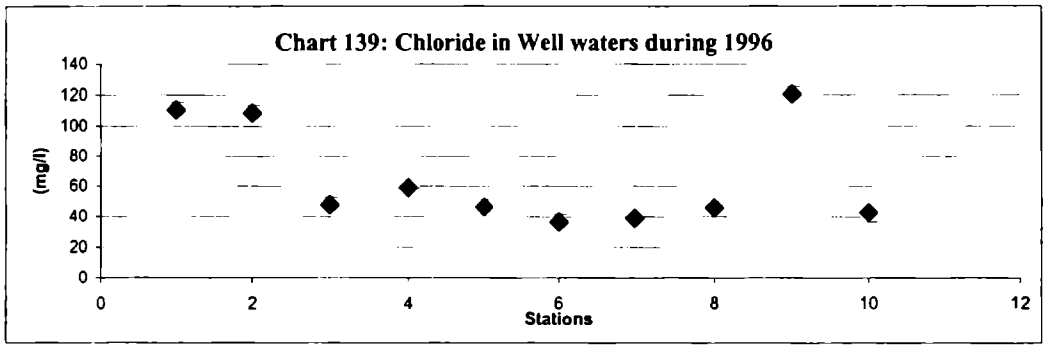


Chart 139: Chloride in Well waters during 1996
(mg/l)
140
120
100
80
60
40
20
0
0
2
4
6
8
10
12
Stations

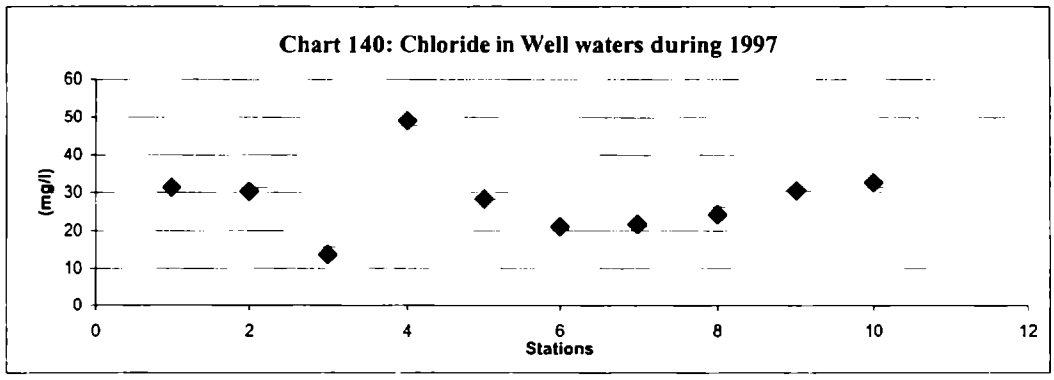


Chart 140: Chloride in Well waters during 1997
(mg/l)
60
50
40
30
20
10
0
0
2
4
6
8
10
12
Stations

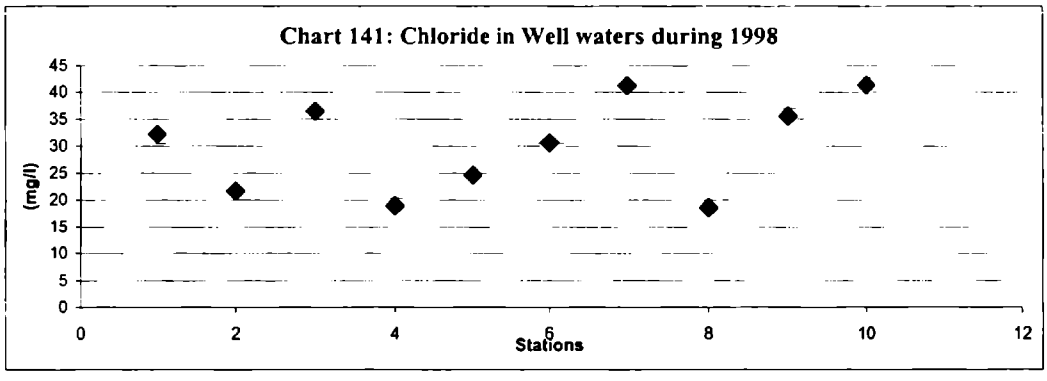


Chart 141: Chloride in Well waters during 1998
(mg/l)
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

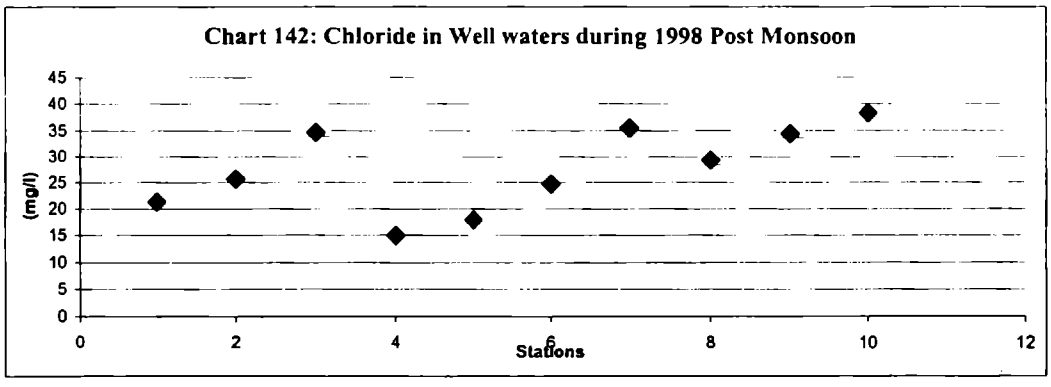


Chart 142: Chloride in Well waters during 1998 Post Monsoon
(mg/l)
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

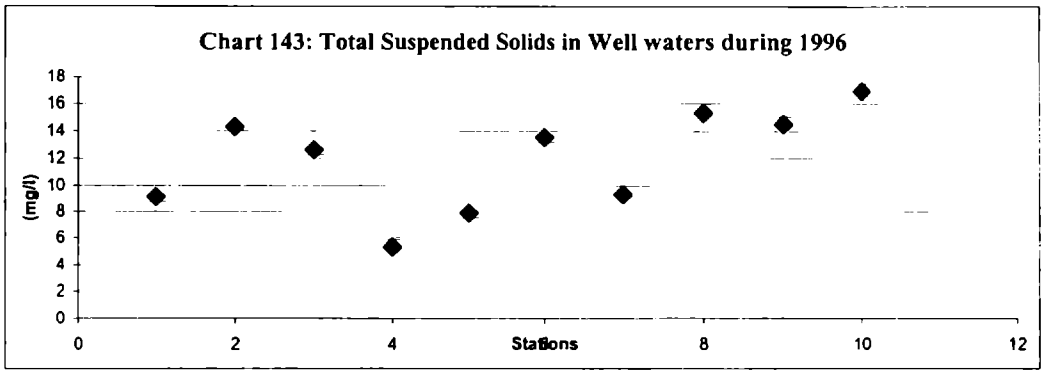


Chart 143: Total Suspended Solids in Well waters during 1996
(mg/l)
Stations

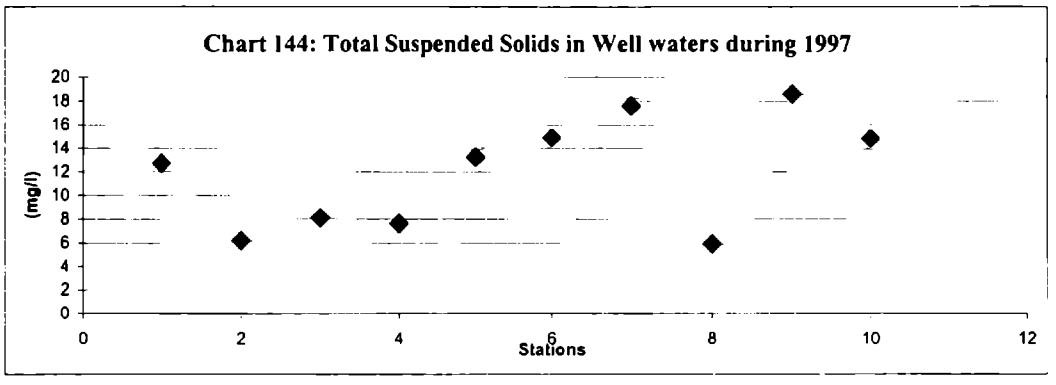


Chart 144: Total Suspended Solids in Well waters during 1997
(mg/l)
Stations

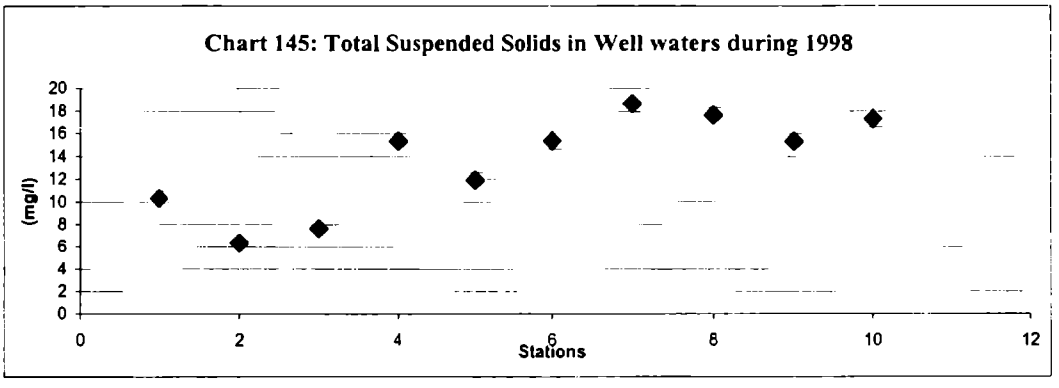


Chart 145: Total Suspended Solids in Well waters during 1998
(mg/l)
Stations

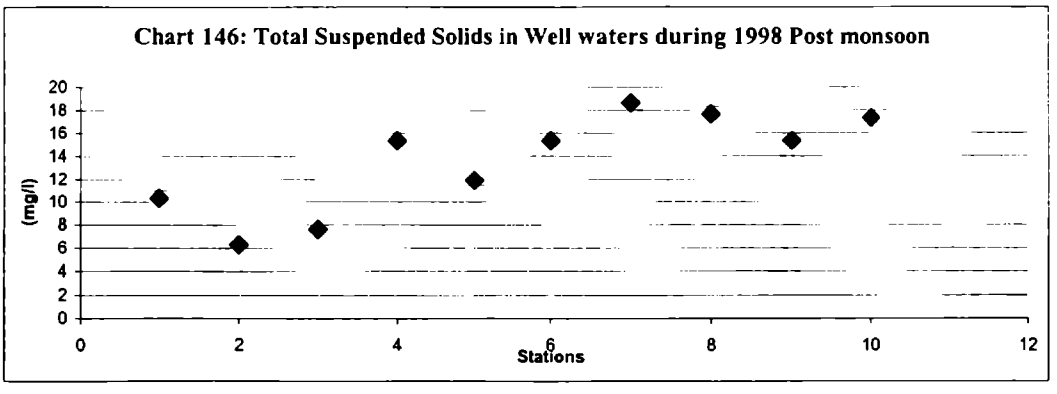


Chart 146: Total Suspended Solids in Well waters during 1998 Post monsoon
(mg/l)
Stations

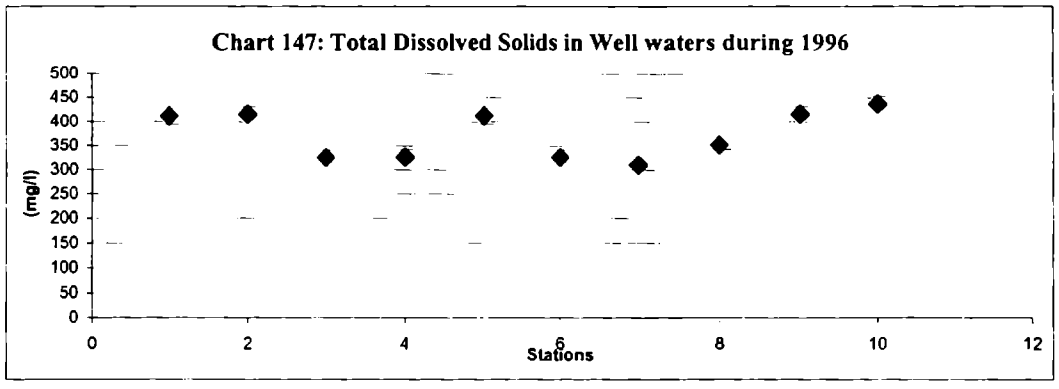


Chart 147: Total Dissolved Solids in Well waters during 1996
(mg/l)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

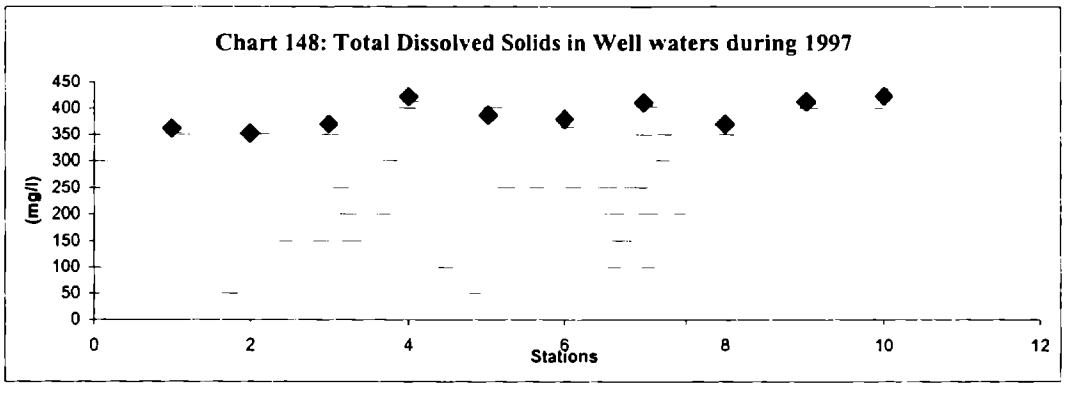


Chart 148: Total Dissolved Solids in Well waters during 1997
(mg/l)
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

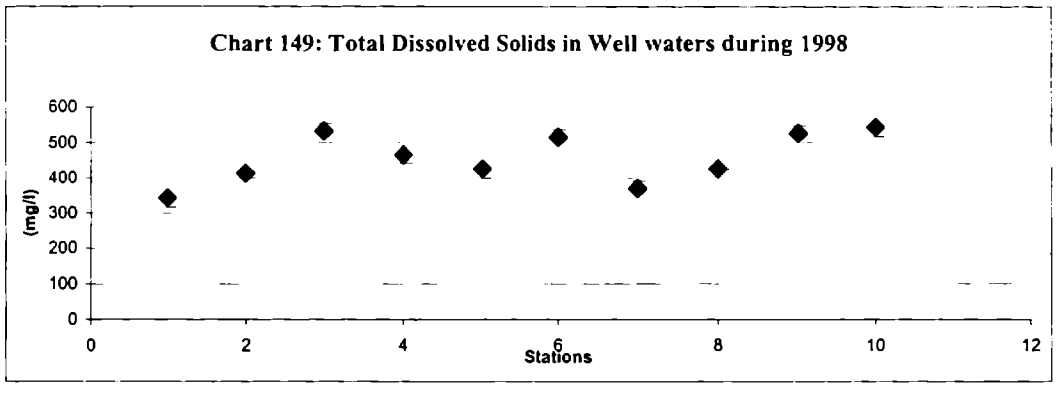


Chart 149: Total Dissolved Solids in Well waters during 1998
(mg/l)
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Stations

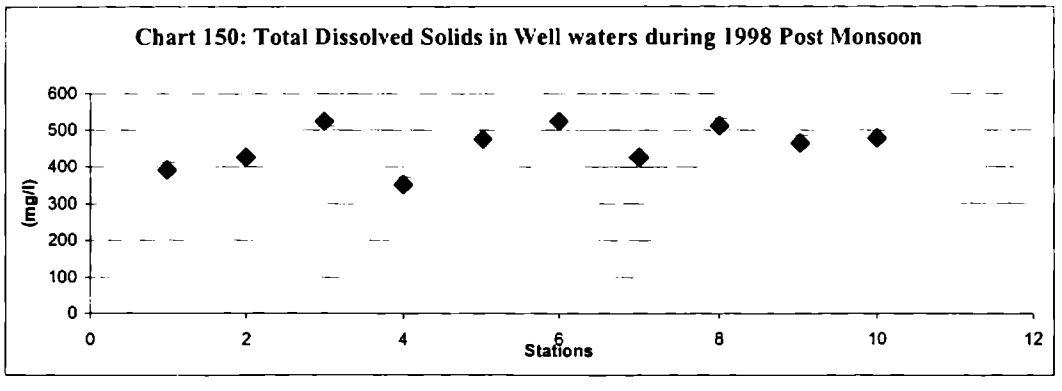


Chart 150: Total Dissolved Solids in Well waters during 1998 Post Monsoon
(mg/l)
600
500
400
300
200
100
0
0
2
4
6
8
10
12
Stations

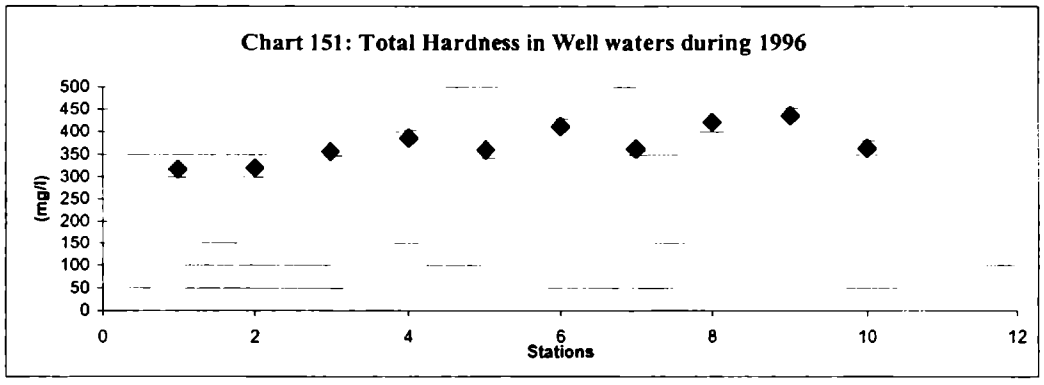


Chart 151: Total Hardness in Well waters during 1996
(mg/l)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

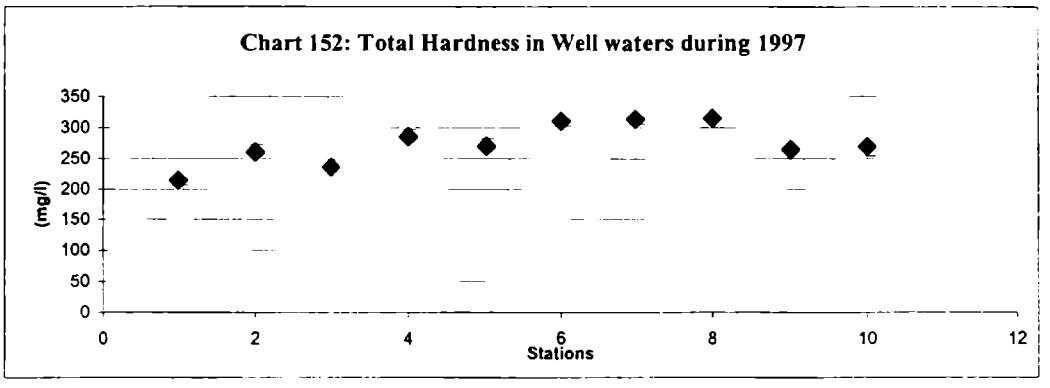


Chart 152: Total Hardness in Well waters during 1997
(mg/l)
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

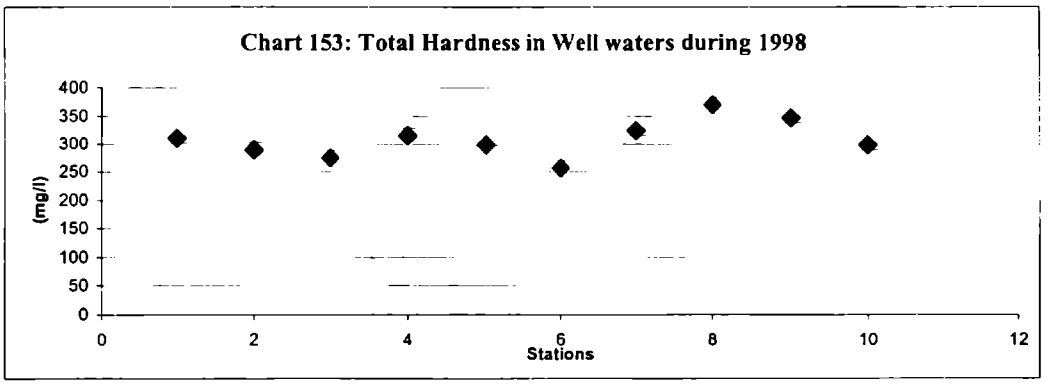


Chart 153: Total Hardness in Well waters during 1998
(mg/l)
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

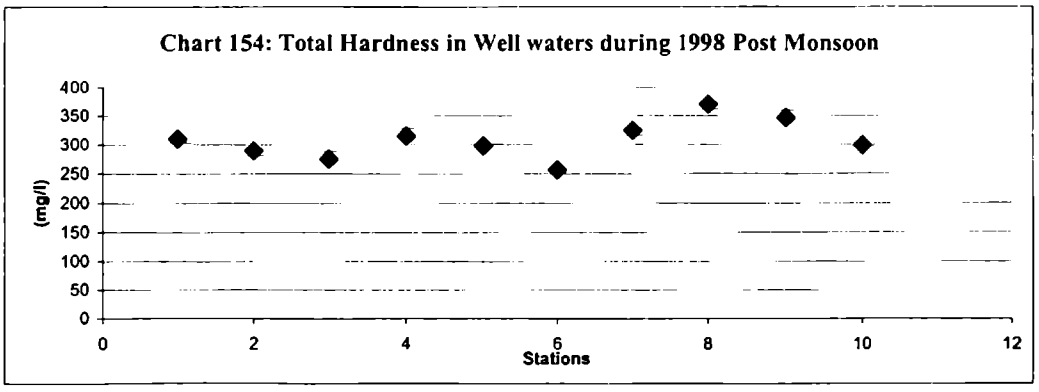


Chart 154: Total Hardness in Well waters during 1998 Post Monsoon
(mg/l)
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Stations

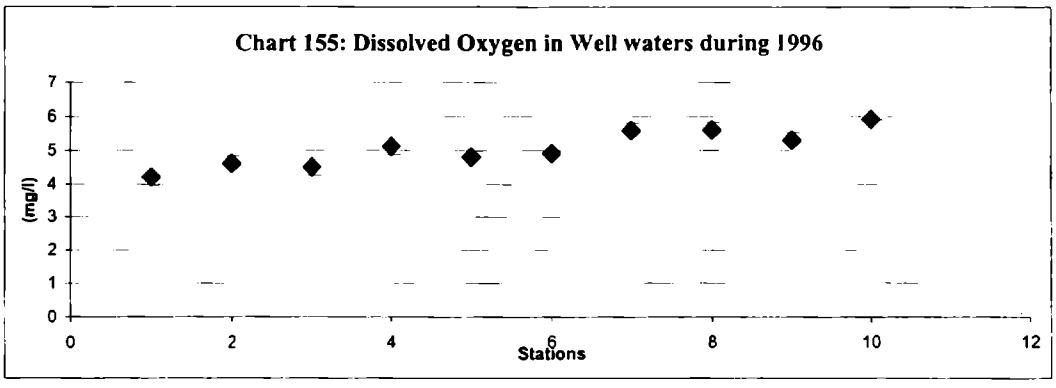


Chart 155: Dissolved Oxygen in Well waters during 1996
(mg/l)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Stations

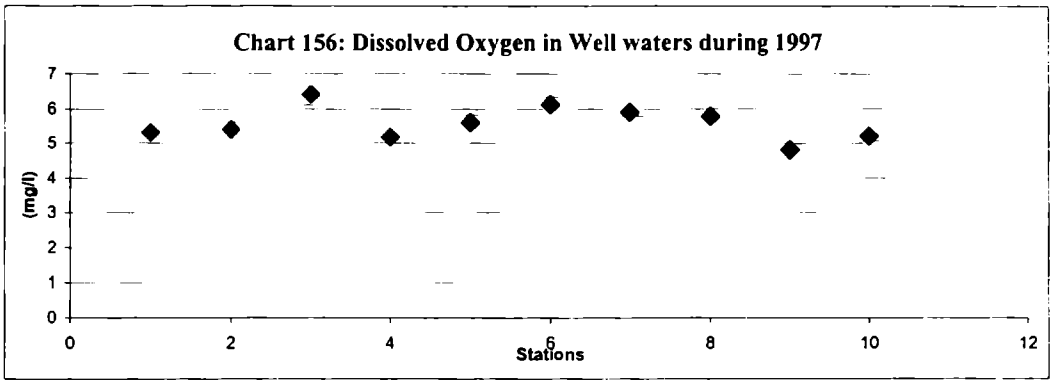


Chart 156: Dissolved Oxygen in Well waters during 1997
(mg/l)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Stations

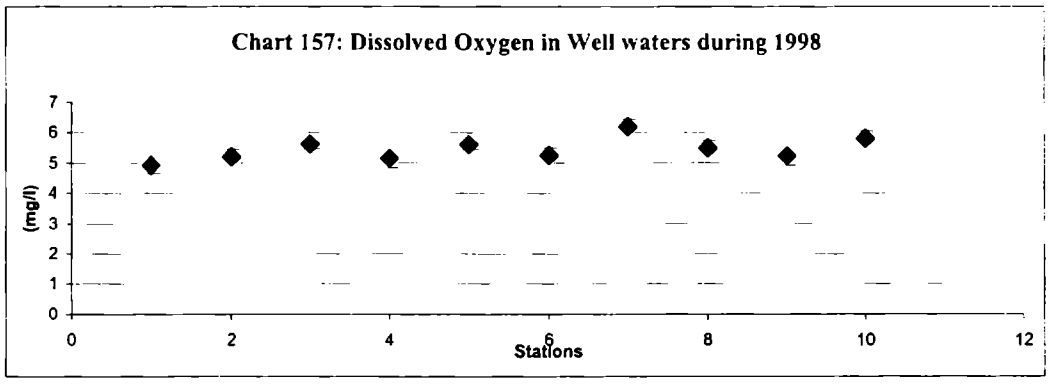


Chart 157: Dissolved Oxygen in Well waters during 1998
(mg/l)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Stations

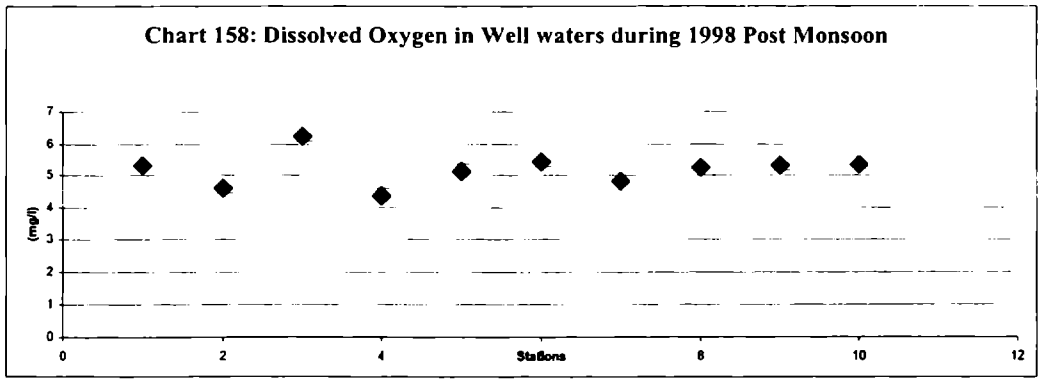


Chart 158: Dissolved Oxygen in Well waters during 1998 Post Monsoon
(mg/l)
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
Stations

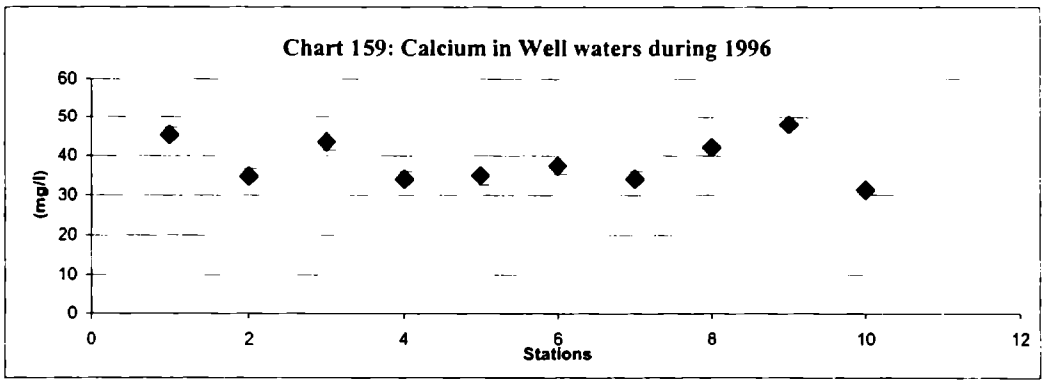


Chart 159: Calcium in Well waters during 1996
60
50
40
30
20
10
0
(mg/l)
0
2
4
6
8
10
12
Stations

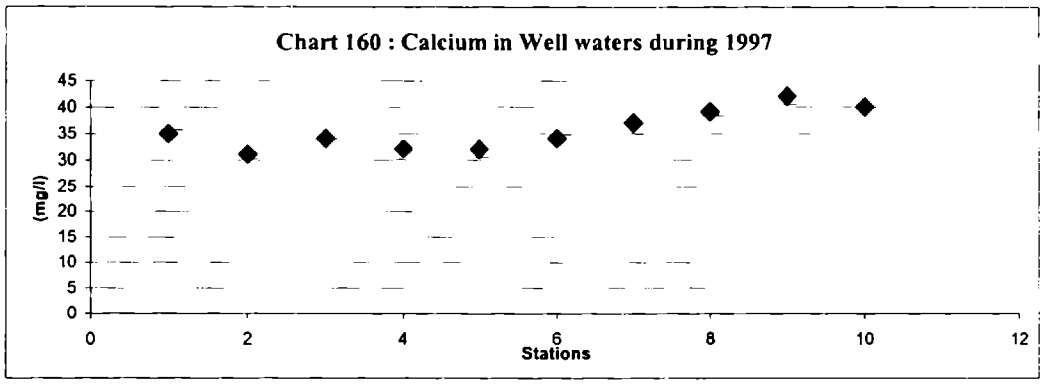


Chart 160 : Calcium in Well waters during 1997
45
40
35
30
25
20
15
10
5
0
(mg/l)
0
2
4
6
8
10
12
Stations

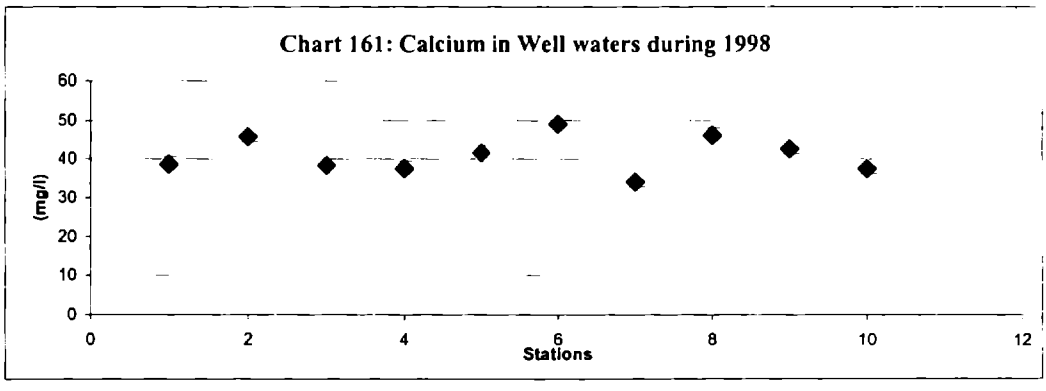


Chart 161: Calcium in Well waters during 1998
60
50
40
30
20
10
0
(mg/l)
0
2
4
6
8
10
12
Stations

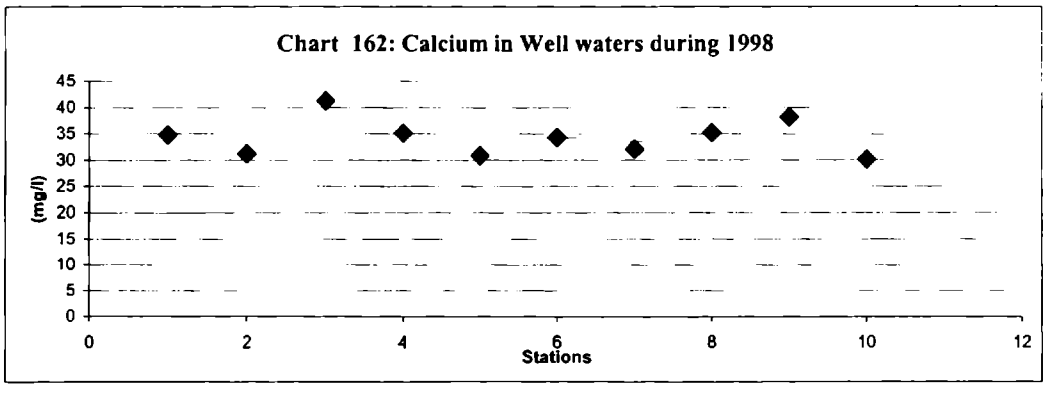


Chart 162: Calcium in Well waters during 1998
45
40
35
30
25
20
15
10
5
0
(mg/l)
0
2
4
6
8
10
12
Stations

Chart 163: Magnesium in Well waters during 1996

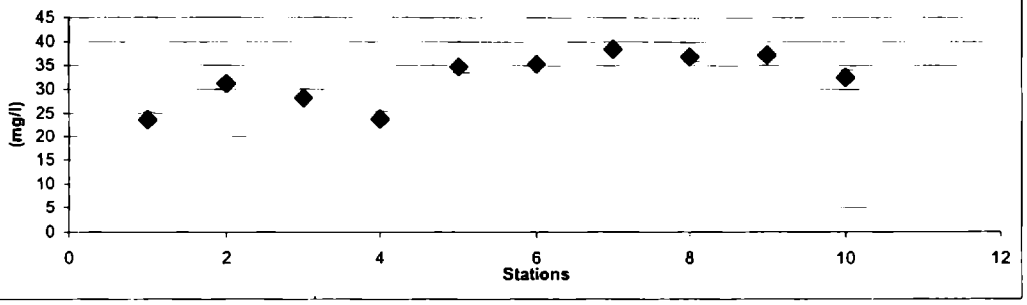


Chart 164: Magnesium in Well waters during 1997

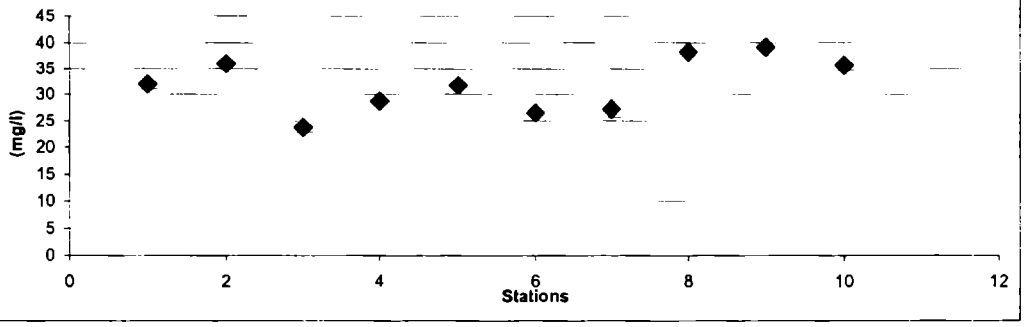


Chart 165: Magnesium in Well waters during 1998

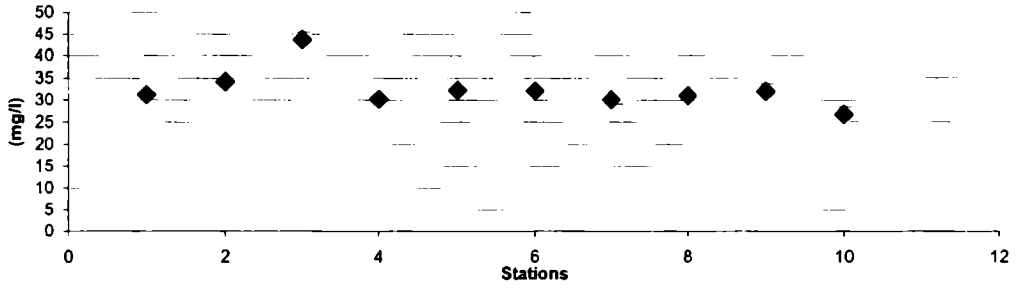
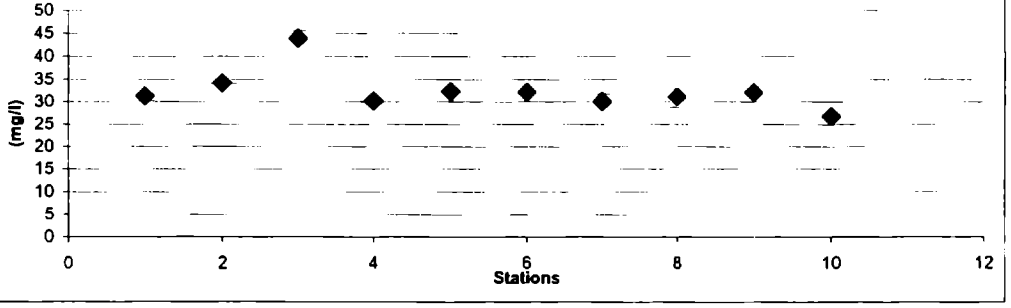


Chart 166 : Magnesium in Well waters during 1998 Post Monsoon



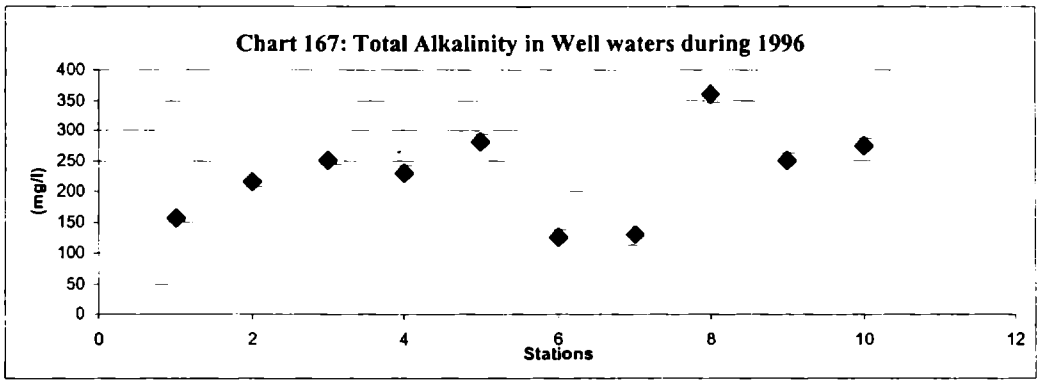


Chart 167: Total Alkalinity in Well waters during 1996
400
350
300
250
200
150
100
50
0
(mg/l)
0
2
4
6
8
10
12
Stations

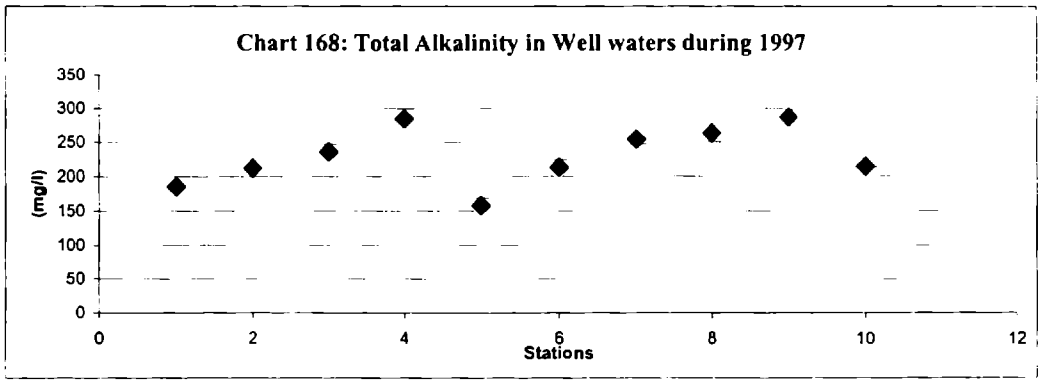


Chart 168: Total Alkalinity in Well waters during 1997
350
300
250
200
150
100
50
0
(mg/l)
0
2
4
6
8
10
12
Stations

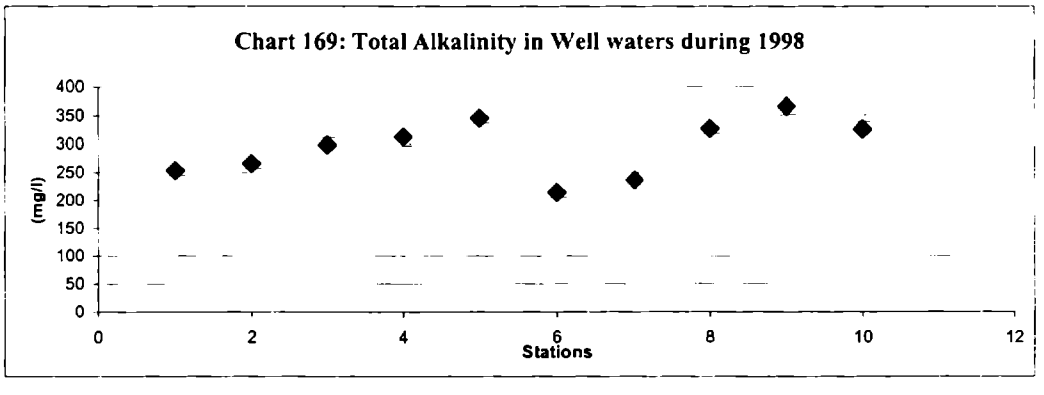


Chart 169: Total Alkalinity in Well waters during 1998
400
350
300
250
200
150
100
50
0
(mg/l)
0
2
4
6
8
10
12
Stations

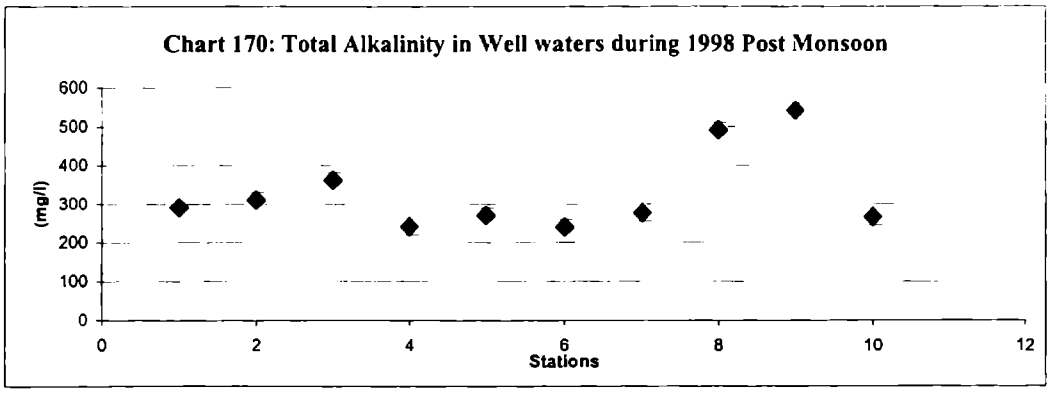


Chart 170: Total Alkalinity in Well waters during 1998 Post Monsoon
600
500
400
300
200
100
0
(mg/l)
0
2
4
6
8
10
12
Stations

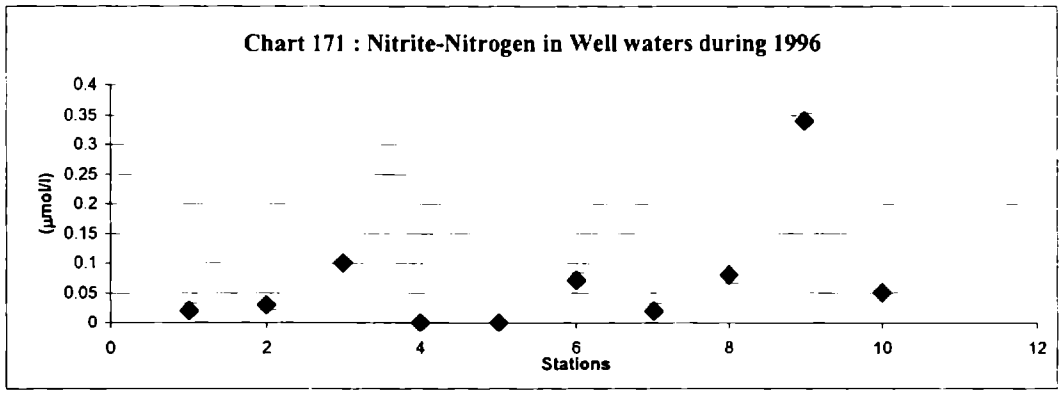


Chart 171 : Nitrite-Nitrogen in Well waters during 1996
(µmol/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
Stations

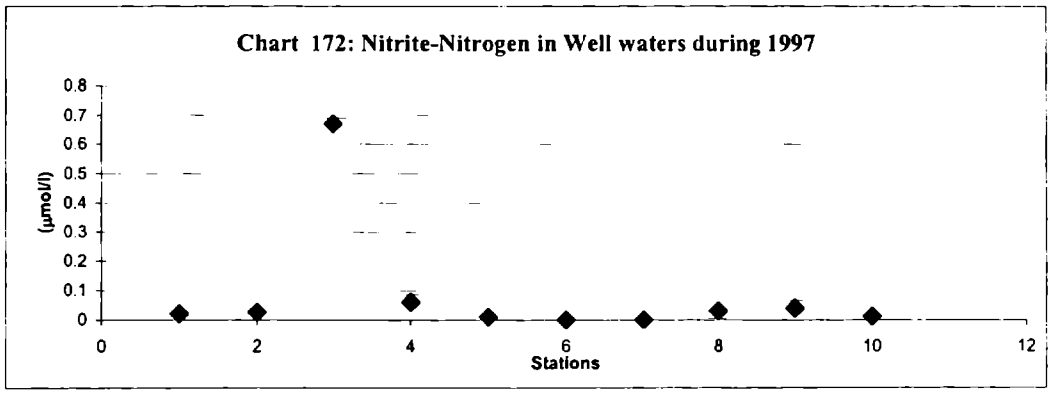


Chart 172: Nitrite-Nitrogen in Well waters during 1997
(µmol/l)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
Stations

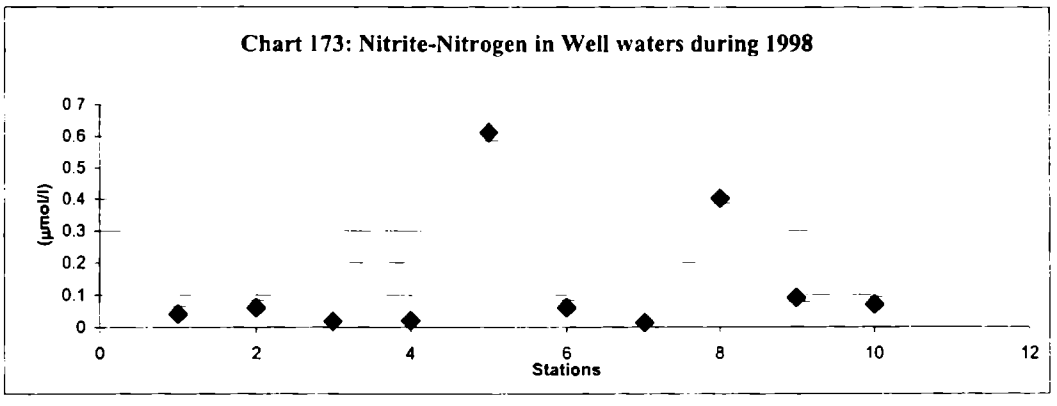


Chart 173: Nitrite-Nitrogen in Well waters during 1998
(µmol/l)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
Stations

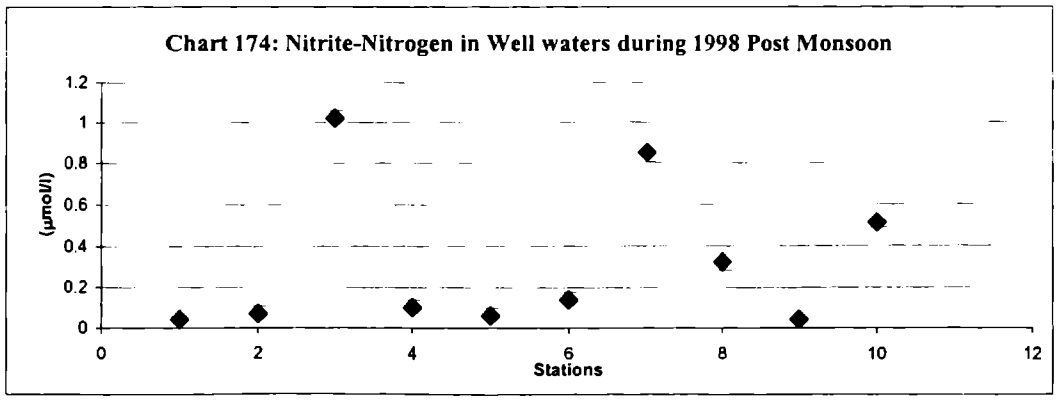


Chart 174: Nitrite-Nitrogen in Well waters during 1998 Post Monsoon
(µmol/l)
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Stations

Chart 175: Nitrate-Nitrogen in Well waters during 1996

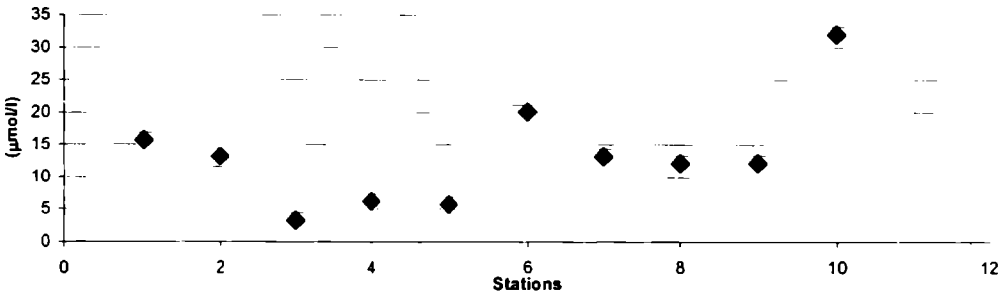


Chart 176: Nitrate-Nitrogen in Well waters during 1997

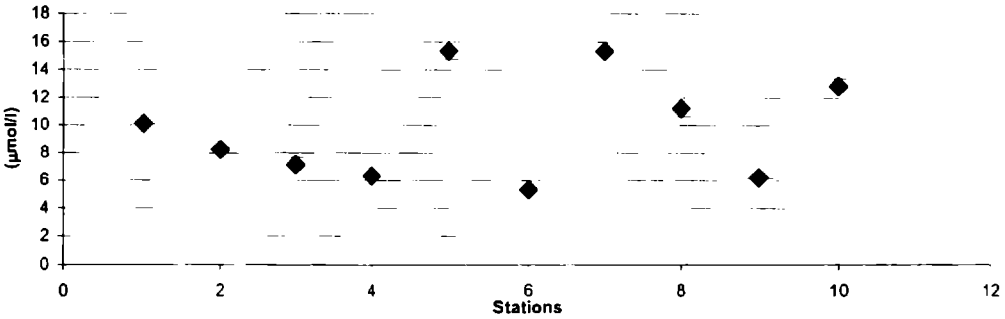


Chart 177: Nitrate-Nitrogen in Well waters during 1998

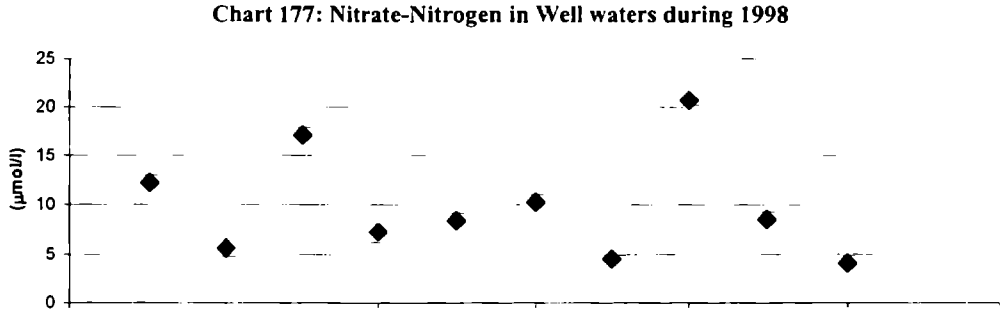
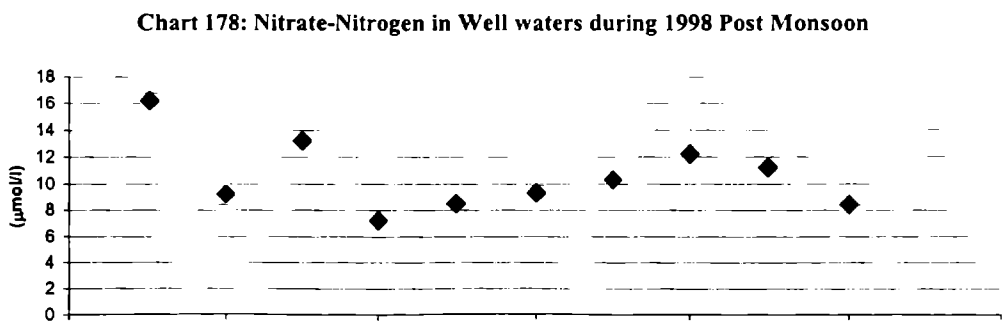


Chart 178: Nitrate-Nitrogen in Well waters during 1998 Post Monsoon



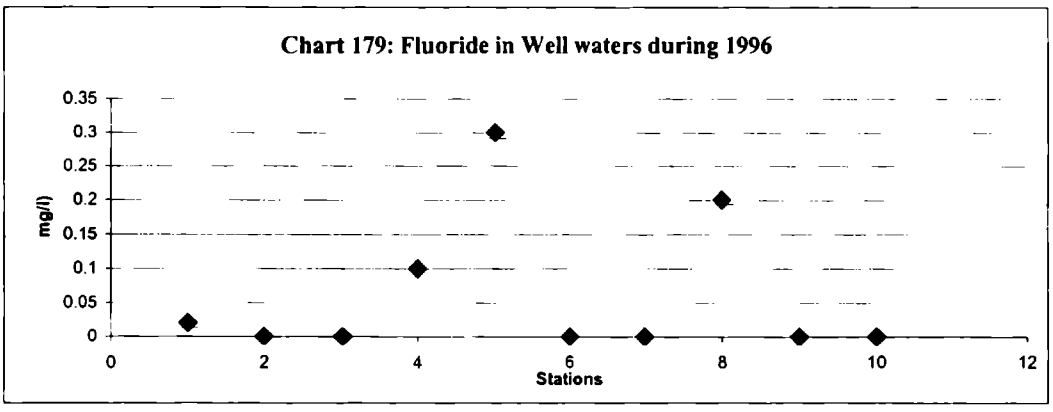


Chart 179: Fluoride in Well waters during 1996
mg/l)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
Stations

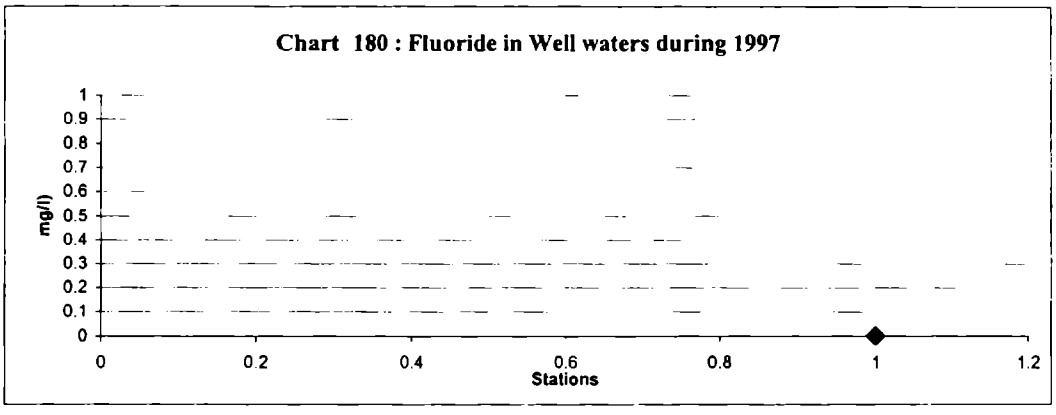


Chart 180 : Fluoride in Well waters during 1997
mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1.2
Stations

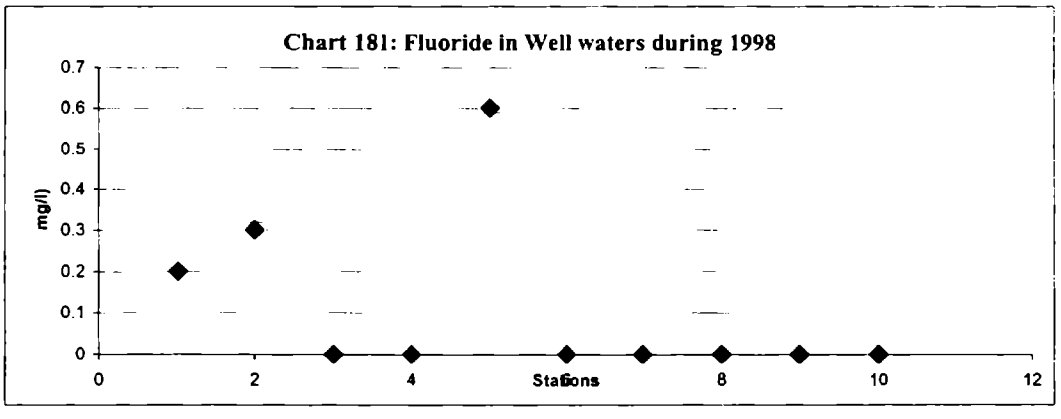


Chart 181: Fluoride in Well waters during 1998
mg/l)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
Stations
8
10
12

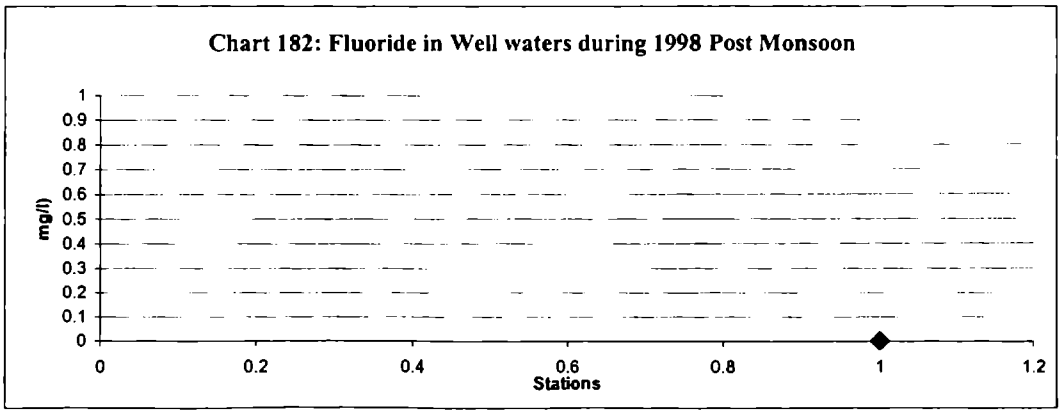


Chart 182: Fluoride in Well waters during 1998 Post Monsoon
mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1.2
Stations

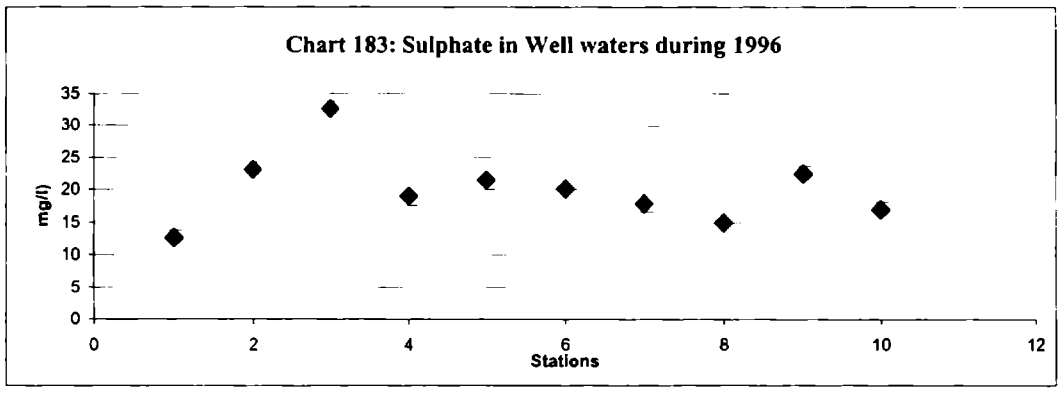


Chart 183: Sulphate in Well waters during 1996
mg/l)
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

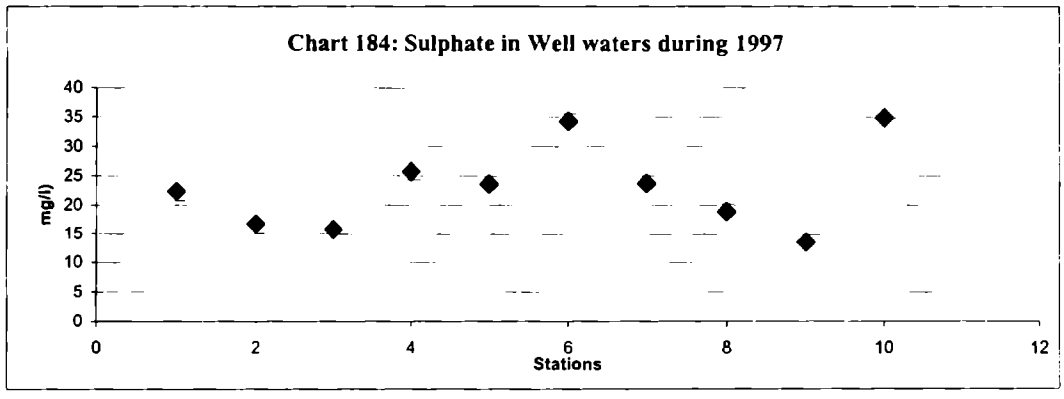


Chart 184: Sulphate in Well waters during 1997
mg/l)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

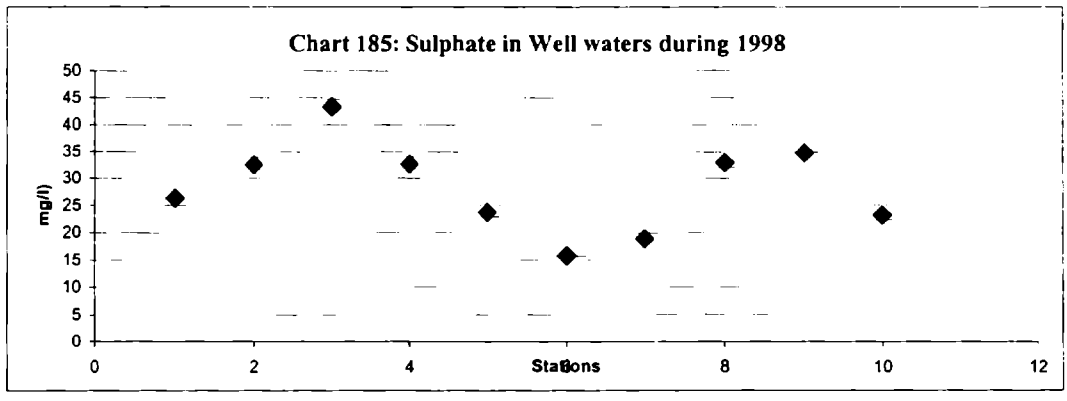


Chart 185: Sulphate in Well waters during 1998
mg/l)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

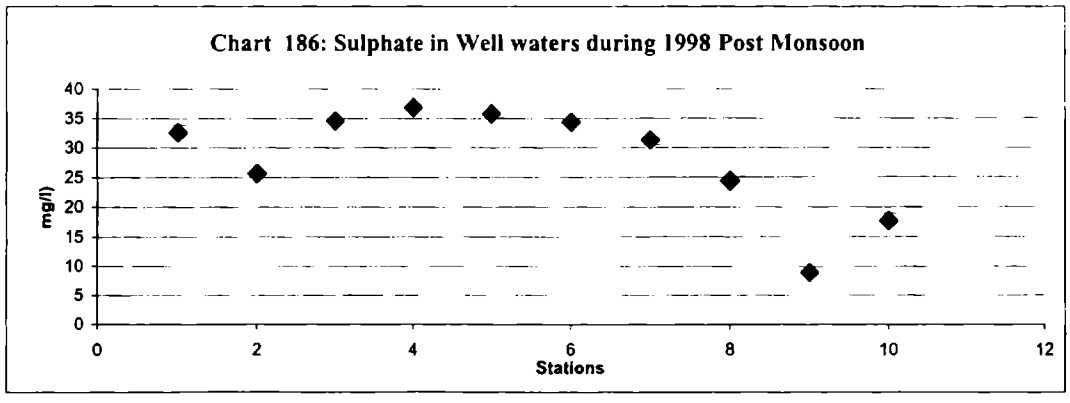


Chart 186: Sulphate in Well waters during 1998 Post Monsoon
mg/l)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Stations

4. MAJOR CONCLUSIONS

The integrated water quality assessment comprising biological, physico-chemical and microbiological characteristics on coastal and ground waters of Andrott island, Lakshadweep Sea has highlighted the following facts. The study has established a pre-requisite for any pertinent work in the Lakshadweep Sea on microbial status, nutrient dynamics, status of dissolved heavy metals and biological productivity. A systematic analysis on well water quality in terms of bacteriological and physico-chemical variables elucidates the status, source and seasonal variation of well water contaminants. The quantum of data would be useful for any management action plan, which is required to implement in the coral ecosystem. The baseline data on the primary and secondary production in seas around the island brings about the Probable Fishery potential Zone of the system. Various data on the potent pollutants of the system will indicates the health status of the eco system.

Marine pollution

The study highlighted on the microbiological characteristics of sea around Andrott islands showed that *Salmonella* like organisms, *Shigella* like organisms and *Proteus* and *Klebsiella* like organisms isolated from the system indicates the faecal contamination of the coastal waters. Faecal streptococci, an indicator of faecal contamination were also present in coastal waters, irrespective of the season. Organisms like *Vibrio cholera* and *V.parahaemolyticus* in large numbers in the coastal waters also depict the extent of faecal contamination. The high counts of *V.cholera* like organisms cautions the chances of its occurrence in edible fish, and other species from the coastal waters. High count of potential pathogens also cautions the chances of their infiltration into the nearby dug wells. Open defecation, along the banks of the island has to be strictly prohibited in view of faecal contamination of seawater,

Physico-chemical characteristics of water around the island showed that water temperature varied from 27.8 to 30.9°C in the sea, which indicated that though, the fluctuation was narrow between stations; there was a slight increase from 1996 to 1998 period especially during pre-monsoon season. The increase is particularly significant that the corals are very sensitive to rise in temperature, which may causes leaching of corals.

High amounts of suspended solids recorded in the nearshore stations of harbour over the period was due to the breakwater construction activities carried out then and there. This has reduced the dissolved oxygen content in the water, which has a direct influence in the overall productivity and caused high turbidity in the system. Moreover, high turbulence and low DO in water are posing great threat to the sensitive corals in the system. Strict adherence to the marine pollution prevention laws should be ensured to limit the extra construction activities along the coast and to restrict over capitalization of mechanized fishing and other activities like coir retting along nearshore that may affect the coastal productivity and the local fishery potential.

The overall dissolved oxygen (2.8 to 5.89mg/l) noted in the transects does not depict a healthy picture in general, especially that at the harbour nearshore. Though, the results of Nitrite-nitrogen, Nitrate-nitrogen and ammonia do not show any wide range of temporal or spatial pattern of distribution, it can be assumed that nitrification is predominant than de-nitrification. Comparatively higher values of ammonia observed in the coastal area showed that there is a disposal of bio-degradable waste in to the system. BOD values recorded in the nearshore stations also attributed to the disposal of domestic and sewage wastes.

The PHC concentration and dissolved trace metals did not show wide fluctuation among the transects. The dissolved trace metal content observed in the study period was well below the reported values elsewhere and within the permissible limits. However there is the slight increase of PHC over the period of study proved an increase in the number of mechanized fishing vessels and activities.

Low productivity and plankton diversity recorded at the nearshore of harbour transect over the period of study attributed to the increased breakwater construction activities at the area which resulted in consequent effects such as high TSS content, low DO, Turbidity and hence decrease in light penetration. The major genera of phytoplankton isolated from the Lakshadweep Sea included *Coscinodiscus*, *Rhizosolenia* and *Chaetoceros*. Comparatively a low primary production, phytoplankton abundance and

chlorophyll pigment concentration was reported for nearshore of all transects and the lowest at breakwater construction station (Harbour transect). However, at offshore stations, a high primary and secondary production was reported. The phytoplankton abundance and diversity were comparatively higher during the post monsoon season. Zooplankton density and biomass showed narrow seasonal fluctuation, but moderately elevated values were observed during the pre monsoon season. Among zooplankton, copepods were the major group, which contributed 45–80% and the percentage composition varied seasonally. Though, the oligotrophic ecosystem did not show a very high primary and secondary production and nutrient concentration, the system concerned was found healthy over the study period except at the near shores, particularly at the harbour transect.

Ground water pollution

Well water quality monitored during the period 1996-1998 clearly reveals that the count of total heterotrophic organisms (TVC) was found to be very high in all the wells, which is an indication of the increased seepage of waste waster into the fresh water lens. However, its high count is not desirable in drinking water especially in a system like Andrott, which support a large number of people.

The enteric group of bacteria, that cause four out of five common water borne diseases, was found prevalent in the dug well waters of Andrott. The results confirmed that coliform contamination in well waters covered all seasons. The potential pathogens such as *Salmonella* like organisms, though a variety of species of them could be the natural inhabitants, were also found occasionally from well waters.

The occurrence of *Shigella* like organisms causing shigellic dysentery, *Proteus* and *Klebsiella* like organisms causing opportunistic infections also revealed the extent of water pollution. Enumeration of *Vibrio cholera* like organisms causing cholera and *V parahaemolyticus* like organisms causing food poisoning also point out the need for disinfection of water as a remedial measure before use.

The physico-chemical analysis reveals that the water temperature fluctuated within a very narrow range. The pH values are with in the BIS desirable limit prescribed for drinking water and generally fall between 7.0 and 8.5. The conductivity values recorded wide fluctuation and some well waters cross the permissible limit which could be easily identified as a result of seawater intrusion due to over draft.

Alkalinity values clearly indicated that the well waters of the island are generally alkaline in nature. Calcium and magnesium hardness also showed that the quality of well waters over the period of 2 years has deteriorated to some extent which indicated seawater intrusion into the fresh water sources. Nitrite, nitrate and sulphate content are also within the prescribed standards. This may be due to the decreased utilization of chemical fertilizers.

Fluorides reported in fresh water samples were in the range of 0 to 0.3 mg/l which is within the permissible limit as per the BIS standard.

The management programme envisaged for the enhancement of water quality is the treatment of domestic sewage. The sewage has to be isolated to one end of the island and disposed off to a distant place at sea after treatment. Overdraft, which leads to infiltration of sea water into the dug wells especially during premonsoon season, has to be minimized with the traditional modes of water withdrawal. Alternative technology for fresh water production (reverse osmosis) can be implemented to meet the fresh water supply. Public should chart out the water and sanitation problems in the island and should bring it into the notice of administrators. Then only, the tiny fragile ecosystem can be saved forever.

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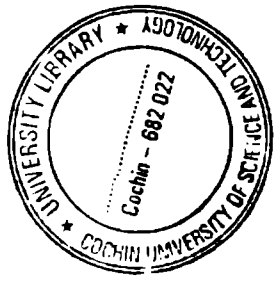

ANNEXURE :

I. Microbiological media composition

1 Nutrient Agar medium

Ingredients (g/l)

Beef extract

Peptic digest of animal tissue- 5.0

Agar- 15.0

Final pH -6.8 _ 0.2

2. Mac Conkey Agar

Ingredients (g/l)

Peptic digest of animal tissue- 17.0

Protease peptone- 3.0

Lactose- 10.0

Bile salts- 1.5

Sodium chloride-5.0

Neutral red-0.03

Agar-15.0,

Final pH- 7.1 ± 0.2

3. M-FC Agar

Ingredients (g/l)

Tryptose-10

Protease peptone. 5.0

Yeast extract- 3.0

Sodium chloride-5.0

Lactose -0.2

4. Xylose Lysine Deoxycholate Agar (XLD)

Ingredients (g/l)

Yeast extract- 3.0

L-Lysine- 5.0

Lactose-7.5

Sucrose- 7.5

Xylose- 3

Sodium chloride-5.0

Sodium Deoxycholate- 2.5

Sodium thiosulphate- 6.8

Ferric ammonium citrate- 0.8

Phenol red- 0.08.

Agar- 15

Final pH- 7.4 ± 0.2

5. TCBS Agar

Ingredients (g/l)

Peptone, special- 10.0

Yeast extract- 5.0

Sodium thiosulphate- 10.0

Sodium citrate- 10.0

Sodium cholate- 3.0

Oxgall- 5.0

Sucrose- 20.0

Sodium chloride- 10.0

Ferric citrate- 1.0

Bromothymol blue- 0.04

Agar- 15

Final pH -8.8 ± 0.2

6. M-Enterococcus Agar

Ingredients (g/l)

Casein enzymic hydrolysate- 15.0

Papaic digest of soyameal- 5.0

Yeast extract- 5.0

Dextrose- 2.0

Dipotassium phosphate- 4.0

Sodium azide- 0.4

2, 3, 5 triphenyl tetrazolium chloride- 0.1

Agar- 15

Final pH- 7.2 ± 0.2

II. Chemical parameters

1. DO

Reagents:

1. Winkler- A (WA): Manganous chloride (400g) was dissolved in 1000ml distilled water (DW) and stored in a polyethylene bottle.

2. Winkler-B (WB): Potassium iodide (360g) and 100g of sodium hydroxide were separately dissolved and mixed in 1000ml distilled water, stored in a polyethylene bottle.

3. Sulphuric acid (9N), diluted from Conc. H_2SO_4.

4. Sodium thiosulphate solution (Approximately 0.02 N): Dissolved 5g sodium thiosulphate in DW and made up to 1000ml in a volumetric flask. Stored in a stoppered glass bottle.

5. Starch indicator solution: Dissolved 1g starch in 100ml hot distilled water, quickly heated the suspension to boil in order to complete the dissolution of starch, and cooled.

6. Alkaline Potassium iodide solution (0.01N): Potassium iodide (AR) of 0.3567g was dissolved in 1000ml distilled water in a volumetric flask.

2. Inorganic phosphate

Reagents:

1. Sulphuric acid (9.0 N) Added carefully 250 ml concentrated Sulphuric acid to a 1 litre volumetric flask containing 750 ml distilled water and dilute to 1000 ml.
2. Ammonium molybdate solution: Dissolved 1.25 g ammonium molybdate tetra hydrate (AR) in 125 ml distilled water. Stored in a plastic or glass bottle.

3. Potassium antimonyl tartrate solution: Dissolved 0.5 g potassium antimonyl tartrate (AR) in 20 ml distilled water. Stored in glass bottle.
4. Mixed reagent: Added slowly while stirring 125 ml molybdate solution to 350 ml 9.0 N H_2SO_4. Then added 20 ml titrates solution. Mixed by shaking and stored in a glass bottle.
5. Ascorbic acid solution Dissolved 10 g ascorbic acid in 50 ml distilled water and added 50 ml 9 N H_2SO_4. The reagent was stored in an amber coloured bottle, in refrigeration, and could be used for a week.
6. Phosphate standard solution: Weighed 0.1361g of potassium dihydrogen phosphate (AR) already dried at 100 ^{O}C in an oven and cooled in a desiccator and dissolved in 100 ml DW containing 1 ml of 9.0 N H_2SO_4. This solution contains 10 µmol PO_4^{-3} /ml.

3. Silicate

Reagents:

1.Molybdate reagent: Dissolve 4.0g of analytical reagent quality ammonium paramolybdate, $[(NH)_{46} MO_7 O_{24}.4H_2O]$ in 300ml of distilled water. Added 12.0ml of concentrated hydrochloric acid, mix and make the volume to 500ml with distilled water. Store the solution in polythene bottle.

2. Metol-sulphate solution: Dissolve 6.0g of anhydrous sodium sulphite $Na_2 SO_3$, in 500ml of distilled water and then added 10ml of metol (p-aminophenol sulphate).

3. Oxalic acid solution: Prepare a saturated oxalic acid solution by shaking 50g of analytical reagent quality oxalic acid dihydrate $[(COOH)_2, 2H_2O]$ with 500ml distilled water; decant the solution from the crystals for use.

4. Sulphuric acid solution (50%v/v): Pour slowly 250ml of concentrated H_2SO_4 into 250 ml of distilled water, cool and make up to 500ml with distilled water.

5. Reducing agent: Mixed 100ml of metol-sulphate solution with 60ml of oxalic acid solution. Added slowly with mixing 60ml of the 50 % Sulphuric acid solution and made the mixture to a volume of 300ml with distilled water.

4. Total phosphorus and Total nitrogen

Reagents:

1. Ammonium free water (double distilled water)
2. Sodium hydroxide (0.375 M): Dissolved 15.0 g sodium hydroxide and diluted to 1000 ml with double distilled water, stored in a tightly stoppered polythene bottle.
3. Oxidising reagent: Dissolved 5.0 g purified potassium persulphate ($K_2S_2O_8$) and 3.0 g phosphoric acid (H_3PO_3) (AR) in 0.375 N NaOH, mixed well and stored in a tightly stoppered polythene bottle and covered with aluminium foil.
4. Standard stock organic nitrogen solution: Dissolved EDTA disodium salt (0.1862 g) in ammonia free distilled water (100 ml) and stored in a glass bottle and refrigerated. The standard contained 10µmol organic nitrogen/ml.

5. Ammonia -Nitrogen

Reagents:

1. NaOH (1N)
2. Phenol Reagent (Phenol + Sodiumnitroprusside)
3. Tri-Sodium citrate buffer
4. Hypochlorite Reagent

Standard Stock Solution is prepared by using dry A.R..Ammonium Chloride, add a drop of Chloroform for preservation.

6. Nitrite-Nitrogen

Reagents:

1. Double distilled water (check for absence of nitrite)
2. Sulfanilamide solution (1%): Dissolved 2.5 g sulfanilamide in 25 ml conc. hydrochloric acid and made upto 250 ml with distilled water and stored in an amber coloured glass bottle.
3. N-(1-naphthyl) – ethylene diamine dihydrochloride (1%) Dissolved 0.25 g in 250 ml water and stored in an amber coloured glass bottle.
4. Nitrite standard solution:

Dissolved 0.690 g anhydrous sodium nitrite (dried at 100°C for 1 hr) in 100 ml distilled water and diluted to 1000 ml in a volumetric flask. The solution contains 10 µmol NO_2-N/ml; the solution was stored in an amber coloured glass bottle.

5. Nitrite working standard solution: Pipetted out 10 ml of stock solution into a 500 ml volumetric flask and diluted to 500 ml mark. Transferred 5.0 ml of this solution to another 500 ml flask and the volume made upto the mark. This standard has 2 µmol NO_2-N/l.

7. Nitrate- Nitrogen

Reagents:

1. Double distilled water (checked for absence of nitrate and nitrite)

2. Ammonium chloride buffer: Dissolved 10.0 g of ammonium chloride (AR) in 1000 ml water. Stored in a polyethylene bottle and the pH adjusted to 8.5 with ammonia.

3 Sulfanilamide solution and N-(1-naphthyl)-ethylene diamine dihydrochloride solution: (Refer the case of NO_2-N Nitrite standard solution)

4. Nitrate standard solution Dissolved 1.011 g dry potassium nitrite (previously dried at 105°C to constant weight) in 100 ml water and made upto 1000 ml in distilled water. The stock solution contained 10 µmol/ml NO_3-N.

5. Nitrite working standard: The stock solution was diluted in a volumetric flask to prepare a standard having a concentration of 5 µmol NO_3-N/l. For this 5 ml of the stock solution was diluted to 1000 ml and out of this 10 ml was again diluted to 100 ml with distilled water.

6. Cadmium metal filings: 40-60 mesh size (E Merck No. 120882)

7. Copper sulphate solution (1%): 10 g [CuSO4.5H2O] dissolved in 1000 ml water.

8. Cadmium and Lead

Reagents

All dilutions in the preparation of reagents and standards are made using pure water obtained from the Milli- QR

1 Methyl Isobutyl Ketone (MIBK)

2. Ammonium Pyrolidine Dithio Carbamate (APDC) solution (2 %). Dissolved APDC (5g) in water (500 ml). This compound dissolves completely in water. However, in case

the difficulty arises in dissolving the compound completely, the APDC solution may be filtered through Whatman No.1 filter paper.

3. Concentrated Nitric acid of Supra pure grade.
4. Metal standard stock solutions. Standard litrisol R ampoules were used for preparing standard stock solutions containing 1000 µg/ml of cadmium or lead.

9. PHC

Reagents ;

1. Spectra grade n-Hexane (Double distilled)
2. Anhydrous sodium sulphate (AR)
3. Chrysene (Topped at 100°C: Dissolve 1.0 mg of chrysene in 100 ml of double distilled hexane (10 µg oil/ml)

10. BOD

Reagents Same as in DO

11. Mercury

Reagents

1. 500 ml of 1 % K MNO_4 in 10 % of H_2SO_4 (Dissolved 5 g of K MNO_4 in water and added carefully it to 50 ml of H_2SO_4 and made up to a volume of 500 ml using distilled water).
2. 250 ml of 20 % NAOH (Dissolved 50 gm of NAOH pellets in distilled water and made up to a volume of 250 ml).
3. 100 ml of 20 % Stannous chloride ($SnCL_2$) in 10 % HCL. 20g of $SnCL_2$ was taken in a beaker. Added 10 ml Conc. HCL and dissolved while warming in a burner. Boiled for 1 min. cooled and diluted with distilled water to make 100 ml. Added 1-2 g Tin metal pellets after the preparation of the solution.

12. Chlorides

Reagents:

K_2CrO_4 solution: Dissolve 50 g K_2CrO_4 in distilled water and diluted to 1 litre with distilled water.

Standard $AgNO_3$ solution (0.0141N): Dissolved 2.395g $AgNO_3$ in distilled water and diluted to 1 L. It was standardized against 0.0141N NaCl and stored in a brown coloured bottle. 1 ml of this solution 500 mg of Cl^-

13. Fluorides

Reagents

1. Stock fluoride solution (0.221 g/l). Dissolve 221 mg anhydrous sodium fluoride in distilled water and diluted to 1L.

2. Preparation of fluoride standards: 10 ml of stock solution was diluted to 100 ml. Prepared a series of standard fluoride solutions in the range of 0.0 to 5.0 mg/l at intervals of 0.5 mg/l, by dilution of stock solution with distilled water.

3. SPANDS solution: Dissolve 958 mg SPANDS, (Sodium 2- (parasulphophenylazo)-1,8-dihydroxide-3,6 naphthalene dilsulphonate) in distilled water and diluted to 500ml.

4. Zirconyl –acid reagent: Dissolve 133 mg zirconyl chloride octahydrate($ZrOCL_2$. 8 H_2O) in 25 ml of distilled water. Added 350 ml conc. HCL and diluted to 500 ml with distilled water.

5. Mix solution (Acid zirconyl + SPANDS reagent)

6. Reference solution: Added 10 ml of SPANDS solution to 100 ml distilled water. Diluted 7 ml conc. HCL to 10 ml and added to diluted SPANDS solution.

7 Sodium arsenate solution: dissolved 5.0 g $NaAs0_2$ and diluted to 1 L with distilled water.

14. Sulphate

Reagents

1 NaCl-HCl solution: Dissolve 240g of sodium chloride in a little distilled water and then the volume was made to 1L with distilled water

2. Glycerol-ethanol solution: 50ml of glycerol was added to 100ml of ethyl alcohol and shaken well.

3. Barium chloride: Dry crystals.

4. Standard sulphate solutions: Dissolved 0.1479g of anhydrous Na_2SO_4 in distilled water to make the volume 1L. This solution contained 100mg sulphate/l. Standards of various strengths were prepared, preferably from 0.0 to 40.0 mg/l at the intervals of 5mg/l by diluting the stock solution.

15. Total Alkalinity

Reagents:

1. 0.02N H_2SO_4 ie, 1 ml 0.02N H_2SO_4 = 1 mg $CaCO_3$
2. Phenolphthalein indicator
3. Methyl orange indicator

16. Total Hardness

Reagents:

1. Buffer solution: dissolve 16.9 g of NH_4CL in 143 ml of NH_4OH, diluting this to 250 ml with deionised water.
2. Erichrome Black T indicator: 0.2 g Erichrome Black T dye was dissolved in 15 ml of triethanol amine with the addition of 5 ml of absolute ethanol to reduce the viscosity. Added two drops of indicator per 50 ml of the solution to be titrated. 3
3. Standard EDTA solution (0.01 M): Weighed out 3.723g of A R sodium ethylene diamine tetra acetate dihydrate (EDTA) dissolved in water and diluted to 1000 ml. 1 ml 0.01 M EDTA solution = 1 mg of $CaCO_3$
4. Standard calcium solution: Weighed out 1 g anhydrous $CaCO_3$ powder into a 500 ml Erlenmeyer flask. 1:1HCL is added, little at time, until all $CaCO_3$ has dissolved. Added 200 ml distilled water and boiled for few minutes to expel CO_2. Cooled and added a few drops of methyl red indicator, and adjusted to the intermediate orange colour by adding (3N NH_4OH + 1:1HCl) as required. This was diluted to 1000 ml, with distilled water. 1 ml Ca solution = 1 mg of $CaCO_3$.
5. Sodium hydroxide (0.1 M): 0.4 g NaOH was dissolved in 1000 ml distilled water.

17. Calcium Hardness

Reagents:

1. Sodium hydroxide (1 N)
2. Murexide (ammonium purpurate)

Murexide (0.2g) was mixed with 100g NaCl and ground well to get a uniform coloured mixture. Titration was conducted immediately after adding indicator because it is unstable under alkaline conditions. This indicator changes from pink to purple at the end point.

3. Standard EDTA solution (0.01M)

EDTA of 3.723g (AR Sodium Ethylene Diamine Tetra Acetate dehydrate) dissolve in distilled water and diluted to 1000ml.

1ml 0.01m EDTA solution = 1mg of $CaCO_3$

III. Biological parameter

1. Chlorophyll *a*

Reagents .

1. $MgCO_3$ suspension 1%
2. 90 % aqueous acetone

2. Primary productivity

Reagents

1. Sodium bicarbonate
2. HCL (0.5 N)
3. Ethanolamine

Slide 1: Onboard Sampling at Lighthouse Transect

Slide 2: Phytoplankton Collection at Helipad Nearshore

LIST OF PUBLICATIONS

In connection with the thesis, the following research papers are published:

1. **Bijumon K B**, Madusoodananpillai G, Anilkumar N C and OusephP P, (1999), Primary production, Chlorophyll *a* and related hydrography of Lakshadweep sea. Proceedings of the Eleventh Kerala Science Congress, p.p. 315-318.

2. Madhusoodanan Pillai G, **Bijumon K.B**, Satheeshkumar C S, and Ouseph P.P, (1998), Assessment of indicator microbial population in relation to few possible human pathogens in surface waters along south west coast of India, Proceedings of the Tenth Kerala Congress, p.p.205-207.

3. **Bijumon K.B,** Madhusoodanan Pillai G, and Ouseph P.P (1998), Environmental degradation of marine ecosystem at Veli due to the discharge of TTP effluents along the south west coast of India, Proceedings of the Tenth Kerala Congress, p.p.384-386.

4. **Bijumon K.B,** Anilkumar N.C, Ramalingam Pillai A and Ouseph P.P (1997), Distribution and composition of plankton along the south west coast of India, Proceedings of the Ninth Kerala Congress pp 402.

5. **Bijumon K.B,** Robin R S, Sunilkumar S, and Ouseph P.P, (2000), Effect of factory effluent on the biological productivity of coastal marine system at Veli, Thiruvananthapuram, Proceedings of the Twelth Kerala Congress, p.p. 592-594.

6. Madhusoodanan Pillai G, **Bijumon K.B** and Ouseph P.P (1999), Assessment of Chemical and Bacteriological quality of drinking water in Kadmat Island, Lakshadweep, Proceedings of the Eleventh Kerala Congress, p.p.1-4.

7. Anilkumar N C, **Bijumon K B,** Sudheesh S and Ouseph P P (1997), Water quality and microbial population of the Kavaratti lagoon – Lakshadweep sea – a semi diurnal study. Proceedings of the Ninth Kerala Congress, p.p.401-402.