MARINE INDUSTRIAL POLLUTION: A SPECIFIC CASE STUDY OF THE LEBANESE COAST

by

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ABSTRACT

MARINE INDUSTRIAL POLLUTION: A SPECIFIC CASE STUDY OF THE LEBAINESE COAST

A field survey was conducted starting 21 May through 16 August (three months) at two sites, Eli-Helwe site and Selaata site, to document aggression sources and characterize the coastal waters near these sites. Photographic documentation was taken, visual observations noted, and water samples were collected from seven stations (six at Selaata, one control at Eli-Helwe) during the survey. The samples were physically characterized in the field (temperature, dissolved oxygen (DO), turbidity, salinity, conductivity, total dissolved solids (TDS), and pH) and chemically and biologically analyzed for a series of constituents in the laboratories at the Lebanese American University (nitrate, nitrite, orthophosphate, biological oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform and total coliform bacteria).

While the seawater temperature varied from 20.81°C to 28.84 °C, salinity ranged from 37.77 %o to 39.28 %. Though, the values of BOD and COD fluctuated widely, pH, conductivity, TDS, turbidity, nitrate and DO values had narrow fluctuations. The concentrations of nitrite, orthophosphate were 0 - 0.019mg/l, 0 to 7.81 mg/l respectively. The number of total coliform and fecal coliform bacteria was within the guideline limits. The parameters tested in this study show that their concentrations are considerably higher in Selaata than in Eli-Helwe. The location of the stations near and around the Lebanese Chemical Company (LCC) indicates LCC as the most likely source of contamination. Results of the present study show that Selaata and its immediate vicinity remain polluted while Eli-Helwe area is within the acceptable levels.

The information and views presented are intended to provide a basic prelude of awareness to marine water environmental pollution. They are also intended to
inform and promote discussion for the public, organizations and decision makers who are concerned about the deterioration of the quality of the water environment that is being used.

The results obtained have been used to establish baseline data for future testing and to produce a report on overall seawater quality of the Selaata area to be presented to the Lebanese American University.
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Abiotic: Not alive, non biological. It refers to chemical, physical, and geological features of the environment.

Acute: Chronic, at a turning point and coming sharply into a crisis.

Aerated: To put air into a liquid.

Acrobic Bacteria: Bacteria that can not survive and live without oxygen.

Agricultural Runoff: To allow liquid to flow out from farms and agricultural factories.

Algal (Spring) Blooms: referring to obnoxious and excessive growths of algae caused by excessive nutrient loadings that can regulate their buoyancy to float high in the water column to obtain sunlight.

Ambient: Surrounding, pertaining to the current environmental conditions.

Amenities: Surroundings or circumstances that make life easy and pleasant.

Anaerobic: Living in the absence of oxygen.

Animate: Living things such as animals and plants. Gives life to.

Anoxia: A condition when the water becomes totally depleted of oxygen and results in the death of any organism that requires oxygen for survival.

Anthropogenic: Of human origin or human induced, e.g., human sources of pollutants.
Atmospheric Deposition: The process whereby air pollutants are deposited on land and water, sometimes at great distances from their original sources.

Auspices: Helped and favored by.

Autoclave: An oven-like vessel used for sterilization of equipment, carrying out chemical reactions at high temperature and pressure.

Biodegradability: Ability to breakdown organic compounds into harmless products by the action of living things.

Biogeochemical Fate: Short for biological, geological, and chemical; often used to describe cycling of elements in the sea.

Biota: Refers to all organisms of all species living in a particular area or region.

Carbonate Buffering System: the most important buffer system in natural surface waters, consisting of a carbon dioxide, water, carbonic acid, and bicarbonate and carbonate ion equilibrium that resists changes in the water’s pH. If acid is added to this buffer solution, the equilibrium is shifted and carbonate ions combine with the hydrogen ions to form bicarbonate. Subsequently, the bicarbonate then combines with the hydrogen ions to form carbonic acid, which can dissociate into carbon dioxide and water. Thus the system pH is unaltered although acid was introduced.

Catchment Area: The area from which a lake or river gets its water.

Coastal Waters: The sea within 5.6 Km of the shore.

Decree: An official decision by the government.
Detritus: Dead or decaying organic matter, such as twigs, leaves, dead organisms, fecal pellets, and mucus products from plankton.

Dioxin: Proven carcinogen according to the World Health Organization. Interferes with the body’s endocrine system. Causes reproductive and developmental problems.

Diurnal: Active in the daytime rather than the nighttime. (Double check)

Drainage Basin: Geographic land area draining into a lake or a river.

Dredging: Bringing up mud from the bed of the sea and disturbing the sediment.

Ecology: The scientific study of the pattern of relations of plants, animals, and the people to each other and to their surroundings.

Ecosystem: All of the interacting organisms (biotic and abiotic) in a defined space in association with their interrelated physical and chemical environment.

Effluents: Liquid discharge, in a treated or untreated condition, to a body of water from a defined or point source. Consisting of a mixture of waste and water usually produced from an industrial process or sewage.

Encroachment: The act or result of going beyond what is right and natural.

Eutrophication: The natural and artificial addition of nutrients to a water body, which may lead to depleted oxygen concentrations. It is a natural process that is frequently accelerated and intensified by human activities.

Fertilizer: Any type of chemical or natural substance that is put on the land to make crops grow better.
Food Web: A schematic depiction of the feeding interactions in a community.

Freshwater: Water living in rivers or inland lakes, not belonging to the sea.

Genera: A division of living things which usually includes several closely related species.

Global Warning: Changes in the surface-air temperature, referred to as the global temperature, brought about by the greenhouse effect which is induced by emission of greenhouse gases into the air.

Holistic: Considering, incorporating or identifying with many components of the whole system, not excluding seemingly extraneous factors or impacts

Humic Substances: heterogeneous yellow-black organic materials that include most of the naturally dissolved organic matter in water.

Hydrologic cycle: The movement of water in and on the earth and atmosphere through processes such as precipitation, infiltration, runoff, and evaporation.

Hypoxia: A condition where very low levels of dissolved oxygen are in the water column.

Inland: Placed inside the country, not near the coast.

Inorganic Compounds: substances of mineral, not carbon origin.

Latitude: Angular distance north and south of the equator.

Locale: A place where something particular happens or happened.

Longitude: The position on the earth east or west from Greenwich.
Maritime: Situated or found near the sea.

Nitrification: The process of transforming ammonium (NH4+) into nitrate (NO3-) with nitrite (NO2-) as an intermediate product in order to yield chemical energy that is used to fix carbon dioxide into organic carbon.

Non-point Source: Pollution that enters water from sources that can not be traced to a single point. Generally initiated by storm water runoff from agricultural, urban, construction, and other land uses.

Nutrients: Any of a necessary complement of organic or inorganic elements or compounds that are considered essential to the biological growth of an organism.

Organic Compounds: Compounds of carbon, oxides, metallic carbonates and related compounds.

Organic Waste: Substances that contain carbon atoms and carbon-carbon bonds.

Photosynthesis: The chemical reaction in plants that utilizes light energy from the sun to convert water and carbon dioxide into simple sugars. This reaction is facilitated by chlorophyll.

Phytoplankton: Microscopic, marine floating plants, mainly algae that get their energy from sunlight, live suspended in bodies of water.

Point Source Pollution: A specific discharge that is traceable to a distinct source (pipe, ditch, container, etc.) such as those from wastewater treatment plants or industrial facilities.
Pollutant: A contaminant that adversely alters the physical, chemical, or biological properties of the environment. The term includes toxic metals, pathogens, contaminants and impurities.

Precipitation: The settling out of water from cloud, in the form of rain, hail, fog, snow, etc. (also the formation and settling out of solid particles in solution).

Sludge: the solid portion remaining from the treatment of municipal, industrial and waste water that contains organic matter and a whole community of algae, fungi, bacteria and protozoan that consume it.

Substratum: A solid surface on which an organism lives or to which it is attached.

Thermal Pollution: The excessive raising or lowering of water temperature above or below normal seasonal ranges in seas and oceans as a result of discharge of hot or cold effluents into such water.

Tidal Changes: The periodic rise and fall of the sea surface due to gravitational attractions of the Sun and Moon acting on the rotating Earth.

Wastewater: Water that contains waste from homes, factories, offices, industries and the like.

Wastewater Treatment Plant: Facility that uses a combination of physical, chemical, and biological process to treat wastewater from domestic and industrial sources.

Water Body: Landscape features compromising ant body of water, standing or flowing, including the water column, littoral zones and bed, such as the sea, lakes, river or stream, etc.
Water Column: Refers to a vertical expanse of sea water stretching from the ocean surface to just above the ocean floor.

Water Cycle: The paths water takes through its various states- vapor, liquid, solid- as it moves throughout the ocean, atmosphere, groundwater, streams, etc.

Water Masses: A discrete region or volume of sea water that exhibits consistent physical properties such as temperature, salinity and density. Different water masses tend to mix together very slowly.

Waterway: A canal where the water is deep enough for ships to navigate.

Xenobiotics: Man-made chemicals.
Abbreviations


BBSR: Bermuda Biological Station for Research.

BOD: Biological Oxygen Demand.

CCREM: Canadian Council of Resources and Environment Ministers.

CEC: Council of the European Communities.

CEP: Caribbean Environment Program.


CFU: Colony Forming Unit.

CIESE: Center for Improved Engineering and Science Education.

COD: Chemical Oxygen Demand.

CDR: Council for Development and Reconstruction

CSR&D: Center for Sponsored Research and Development.

DO: Dissolved Oxygen.
EEA: European Environment Agency.

EMPACT: Environmental Monitoring for Public Access and Community Tracking Project.

EPA: Environmental Protection Agency.

EUCC: European Union for Coastal Conservation.

FC: Fecal Coliform.

GESAMP: Group of Experts on Scientific Aspects of Marine Environmental Protection.

GPS: Global Positioning System.

GREEN: Global Rivers Environmental Education Program.

IFREMER: French Research Institute for Exploitation of the Sea.

ITMEMS: International Tropical Marine Ecosystem Management Symposium.

KRWW: Kentucky River Watershed Watch.

LAU: Lebanese American University.

LPO: Laboratoire de Physique des Oceans.

MPA: Marine Protected Areas.

OECD: Organization for Economic Cooperation and Development.
SOGREAH: Société Grenobloise d'études et d'application hydraulique, campagne de mesure.

TC: Total Coliform.

TDS: Total Dissolved Solids.


USEPA: United States Environmental Protection Agency.

WHO: World Health Organization.


YSI: Yellow Springs Instrument.
Chapter 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Environment as a whole

In the context of the global community, water compromises nearly three fourths of the earth's surface. Although tremendous diversity of life exists in aquatic ecosystems, a commonality among organisms is their close association with the environment (Kleinow & Goodrich, 1994).

The properties of water vary naturally depending on the surrounding environment, so data collected about water quality must be interpreted in the context of the waterbody's particular environment (Commonwealth of Australia, 2002).

The environment has been defined as all the inanimate compartments such as air, soil, and water and all the animate components such as plants and animals that surround a particular individual organism or population of organisms (Shane, 1994). The environment has a capacity to cope with discharges of waste without suffering deleterious effects on its biological systems. This ability to cope is known as the assimilative capacity (Cairns, 1977) or as the environmental capacity (Pravdic, 1985; Portmann & Lloyd., 1986) of a given area.

1.2 Marine environment

For the marine domain a definition of environmental capacity proposed by the UN's Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) is "a property of the environment, defined as its ability to
accommodate a particular activity, or rate of activity, without unacceptable impact" (Pravdic, 1985). The concept is based on the following assumptions:

1- That a certain level of some contaminants may not produce any undesirable effect on the marine environment and its various uses.
2- That each environment has a finite capacity to accommodate some wastes without unacceptable consequences.
3- That such capacity can be quantified, apportioned to certain activity, and utilized.

The problems with these assumptions are that there is no definition of what an undesirable effect is or how it will be measured, or how the capacity of a given area can be predicted or measured (Gray, 1998).

The conservation of the environment does not mean strictly an environment without any kind of intervention but rather the opposite; it implicates a good planning, administration and management of the resources in order to succeed in reaching the goal of improvement of the quality of life and succeed in maintaining it in time. It strives to achieve a balance between use and protection (Bergasa et al., 2002).

1.3 Ecological risk assessment

Ecological risk assessment is a process that evaluates the probability or likelihood that adverse ecological effects will occur (or have occurred or are occurring) as a result of exposure to stressors from various human activities (USEPA 1986b, 1992; Norton et al. 1992; Suter 1993, 1995). Stressor is a term describing something chemical, physical or biological in nature, which can cause adverse effects on non-human ecological components ranging from organisms, populations and communities, to ecosystems. Thus, industrial chemicals are examples of chemical stressors that are introduced into the environment
intentionally or unintentionally from human activities and cause possible adverse (toxic) effects (Smrček & Zeeman, 1998).

Most of the experience lies with assessing the risks of man-made chemicals, or as they are commonly called xenobiotics, such as pesticides and a wide array of industrial chemicals. However, the basic concepts of ecological risk assessment are also applicable to nonchemical stressors such as changes in the environmental conditions such as water temperature and pH (Rodier & Zeeman, 1994).

Activities which do not need to be located in the coastal zone should be located elsewhere. All activities which are likely to have an adverse impact on the coastal or marine environment should be subject to environmental impact assessment at the earliest stages, with negative impacts avoided to the maximum extent possible (Salman, 1996).

1.4 Physical, chemical, biological changes in the environment

Natural waters cannot be easily defined, but can be described in terms of the physical (qualitative), chemical and biological (quantitative) conditions present. The physical condition should consist of clean water with an ambient temperature, and free from most suspended solids, coloration, surface foam, obnoxious odor. The chemical condition should ensure that there is adequate oxygen, a correct balance of dissolved chemical nutrients to support life, and an absence of excessive organic matter, and toxic substances. Biologically, most natural waters contain a range of microorganisms, plants and animals that exist in a balanced ecological state (Dix, 1981).

Not all impurities water encounters during the hydrologic or water cycle present a problem, but diverse and complex natural processes continually change coasts physically, chemically, and biologically, at scales that range from microscopic
(grains of sand) to global (changes in sea level). Regional and local characteristics of coasts control the differing interactions and relative importance of these natural processes. Human activity adds yet another dimension to coastal change by modifying and disturbing, both directly and indirectly, the coastal environments and the natural processes of change (Williams et al., 1991).

With the expansion of the chemical industries in the developed countries from the 1920s onward, increased chemical discharges and emissions resulted; these discharges visibly affected aquatic ecosystems (Smrček & Zeeman., 1998). Over the past 20-30 years, international efforts to regulate new and existing chemicals, as well as pesticides and to assess their hazard and risk have been extensive and ongoing (Zeeman, 1997).

In order for a chemical to pose a risk in the environment, two conditions must be met. First, the chemical has to have an inherent ability to cause some undesirable or hazardous ecological effect. Second, the chemical has to be present in the environment (and exposure must occur) at sufficient levels to cause adverse effects in the organisms of concern or the water bodies of concern (Rodier & Zeeman, 1994).

1.5 Risk of pollution

Chemicals discharged into the environment may lead to alternations in background concentration levels. If these changes are statistically significant increases, then this is called contamination. Contamination may or may not lead to effects on biological systems. It is usually only when effects can be measured that are related to the contamination that pollution is invoked. This distinction between contamination of the environment and pollution is important (Gray, 1998).

Pollution is caused by the need to dispose of waste, which may be defined as
any gaseous, solid, or liquid material that is discarded because it has no further apparent use for the owner, industrial processor or manufacturer (McEldowney & McEldowney, 1996; Dix, 1981). If not properly managed, its impact on the environment is seen as a change in the composition of air, water and soil in ways that are to some extent harmful to living things, irreversible, and that have already in places reached disastrous proportions (Haddad, 1998).

The European Union's Dangerous Substance Directive (CEC, 1976) defines pollution of waters as: “..... the discharge by man, directly or indirectly, of substances or energy into the aquatic environment, the results of which are such as to cause hazards to human health, harm to living resources and to aquatic ecosystems, damage to amenities or interference with other legitimate uses of water.”

1.6 Natural variation of seawater

The quality of the water varies greatly. Not only is there variation in space, but even at one location, the conditions may change significantly over different time intervals. This great variability is influenced by the following factors (Suman et al., 2003):

- Drainage (dry vs. rainy)
- Season (winter vs. summer)
- Topography (absence or presence of wide plains)
- Type of shoreline (rocky, sandy, etc.)
- Configuration/complexity of the coastline (open, bay, etc.)
- Variation in the tidal changes
- Rainfall pattern
- Wind pattern
These factors determine the physical conditions of a locale. Physical and chemical parameters that would change based on the mix of the above "forcing functions" include:

♦ Temperature
♦ Current speed
♦ Wave action
♦ Concentrations of oxygen, organic materials, nutrients, inorganic materials.
♦ Salinity
♦ Turbidity and illumination.

Superimposed on this natural variation are the inputs to the near shore environment resulting from human activities. Human activities not only exacerbate the effects of a number of the forcing functions, they add new factors, such as chemical and solid waste pollutants and sewage and agricultural nutrients (Suman et al., 2003).

1.7 Seawater pollution in general

Pure, unpolluted water is an essential resource to the environmental balance of the world. Water has life-giving properties which are crucial to the world's global ecosystem. In some areas of the world, seas have become so polluted that ecosystems and the health of plants, animals, and humans are threatened. Economic development and human disregard have caused a decline in the quality of water and marine life all over the world. In recent years, many nations have realized the problem of sea and other water pollution. Some of these nations are taking steps to control or clean up the polluted waters; however, more must be done. Specifically, sea water pollution can cause many different problems. The origination and spread of serious disease to humans and animals can result from sea pollution. Sea water pollution also destroys the habitats of many species of fish and other animals (Dopp, 1996).
Water pollution is a serious problem for the entire world. Accidental and purposive hazardous dumping has contributed to the problem of sea pollution (Dopp, 1996). The sea receives inputs of contaminants from a variety of sources. The most direct inputs are often from point sources, that is, pipe discharges or illegal dumping of wastes directly into the water body. Among the wastes discharged in this manner are municipal (untreated, partially treated sewage) and industrial wastewater. This wastewater contains a wide variety of inorganic and organic pollutants. Nonpoint sources, primarily urban and agricultural runoff, water runoff from farmers, urban areas, mining, forestry, and construction, the dredging and filling of waterways which churns up bottom sediment, atmospheric deposition (i.e. lead from internal combustion exhaust, acid rain), artificial or uncontrolled temperature variations (i.e. power plant cooling water) and algal decomposition and other pollutants that all degrade water quality are important sources of contaminants discharged into estuaries and rivers that later empty into the sea. Acute water quality problems are characterized by sudden, easily recognizable changes in smell, surface appearance, or turbidity of the water (Weis & Weis, 1994; Wasserman et al., 1995).

In the water environment, pollutants quickly spread over large distances from the sources of pollution. Chemicals discharged into the marine environment will be transported by currents and, depending on their physiochemical properties, will be chemically transformed or modified by both abiotic and biotic processes (mostly by microorganisms). The resulting products may have different environmental behavior and toxic effects than the chemical discharged. The type of exposure of the chemical and the nature of the organisms that are exposed will determine whether or not there are detrimental effects (Gray, 1998).

1.8 Lebanon’s coastal area

The known and accepted definition of coastal zone is “that part of the land affected by its proximity to the sea and that part of the ocean affected by its
proximity to the land” (US Commission on Marine Science, Engineering and Resources, 1980). Coastal zone management should focus on improving the understanding of the coastal processes.

The coastal zone in Lebanon is suffering from chronic mismanagement that resulted in the proliferation of illegal use of the maritime public domain, seizure of the public right to access an uninterrupted maritime domain, degradation of key archeological and natural sites along the coast of Lebanon, hazards to the ecological balance and diversity of Lebanese shores (CDR, 2000).

1.8.1 Physical context

Lebanon lies on the eastern shore of the Mediterranean Sea and has a width ranging between 40 to 80 km (Figure 1). Lebanon enjoys a coastal zone that stretches along 225 kilometers from Arida in the north to Naqoura in the south, covering 162,000 hectares of coastal plains and hills, or 16 percent of Lebanon’s surface area, where 2.6 million inhabitants, or 70 percent of the population, live. Lebanon’s economic activity is concentrated in this zone which contributes about three quarters of the national income (Saab, 2003).

The Lebanese coast is a narrow strip extending along the Mediterranean Sea and bound to the east by the Mount Lebanon mountain range. The width of the coastal plain attains its maximum at the northern and southern extremities of the country.

The Lebanese shore can be classified into sandy and rocky shores (figure 2). Sandy shores are relatively poor in biodiversity and productivity. Rocky habitats, closer to the shores, are vulnerable to pollution from the domestic and industrial sources; hence the need for protection (El Souri, 1998).
1.8.2 Climate and Meteorology

The climate of Lebanon is influenced by the physiography of the country. The regional climate of the Lebanese coast is thermo-Mediterranean humid with a

Figure 1: Geomorphologic regions of Lebanon
Figure 2: Types of beaches along the Lebanese coast
subtropical tendency in the south. Summers are hot and dry; winters are mild and wet. Snowfall is very rare along the coastal area. The average annual temperature of air under cover is 20.1°C; average annual precipitation is 741mm; annual precipitation along the coast is 890mm/yr; average annual number of rainy days is 74; and average relative atmospheric humidity is 68% (El Souri, 1998). The mean temperature along the coastal plains is 26.7°C during the summer and 10°C in the winter. January is the coldest month with daily mean temperatures falling to -4 °C in the mountains and 7 °C along the coast. The warmest months are July and August, when mean daily temperatures exceed 28 °C in the mountains and 33 °C along the coast. The variations between day and night temperatures are mild (6-8 °C) (Blanchet, 1976).

1.8.3 Winds

Dominant wind directions are south westerly winds; continental east and south-easterly winds are also frequent. Two mountain ranges have a major impact on wind direction, and contribute to reducing the incidence and strength of the south-easterly and north-westerly winds on the mountain backed shoreline (CDR, 2000). Strongest winds are generally observed during the fall season when speeds can reach 90 km/h during stormy weather conditions. Typical wind speeds vary however between 10 and 20 km/h (El-Fadel et al., 2000).

1.8.4 Waves

Waves along the Lebanese coast are characterized by weak amplitude and a short wave length. The period of the waves (the time interval between the waves) ranges from 5 to 7 seconds. The strongest waves reported along the coast of Lebanon occurred on February 1936 when waves reached 7 meters height. Waves are generally strongest between January and March. April and May are characterized by alternating periods of calm and rough sea. In June, July and August, the waves are regular and weak. The sea is extremely calm during the
period extending from September to October; and the waves are very weak. December is either an extension of the fall calm sea regime or a start of the agitated winter regime. Waves generally originate from a south or south-westerly direction except from September to November when no predominant pattern can be discerned (SOGREAH, 1986).

1.9 Seawater pollution in Lebanon

Lebanon does not have ambient standards for seawater quality. The main sources of environmental stress along the Lebanese coastline include contaminated surface waters, raw domestic and industrial wastewater discharges, agricultural runoff, solid waste dumps, and accidental oil spills (figure 3). Basically there are three major routes through which pollutants are transported to the sea, namely terrestrial, atmospheric, and maritime (El-Fadel et al., 2000). The industrial sector (Appendix C) evolved during the post war period whereby 57% of the establishments were founded between 1990 and 1994. This sector has as much as 23,000 establishments in the fields of agriculture, fertilizers, mining and quarrying, manufacturing and construction employing some 140,000 persons. Most of the industries are located in close proximity to coastal and surface water bodies (figure 4). As there are no adequate wastewater networks, most establishments, tend to discharge their waste, illegally and informally, into adjacent rivers, seas and water bodies (Figures 5 & 6) hence posing a serious threat to the water quality (CDR, 2000).

Discharge of industrial by-products or wastes is performed illegally through waste water emissions. Discharged products are of all kinds, their toxicity is variable and their origins are diverse. The most polluting industries in Lebanon are chemical fertilizer industries, tanneries, dairy industries, paper industries and cement industries (Table 1). It is appropriate, at present, to consider these discharge forms as dangerous water pollution sources. Even though the discharged volumes are relatively small and the polluting agents could be
neutralized chemically at the source. The high cost of such treatment incites the industrials to get rid of their wastes in an illegal and careless manner (CDR, 2000).

Figure 3: Contamination of water resources
Figure 4: Industrial zones of Lebanon
Figure 5: Water resources affected by industrial activities
In 1992, as part of the United Nations Environment Program for the Mediterranean Sea, a report was published assessing the state of the environment in Lebanon. It stated that "most industrial firms on the coast discharge their waste waters into the sea without any treatment". The industrial sector in Lebanon is relatively small, and the absence of many primary manufacturing industries leans to the assumption that much of the waste
produced, could be managed and treated appropriately and effectively (Stephenson et al., 1998).

Table 1 Locations of major environmental stresses.

<table>
<thead>
<tr>
<th>Location</th>
<th>Water body</th>
<th>Type of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zahle/ Ch-taura</td>
<td>Berdouni/ Litani – Sea</td>
<td>Food processing, wineries, tanneries and paper factories</td>
</tr>
<tr>
<td>Anjar</td>
<td>Litani – Sea</td>
<td>Sugar beet factory</td>
</tr>
<tr>
<td>Machghara</td>
<td>Litani – Sea</td>
<td>Tanneries, glue factories</td>
</tr>
<tr>
<td>Zouk</td>
<td>Sea</td>
<td>Power plant</td>
</tr>
<tr>
<td>Jbeil</td>
<td>Nahr Ibrahim – Sea</td>
<td>Paper plant</td>
</tr>
<tr>
<td>Batroun</td>
<td>Sea</td>
<td>Cement factory</td>
</tr>
<tr>
<td>Chekka</td>
<td>Sea</td>
<td>Cement factory</td>
</tr>
<tr>
<td>Bchamoun</td>
<td>Ghadir – Sea</td>
<td>Leather tanning</td>
</tr>
<tr>
<td>Jdeideh</td>
<td>Nahr El-Mout – Sea</td>
<td>Quarries</td>
</tr>
<tr>
<td>Saida</td>
<td>Sea</td>
<td>Tanneries</td>
</tr>
</tbody>
</table>

At the dawn of the new millennium, Lebanon is drowning in its own wastes. Dozens of waste dumps all over the coastline and inland are a major source of marine and underground pollution due to the toxic leachate they generate and the dioxins produced. Due to the lack of an environmental policy, there are no defined plans to rehabilitate these dumps in Lebanon. In the meantime, their toll on public health and the environment becomes more and more widespread (Al-Hajj, 2000).

Sustained environmental abuse is widespread throughout Lebanon because the authorities are not reinforcing any accountability or demanding any shift to environmentally friendly solutions (Al-Hajj, 2000). The Lebanese coasts are reaching a crisis. Threats to coasts and to coastal communities are growing as
development, recreation, and waste disposal activities increases, often in conflict with long term natural processes (Williams et al., 1991). Lebanon produces more than 4 thousand tones of household waste, about 12 tones of clinical waste and about 236 thousand tones of industrial waste (Figure 7) that are chaotically discharged into the sea and rivers per year (Al-Hajj, 2001). Although there are significant discharges into the sea, Lebanon's coastal waters have not experienced any eutrophication problems so far.

1.10 Purpose of the research

The impact of industrial wastewater is not well documented in Lebanon, although deleterious effects are suspected near large factories such as in the Lebanese Chemicals Company, "LCC" in Selaata (El Souri, 1998). The area of Selaata is one of the most serious examples to give of the many polluted areas in Lebanon that have come about through a lack of knowledge about which chemicals are being used and released into the environment.

The present research, therefore, proposes a comparison of two areas regarding influences of human intervention and to be capable to predict coastal behavior at management scales. The results of the study will be useful for local municipalities to aid in mitigating existing problems and, in long term, to plan the future coastal development. The first area is where the LCC allegedly discharge its effluents into the sea in the town of Selaata; the other area is relatively unexposed to chemical effluents from chemical companies and is situated in El-Helwe, Jbeil.

The overall purposes of this experiment are as follows:

1- To identify the polluting waters in Selaata
2- To discuss the range and environmental significance of the parameters.
3- To propose an appropriate and effective means of waste management and treatment.
4- To raise awareness to the Government and people of Lebanon.

Figure 7: Profile of environmental stress
1.11 Selaata and El-Helwe

"Ras Selaata", located 55 km north of Beirut, was referred to, as the "flower" of the Lebanese coast and was famous for its natural harbor, its abundant and unique marine life, sandy hills and trees. Nowadays, however, Selaata is regarded as little more than a dying coast, where one factory in particular dominates the environment and the quality of the land, sea and air (Al Hajj et al., 2000).

The conditions in the terrestrial environment have a parallel to those prevalent in the marine environment. No comprehensive survey has been carried out, but divers near the coast of Selaata have discovered extensive areas of seabed covered with layers of sludge and waste. These appear to be essentially devoid of marine life. The discharges of waste over the forty-seven years of operation of the plant have blanketed the seabed (Al-Hajj et al., 2000).

Winds from the south and west sectors predominate but the foothills of Mount-Lebanon just inland may present a barrier to dispersion and emissions from the factory, thus affecting the ambient concentration of these pollutants in Batroun and nearby areas (Haddad, 1998).

On the other hand, "El-Helwe", is located 45 km north of Beirut. The shoreline extends to about 1550 meters of breathtaking sceneries and is abundant with marine life. There are no chemical companies or industries in the vicinity of the shore.

1.12 Seawater constituents

Seawater is a complex mixture of dissolved inorganic material and dissolved gases (Table 2). All the atmospheric gases are present in solution in seawater. Oxygen typically varies between 0-8.5 ml/L, with the higher values close to the
surface. Carbon dioxide is present primarily as bicarbonate ions, and is the major factor controlling the pH of seawater (Suman et al., 2003)

A number of minor constituents of seawater can be considered as essential nutrients for plant growth. These nutrients include nitrogen (as nitrate), phosphorous (as phosphate), silicon (as silicate), iron and manganese. Of these, nitrate and phosphate are considered the controlling nutrients (Tait & Dipper, 1998).

The sources of nutrients in surface waters can be broadly divided as natural and anthropogenic. Natural sources are generally ubiquitous; however, their contribution is usually low because, over the course of time, natural systems have established balances between the production and consumption of nutrients. Anthropogenic sources arise from many activities such as domestic and animal wastes, agricultural runoff, municipal wastewater, and industrial wastes (Antweiler et al., 1995).

To estimate the hazard of different pollutants, not only their hazardous properties should be taken into account, but other factors, too. These include the volumes of their input into the environment, the ways and scale of their distribution, the patterns of behavior in the water ecosystems, their ability to accumulate in living organisms, the stability of their composition, and other properties (Patin, 1999).

In attempting to determine the impact of pollutants in the environment, one must be cognizant of other changes that are continually occurring around. For example, recreation, control and supply of water, and other related activities all have significant and often major effects on pollutant concentration (Shane, 1994).
### Table 2: Major Constituents of Ocean Water (S = 35.00‰)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>g/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>10.770</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.300</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.412</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.399</td>
</tr>
<tr>
<td>Strontium</td>
<td>0.008</td>
</tr>
<tr>
<td>Chloride</td>
<td>19.340</td>
</tr>
<tr>
<td>Sulphate (as SO₄)</td>
<td>2.710</td>
</tr>
<tr>
<td>Bromide</td>
<td>0.067</td>
</tr>
<tr>
<td>Carbon (present as bicarbonate, carbonate, and molecular carbon dioxide)</td>
<td>0.023 at pH 8.4 to 0.027 at pH 7.8</td>
</tr>
</tbody>
</table>

Source: Tait & Dipper, 1998

### 1.13 Environmental Indicators

Environmental indicators are physical, chemical and biological measures that best represent the key elements of a complex ecosystem or environmental issue. An indicator is embedded in a well-developed interpretive framework and has meaning beyond the measure it represents.

The set of key indicators must be the minimum set which, if properly monitored, will provide rigorous data describing the major trends in, and impacts on, both Selaata and El- Helwe areas. It should include:

- Indicators of the extent of the major pressures exerted on the elements; and
Indicators of responses to either the condition or changes in the condition of the ecosystems and their elements (Fairweather & Napier, 1998).

Thus, indicators should:

- serve as a robust indicator of environmental change;
- be scientifically credible and monitored regularly with relative ease;
- be easy to understand and cost-effective;
- where possible and appropriate, be consistent and comparable with other countries' indicators;
- be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time.
- provide an early warning of potential problems (Commonwealth of Australia, 1994).

It has been settled down a net of sample points along the coast were a systemic study will be carried out. The samples of water will be used in order to analyze a collection of parameters that are usually enough to characterize and typify the quality. Those variables are, out of all, the following:

Physical parameters include water temperature (°C), dissolved oxygen (mg/l), turbidity (NTU), salinity (ppt), conductivity (mS/cm), total dissolved solids (g/l), and pH. The chemical makeup was investigated by measuring the magnitude and composition of nitrate (mg/l), nitrite (mg/l), orthophosphate (mg/l), biological oxygen demand (mg/l), and chemical oxygen demand (mg/l). Two biological
parameters, fecal coliform bacteria and total coliform bacteria were qualitatively examined.

1.14 Physical Parameters

1.14.1 Temperature

1.14.1.1 Overview

The sea receives from the Sun, and exchanges with the atmosphere, huge amounts of heat. The ocean plays an important role in the Earth climate by storing, releasing or transporting to large distances that heat (Carion, 2003). The continual circulation of the oceans and their enormous heat capacity ensure that the extent of temperature variation in the sea is small despite great geographical and seasonal differences in absorption and radiation of heat (Tait & Dipper, 1998).

Natural seawater temperature ranges from 20°C to 29°C, with the optimum condition at 24°C (Radke et al., 2003). Lebanese Seawater temperature is coldest in February (17.6 °C) and warmest in August (27.5 °C) (Abboud- Abi Saab, 1986; Kouyoumjian & Belian, 1985) while marine water is on average 2°C warmer than ambient temperature from November till February, air temperatures are slightly higher than water temperatures from April till July (Abboud- Abi Saab, 1986). Beginning the month of April, a thermocline is formed near the surface of the sea (Abboud- Abi Saab, 1986), with an average temperature of 27 °C in the top layer (50 meters) (CDR, 2000).

Temperature, probably the most easily measured parameter, is a critical factor influencing several aspects of the sea’s ecosystem. It influences biological activity and many chemical variables in the sea (USEPA, 1993). Temperature,
therefore, is an important physical parameter which to some extent regulates many of the beneficial uses of water (USEPA, 1986c).

Warm waters are more susceptible to eutrophication- a build up of nutrients and possible algal blooms- because photosynthesis and bacterial decomposition both work faster at higher temperatures. By contrast, salts are more soluble in warmer water, so temperature can affect the water’s salinity (Tait & Dipper, 1998).

1.14.1.2 Factors that affect and are affected by temperature

Water temperature influences the conductivity, density, and pH, rate of chemical reactions and biological activities of seawater. Water temperature in coastal areas changes naturally, as part of daily and seasonal cycles, with variations in air temperature, currents and local hydrodynamics. These changes do not eliminate indigenous aquatic populations, but affect the existing community structure and the geographic distribution of species. Water temperature anomalies are caused by human activities. Some specific causes of water temperature variation in coastal waters may include:

- Discharges of "cooling" waters from power plants and municipal or industrial effluents are a source of thermal pollution in the coastal zone.
- Changes in air temperature and shifts in currents occurring in response to global warming (Radke et al., 2003).
- Exposure to sunlight and amount of shade
- Turbidity of water
- Seasons of the year

1.14.1.3 Environmental Consequences

Temperature (along with salinity) affects the density and thus the stability of the water column. This in turn profoundly affects many biological processes in the
upper ocean. Warmer water is less dense and thus tends to stay on top of colder water. During winter, storm winds mix the water column, and the temperature is nearly uniform in the top several hundred meters. As spring approaches, increasing solar radiation warms the surface waters and this warmer, buoyant water stays on top. This increases the stability of the water column, preventing deeper, nutrient-rich water from being mixed into the surface from below. The stable surface layer keeps the phytoplankton near the surface where there is plenty of light, plus plenty of nutrients brought to the surface by winter mixing. This combination of conditions allows the organisms to grow rapidly, and a spring bloom occurs (Malmquist et al., 1998).

Temperature plays many roles in the sea. As water temperature increases, the capacity of water to hold dissolved oxygen becomes lower and the biological oxygen demand increases. Many species regulate the timing of important events, such as reproduction and migration, according to specific water temperatures.

Many industrial processes use water for cooling purposes leading to thermal pollution when heated cooling water is released into streams, lakes and seas, thus changing the basic viable conditions for the survival of the marine life (Khawlie, 1991). This reduces the solubility of oxygen, and the oxygenation may be further reduced by increased oxygen consumption by animals and bacteria, and by reduced vertical mixing due to thermal stratification (Tait & Dipper, 1998).

1.14.2 Salinity

1.14.2.1 Overview

Salinity is a measure of dissolved salts in seawater (Sieracki, 2003). It is roughly the number of grams of dissolved matter per kilogram of sea water (Talley, 2000). Salinity, or salt content, is expressed in parts per thousand (ppt) because there are 1,000 grams in one kilogram (Prescott, 2002). Salinity changes
whenever the ocean exchanges water with the atmosphere through rain (precipitation) or evaporation (Carton, 2003).

Sea salts mostly come from the weathering of rocks on land and from the interior of the earth (Reynolds & Kelly, 2004). The amount of dissolved inorganic materials is what gives seawater its salinity. Because this amount is typically 35g/Kg, the salinity of seawater is typically 35‰. Water salinity in Lebanon ranges between 34 ‰ to 39‰ with an average of 38 ‰. This is a relatively high value compared to an average salinity of 36.5 ‰ in the Western Mediterranean basin (Abboud- Abi Saab, 1986; Kouyoumjian & Belian, 1985). Measures of salinity indicate whether the chemical nature of aquatic ecosystems is being altered and provides a warning of the potential loss of native biota (ANZECC/ARMCANZ, 2000 a).

1.14.2.2 Factors that affect Salinity

The salinity in a marine ecosystem may be affected by a number of factors. Some decreases in salinity may be attributed to human activities such as coastal land clearing and urban development, others to nature such as an increase in freshwater runoff due to high rainfall, whereas evaporative concentration may lead to an increase in salinity levels (Hatcher, 1989).

1.14.2.3 Environmental Consequences

Probably the most important aspect of salinity with regards to water quality is its effect on aquatic organisms. Cell membranes are greatly affected by the salinity of surrounding water. Fluctuating salinity can physically damage membranes, and concentrated salts can alter protein structure. Salinity can affect specific gravity, density, and therefore buoyancy. Salinity is also important because it can cause water to enter or leave a cell through the membrane, changing the cell's
overall water balance (Garrison, 1993). The health of the aquatic environment may decline or be entirely lost as salinity rises.

1.14.3 pH

1.14.3.1 Overview

Lebanese seawater has acceptable levels of pH ranging from 6.9-8.2, (CDR, 2000) since lower or higher values are likely to be harmful to aquatic life (Palmer, 1999). Environmental problems arise when the pH level of precipitation drops below the 5.6 threshold or rise above 9. Values of pH outside the expected range should be considered indications of industrial pollution. Changes in pH can alter other aspects of the water's chemistry, usually to the detriment of native species (Kern, 1998). If pH changes to beyond the preferred range of an organism, physiological processes may be adversely affected. When measuring pH, one must be aware of the potential effect of pH on daily changes in photosynthetic activity of aquatic plants (Commonwealth of Australia, 2002). pH decreases at night when dissolved carbon dioxide and carbonate accumulate in the absence of photosynthesis (ANZECC/ARMCANZ, 2000 a).

1.14.3.2 Factors that affect pH of water

A wide variety of factors may have an effect on the pH of water. These include:
♦ Bacterial activity
♦ Salinity levels. pH levels fluctuate over time, the slightly alkaline pH of seawater is due to the natural buffering from the carbonate and bicarbonate dissolved in the water (Carbonate buffering system).
♦ Rate of photosynthesis and respiration. pH levels are related to Dissolved Oxygen (DO) levels. As DO levels rise and carbon dioxide levels decrease with photosynthesis, pH will increase, and vice versa.
- Water turbulence. The more the precipitation runoff is mixed with seawater, the more the acid levels are diluted and the water's natural buffering capability can be implemented.
- Chemical constituents in runoff flowing into the water body. Chemical toxins released into the water by poorly sealed sewage lines, chemical spills or dumping of harmful cleaners or other substances into seawater can have dramatic effects on pH levels.
- Human activities (in and outside the drainage basin) such as acid drainage from coal mines and acid precipitation. Human activities that cause large, short-term swings in pH or long-term acidification of a water body are exceedingly harmful. For instance, algal blooms, which are often initiated by an overload of nutrients, can cause pH to fluctuate dramatically over several hours, greatly stressing local organisms (Kern, 1998).
- Rainfall
- Time of day and water temperature
- Discharges of industrial wastes
- Dusts and gases picked up from the air
- Geology and soils (Commonwealth of Australia, 2002).

1.14.3.3 Environmental Consequences

pH changes in aquatic ecosystems need to be measured for two reasons:
- Low pH can cause direct adverse effects on fish and aquatic insects (CCREM, 1991 & USEPA, 1986a).
- pH changes (particularly reduced pH) can result in the toxicity of several pollutants (ammonia, cyanide, aluminum) to significantly increase (Collier & Winterbourn, 1987 & Alabaster & Lloyd, 1982).
1.14.4 Turbidity

1.14.4.1 Overview

Turbidity is the measure of water clarity or murkiness. The American Public Health Association (APHA) defines turbidity as an "expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample." Turbidity results from soluble colored organic compounds and suspended particulate matter in the water column. Suspended particulate matter may include clay, silt, detritus, algae and organisms (Radke et al., 2003). Common types of matter suspended in water include small pieces of soil, sewage, industrial waste, and microorganisms (Spurlock, 2001). In general, the more material that is suspended in the water, the greater is the water's turbidity and the lower its clarity. The amount of turbidity measured depends on the size, shape, color and refractive properties of the particles. In this experiment turbidity is reported in Nephelometric turbidity units (NTUs). Acceptable levels should be 25 NTU's or less (Boyle, 2000).

1.14.4.2 Factors that affect Turbidity

Any natural or artificial process that places suspended matter in water is a cause of turbidity. Natural disasters, wave action and storms can add solid matter to waterways. Many human activities around waterways increase turbidity. People sometimes use waterways to dump garbage and dispose of waste (Spurlock, 2001). Other causes of turbidity in coastal waters include: shoreline erosion, dredging, humic substances (Radke et al., 2003). Turbidity is affected by:

- Rainfall and catchment runoff
- Bed and bank erosion
- Storm water
- Industrial Waste discharge
- Chemical Spills
- Soil Erosion
- Excessive algal growth
- Vegetation
- Salinity
- Sewage
1.14.4.3 Environmental Consequences

Generally, humans prefer less turbid water. Water clarity is a major determinant of the condition and productivity of an aquatic system, and of the tractability of water for human consumption, recreation and manufacturing, (Radke et al., 2003) also for aesthetic and health reasons (Spurlock, 2001). Turbidity can be an indication of poor water quality. It can indicate and support the growth of harmful bacteria (Spurlock, 2001). Increased turbidity can change an ecosystem significantly. The most obvious effect of increased turbidity is a reduction in light available for photosynthesis that in turn affects aquatic life relying on plants for food (Radke et al., 2003). Water becomes warmer as suspended particles absorb heat from the sunlight and causes oxygen levels to fall. The combination of warmer water, less light and oxygen depletion makes it impossible for some forms of aquatic life to survive (GREEN, 1999).

1.14.5 Dissolved Oxygen Concentration

1.14.5.1 Overview

An essential gas for healthy maintenance of seas and oceans, dissolved oxygen (DO) is soluble microscopic molecules that are in the air spaces between water molecules (Palmer, 1999). It is a measure of the quantity of oxygen present in water (Commonwealth of Australia, 2002). Oxygen is vital for the respiration of nearly all biological life, and it is essential that water should be well aerated for the continued survival of aquatic life. Aeration involves atmospheric oxygen diffusing, or passing from the air, through the water surface into the sea (Dix, 1981). DO concentrations reflect equilibrium between oxygen-producing processes (e.g. photosynthesis) and oxygen-consuming processes (e.g. aerobic respiration, nitrification), and the rates at which DO is added to and removed from the system by atmospheric exchange (aeration and degassing) and
hydrodynamic processes, otherwise known as the oxygen balance (Connell & Miller, 1984).

Dissolved oxygen is a valuable tracer for water masses (Millero & Sohn, 1992) and is a sensitive indicator for biological and chemical processes occurring in the sea. Oxygen concentrations are traditionally reported as mg/L. Concentrations of over 9 mg/L are indicative of good water quality in terms of oxygen (EEA, 1998). When levels drop to 3-5 mg/l, a condition known as hypoxia, many species will move elsewhere and immobile species may die. A second condition known as anoxia occurs when the water becomes totally depleted of oxygen i.e. below 0.5 mg/l (USEPA, 1993).

1.14.5.2 Factors that affect dissolved oxygen concentration

The dissolved oxygen concentration of a water body represents the status of the system at the point and moment of sampling. Dissolved oxygen is usually near saturation in surface waters due to diffusion from the air and production by aquatic plants. However, oxygen concentration decreases with depth due to bacterial oxidation of organic matter and respiratory activities of organisms (Weis & Weis, 1994). It can also vary significantly between day and night as photosynthesis by algae during the day can greatly increase oxygen levels. In the absence of photosynthesis at night, the respiration of algae and other aquatic life consumes oxygen and oxygen levels can decrease significantly (EEA, 1998). It is lowest just before dawn, when photosynthesis resumes (Munson et al., 2003) and greatest during the afternoon when there is the most intense light (Palmer, 1999). The DO concentrations may vary widely over a twenty-four hours period, particularly in systems where there is significant nutrient enrichment. The full diurnal range of DO must be known before the data can be properly interpreted, and preferably the diurnal range over a number of days (ANZECC/ARMCANZ,
2000 a). At the very minimum, a measurement should be taken at midday and dawn to approximate the diurnal range (Radke et al., 2003).

Another physical process that affects DO concentrations is the relationship between water temperature and gas saturation. Cold water can hold more of any gas, in this case oxygen, than warmer water. Warmer water becomes saturated more easily with oxygen. As water becomes warmer it can hold less and less DO. So, during summer months in the warmer top portion of a sea, the total amount of oxygen present may be limited by temperature (Munson et al., 2003).

Seasonal changes also affect dissolved oxygen concentrations. Warmer temperatures during summer speed up the rates of photosynthesis and decomposition. When all the plants die at the end of the growing season, their decomposition results in heavy oxygen consumption. Other seasonal events, such as changes in sea water levels, volume of inflow and outflow, currents also cause natural variations in DO concentrations (Munson et al., 2003). As salinity increases, the amount of oxygen that water can hold decreases substantially (USEPA, 1993).

In summary, DO concentrations are affected by:

- Water temperature
- Photosynthesis by aquatic plants
- Respiration by aquatic plants and animals
- Breakdown of organic materials in the water
- Water movement and mixing
- Daily and seasonal cycles
- Removal of vegetation

- Flow (discharge)
- Salinity
- Depth
- Presence of nutrients
- Chemicals in the water
- Thermal contamination
1.14.5.3 Environmental Consequences

How can humans affect the levels of dissolved oxygen? Any action that affects the temperature of the seawater will affect the DO levels. Humans can also disrupt the natural balance of photosynthesis and respiration intentionally or accidentally by adding nutrients to the seawater (Palmer, 1999).

A high input of nutrients to a water body can cause an increase in plant growth in turn leading to an increase in organic matter that creates an oxygen demand when it degrades. Low oxygen levels in water are caused mainly by organic pollution resulting from the discharge of poorly treated or untreated wastewater, sewage, animal wastes, soil erosion, thermal pollution, and waste from industrial plants. This leads to an increase in microbiological activities and a decrease in plant and animal species and a reduction in water quality i.e. taste pour and smell bad. This in turn affects the use of water purposes (EEA, 1998; Palmer, 1999).

1.14.6 Total Dissolved Solids

1.14.6.1 Overview

Total Dissolved Solids (TDS) can be estimated by measuring the specific conductance of the water. TDS is the sum of all materials dissolved in the water. TDS consist of minerals, organic matter, and nutrients that have dissolved in water - the ions and compounds that you cannot see in the water. Water is known as the universal solvent because of its ability to dissolve, to some degree, most elements and compounds. The major components of TDS of natural waters include: bicarbonate (HCO₃⁻), calcium (Ca²⁺), sulfate (SO₄²⁻), hydrogen (H⁺), silica (SiO₄⁴⁻), chlorine (Cl⁻), magnesium (Mg²⁺), sodium (Na⁺), potassium (K⁺), nitrogen (NO₂⁻, NO₃⁻), and phosphorus in the form of phosphate (PO₄³⁻). They do not include gases, colloids, or sediment. They have been listed more or less in
order from most concentrated to least concentrated in typical waterways (Palmer, 1999).

Total dissolved solids is a complex water quality parameter because it is directly linked to so many chemical and biological processes (Palmer, 1999). The average concentration of total dissolved solids for seawater is 35 g/L (Brown et al., 1999). Each region has a specific, normal TDS level - some high, some low. Ecosystems are adjusted to local conditions; therefore, a large change in TDS concentrations will disrupt the system and increase its overall sensitivity (Palmer, 1999).

1.14.6.2 Factors that affect TDS

The natural sources of dissolved solids are rocks, bedrocks, and soils. As water comes in contact with them, minerals will dissolve to some degree. The greater the land area that water has to come in contact with soils and rocks, the more likely the TDS levels will be higher (Palmer, 1999). Other sources come from leaves, silt, industrial waste, sewage and runoff from urban areas.

Total dissolved solids are also different than conductivity. Total dissolved solids measures the amount of ions in water, while conductivity measures those ions' ability to conduct electricity. Usually there is a strong positive correlation between conductivity and TDS, but there is still a difference between the two. Because total dissolved solids are related to so many other chemical parameters and processes, humans can increase TDS levels in a number of ways such as poor farming practices and construction. Since nutrients are a component of TDS, any human practices that contribute nutrients to the sea will increase TDS levels (Palmer, 1999).
1.14.6.3 Environmental Consequences

A sudden or extreme change in TDS can be detrimental to aquatic life (Palmer, 1999). Concentration of TDS that are too high or too low may limit the growth and may lead to the death of many aquatic organisms because the density of TDS determines flow of water in and out of an organism's cells (osmosis). High levels of TDS may reduce water clarity, which contributes to a decrease in photosynthesis and lead to an increase in water temperature. High TDS concentrations may add a laxative effect to the water or cause the water to have an unpleasant mineral taste (GREEN, 1999).

1.14.7 Conductivity

1.14.7.1 Overview

Conductivity is a measure of water's ability to carry an electric current. It is the substances dissolved in the water which determine how conducive the solution will be. It is sensitive to variations in dissolved solids, mostly mineral salts. Water temperature affects conductivity; the standard temperature for conductivity measurement is 25°C (Peer & Merrit, 1991). Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems (Brown & Caldwell, 2001). Seawater has a conductivity of 53 millisiemens per centimeter (mS/cm) at 25°C (Holmes-Farley, 2004).

1.14.7.2 Factors that affect conductivity

Conductivity estimates the amount of total dissolved solids or the total amount dissolved ions in the water. Conductivity is controlled by:
Geology (rock types): the rock composition determines the chemistry of the sea.

Evaporation of water from the surface of the sea concentrates the dissolved solids in the remaining water and therefore it has higher conductivity.

Bacterial metabolism.

Other sources of ions to the sea: there are a number of sources of pollutants which may be signaled by increased conductivity, those being wastewater from sewage treatment plants, industrial discharges, urban runoff from roads, and agricultural runoff (Munson et al., 2003).

Conductivity is also affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations. As concentrations of dissolved solids increase, conductivity increases. It is also affected by temperature: the warmer the water, the higher the conductivity (GREEN, 1999). As the concentration of salts in the water increases, conductivity rises, thus, the greater the salinity, the higher the conductivity (USEPA, 1993).

1.15 Chemical Parameters

1.15.1 Nitrate

1.15.1.1 Overview

Nitrogen is a very common element found in many forms throughout the environment (occurs in waterways as nitrate (NO$_3$), nitrite (NO$_2$) and ammonia (NH$_3$)). Determination of nitrate plus nitrite in surface waters gives a general indication of the nutrient status and level of organic pollution. Nitrate is the most chemically stable form of nitrogen, and an important nutrient for plants and animals. Found naturally in waterways from rock weathering but excessive amounts causes significant water quality problems (Palmer, 1999). As nitrate is
soluble, stable over a considerable range of conditions, and easily taken up by aquatic organisms, it is the most meaningful form to test. It is considered to be the primary limiting nutrient in marine ecosystems (Commonwealth of Australia, 2002). Small amounts of nitrate occur in all natural waters, and these are sufficient to maintain balanced biological growth (Dix, 1981). Unpolluted waters have a nitrate level less than 1 mg/l (Commonwealth of Australia, 2002) but in an effluent of industrial and wastewater factories it can range up to 30 mg/l. Excess nitrites can cause hypoxia and can become toxic to warm-blooded animals at higher concentrations (10 mg/l or higher) under certain conditions (GREEN, 1999).

1.15.1.2 Factors that affect nitrate

♦ Rock type and geology
♦ Nitrogen-containing fertilizers
♦ Industrial discharges
♦ Decomposing plants and animals
♦ Vegetation
♦ Seasonal conditions
♦ Animal and human wastes (sewage)
♦ Runoff

1.15.1.3 Environmental Consequences

Nitrogen containing compounds act as nutrients in seawater. Nutrient impacts on coastal waters vary as a function of both the loads and bioavailability of the nutrients, and the extent to which hydrodynamic features (e.g. water volumes, residence times and extent of mixing) and turbidity levels modulate the stimulatory effects of nutrients on plants and algae (Radke et al., 2003; Harris, 2001).

The determination of nitrate helps the assessment of the character and degree of oxidation in sea waters (Ballance, 1996 b). Oversupply of nitrates lead to eutrophication. High levels of nitrates stimulate algae and aquatic plant growth. Aerobic bacteria populations then increase because of the large amounts of
organic matter now available in the water. The resulting elevated bacteria populations deplete much of the dissolved oxygen found in the water. Excessive algal growth creates a soupy green stream, visually displeasing (Palmer, 1999). Nitrate reactions ($\text{NO}_3^-$) in water cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the water body will die. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater. Bacteria in water quickly convert nitrites ($\text{NO}_2^-$) to nitrates ($\text{NO}_3^-$). (KRWW, 2003).

1.15.2 Nitrite

1.15.2.1 Overview

Nitrites are the inorganic free state of nitrogen. It is a transitional compound in the biological cycle. Nitrite is an unstable, intermediate stage in the nitrogen cycle and is formed in water either by oxidation of ammonia to nitrate or by the reduction of nitrate (Balance, 1996 b). They are unstable and relatively short lived because in aerobic conditions, as soon as they are formed, they are rapidly oxidized to nitrates by nitrobacter microorganisms. Nitrite is present in relatively low concentrations in seawaters even if high concentrations of ammonia and nitrate are present due to nitrification and the presence of oxygen, but higher concentrations are found in polluted waters where anaerobic conditions are often found (Dojlido & Best, 1993; Nordin & Pommen, 1986). Nitrite is toxic to humans and other animals (Commonwealth of Australia, 2002). The level of nitrite in seawater is usually very low ($< 0.005$ mg/l), concentrations of greater than 0.010 mg/l can be regarded as a sign of anthropogenic contamination (Nordin & Pommen, 1986).
1.15.2.2 Factors that affect nitrite

Since nitrite is an unstable intermediate form between nitrates and ammonia, it is generally not generated from natural sources in the form of nitrite. It may, depending on the environmental conditions, be transformed from nitrate or ammonia and its presence is an indicator of high concentrations of either of these compounds (Nordin & Pommen, 1986). Nitrites are sometimes added to industrial water to inhibit corrosion and, in this way, they can be discharged to surface waters (Dojlido & Best, 1993).

- Rock type and geology
- Nitrogen-containing fertilizers
- Industrial discharges
- Decomposing plants and animals
- Vegetation
- Seasonal conditions
- Animal and human wastes (sewage)
- Runoff

1.15.2.3 Environmental consequences

High nitrite concentrations are generally indicative of industrial effluents and are often associated with unsatisfactory microbiological quality of water. Because nitrites are quickly converted to nitrates, they indirectly accelerate the process of eutrophication which causes a significant increase in the growth rate of algae and other aquatic plants. Under acid conditions, nitrites lead to the formation of nitrous acid which can react with secondary amines to form nitrosamines many of which are known to be carcinogenic (APHA, 1998).

High concentrations of nitrite can produce "brown blood disease" in fish. Nitrite enters the bloodstream through the gills and turns the blood a chocolate-brown color. Brown blood cannot carry sufficient amounts of oxygen, and affected fish can suffocate despite adequate oxygen concentration in the water (Murphy, 2000).
1.15.3 Orthophosphate

1.15.3.1 Overview

Phosphorus is one of the basic building blocks of living matter. It is present in every living creature, and in the water. One can readily test for one of the common forms of phosphorus in seawater, inorganic phosphorus (Holmes-Farley, 2002). In seawater, inorganic phosphorus (also referred to as orthophosphate or soluble reactive phosphorus, SRP) occurs chiefly as ions of $\text{HPO}_4^{2-}$, with a small percentage present as $\text{PO}_4^{3-}$ (Karl et al., 1990). Orthophosphates, in the concentrations that occur in natural waters, are not harmful to health. Its concentration in seawater varies greatly from place to place, and also with the time of day. Surface waters are greatly depleted in phosphate, relative to deeper waters, due to biological activities that serve to sequester phosphate in organisms. Typical phosphate ocean surface concentrations are very low, sometimes as low as 0.005 mg/l (Suman et al., 2003).

1.15.3.2 Factors that affect Orthophosphate

There are many sources of phosphorus, both natural and human. These include:

- Rock type and geology
- Decomposing plants and animals
- Soil Type
- Phosphate-containing fertilizers
- Industrial discharges
- Seasonal conditions
- Urban Runoff
- Wastewater treatment plants
- Animal and human wastes (USEPA, 1997; Commonwealth of Australia, 2002).

1.15.3.3 Environmental consequence

In most waters phosphorous availability limits plant growth because it is present in very low concentrations. This is because it is strongly adsorbed onto organic matter. Algae and large aquatic plants rapidly take up any remaining “free”
phosphorus, in the form of inorganic phosphates. A sudden increase in orthophosphate in seawater can stimulate great increases in the growth of algal bloom that produces toxins and can cause large deficits of dissolved oxygen (Commonwealth of Australia, 2002).

1.15.4 Biological Oxygen Demand (BOD)

1.15.4.1 Overview

Microorganisms such as bacteria are responsible for decomposing organic waste. When organic matter such as dead plants and animals, leaves and woody debris, grass clippings, sewage, food waste or even industrial waste is present in a water supply, the bacteria will begin the process of breaking down this waste. When this happens, much of the available dissolved oxygen is consumed by aerobic bacteria, robbing other aquatic organisms of the oxygen they need to live (Hotaling, 2001). The Biological Oxygen Demand is the measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions (Brown & Caldwell, 2001). It is the most widely known measure of assessing the water pollution potential of a given organic waste. On an average, the demand for oxygen is directly proportional to the amount of organic waste, which has to be broken down. Hence, BOD is a direct measure of oxygen requirement and indirect measure of biodegradable organic matter (Benefield & Randall, 1980). BOD is an empirical test in order to evaluate the ultimate aerobic biodegradability of organic compounds in water. When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive (Hotaling, 2001).

A (BOD) level of 1-2 ppm is considered very good. There will be not much organic waste present in the water supply. A water supply with a BOD level of 3-
5 ppm is considered moderately clean. In water with a BOD level of 6-9 ppm, the water is considered somewhat polluted because there is usually organic matter present and bacteria are decomposing this waste. At BOD levels of 100 ppm or greater, the water supply is considered very polluted with organic wastes. If there is no organic waste present in the water, there would not be as many bacteria present to decompose it and thus the BOD will tend to be lower (Hotaling, 2001).

1.15.4.2 Factors that affect BOD

♦ Type of microorganisms       ♦ Nutrient levels
♦ Organic compounds present in the water       ♦ Toxic substances
♦ Dissolved Oxygen Concentration       ♦ pH (Dojlido & Best, 1993)

High biological oxygen demand can be caused by:
♦ High levels of organic pollution, caused usually by poorly treated wastewater.
♦ High nitrate levels which trigger high plant growth.

Both result in higher amounts of organic matter in the sea. When this matter decays, the microbiological activity uses up the oxygen. BOD is therefore one of the main parameters used in wastewater treatment for controlling discharges (EEA, 2001).

1.15.4.3 Environmental Consequences

Discharge of effluents with high BOD result in deoxygenation of receiving waters, resulting in:
♦ Loss of biodiversity
♦ Generation of hydrogen sulfide (H$_2$S) and creation of public nuisance;
♦ Damage to fish spawning (Bark, 1998).
1.15.5 Chemical Oxygen Demand

1.15.5.1 Overview

The Chemical Oxygen Demand (COD) is the measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water (Brown & Caldwell, 2001). It is an important and rapidly measured variable for characterizing water bodies, sewage, industrial wastes and treatment plant effluents (Ballance, 1996 b). COD values in unpolluted seawater should not exceed 40 mg/l (CDR, 2000).

COD is a useful parameter for measuring the pollution strength of natural waters. The test is based on the principle that most organic compounds are oxidized to CO$_2$ and H$_2$O by strong oxidizing agents under acid conditions (Benefield & Randall, 1980). Although it might be expected that the ultimate BOD of a sample would approximate the COD, in most cases this is not true. Generally COD values are greater than the BOD because more organic compounds can be chemically oxidized than can be biologically oxidized.

The major disadvantage of the COD test is that it is not capable of distinguishing between organics which are biodegradable and those which are not. Furthermore, some compounds may be only partially oxidized and some inorganic compounds can be oxidized and can cause erroneously high results (Benefield & Randall, 1980).

1.15.5.2 Environmental Consequences

High COD values result in public health problems. The biological stabilization of wastewater with high COD concentrations in the aquatic environment can lead to the depletion of natural oxygen resources and will adversely affect the aquatic life in this environment (Attalah et al., 1999).
1.16 Biological Parameters

1.16.1. Fecal Coliform and Total Coliform

1.16.1.1 Overview

Bacteria are extremely important in the sea. They are microscopic single-celled organisms that function as primary decomposers in the sea by breaking down plant and animal remains. This activity releases nutrients previously locked up in the organic matter into the food web. Bacteria live in water, on the surface of the water, in the bottom sediments, on detritus, and in and on the bodies of plants and animals (USEPA, 1993). They play a part in every nutrient cycle in the ocean, in carbon fixation and waste degradation (Malmquist et al., 1998).

Water is a necessary medium for bacterial colony health and reproduction because it transports nutrients and its temperature stability provides an environment conducive to growth. Nutrient rich environments may encourage the growth or persistence of fecal coliform (FC). This possibility should be considered when an unusually high result is obtained from water that was thought to be relatively clean (Bartram & Pedley, 1996).

Bacterial contamination of water is commonly assessed by measuring total coliform (TC) and fecal coliform bacteria. Total coliform are a group of closely related Gram-negative bacterial genera that all share a useful diagnostic feature: the ability to metabolize (ferment) the sugar lactose (USEPA, 1993). Total coliform bacteria are found in vegetation, animal wastes, sewage and soil (Peer & Merrit, 1991), thus, the usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin (USEPA, 1997). Total coliform should not exceed 500 Colony Forming Units (CFU)/ 100 ml (CDR, 2000). Fecal coliform are a subgroup of the total coliform bacteria. Fecal coliform are the bacteria that live in the
digestive tract of warm-blooded animals, namely mammals, including humans. They come from animal feces (Spurlock, 2001). They die quickly when outside the body, therefore fecal coliform in water indicates a recent nearby problem (Peer & Merrit, 1991). These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals (EMPACT, 2001).

The three most important sources of human fecal contamination of water environments for public health purposes are typically sewage, riverine discharges and contamination from bathers (including excreta). Other sources of human fecal contamination include agricultural runoff, shipping and local boating (WHO, 2003).

Actually, the fecal coliforms themselves usually aren't dangerous to life. However, if fecal coliform counts are high i.e. over 100 CFU/100 ml in 90% of seawater samples (CDR, 2000), there is a greater chance that pathogenic organisms are also present. The fecal coliform test acts as an indicator to these pathogens.

1.16.1.2 Factors that affect Fecal and Total Coliform

Coastal beaches are the subject of extensive water quality monitoring to detect fecal contamination from human activities, such as wastewater discharge, industrial input, and surface runoff. Included in many of these monitoring programs is measurement of indicator bacteria, such as total coliforms and fecal coliforms. Bacterial indicators are used in preference to direct tests for pathogens because bacteria indicator measurements are less expensive (Haile et al., 1999), and because pathogens are scarce in water making it time consuming to test them directly (GREEN, 1999). The survival rate of fecal bacteria is dependent on environmental stresses such as temperature, solar radiation, nutrients, osmotic pressure, presence of toxins, and salinity (Darakas, 2002).
1.16.1.3 Environmental Consequences

Significant disease problems that can be contracted in waters with high fecal coliform counts by humans are diarrhea, dysentery, cholera, typhoid fever, tetanus, hepatitis A, shigella, gastroenteritis, and ear infections amongst others. Most bacteria enter through open wounds, but some can be ingested, and a few will even tunnel through the skin. Large numbers of fecal coliform are also detrimental to other life and make the water cloudy, less desirable for all sorts of activities; they also cause unpleasant odors and an increased oxygen demand (Mitchell & Stapp, 1992; Spurlock, 2001).
Chapter 2

MATERIALS AND METHODS

2.1 Study Duration

The appropriate length of the study is an important decision. Given the variability of the parameters in question and financial support, three months (summer season) is a good duration period for sampling, collecting and analyzing the data.

2.2 Sampling Design

Normally, the design of any investigation, and particularly a monitoring program that is to be ongoing, cannot be settled without a pilot study. This short period of intensive monitoring (in the two areas) outlines the nature of the prevailing system and particularly its temporal and spatial variability. Then a choice can be made about the sampling regime and frequency that should provide a representative profile of the system for each measurement parameter and piece of information required. It can decide on appropriate numbers of replicate samples to provide the precision required for the statistical analyses used in the study (ANZECC & ARMcanZ, 2000 b). Cost is often a limiting factor in designing sampling programs.

The current study was carried out in the Selaata and El-Helwe areas. The sampling strategy is primarily controlled by the objectives of the investigation and by the expected or known spatial and temporal variability of the analyte concentrations in the study area. Based on this information, an adequate sampling scheme is developed outlining the vertical resolution and frequency of sampling. During field work, one must be aware that the constituents dissolved or dispersed in the sea vary from place to place and with time (season) because of physical and biogeochemical processes. On the other hand, samples taken from
the vessel should, as far as possible, represent the conditions in a water body or at a given geographical location. Even with the use of arm-long gloves, hand sampling involves certain contamination risks (Brugmann & Kremling, 1999).

2.2.1 Selection of Sampling Sites

The location of sampling sites can be random or selected. Random location is inevitably more expensive than careful selection and it is thus common to cluster sampling sites near known discharges and have fewer or none in areas known intuitively to be unaffected (Williams, 1998). When ecological impacts are being assessed, sites will normally be located relative to the likely disturbance (ANZECC & ARMCANZ, 2000 b). Selection of a water-quality site is determined by the data quality objectives. Although hydraulic factors in site location must be considered, it is more important to consider factors that affect the water-quality data (Wagner et al., 2000). In this research, one site (Selaata) is located near the problem to be addressed. The other site (El-Helwe) is the control or reference site. Care needs to be taken to ensure that the sites are closely matched to each other. Samples were collected from preselected sampling stations (table 3).

Table 3: Sampling information data

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>El-Helwe</td>
<td>34°16.53 N</td>
<td>35°39.02 E</td>
<td>100m offshore</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Selaata</td>
<td>34°16.53 N</td>
<td>35°39.16 E</td>
<td>outfalls</td>
<td>Rocky site</td>
</tr>
<tr>
<td>3</td>
<td>Selaata</td>
<td>34°16.57 N</td>
<td>35°39.13 E</td>
<td>outfalls</td>
<td>Rocky site</td>
</tr>
<tr>
<td>4</td>
<td>Selaata</td>
<td>34°16.53 N</td>
<td>35°39.09 E</td>
<td>outfalls</td>
<td>Rocky site</td>
</tr>
<tr>
<td>5</td>
<td>Selaata</td>
<td>34°16.49 N</td>
<td>35°39.11 E</td>
<td>50 m offshore</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Selaata</td>
<td>34°16.52 N</td>
<td>35°39.08 E</td>
<td>150m offshore</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Selaata</td>
<td>34°16.53 N</td>
<td>35°39.02 E</td>
<td>250m offshore</td>
<td></td>
</tr>
</tbody>
</table>

Figures 8, 9, 10 show stations 2, 3 and 4 respectively, which are the closest stations to the LCC. Due to the rocky shoreline it was not possible to collect
effluent samples directly from these pipes, and the samples were collected approximately 15 meters away from the discharge pipes. Figure 11 shows the author sampling at station 5. A permission to enter and sample the waters near the LCC was required from the Lebanese Army Intelligence every time before going out.

Figure 8: Station 2—outfall at the LCC Factory
Figure 9: Station 3 - outfall at the LCC factory

Figure 10: Station 4 - outfall at the LCC factory
2.2.2 Sampling Frequency

A sample of water is taken and analyzed so as to provide information on the quality of that body of water at the time of the sampling. Repeated sampling at the same site can provide information of changes in quality over the time period of the sampling program. The sampling frequency in this research is a weekly basis pattern. Each week, samples will be taken twice a day, once at dawn because of the respiration of the aquatic organisms and once at midday because of photosynthesis. Samples were taken randomly at the stations on two Mondays, two Tuesdays, two Wednesdays, two Thursdays, two Fridays, one Saturday and one Sunday that were also randomly selected. Sampling was conducted at 4:30 till 6:30 am and from 1:30 till 3:30 pm on each occasion.
2.2.3 Sample Numbers

An important aspect of the sample design is the number of samples to be collected. This depends largely on the nature of the investigation. The coast was divided randomly into sectors in order to acquire the most number of samples of the parameters in question for their evaluation to determine the environmental quality of the coasts. In this type of design, samples should be taken more than once and at more than one location.

2.3 Selection of Measurement Parameters

The selection of measurement parameters is a vital element of the project. A wide range of physical, chemical, biological, ecotoxicological and ecological measurement parameters can be used to provide information on water quality. There is no simple or single physical or chemical measurement parameter that defines the quality of water. The choice of measurement parameters depends on the environmental values assigned to the water body (ecosystems, drinking water, recreation, industry, etc.) and therefore on the objectives of the study. Chemical measurements provide concentrations of specific contaminants that might be the cause of specific effects or modifiers of them (ANZECC & ARMCANZ, 2000 b).

2.4 Sample Collection

Two principles of sampling are of fundamental importance: firstly, the sample must be representative of the body of water from which it is taken; secondly, the concentration of the substances present in the sample should not change between the time of sampling and the analysis (Dohjido & Best, 1993). The concentrations of nutrients and other bioactive elements are liable to change due to the activity of microorganisms naturally present in seawater. Therefore, as a
general rule, samples should not be exposed unnecessarily to light and analyzed within a few hours after collection (Kremling & Brugmann, 1999).

How to collect the samples is of utmost importance. It is critical to the accuracy of the results to obtain representative samples and avoid sample contamination. A typical sample collection protocol for sea waters might incorporate the following guidelines, among others:

♦ Collect samples in areas of greatest interest, where the water is about 15 to 30 cm below the water surface in both deep and shallow waters.

♦ Specify appropriate sample containers and indicate acceptable holding times.

♦ Remove the sample container cap carefully, ensuring that the inside of the cap is not touched, nor is the lip of the sampling container, and face into the waves to avoid sample container contamination (USEPA, 2002).

♦ Fill the bottle completely and recap it carefully

♦ Sample from the same location

♦ Sample at the same time each day

♦ Handle, test and analyze in the same way (Commonwealth of Australia, 2002).

Bad sampling can give rise to erroneous results, and from these data, wrong decisions can be made.
2.5 Sampling Equipment

For a large water body a boat would be needed. Other equipment that will be needed are:

- Sterilized bottles for the samples (autoclaved)
- Containers to carry the samples
- Plastic disposable gloves
- Ice bags to keep the samples cool
- YSI MPS (Multi Probe System) for the field measurements
- Record sheets and pens
- HACH DR 2010 spectrophotometer
- Global Positioning System (GPS)
- Pocket Turbidimeter

2.5.1 YSI 556 MPS

The rugged and reliable YSI 556 MPS combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multi-parameter system. Featuring a waterproof, impact-resistant case, the YSI 556 MPS simultaneously measures dissolved oxygen, conductivity, temperature, pH, total dissolved solids, and salinity. A simple cellular phone style keypad and large display make the instrument easy to use. All of the sensors, except temperature, require periodic calibration to assure high performance (YSI Environmental, 2002). Within one hour of beginning a sampling run, the YSI probe was calibrated in the laboratory using methods described in the YSI 556 MPS Operations Manual.

2.5.2 Global Positioning System (GPS)

In order to sample exactly at the same spot every week, a GPS instrument was used to locate the longitude and latitude of the sampling area thus becoming more accurate in locating the same spot over and over again.
2.5.3 Pocket Turbidimeter

The Pocket Turbidimeter Instrument operates on the nephelometric principle of turbidity measurement. The instrument measures turbidity with a 5-ml sample cell up to 400 units in NTU measurement mode at a wavelength of 880 nm. Calibration is done with standards provided by the Hach Company (Hach, 1998).

2.6 Field Tests

A significant advantage of field analysis is that tests are carried out on fresh samples whose characteristics have not been contaminated or otherwise changed as a result of storage in a container. Some variables must be measured in the field or very soon after the sample has been collected (Ballance, 1996 a).

Field analysis at the same time of day is necessary for temperature, pH, dissolved oxygen, conductivity, total dissolved solids, and salinity. Using an YSI 556 Multi Probe System instrument the parameters were measured 5 cm from the surface. The instrument was calibrated prior to and after each sampling trip to ensure accurate measurements.

Turbidity is best measured on site using a turbidimeter, but if necessary can be measured later, within 24 hours of sampling to avoid biodegradation, pH changes and settling of particles which will give misleading results, provided the sample bottles are filled completely, leaving no air gap at the top and refrigerated at 4°C (Commonwealth of Australia, 2002; Caux et al., 1997).

Another advantage of field analysis is that samples are highly unlikely to lose the labels that identify the time and place of sampling. Loss of such identification would be disastrous.
The limitations of field analysis must, however, be recognized. Some of the methods used in field analysis produce less accurate results than those that can be used in a well-equipped laboratory. In addition, the limits of detection and the reproducibility of field analyses will often be less than is possible with laboratory methods. Furthermore, it is difficult to implement an analytical quality program when analyses are done in the field, although some attempt should be made to control the quality of field results (Ballance, 1996 a). Field data sheets were present to document each sampling event. The field data sheets record site name, date, time of each sample, weather conditions and other relevant information (Appendix D).

2.7 Laboratory Tests

For all other parameters, sample bottles were sterilized by autoclaving (Selecta, Spain). All samples were maintained on ice and in dark from collection in the field through transport directly to the lab were the chemical analyses were performed. All samples must be warmed to room temperature before running the test. To analyze the samples of nitrate, nitrite, orthophosphate, and COD one should follow the particular directions in the HACH DR 2010 procedures manual.

Nitrate Samples must be tested within 48 hours of collection. Samples must be stored at 4°C if they are to be analyzed later. Testing for nitrate is done using the Cadmium Reduction Method. The determination of nitrite should be made promptly on fresh samples to prevent bacterial conversion of the nitrite to nitrate or ammonia (Balance, 1996 b). Store at 4°C if samples are to be analyzed within 48 hours. Testing for nitrite is done using the Diazotization Method (HACH, 1997). Orthophosphate should be measured within 24 hours of sampling (Commonwealth of Australia, 2002) during that time the samples are stored at 4°C. Testing for Orthophosphate is done using the Ascorbic Acid method (HACH, 1997). Test COD samples without delay. If delay is unavoidable, preserve samples by acidification to pH ≤ 2 using concentrated sulfuric acid (H₂SO₄) and
refrigerate at 4°C. Samples can be stored in this way for up to 28 days (APHA, 1998). Testing for COD is done using the Reactor Digestion Method (HACH, 1997).

BOD test should be carried out as soon as possible after the samples have been taken. If analysis is not started within 2 hours of sample collection, keep samples at or below 4°C from the time of collection (APHA, 1998). If samples are kept at room temperature for several hours, the BOD may change significantly, depending on the character of the samples. In some instances it may decrease and in others increase (Ballance, 1996 b). The bottles should be black to prevent photosynthesis (USEPA, 1997).

The most widely used and accepted measure of biodegradable organic content of wastewater is the 5 day, 20°C BOD value. The analytical procedure is outlined below:

1- A standard 300 ml BOD is filled completely with the wastewater of which the BOD is to be measured and the bottles are sealed.
2- The bottle is incubated at 20 °C for 5 days in total darkness after which its oxygen content is measured.
3- The amount of oxygen that is consumed during the five days is reported as BOD5 (5-day BOD) value of the sample.

There are two instruments used to measure BOD at LAU laboratories. The first one is the BOD Sensor. The second instrument is the BODTrak and both follow the above procedure. The actual environmental conditions of temperature, biological population, oxygen concentration are impossible to reproduce in the test; hence, care must be exercised in extrapolating the results. Though this test has been used for many years for monitoring the quality of water pollution involving oxygen, the limitation for this test is that it takes 5 days to complete.
Bacteria should be monitored on a weekly or monthly basis. In addition, it may be extremely helpful to monitor during or immediately after effluent runoff events (USEPA, 1993). Bacteria can be difficult to sample and analyze, for many reasons. Natural bacteria levels in seas can vary significantly and absolutely sterile conditions are required to collect and handle samples (USEPA, 1997). Several precautions should be made to ensure good samples: stay clear of algal blooms, surface debris, and oil slicks. Wear gloves when collecting water samples. Analysis of the sample should be done within six hours of the time when the sample was collected (USEPA, 1993).

Membrane filtration is the method of choice for the analysis of fecal coliform and total coliform. A measured volume (100 ml) of seawater is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 μm. Bacteria are retained on the surface of the membrane which is placed on a suitable selective medium (EMB) in a sterile container and incubated at an appropriate temperature for 48 hours. Filtration apparatus should be disinfected between analyses of consecutive samples and sterilized at intervals. Incubators are capable of maintaining a temperature to within ± 0.5 °C of 37 °C for total coliforms and to within ± 0.25 °C of 44.5 °C for fecal coliforms. Choice of temperature depends on the indicator bacteria and the medium. Given the complexity of the analysis procedure and the equipment required, field analysis of bacteria is not recommended.

2.8 Statistical Analysis

The Statdisk V 9.1(ninth edition) for elementary statistics was used as the statistical analysis method. The Student T-Test was used to locate difference between two independent stations. Significance was considered when P value < 0.05.
2.9 Sources of error

The sampling, sample storage and sample preparation stages prior to analysis, represent potentially greater sources of error than the chemical analysis (Batley, 1999). Even when every effort is made to obtain as representative a sample as possible, further problems can arise before the analysis is carried out because of contamination. These can be summarized as follows:

Alternations in the sample bottle. Even though a sample bottle has been cleaned scrupulously, the water sample can still change once it is in the bottle. Thus some types of glass contain lead, zinc and iron which are leached out into the water. Alternatively, constituents in the water can be adsorbed into the walls of the bottle (Dojlido & Best, 1993).

Changes in the constituents with time. Once the sample is in the sample container, chemical changes can take place in the time it takes to transport the sample to the laboratory. Microorganisms in the water consume biodegradable organic constituents as well as oxidize ammonia to nitrate and use up phosphates. The temperature in the transport vehicle affects the samples unless precautions are taken. Changes in water temperature alter the rate of chemical reactions (Dojlido & Best, 1993). Careful packaging can prevent damage to the bottles and loss of the sample. In general, the shorter the time between collection and analysis, the more reliable the results will be.

Environmental data are frequently characterized by large measurement errors, missing data points, and data near or below the detection and quantitation limits (Gilbert, 1987). Deliberate release of contaminants may coincide with extreme hydrological conditions to take advantage of the large dilution factors available then. The practice of sampling at a certain time of day, without regard to the changes that occur between daylight and darkness, can result in misleading data (ANZECC & ARMCANZ, 2000 b).
Turbidity readings are affected by floating debris, entrained air bubbles, and other particles in the water that may collect on or near the optic sensor during data collection (Wagner et al., 2000).

To avoid contamination and contact with possibly toxic chemicals, never put your thumb over test tubes and shake them. Wash all glassware with distilled water after each use.

Inaccuracy in the measuring device, an impurity in the reagent, contamination in the apparatus used to carry out the analysis; all can be sources of errors when doing the analysis. Other sources of error in field sampling include location certainty so that the same site can be resampled, sample labeling, and the recording of appropriate field observations and measurements (Batley, 1999).
Chapter 3

RESULTS

This section includes results from monitoring of the physical, chemical, and biological parameters at all stations for the time period of May - August 2004. This section provides a quantitative analysis of the level of pollution detected along the coast of Selaata and El Helwe areas. Samples collected close to the LCC exhibited concentrations of pollutants higher than those obtained from the background samples. Several water quality indicators exceeded standard criteria presented in Chapter 1. Chronic water quality problems observed at certain stations are discussed and possible causes are suggested.

3.1 Temperature

Variations of the seawater surface temperature during the period of the study are provided in figure 12. The lowest value (20.81°C) was recorded in station 1 on day 1 and highest value (28.84°C) at station 4 on day 12. The mean water temperature at the seven sampling stations ranged between 25.75°C and 26°C at dawn, while at noon it ranged between 26.17°C and 26.56°C. All values are within the guideline limits of seawater temperature with no significant changes between the stations during the different sampling days.
Figure 12: Surface seawater temperature (°C) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12).

3.2 Salinity

Figure 13 shows the salinity variations of seawater at all stations during the period of the study. The lowest value (37.77 ‰) was recorded in station 1 on day 3 while the highest value (39.28 ‰) recorded was at station 3 on day 4. The average of seawater salinity of Selaata and its vicinity ranged between 39.07‰ and 39.1‰ at dawn, 39.11‰ and 39.14‰ at noon, while that of El-helwe ranged between 38‰ and 38.07‰ respectively. All values are within the guideline limits of seawater salinity with significant changes between station 1 and each of the other stations at different sampling days.
Figure 13: Surface seawater salinity (‰) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12). a = p < 0.05 with respect to station 1 (control)

3.3 pH

The highest pH value (8.28) was recorded in stations 1 and 6 on days 1 and 9 respectively, and lowest value (7.12) in station 3 on day 5. The average pH ranged between 7.87 to 8.05 at dawn, and 8.11 to 8.2 at noon. All values are within the guideline limits of pH in seawater with significant changes between stations during different sampling days. The variation in the values of pH in all stations is shown in figure 14.
Figure 14: Surface seawater pH per station (Morning, Noon, Average) as determined in Selatil and El-Helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12). a = Station 1 vs Stations 2, 3, 4, 5 (p< 0.05). b = p< 0.05 vs Stations 6, 7. c = Station 3 vs Stations 5, 6, 7 (p< 0.05).

3.4 Turbidity

Figure 15 show the turbidity variations of seawater at all stations during the period of the study. The highest turbidity value (47 NTU) was recorded in station 2 on day 4 and lowest value (1 NTU) in station 7 on day 12. The average turbidity ranged between 2 to 12 NTU at dawn and 1 to 10 NTU at noon. Overall, all values were within the guideline limits of turbidity in seawater with significant changes between stations during different sampling days.
Figure 15: Surface seawater turbidity (NTU) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12). a = Station 1 vs Stations 2,3,4,5 (p< 0.05). b = p< 0.05 vs Stations 4, 5, 6, 7. c = p< 0.05 vs Stations 6, 7.

3.5 Dissolved Oxygen Concentration

Figure 16 show the DO variations of seawater at all stations during the period of the study. The lowest value (5.92 mg/l) was recorded in station 3 on days 7 and 9 and highest value (8.71 mg/l) in station 1 on day 11. The average dissolved oxygen concentration ranged between 6.26 mg/l to 6.9 mg/l at dawn, and 7.19mg/l to 8.2 mg/l at noon. Except for a few occasional significant low values at stations 2, 3, and 4, all stations are within the guideline limits during different sampling days with statistical significance between stations.
Figure 16: Surface seawater dissolved oxygen concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12). a = Station 1 vs all other Stations (p< 0.05). b = p< 0.05 with respect to stations 6 and 7.

3.6 Total Dissolved Solids

Figure 17 show the TDS variations of seawater at all stations during the period of the study. The lowest value (36.44 g/l) was recorded in station 1 on day 3 and highest value (37.78 g/l) at station 4 on day 4. The average TDS ranged between 36.66 g/l to 37.39 g/l at dawn, and 36.58 g/l to 37.44 g/l at noon. All values are within the guideline limits of seawater TDS with significant changes between station 1 and each of the other stations during different sampling days.
Figure 17: Surface seawater total dissolved solids (g/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12). a = p< 0.05 with respect to station 1 (control).

3.7 Conductivity

The conductivity variations of seawater at all stations during the period of the study are shown in figure 18. The lowest value (55.84 mS/cm) was recorded in station 2 on day 3 and highest value was (57.85 mS/cm) recorded at station 2 on day 10. The average conductivity ranged between 56.86 mS/cm to 57.05 mS/cm at dawn, and 57.31 mS/cm to 57.43 mS/cm at noon. All values are within the guideline limits of seawater conductivity with no significant changes between stations during different sampling days.
Figure 18: Surface seawater conductivity (mS/cm) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period. Bars denote mean ± SEM (n=12).

3.8 Nitrate

Figure 19 show the nitrate variations of seawater during the period of the study at all stations. The lowest value (0.1 mg/l) was recorded in all stations on all days except days 2, 4 and 11, and highest value (0.8 mg/l) in station 3 on day 2. The average nitrate concentration ranged between 0.19 mg/l to 0.36 mg/l at dawn, and 0.19 mg/l to 0.44 mg/l at noon. All values are within the guideline limits of seawater nitrate with significant changes between stations during different sampling days.
Figure 19: Nitrate concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs Stations 2, 3, 4, 5 (p< 0.05). b =p< 0.05 vs Stations 6, 7. c = Station 3 vs Stations 5, 6, 7 (p< 0.05). d = Station 5 vs Stations 7 (p< 0.05).

3.9 Nitrite

Figure 20 show the nitrite variations of seawater at all stations during the period of the study. The lowest value (0 mg/l) was recorded in station 1 on day 4 and the highest value (0.019 mg/l) at station 4 on day 1. The average nitrite concentration ranged between 0.0020mg/l to 0.0062mg/l at dawn, and 0.0019 mg/l to 0.0057mg/l at noon. Occasional high values were detected at stations 2, 3, and 4, while the rest of the stations were within the guideline limits with significant changes between stations during the different sampling days.
Figure 20: Nitrite concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs Stations 2, 3, 4, 5 (p< 0.05). b = p< 0.05 vs Stations 6, 7. c = Station 3 vs Stations 5, 6, 7 (p< 0.05). d = Station 5 vs Stations 7 (p< 0.05).

3.10 Orthophosphate

Figure 21 show the orthophosphate variations of seawater at all stations during the period of the study. The lowest value (0 mg/l) was recorded in station 1 on days 6, 8, 9, 10, 12 and highest value (7.81 mg/l) at station 3 on day 8. The average orthophosphate concentration ranged between 0.0005 mg/l to 4.28 mg/l at dawn, and 0.0006 mg/l to 5.2 mg/l at noon. Significant high values of orthophosphate in Selaata stations were measured on all sampling days.
Figure 21: Orthophosphate concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs all other Stations (p< 0.05). b = Station 2 vs Stations 3, 7 (p< 0.05). c = Station 3 vs Stations 4, 5, 6, 7 (p< 0.05). d = Station 4 vs Stations 6, 7 (p< 0.05). e = Station 5 vs Stations 7 (p< 0.05).

3.11 Biological Oxygen Demand

Figure 22 show the BOD variations of seawater during the period of the study at all stations. The lowest value (1 mg/l) was recorded in station 1 on days 4, 6, 11 and highest value (117mg/l) at station 3 on day 1. The average BOD concentration ranged between 2.33 mg/l to 64.41 mg/l at dawn, and 6.91 mg/l to 74.83 mg/l at noon. Significant high values of BOD in Selaata stations were detected, while station 1 showed no significant changes and was within the guideline limits of BOD in seawater.
Figure 22: BOD concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs all other Stations (p< 0.05). b = p< 0.05 with respect to stations 6 and 7.

3.12 Chemical Oxygen Demand

The variations in the COD values at all stations during the period of the study are shown in figure 23. The lowest value (14 mg/l) was recorded in station 1 on days 2, 7, and 10 and highest value (255mg/l) at station 3 on day 1. The average COD values ranged between 21.8 mg/l to 152.75 mg/l at dawn, and 31.9 mg/l to 168 mg/l at noon. High values were measured at Selaata, while station 1 showed values within the guideline limits of COD in seawater.
Figure 23: COD concentrations (mg/l) per station (Morning, Noon, Average) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs all other Stations (p< 0.05). b = p< 0.05 with respect to stations 6 and 7.

3.13 Fecal Coliform and Total Coliform

Figures 24 & 25 show the Fecal Coliform and Total Coliform bacteria variations of seawater at all stations during the period of the study, respectively. FC and TC bacteria had narrow fluctuations ranging from 0 CFU/100 ml to 2 CFU/100 ml and 0 CFU/100 ml to 12 CFU /100 ml at all stations respectively. The lowest value (0 mg/l) was recorded in all stations for both FC and TC and highest value (2 CFU/100 ml) in stations 2, 4 at days 2 and 1 respectively for FC, and (12 CFU /100 ml) in station 2 at day 1 for TC. All values are within the guideline limits of seawater for FC and TC bacteria with no significant changes among stations for the FC, and significance among few stations for TC.
Figure 24: Fecal Coliform concentrations (CFU/100 mg/l) per station (Morning, Noon) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12).

Figure 25: Total Coliform concentrations (CFU/100 mg/l) per station (Morning, Noon) as determined in Selaata and El-helwe areas subjected to a 3 month observation period of surface seawater. Bars denote mean ± SEM (n=12). a = Station 1 vs Station 3 (p< 0.05). b = Station 3 vs Stations 6, 7 (p< 0.05).
Chapter 4

DISCUSSION

The “Lebanese Chemicals Company” (LCC), a fertilizer company in the village of Selaata, north of Lebanon started operating in 1957, since then, the catalogue of environmental problems caused by the company’s operations has continuously grown (Appendix A). Changes on the land were mirrored by those taking place in the sea as a result of the factory discharges (Al- Hajj et al., 2000). LCC pumps 25 thousand cubic meters of toxic effluents directly into the sea on a daily basis. This pollution is contributing to the degradation of the marine life in the area and jeopardizing public health (Al- Hajj, 2000). Fish populations in the vicinity of the factory progressively disappeared and displaced by the poor water quality. In short, the unique ecosystems of the sea were severely degraded and the bay, which had supported the livelihood of many fishermen, is to all intents and purposes regarded as effectively dead (Al- Hajj & Muscot, 2000).

It is clear that the ability to define precisely the acceptable or unacceptable concentrations of a waterborne pollutant requires further research. At the present time marked changes in water quality, as indicated by increased levels of BOD, COD amongst others may be used as a warning of potential changes, but the precision of prediction of the expected consequences is still poor (Davies & Brown, 1992).

For all the components tested in this work, their concentrations are considerably higher in Selaata than in El Helwe. The location of the stations near and around the LCC indicates the LCC as the most likely source of contamination. The existence of elevated levels of contaminants in the zones of high bioproductivity is extremely ecologically alarming (Patin, 1999).
Highest temperatures were found during the month of August (28.72°C) and lowest temperatures occurred during the month of May (22.36°C). The variations between noon and dawn temperatures are mild (Blanchet, 1976), because of the continual circulation of the oceans and their enormous heat capacity that the extent of temperature variation in the sea is small despite great geographical differences (Tait & Dipper, 1998). It is noted that the average temperature of the seven stations showed no statistical significance during the study period (figure 12).

The salinity data show that the seawater at the two sites is least subjected to fluctuations, and was relatively constant during the three month period (figure 13). As a result of Aswan dam in Egypt, salinity increased in Lebanese seawater which can be seen in the Selaata region (39.07-39.14%). Statistical significance was noted between station1 (38–38.07%) and each of the stations (39.07-39.14%) which could be due to the larger freshwater input from the springs located undersea at El-helwe area.

The pH generally was within the guideline limitations in waters of Selaata (8.05) and that of El-Helwe (8.12) with no unusual pH values recorded at any time. pH at noon was higher than at dawn b/c of the rate of photosynthesis and respiration since pH levels increase as DO levels increase and vice versa. The pH of seawater is fairly stable because it is highly buffered, but the short lived, significant local variations of slightly lower pH in Selaata stations 2, 3, 4, 5 with respect to station 1 of El-helwe, and stations 6 and 7 of Selaata on certain days (figure 14) may be attributable to industrial discharges from the LCC. These variations can result in the toxicity of several pollutants to significantly increase (Collier & Winterbourne, 1987).

Although not statistically significant, a slight increasing turbidity trend was observed at stations 2 and 3 (figure 15). These increases might be due to the stations proximity to the effluent outfalls of the LCC indicating that a large portion
of suspended material is being transported into the sea from the LCC causing reduction in light available for photosynthesis. Seawater becomes warmer as suspended particles absorb heat from the sunlight causing DO levels to fall affecting aquatic life negatively (Radke et al., 2003). Turbidity levels decreased offshore due to the fact that the stations are located far from the outfalls of LCC.

The dissolved oxygen concentration of a water body represents the status of the system at the point and moment of sampling. Spatially, the levels of average dissolved oxygen were lowest in the three Selaata stations (2, 3, and 4) nearest to the effluent outfalls followed by stations 5, 6, then 7 and highest in station 1 of El-helwe throughout the entire study. The relatively low DO levels recorded (figure 16) could be attributed to the increase in the water temperature during the summer season because warmer water becomes saturated more easily (Munson et al., 2003). Stations 2, 3, 4, and 5 were negatively significant than stations 6 and 7, which could be attributed to the biodegradable organic matter loading from LCC, microbial activity, discharge of high BOD waste and orthophosphate that help diminish DO levels. Station1 was significant than each of the Selaata stations mainly because as salinity increases, the amount of oxygen that seawater can hold decreases substantially (USEPA, 1993) plus the above mentioned reasons. DO levels at the seven stations were lower at dawn than at midday due to respiration.

TDS data show that the water at the two sites was not subjected to severe fluctuations. At all stations TDS was within the guideline limitations with significance between station 1 and the rest of the stations (figure 17), most likely a result of the melting of the rocks under the effluent outfalls of the LCC. Conductivity data showed no severe fluctuations and fall within the guideline limitations (figure 18).

The average levels of nitrate and nitrite in Selaata and its vicinity were slightly higher than those at El-helwe. Nitrate and nitrite levels were found to be within
the guideline limitations at all stations. Stations 2, 3, 4 showed, at certain days an amount of nitrate and nitrite slightly above the guideline limitations which indicate that much of these nutrients is imported from the LCC's outfalls. Moving outwards into the sea (stations 5, 6, 7), nitrate and nitrite levels decreased, most likely as a result of uptake by primary producers and dilution (figures 19 - 20). Stations 2, 3, 4, and 5 were negatively significant than station 1 indicating that this significance could be due to the wastewater discharges of the LCC factory.

Orthophosphate concentrations are extremely high at stations 2, 3, 4, and 5 where industrial wastes are discharged compared with the open sea values of stations 1, 6, 7 (figure 21). The highest concentration of orthophosphate observed in the present study is in station 3 indicating that the primary outfall for discharging phosphorous is at this station. Station 2 increased significantly than station 7 and significantly decreased than station 3, station 3 was significantly higher than stations 4, 5, 6, and 7, station 4 was also significantly higher than stations 6 and 7, station 5 was significantly greater than station 7, noting that the stations located furthest away from the LCC outfalls has the lowest concentration of orthophosphate and vice versa. A sudden increase in orthophosphate can stimulate great increase in the growth of algal blooms that produces toxins and cause large deficits of DO (Commonwealth of Australia, 2002).

BOD and COD values at all Selaata stations (figures 22- 23) were much elevated than El-helwe station which might be due to the high organic content carried by the industrial effluents. BOD can be caused by high nutrient levels and can cause deoxygenation of the seawater. High concentrations of BOD lead to negative effects such as anoxia and hypoxia from eutrophication, reduced populations of fish and shellfish, reduction in diversity of species and imbalance in food-chain materials (CDR, 2000). Selaata is considered much polluted with organic wastes. The biological stabilization of wastewater with high COD concentrations in the aquatic environment can lead to the depletion of natural oxygen resources and will adversely affect the aquatic life in this environment (Attalah et al., 1999). At
El-Helwe, BOD and COD levels fell within the normal range of 10 mg/l and 40 mg/l, respectively.

The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to the water. In the present study, the density of both FC and TC bacterial populations was observed in the following order: station 4 > station 2 > station 3 > rest of stations (figures 24-25). FC and TC were present in low amounts or not present offshore, while they increased on the shoreline but within the normal range, the reason is related to natural variability and because they are not perfectly and uniformly mixed (Heufelder, 1997). The low loads of FC and TC indicates that the area is that heavily populated.

Starting from 21 May through to 16 August 2004 a study was conducted on selaata and el-helwe areas. After three months (Summer season) of testing, it has been concluded that selaata did not meet the acceptable standards of many chemical and physical parameters. Additionally, qualitative tests for fecal and total coliform bacteria conducted through the three months period indicated little or no presence of these organisms at the two sites. Since the values of indicator bacteria at all stations show that their load is below the limit of 100 CFU/100ml, El-Helwe beach is safe for recreational and other water sports. While Selaata can be safe from bacterial contamination, it is not safe for recreation because of the high pollution caused by the industrial effluents on the sea, aquatic life and humans.

It also must be mentioned that the chemical parameters measured were organic in nature. No testing of volatile organic compounds such as oils and gasoline derivatives or synthetic organic, or metals/heavy metals was conducted. One would be most curious as to what the results of tests for these compounds might reveal. In addition, ecological damage on the plantation and animal life in Selaata was not assessed mainly because of security reasons since workers from the factory would not allow it.
The Lebanese Chemical Company is a clear example of how the Lebanese legislation which is far from being satisfactory is not being implemented properly. The Lebanese authorities need to draft new regulations based on regional conventions such as Barcelona and OSPAR (Appendix B). A program and a plan (Table 4) should be implemented that eliminate pollution deriving from land-based sources and activities, in particular to phase out inputs of the substances that are toxic, persistent and liable to bioaccumulate. Lebanon a member of the Barcelona convention has not yet ratified the last amendments protocols. A first step will be the ratification and then a national action plan and program containing measures and timetables for their implementation (Al-Hajj & Muscot., 2000). A second step would be to establish the toxic inventory on the use of chemicals that will be the central database in Lebanon and make it accessible to the public (Al-Hajj, 2000).

The production of waste can not be eliminated, and the disposal of waste is a necessity. It is generally accepted that the diversity and quantity of wastes produced will continue to increase in the future. If these two factors could be reduced, then disposal problems and the pollution caused might be reduced. In other words, the problems of waste should be tackled at their source; before, and not after wastes have been discharged into the environment.

The same severe threats afflict the coastal region of Lebanon from north to south: unregulated disposal of solid waste, wastewater, oil residue, chemical pollution, privatization of the coastline, and beach quarrying. Of the 4000 tons of solid waste generated everyday, some 3000 tons are dumped alongside the coast or reach the sea through rivers and streams (Saab, 2003).

Numerous projects are underway to construct treatment plants in Tripoli, Chekka, Batroun, Jbeil, Tabarja, Dora, Ghadir, Chouf, Saida, and Tyre. It is expected, by
the year 2005 that about 70% of the domestic and commercial wastewater generated in Lebanon will be collected and treated at a wastewater treatment

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| Environmental objectives       | Restoration and protection of the area, reduction of discharges into the marine environment, setting of discharge standards |

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facility before final disposal. This value is likely to reach 90% by the year 2040 depending on the location. While a national industrial wastewater action plan has been prepared, no provisions have been made to date for the treatment of industrial wastewater (CDR, 2000).

Without industrial wastewater treatment, pollution load into surface and coastal waters likely would increase and could reach unacceptable levels in the following industrial hotspots: Chekaa, Selaata (industrial discharges), Zouk Mosbeh- Zouk Mkayel (beaches, dyes, etc.), Dora industrial area (petroleum storage, tanneries, etc.), Shoueifate, Ain Anoub, Bchamoun industrial areas (wastewater discharges), and Ghazieh coast and Saitaniq river (tanneries, soap factories) (El Souri, 1998).

It is imperative that LCC stop the discharge of toxic effluents into the marine environment as well as end its reckless behavior towards the people and the marine environment.

Essentially, the risk assessment determines whether contaminants at a site are a current or a future risk to human health or other environmental organisms under a “no action” alternative (i.e., without remediation of the site). The baseline risk assessment thus provides the basis for determining whether remedial actions are necessary (USEPA 1988a, b, 1989, 1991).

Although the oceans have a high capacity for absorbing waste (“assimilative capacity”), the bulk of LCC’s waste is not discharged into the vast deep ocean, but into shallow waters with far more less assimilative capacity since stations near the effluent outfalls have much higher contamination than stations in the background as shown in the above results. The competing demands on these shallow waters (i.e., industry vs. conservation) are often unreconcilable. Good management is therefore needed to optimize the uses of these waters. Technology has been developed to treat most point sources, but high costs are
associated with the processes. It is much more difficult to manage nonpoint sources. Waste reduction is preferable to treatment (Weis & Weis, 1994).

Scientists need to develop predictive ecological hazard assessments to determine what effects a contaminant will have on a given resource. Such assessments will play an important role in environmental decisions. A hazard assessment is an objective, but probabilistic, calculation requiring data on environmental concentration of pollutants, levels of exposure to the organism, and biological effects. Holistic strategies need to focus on contaminant loading, determination of physical transport, biogeochemical fate, and ecological effects. Mathematical models need to be developed for the behavior of contaminants in the ecosystems they enter (Weis & Weis, 1994).

Lebanon's infrastructure for gathering water data is very weak to nonexistent, and this reflects negatively on the quality and accuracy of currently available data. Although there are many factors that contribute to the water quality crisis in Lebanon including factors such as lack of funds, lack of access to appropriate technologies, and inadequate expertise at the national and local levels, the fundamental root cause is institutional and policy failure at national levels. Only when this is recognized and accepted by the national government will there be the opportunity to make significant change through the processes of financial and technical aid.

Although the data presented here provide only a brief glimpse of the water quality of the Selaata area, much remains to be learned about the sources, fates, and effects of contaminants on human health and aquatic ecology. The data presented represent a benchmark for future references. They indicate critical areas where research is needed to more clearly define potential problems, and provide a baseline against which future changes in the water quality in the Selaata area can be measured. A comprehensive characterization of natural

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water quality therefore requires a large amount of data. Water quality data is expensive and time-consuming to acquire.

How fully and wisely Lebanon uses the sea in the decades ahead will affect profoundly its security, its economy, its ability to meet increasing demands for food and raw material, and the quality of the environment in which its people live. Today, man's damage to the marine environment too often is ignored because of immediate economic advantage. To maximize the present economy at the expense of the future is to perpetuate the pattern of previous generations, whose sins against the planet we have inherited.

A serious handicap to scientific marine research is the diminishing number of relatively unaltered areas where natural processes can be observed. It is recommended that representative coastal sites be established as natural preserves for conduct of studies necessary to establish a proper base from which the effects of man's activities can be determined and ultimately predicted (Stratton, 1969).
Appendix A

Facts and Figures about the LCC

Appendix A states in an elaborated way, facts and figures about the Lebanese Chemical Company including products and major incidents (Table 5).

Phosphate fertilizers produced by LCC are derived from phosphate ore. In addition to phosphate minerals, there ores can contain significant amounts of a wide range of impurities, including heavy metals and naturally occurring radionuclides (Bridgen et al., 2002).

The production of fertilizers from phosphate ore using the processes employed by LCC results in the formation of large quantities of solid wastes, which is primarily calcium sulfate, commonly known as phosphogypsum (Bridgen et al., 2002).
Table 5: Facts and figures about the Lebanese Chemical Company

<table>
<thead>
<tr>
<th>Lebanese Chemical Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Established in 1957</td>
</tr>
<tr>
<td>Ranked among the 10 leading industrial enterprises in Lebanon</td>
</tr>
</tbody>
</table>

**Products:**
1. Triple Superphosphate (TSP) fertilizer
2. Simple Superphosphate (SSP) fertilizer
3. Phosphoric Acid ($H_3PO_4$)
4. Sulfuric Acid ($H_2SO_4$)
5. Aluminum Sulfate ($Al_2(SO_4)_3$)

**Annual Turnover:** not declared  
**Sales:** Undeclared  
**Export:** 36,622,000$

97% of products are exported. Between 1985 and 1989, LCC stopped production for reasons related to the Lebanese Civil War. LCC is considered to be amongst the leading exporting companies in Lebanon.

**Employees:** 220

It exports to Italy, Belgium, France, Spain, Greece, Portugal, UK and Turkey. LCC is linked to a major Belgium based international trading company helping it to access the world market.

LCC’s chemical ware discharge directly into the Mediterranean Sea.

Major incidents: On March 8, 1999 a ship loaded with sulfuric acid floundered on the rocks posing the risk of 6000 tones of acid spilled along the coast. A major catastrophe was avoided by a sheer miracle.

LCC’s figures are based on company’s records (Attalah 1999).
Appendix B

Laws of the sea

Appendix B states the laws of the sea set by the Lebanese government, in addition to the international laws and conventions that Lebanon has signed but not yet ratified.

The following laws have been set by the Lebanese government, in an attempt to protect its coast and waters from further losses.

Decree number 144 of 10/6/1925 considers the sea, as far as the limit of high waters, as well as the bed and the substratum of the territorial sea, i.e. a width of 12 miles from the coast, as an inalienable, in defensible public maritime domain.

The Order in council number 4810 of 24/6/1966 was passed to regulate urban development on the coast. Under this Order in Council, only industrial or touristic exploitation of public interest can appropriate any part of the coast, and on condition that it does not disturb the continuity of the coast.

Articles 733, 735 and 736 of the penal code forbid any encroachment upon the public domain, subject to a sentence of 2 years imprisonment.

Law number 14 of 20/8/1990 of the Ministry of Finance declares null and void any occupation of the coast not covered by a legally obtained decree.

Decree number 3899 of 6/8/1993 forbids the extraction of sand or of any other matter from the public maritime domain without the permission of the Ministry of Transport or of the council of Ministries. Article 764 of the penal code punishes any law-breaker.

In addition to these, all Laws on the subject of pollution also aim to protect the sea. Lebanon has ratified almost all the international conventions in the protection of the sea, these being as follows:

International convention on the protection of the sea from pollution by hydrocarbons. The final document was adopted at the London congress on

International convention of intervention at Sea in the case of accidents at sea risk polluting the sea with hydrocarbons, concluded in Brussels on 29/11/1989 (Lebanon adhered by virtue of a law passed by decree number 9226 of 12/10/1974)

Convention on the protection of the Mediterranean from pollution, and two protocols added in appendix (Lebanon adhered by virtue of a law passed by legislative decree number 126 of 30/6/1977)

International convention of 1973 to prevent the pollution of the sea by hydrocarbons, and 1978 protocol (Lebanon adhered by virtue of law number 13183 of 28/5/1983)

Barcelona convention for the protection of the sea (16/2/1976) and the Vienna protocol for the protection from pollution from the land (17/5/1980) and that of Geneva on protected zones (3.4.1982), (Lebanon adhered by virtue of law number 292 of 22/2/1994)


The application of these conventions is the responsibility of the Ministry of Petrol and the Ministry of Transport.

UNEP Mediterranean Action Plan (MAP):

The Mediterranean Action Plan strives to protect the environment and to foster development in the Mediterranean Basin, and has in itself no legal obligations. It was adopted in Barcelona, Spain in 1975 by 16 Mediterranean States and the European

Barcelona Convention for the Protection of the Mediterranean Sea against Pollution:

The governments of the coastal Mediterranean states have been promising to stop the degradation of the sea for two decades. In 1975, all nations bordering the sea met in Barcelona and promised to “take all appropriate measures to prevent, abate and combat pollution in the Mediterranean Sea area and to protect and improve the marine environment in the area.” This so-called Mediterranean Action Plan, launched by the United Nations, was the cradle of what is today known as the Barcelona Convention. The Barcelona Convention contains six protocols, which, if implemented, would lead to the sound protection of the Mediterranean Sea.

The Barcelona Convention is to be seen as a constitution for saving the Mediterranean Sea. It was originally drafted in Barcelona, on February 16, 1976. In 1995, the Convention was amended with a number of necessary steps in order to render it a useful tool for environmental protection.

Paris Convention:

Convention for the Prevention of Marine Pollution from Land-Based Sources (the Paris Convention) which was opened for signature in June 1974 and which entered into force in 1978.

OSLO Convention:

The Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft was signed in February 1972, and entered into force in 1974.
OSPAR Convention:

A meeting of the Oslo and Paris Commissions at Ministerial level was held in Paris on 21-22 September 1992. The most important outcome of this Ministerial meeting was the adoption of a new Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention"), together with a Final Declaration and an Action Plan to guide the future work of the Commissions. The OSPAR Convention did finally enter into force on 25 March 1998. The new Convention, drafted to merge and modernize the Oslo and Paris Conventions, replaced them, but decisions, recommendations and all other agreements adopted under these conventions continue to apply, unless and until they are terminated by new measures adopted under the 1992 OSPAR Convention.

MARPOL Convention:

The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational and accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years. The International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted on 2 November 1973 and covered pollution by oil, chemicals, and harmful substances in packaged form, sewage and garbage, it entered into force on 2 October 1983.

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal:

In the late 1980s, a tightening of environmental regulations in industrialized countries led to a dramatic rise in the cost of hazardous waste disposal. Searching for cheaper ways to get rid of the wastes, "toxic traders" began shipping hazardous waste to developing countries and to Eastern Europe. When this activity was revealed, international outrage led to the drafting and adoption of the Basel Convention on March 22, 1989.
Objectives

The main objectives of the Basel Convention are to:

- ensure that the generation of hazardous waste is reduced to a minimum;
- as much as possible, dispose of hazardous wastes within the country of their generation;
- establish enhanced controls on exports and imports of hazardous waste;
- prohibit shipments of hazardous wastes to countries lacking the legal, administrative and technical capacity to manage and dispose of them in an environmentally sound manner; and
- Co-operate on the exchange of information, technology transfer, and the harmonization of standards, codes and guidelines.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal came into force on May 5, 1992, after being ratified by 20 countries
Appendix C

Legal Status of Current Industrial Zones

As of January 1999, there were 72 industrial zones in Lebanon: 23 zones were decreed; eight were approved by the Council of Ministers but had not been decreed yet; 13 zones were approved by the DGUP and await approval by the Council of Ministers; and at least 28 zones existed de facto, without any form of government approval (Table 6).

Table 6: Legal Status of current industrial zones. Source: URBI (Jan. 1999)

<table>
<thead>
<tr>
<th>Zones Decreed</th>
<th>Zones approved by council of ministers</th>
<th>Zones approved by the GDUP</th>
<th>Others (Informal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Aajaltoun</td>
<td>1- Baalbeck</td>
<td>1- El hirre</td>
<td>1- Naameh-Damour</td>
</tr>
<tr>
<td>2- Aley</td>
<td>2- Halba</td>
<td>2- Amchit</td>
<td>2- Haouch Snied</td>
</tr>
<tr>
<td>3- Baabda</td>
<td>3- Qalamoun</td>
<td>3- Bahsas</td>
<td>3- El Mansourieh</td>
</tr>
<tr>
<td>4- Bauchrich</td>
<td>4- Sibline</td>
<td>4- Beit mery</td>
<td>4- Halat</td>
</tr>
<tr>
<td>5- Dbaye</td>
<td>5- Sin el fil</td>
<td>5- Broumana</td>
<td>5- Qraia</td>
</tr>
<tr>
<td>6- Fanar-roumieh</td>
<td>Taalabaya</td>
<td>6- Dekwaneh</td>
<td>6- Toul (Nabatiye)</td>
</tr>
<tr>
<td>7- Ghazir</td>
<td>7- Saadnayel</td>
<td>7- Ghazieh</td>
<td>7- Deir Nbour (Zghorta)</td>
</tr>
<tr>
<td>8- Hosrayel</td>
<td>8- Zouq</td>
<td>8- Hadethi-Baalbek</td>
<td>8- Helmel (Al Mansoura)</td>
</tr>
<tr>
<td>9- Majdel-anjar</td>
<td></td>
<td>9- Kfarchima</td>
<td>9- Qleiaat (Al Roumoul)</td>
</tr>
<tr>
<td>10- Mkalles</td>
<td></td>
<td>10- Chouefiat</td>
<td>10- Mazraat Bsafor</td>
</tr>
<tr>
<td>11- Nabatiye</td>
<td></td>
<td>11- Baabdate-Sfiel</td>
<td>11- El Qaa (Ras Baalbeck)</td>
</tr>
<tr>
<td>12- Taanayel</td>
<td></td>
<td>12- Hsoun (Jbeil)</td>
<td>12- Semqaniye</td>
</tr>
<tr>
<td>13- Bablieh</td>
<td></td>
<td>13- Al Safira (Kab-Elias)</td>
<td>13- Majdel (Amioun zonet)</td>
</tr>
<tr>
<td>14- Ain anoub</td>
<td></td>
<td></td>
<td>14- Jouar (Mtn)</td>
</tr>
<tr>
<td>15- Insariye</td>
<td></td>
<td></td>
<td>15- Chouei (Mtn)</td>
</tr>
<tr>
<td>16- Bablieh</td>
<td></td>
<td></td>
<td>16- Hammana (Mtn)</td>
</tr>
<tr>
<td>17- Mina</td>
<td></td>
<td></td>
<td>17- Selaata</td>
</tr>
<tr>
<td>18- Makse</td>
<td></td>
<td></td>
<td>18- Ede (Jbeil)</td>
</tr>
<tr>
<td>19- Nahr Ibrahim</td>
<td></td>
<td></td>
<td>19- Sarba (Jounieh)</td>
</tr>
<tr>
<td>20- Chekka-Enfe</td>
<td></td>
<td></td>
<td>20- Ain Akrine (Batroun)</td>
</tr>
<tr>
<td>21- Mazraat Yachoua</td>
<td></td>
<td></td>
<td>21- Basbin (Chouman)</td>
</tr>
<tr>
<td>22- Choueifat</td>
<td></td>
<td></td>
<td>22- Baoura (Aley)</td>
</tr>
<tr>
<td>23- Bechamoun</td>
<td></td>
<td></td>
<td>23- Baaqline</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24- Beddavi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25- Bourj Hammoud</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26- Saida</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>27- Tyr</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28- Zahle</td>
</tr>
</tbody>
</table>

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Appendix D

Data Collection Sheet

SAMPLE NUMBER:  
SAMPLE DATE:  
LATITUDE:  
CURRENT WEATHER:  
WIND SPEED:  
WATER SURFACE:  

SAMPLE TIME:  
SITE NAME:  
LONGITUDE:  
WIND DIRECTION:  
AIR TEMPERATURE:  
WATER COLOR:  

FIELD TESTS

TEMPERATURE:  
PH:  
TOTAL DISSOLVED SOLIDS (TDS):  
DISSOLVED OXYGEN CONCENTRATION:  
SALINITY:  
CONDUCTIVITY:  
TOTAL CHLORINE:  
FREE CHLORINE:  

LABORATORY TESTS

BIOLOGICAL OXYGEN DEMAND:  
CHEMICAL OXYGEN DEMAND:  
TURBIDITY:  
FECAL COLIFORM:  

NITRATE:  
NITRITE:  
ORTHOPHOSPHATE:  
TOTAL COLIFORM:  

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Appendix E

Selected Photographs

Selected photographs that have been taken during several trips to the LCC (Selaata) and clearly illustrates the level of environmental stress along the coast.

Figure 26: LCC Factory
Figure 27: Sea Water Pollution at LCC (station 2)

Figure 28: Sea View of the LCC (station 3)
Figure 29: Far View of the LCC

Figure 30: Pollution at Station 2 – LCC
Figure 31: The author sampling at Station 4 - LCC

Figure 32: Mission Accomplished
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& resource management division, Ministry of Environment, Lands and Parks.


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Emergency and Remedial Response, U.S. Environmental Protection Agency.


