INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.



A Bell & Howell Information Company 300 North Zeeb Road, Ann Arbor MI 48106-1346 USA 313/761-4700 800/521-0600

THE SEA SHORE CONTAMINATION OF THE LEBANESE COAST

BY

ZIAD S. KORTBAOUI

Department of Agricultural and Biosystems Engineering

of

Macdonald Campus McGill University Montreal, Quebec

July, 1997

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements of the degree of Master of Science.

©Ziad S. Kortbaoui, 1997



National Library of Canada

Acquisitions and Bibliographic Services

395 Wellington Street Ottawa ON K1A 0N4 Canada Bibliothèque nationale du Canada

Acquisitions et services bibliographiques

395, rue Wellington Ottawa ON K1A 0N4 Canada

Your file. Votre reference

Our his Notre reference

The author has granted a nonexclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission. L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-37136-0

Canadä

Dedication

To whom I belong

My Father Samir A.Kortbaoui

My Mother Georgette Y. F. Kortbaoui

My country Lebanon.

<u>Abstract</u>

Sea shore contamination of the Lebanese coast

Sea water samples were collected from different sampling stations along the Lebanese coast in the summer of 1994. Chemical, biological and physical analysis were conducted to assess the recreational water quality in Lebanon.

Some 125 samples were then analyzed for the presence of Cadmium and Mercury by atomic absorption spectrophotometry. Cadmium content, holding a mean 0.77 μ g/L, was generally low for most areas with only a few elevated readings in Tripoli (1.89 μ g/L), Checca (1.83 μ g/L), Kaslik (0.79 μ g/L), Beirut (1.19 μ g/L) and Ramlet Al-Bayda (1.77 μ g/L). Mercury content, holding a mean value of 0.06 mg/Kg (wet weight), was below the accepted tolerance limit of 0.5 mg/Kg for all sampling sites.

Some 128 samples were then analyzed for fecal coliforms (Escherichia coli and Streptococcus Feacalis). Approximately, 50% of the sampling stations showed satisfactory results (less than 100 colonies/100 ml). High counts of fecal coliforms, over 500 colonies/100 ml, collected at Dora, Ramlet Al-Bayda and Antelias, reveal poor sea water quality and a public health hazards to swimmers and fishermen.

Some 36 samples were collected and analyzed for dissolved oxygen (DO), pH, salinity and temperature. For all sites sampled, DO averaged 4.03 mg/L, pH averaged 7.97, salinity averaged 38.77 ppt and temperature averaged 27.9°C.

The degree of pollution was found to be related to population density, industrial and human activity, continental runoffs and hydrological and meteorological conditions.



Résumé

Contamination du littoral de la côte Libanaise

Des échantillons d'eau de mer ont été recueillis à partir de différents points de prise s'êtendant le long de la côte Libanaise, pendant l'été 1994. Des analyses chimiques, biologiques et physiques furent effectuées dans le but d'évaluer la qualité de l'eau récréative au Liban.

125 échantillons furent ensuite soumis a des analyses par absorbtion atomique spectrophotometrique pour détecter la présence de cadmium et de mercure. Le contenu en cadmium, moyenne de 0.76 μg/l s'est révélé bas pour la plupart des régions; seules les villes suivantes ont eu des valeurs nettement supérieures la moyenne: Tripoli (1.89 μg/l), Checca (1.83 μg/l), Kaslik (0.79 μg/l), Beyrouth (1.19 μg/l), et Ramlet-El-Baida (1.77 μg/l).

Le contenu en mercure, moyenne de 0.06 mg/kg (poids humide), s'est révélé être, pour tous les échantillons, infèrieure à la limite de tolêrance acceptée de 0.5 mg/kg.

Quelques 128 échantillons furent analyzës pour détecter la presence de bactéries coliformes fécales. Prês de 50% des points de prise d'échantillons ont révélé des résultats satisfaisants (moins de 100 colonies/100cc), par contre, la qualité de l'eau de mer aux niveaux de Dora, Ramlet-El-Baida et Antelias s'est révélée mauvaise: les valeurs élevées de500 colonies/100cc de bactéries coliformes fécales ont été atteintes. Ces valeurs détectent un danger trés net pour les nageurs et les pêcheurs.

36 échantillons ont ensuite été prélevés et analyzés pour leur teneur en oxygen dissous, leur pH, leur taux de salinité et leur temperature. Pour les échantillons de tous les cites la moyenne de la valeur de l'oxygen dissous est de 4.03 mg/l, la moyenne du pH est de 7.97, l'index de salinité est de 38.77 et la moyenne de temperature est de 27.9. Le niveau de pollution a été trouvé lier a la densité de la popullation, des activités industrielles et humaines, et les conditions hydrologique et meteorologique.

Acknowledgments

I wish to express my gratitude and appreciation to Professor S. Barrington, my research suppervisor, for the support, guidance and patience for the completion of this work. Appreciation and thankfulness is also extended to Professor V.G. Raghavan, Professor I. Alli and Professor W. Marshall for their guidance and advice.

I also wish to express my sincere thanks and appreciation to Dr. P. Malychef, Dr. M. Abi Nader, Nadine Manoli, Anis Khoury and May Faraj for the assisstance and encouragement throughout the project.

On a more personal note, special thanks go to my family, Samir, Georgette, Imad and Rania Cortbawi, a special person Lil Sayegh and very close friend Sam choucha, for their constant encouragement, support and patience. This thesis would have never been accomplished without them.

TABLE OF CONTENTS

<u>CHAPTER</u>

PAGE

Ab	stract
Acl	knowledgments
Tal	ble of Contents i
Lis	t of Tablesv
Lis	t of Figures vi
No	menclature vi

CHAPTER	P.	AGE
1- Introducti	0 n	- 1
1.1	Pollution in the Mediterranean sea	1
1.2	Nature and major sources of pollutants	2
	1.2.1 Waste water	2
	1.2.2 Industrial waste and pesticides	4
	1.2.3 Oil pollution	4
1.3	Pollution source of Lebanese coastal areas	5
	1.3.1 Major pollutants and their sources	5
	1.3.1.1 Municipal and industrial waste waters	5
	1.3.1.2 Municipal refuse	12
	1.3.1.3 Toxic waste	15
	1.3.1.4 Protective laws	18
Objectives : 2 - Literatu	and Scope	19 +
2 - Encratu 7 1	Introduction	
2.1	Sources and Transport noths	20
2.2	Sources and Transport pains	20
	2.2.1 Sources and Controls: Lebanon's case	23
	2.2.2 Types of pollutants	23
	2.2.3 Inorganic pollutants	24
2.3	Composition of sea water	25
2.4	Transport in the environment	26
2.5	Contamination of the atmosphere	26
2.6	Elements in the aquatic environment	28

Trac	e elements in waste waters	29
Char	acteristics of heavy metals	33
2.8.1	Mercury	33
	2.8.1.1 Health effects	35
	2.8.1.2 Occurrence	36
2.8.2	Cadmium	37
	2.8.2.1 Health effects	38
	2.8.2.2 Occurrence	40
	Trace Chara 2.8.1 2.8.2	Trace elements in waste watersCharacteristics of heavy metals2.8.1 Mercury2.8.1.1 Health effects2.8.1.2 Occurrence2.8.2 Cadmium

2.9-The Biological Aspect of Pollution

2.9	General characteristics of the sea 4	11
2.10	Bacteriological quality of coastal waters 4	13
	2.10.1 Case Study: Lebanon 4	13
	2.10.2 Determination of water quality 4	14
2.11	Bacterial contamination of the Lebanese coast 4	15
	2.11.1 Bacterial flora of sea water 4	15
	2.11.2 Species of microorganisms found in sea water- 4	16
	2.11.3 Disease-causing bacteria 4	19
2.12	Indicators of water pollution 5	50
	2.12.1 Escherichia coli 5	51
	2.12.1.1 Ecology 5	51
	2.12.1.2 General characteristics 5	51
	2.12.2 Streptococcus Feacalis 5	52
	2.12.2.1 Ecology 5	52
	2.12.2.2 General characteristics 5	;3
3 - M	terials and Methods 5	55
	3.1 The study area 5	55
	3.2 Sample collection and preparation 5	8
	3.2.1 Collection of cadmium samples 5	;9
	3.2.2 Collection of mercury samples 5	9
	3.2.3 Collection of samples: Physical analysis 6	jO
	3.2.4 Collection of samples: Bacteriological analysis 6	jO
	3.3 Analysis of sea water samples 6	5
	3.3.1-A- Heavy metals 6	5
	3.3.1.1 Preliminary treatment of samples 6	5
	3.3.1.2 Analysis of cadmium and mercury 6	5

	3.3.1.3 Cadmium analysis	66
	3.3.1.4 Mercury analysis	67
	3.3.1.5 Equipment and reagent used	68
	3.3.2-B-Indicator microorganisms	69
	3.3.2.1 Bacteriological analysis	70
	3.3.3- Physiscal analysis	73
	3.3.3.1 Dissolved oxygen (DO)	73
	3.3.3.2 Salinity, temperature, pH	74
	3.3.4 Statistical analysis	74
4- Results	and Discussion	75
4.1	Cadmium	75
4 2	Mercury	80
43	Feacal coliforms	83
4.5	Physical parameters	80
4.4	A A 1 Dissolved oxygen	00
	4.4.1 Dissolved oxygen	90 90
5 - Conclu	lsion	92
5.1	Recommendations	- 94
6 - Referer	1Ces	95

CHAPTER

PAGE

Appendices	105
A- Cadmium sample data	105
B- Mercury sample data	110
C- Feacal coliform data- E.coli	112
D- Feacal coliform data- Streptococcus Feacalis	114
E- Physical parameters data- DO, pH, Salinity, temperature	116

LIST OF TABLES

PAGE

Table 1.1 - Organic load of domestic waste water dischargeinto the Mediterranean directly or through rivers.	3
Table 1.2- Physical, chemical and biological characteristics of waste water and their sources.	7
Table 1.3- Selected pollutants, their pathways and effects.	9
Table 1.4- Weighted mean values of the characteristicsof Beirut raw waste water	10
Table 2.1- Entry routes of pollutants.	22
Table 2.7- Trace metals in New York city waste waters and harbour	31
Table 2.7.1- Contribution of trace metals from waste watertreatment plants.	32
Table 2.9- Major constituents of sea water	42
Table 2.11- Marine fish and shellfish diseases born from bacteria viruses and parasites.	48
Table 4.1.1- Cadmium levels in Lebanon's coastal waters.	78
Table 4.1.2- Highest cadmium level along the Lebanese coast.	76
Table 4.1.3- Major industries located on the coast.	79
Table 4.2- Mean values for weight, length, and total mercuryin four fish specimens tested along the coast of Lebanon.	81

Table 4.3.1- Number of E.coli in the recreational watersof the sixteen study beaches.	
Table 4.3.1- Number of Streptococcus Feacalis in therecreational waters of the sixteen study beaches.	86
Table 4.3.3- Microbial standards for bathing beaches in Lebanon (E.coli).	87
Table 4.3.4- Microbial standards for bathing beachesin Lebanon (Streptococcus Feacalis).	88
Table 4.4- Physical parameters: Variation of	89
concentrations in sampling stations.	

LIST OF FIGURES

Figure 1- Acne appeared to bathers swimming close to toxicbarrels dumped into the sea.		
Figure 3- Structure and cell functions of E.coli.	54	
Figure A and B- The geographic distribution of industries situated along the coast	56	
and the population density	57	
Figure 4- Sampling stations: Cadmium sample collection	62	
Figure 5- Sampling stations: DO, pH, temperature and salinity sample collection.	63	
Figure 6- Sampling stations: E.coli, Streptococcus Feacalis sample collection.	64	
Figure 7- Feacal coliforms culture appearance on m-FC media	72	

NOMENCLATURE

- MF- Membrane Filtration.
- BOD-Biochemical Oxygen Demand.
- GFCM- General Fisheries council for the Mediterranean.
- SMEWW- Standard Methods for the Examination of Water and Waste Water
- CDR- Conseil du Developement et de Reconstruction.
- GESAMP- Group of Experts on the Scientific Aspects of Marine Pollution.
- CEPA- Canadian Environmental Protection Agency.
- IARC- International Agency for Research on Cancer.
- ASTM- American Society for Testing and Materials.
- FAO- Food and Agriculture Organization.
- APHA- American Public Health Association.
- EPA- Environmental Protection Agency.
- WHO- World Health Organization.
- EOA- European Oceanic Association.
- UNEP- United Nation Environment Program.
- APCL- Association de la Protection du Consommateur Libanais.
- PAHO- Pan American Health Organization.
- ADPC- Ammonium Pyrrolidine Dithiocarbamate.
- MIBK- Methyl Isobutyl Ketone.
- H₂O₂- Hydrogen Peroxide.

HNO₃-Nitric Acid.

KMNO₄- Potassium Permanganate.

DO- Dissolved oxygen

1- Introduction

1.1- Pollution in the Mediterranean Sea.

The Mediterranean has always been a crossing point of cultures, and many different peoples have left their mark along its coasts. However, since the beginning of this century, the process of environmental degradation that exists in the Mediterranean has picked up speed. The balance between humans and nature has changed to the point that the Mediterranean today is one of the most polluted seas in the world.

The Mediterranean sea occupies an area of about 3 million square kilometers and an estimated 300 million people live along its shores. Its connection with the Atlantic ocean through the straits of Gibraltar is the major way by which it obtains and, at the same time, gets rid of its waters. Exchange of waters also occurs through the Suez Canal with the Red Sea, and through the Bosphorous with the Black Sea. Other significant sources of water income include the River Rhone. The River Nile is no longer a major source of water into the Mediterranean because of the recently built Aswan Dam (Hafez and Shenouda, 1977; Gerges, 1976).

Because the Mediterranean is almost a closed sea, its pollution is long lasting. The lack of strong currents that enhance mixing, dispersion and dilution of the discharged pollutants constitute another factor leading to the concentration of marine pollutants along the highly populated coastal areas.

1.2- Nature and Major Sources of Pollutants.

The majority of the pollutants discharged into the Mediterranean are those from terrestrial sources. These include urban waste, waste water from domestic and industrial sources, agricultural runoff, and river discharges.

1.2.1-Waste Water

One of the major sources of pollution is waste water discharged from coastal towns. It is a problem in the sense that it affects the marine ecology, as well as the aesthetic and recreational aspects of the beaches around the Mediterranean (Kimor, 1991).

Despite the growing awareness and interest in the protection of the marine environment, coastal towns continue to discharge their waste water either directly into the sea, or indirectly through rivers. About 85% of urban sewage is discharged directly, untreated, and pathogenic micro-organisms in the water can cause diseases among swimmers and fish consumers such as hepatitis, paratyphoid and cholera. In most cases, waste water is discharged into the sea at a distance not exceeding 500 m and seldomly at a distance of 800 m from the coast (GFCM, 1972; Ruivo, 1972). Studies on waste water pollution in the Mediterranean show that the most affected area is the Northwestern part which includes the entire French coast, and part of the Spanish and Italian coasts. Areas with waste water pollution problem can be readily appreciated when BOD₅ values for some coastal regions are compared (Table 1.). Waste water disposal into the marine environment tend to increase during the tourist season due to the increased population along the coastal areas.

Name of	BOD	BOD /Km	Phosphorous	Phosphorous/Km
4154		coastline (tons/year)	content (tons/year)	coastline (tons/year)
Spain	130,000	60	5,000	2.7
Italy	400,000	61	18,000	2.7
Yugoslavia	17,000	27	800	1.2
Malta	8,000	67	320	2.7
Greece	100,000	37	4,500	1.7
Turkey	100,000	36	4,500	1.6
Cyprus	9,600	15	450	0.7
Syria	6,500	36	260	1.4
Lebanon	31,250	149	1,250	6.0
Israel	32,000	145	1,400	6.5

 Table 1. Organic load of domestic waste water discharged into the Mediterranean directly or through rivers

Source: (GFCM, 1972)

1.2.2- Industrial Waste and Pesticides

The Mediterranean suffers from dumping by industry, agriculture and urban centers (Green Peace, 1989; Kimor, 1991). Many of them are a long way from the sea but their pollution is carried by rivers. The amounts of waste dumped per year are the following:

- 120,000 tons of mineral oil

- 12,000 tons of phenols (toxic and bioaccumulative organic substances)

- 60,000 tons of detergents

- 100 tons of mercury

- 3,800 tons of lead

- 3,600 tons of phosphates

1.2.3- Oil Pollution

Green Peace (1989) pointed out that around 2 million tons of oil are released into the Mediterranean marine ecosystem every year, which is a third of the total for the whole world. This waste comes from the different stages in the transport of oil as well as from the loading, unloading and the cleaning of oil tankers undertaken without the necessary precautions. The water used to clean the tankers is often discharged illegally, as many ports lack the necessary infrastructure to receive this waste, despite governmental agreements to provide appropriate installations. Although some countries are making an effort to treat a greater percentage of waste, there is still much to be done in the Mediterranean.

1.3- Pollution sources of Lebanese Coastal Areas

Similar to other Mediterranean countries, most of the population of Lebanon, some four million people, inhabit the coastal strip which is even more enclosed by the Lebanon mountain chains running from south to north, parallel to the coastal line.

It is only natural that industrial complexes follow the same pattern as that of the population, especially in and around the major residential areas like the cities of Beirut, Tripoli, and Sidon.

A natural result of the above is that whatever wastes is created by the population and the industries it will eventually flow into the sea, directly or indirectly. Moreover, Lebanon being a touristic country, the problem of wastes is more magnified during the tourist seasons. Commercial and passenger sea vessels as well as oil tankers also contribute to the sea water pollution, and the situation has reached a state now that it is almost impossible to find a "clean" sea shore area along the Lebanese coastal strip.

1.3.1- Major Pollutants and Their Sources

The principal pollutants of the Lebanese shores are derived mainly from the municipal and industrial waste waters and refuses.

1.3.1.1- Municipal and Industrial Waste Waters

Waste waters is a combination of solid or liquid wastes mixed with surface water, groundwater or storm water, as may be present. It constitutes a health and environmental hazard, and carries pathogenic organisms that are the causal agents of numerous diseases.

Disposal of untreated wastewater into water bodies leads to the formation of anaerobic conditions and the eutrophication of the water body. Wastewater generates malodorous gases, such as hydrogen sulfide and ammonia, that are toxic and that cause psychological stress (Malychef, 1994).

As defined by Metcalf and Eddy (1991), waste water is a mixture of waste generated by human activity and water present as runoff, infiltration, and storage. Wastewater is characterized by its physical, chemical, and biological components. These characteristics and their sources are listed in Table 1.2. Although it varies largely in composition, wastewater can be classified into two major categories: Municipal and Industrial. Municipal wastewater is produced by households, schools, commercial, educational, and recreational institutions. Industrial wastewater, generated by industries, can be specific in composition and concentration depending on the type of industry. Both categories may also contain agricultural wastes in areas of intensive farming where chemical fertilizers and pesticides are used in large quantities to improve crop production. The level of these pollutants is an indication of the contaminating potential of the Some are, therefore, commonly used parameters for the performance wastewater. evaluation of wastewater treatment. These are presented in Table 1.3 (Tripathi et al., 1991; Schierup and Brix, 1990; Cooper et al., 1989; Boutin, 1987; Reddy and de Busk, 1985). The concentration of contaminants and rates of wastewater vary from one location to another, and from country to country (Dalu, 1978). Typical characteristics of the Beirut wastewater presented in Table 1.4, show that it can be classified as strong wastewater (Metcalf and Eddy, 1991; Pescod, 1992).

Table 1.2. Physical, chemical and biological characteristics of wastewater and their sources. (Metcalf and Eddy, 1991).

Characteristics	Sources
Physical properties	
Color	Domestic and industrial wastes, natural decay of organic matter
Odor	Decomposing wastewater, industrial wastes
Solids	Domestic water supply, domestic and industrial wastes, soil erosion, infiltration
Temperature	Domestic and industrial wastes
Chemical constituents	
Organic	
Carbohydrates	Domestic, commercial and industrial wastes
Fats,oils, and grease	Domestic, commercial and industrial wastes
Pesticides	Agricultural wastes
Phenols	Industrial wastes
Proteins	Domestic, commercial and industrial wastes
Priority Pollutants	Domestic, commercial and industrial wastes
Surfactants	Domestic, commercial and industrial wastes
Volatile organic cpds	Domestic, commercial and industrial wastes
Others	Natural decay of organic materials

Table 1.2 (continued)

Characteristics	Sources					
Inorganic						
Alkalinity	Domestic	wastes,	Domestic	water	supply,	groundwater
Chlorides	Infiltration					
Heavy metals	Domestic	wastes,	Domestic	water	supply,	groundwater
Nitrogen	Infiltration					
рН	Industrial v	vastes				
Phosphorus	Domestic a	and agricu	ltural wastes			
Priority pollutants	Domestic,	commerci	al and indust	trial was	tes	
Sulfur	Domestic, commercial and industrial wastes					
Gases	Domestic, commercial and industrial wastes					
H2S	Domestic, commercial and industrial wastes					
Methane						
Oxygen	Decompos	ition of do	mestic waste	25		
Biological constituents	Domestic. commercial and industrial wastes					
Animals	Domestic water supply, surface water infiltration					
Plants						
Protests	Open water courses, treatment plants					
Archaebacteria	Open water courses, treatment plants					
Viruses						
	Domestic wastes, surface water infiltration, treatment plants					
	Domestic v	vastes				

Table 1.3. Selected pollutants, their pathways and effects (Metcalf and Eddy, 1991:EPA,1988).

Pollutant	Pathway and Effect
1. Nitrate- nitrogen Health	Pollution of groundwater, infant water supply, fatal blue Baby Syndrome
Environmental	Eutrophication
2. Ammonia-nitrogen	Transforms to nitrate-nitrogen
3. Ortho-phosphate	
Environmental	Eutrophication
4. BOD	
Health	Water supplies, food chain, crops or animals
Environmental	Soil accumulation, oxygen depletion
5. Suspended solids (SS)	
Environmental	Sludge deposits, anaerobic conditions in the aquatic environment
6. Turbidity	Related to the SS concentration
7. Coliform bacteria	
Health	Water supplies, crops, aerosols, communicable diseases
Environmental	Soil accumulation
8. Odor	
Health	Psychological stress

Table 1.4. Weighted mean values of the characteristics of Beirut raw wastewater (Dalu,

1978)

Characteristics	Concentration
	(in ug/l except where specified)
BOD5	323
	1070
Total solids	12/3
Total fixed solids	737
Total volatile solids	536
Total dissolved solids	856
Dissolved fixed solids	530
Dissolved volatile solids	326
Total suspended solids	417
Suspended fixed solids	207
Suspended volatile solids	210
Settleable solids	5.2
Chlorides	162
Specific conductance: at 25C u-mohs/cm	1161
Total alkalinity as CaCO3	359
рН	7.95
Turbidity JTU	61
Ammonia-Nitrogen	22.6

According to Fawaz and Mallat (1990), at present there is no wastewater treatment in Lebanon. This statement summarizes the present conditions of wastewater treatment in Lebanon. Raw wastewater flows directly into the sea, or other water bodies, or on land. Wastewater networks are available to only half of the population. The other half relies on septic tanks that are not adequately water proof, and on open disposal. Studies done on the amount of wastewater disposed into the sea showed that 78.5 million tons per year of wastewater are discharged into the coastal areas by five major towns, namely, Beirut, Tripoli, Saida, Batroun, and Byblos (Pathan, 1977).

Coastal towns are also responsible for the annual discharge into the sea of 119 to 230 tons of BOD, and 880 tons of solid matter per kilometer of coastline (Ahmad, 1972). In the capital, Beirut, the amount of municipal wastewater reaching the sea annually is reported to be about 66 million tons (Tatcher, 1977). This amount of wastewaters is disposed into the sea through nine major sewage outfalls only few meters in length, in an untreated state. The actual amount of municipal wastewaters entering the city's coastal waters is expected to be more than 66 million tons at present. This is due to the influx of displaced persons taking refuge in Beirut during and after the 1975-1976 events in the country.

1.3.1.2-Municipal Refuse

The disposal of solid waste (a mixture of commercial and household rubbish such as paper, bottles, cans, plastics) has become one of the most urgent and difficult problems of the crowded urban centers of both developed and undeveloped countries, and sea disposal of this waste material is being used increasingly (FAO, 1971). Old car tires, timbers, wire, nylon rope and fishing nets, sludge produces in sewage treatment plants, building and dredging materials are also considerable sources of solid wastes. Many of these are virtually indestructables and may interfere with fishing, navigation or other uses of the sea. Floating or submerged materials can get entangled in the propellers of ships and may cause considerable damages. Dredging spoils deposited on the bottom on the other hand, can modify the substrate unfavorable for the benthic habitat and settlment of larvea.

Solid waste, at present, is disposed of in a caotic manner in open dumps at any location possible. Coastal communities typically use the seashore, or dump into the mouths of rivers flowing nearby. Inland communities use ravines, rivers abandonned excavations, roadsides and other locations where vacant land is convenient and available. There are no operating or use records for these disposal sites, nor is there any attempt to control dumping or to cover the refuse, and in many places open burning is commonly practiced. In warmer weather, flies abound, and undoubtedly there are rodents in these disposal areas.

Municipal refuse is another major source of pollution of the lebanese marine environment. Most of the coastal towns are accustomed to dispose of their refuse in areas

very close to the sea. A significant portion of this refuse is then carried into the sea either by wind and wave action, or deliberately by government officials as was the case in the Normand and Bourj-Hammoud areas prior to the events. Normand and Bourj-Hammoud is the area lying a few kilometers to the north-east of Beirut. It was the place where the refuse collected from Beirut and its northern and northeastern parts, was dumped before the civil war. At the time, it was estimated that the total annual amount of refuse collected from Beirut and suburbs was about 360,000 tons (CDR, 1993). This was the amount dumped at the Bourj Hammoud open dump. Some of this refuse was also pushed into the sea by the help of Bull-dozers. The heavy constituents of the refuse sink to the bottom of the sea at the point of discharge, while the light material floats on the water and is dispersed in all directions. The portion of refuse which is piled on the beach also created unaesthetic effects. The biodegradable portion of the refuse disintegrated in time, but the undegradable part consisting mostly of plastic, rubber, or metallic substances persisted for a long time in the area until dispersed by physical factors along the seashore.

Indiscriminate open dumping of solid waste througout Lebanon is unacceptable, but the lack of financial and technical assisstance prevents implementation of proper treatment processess (Malychef, 1994; APCL, 1994).

Open dumping does not only offend the aesthetic sense and give off objectionable smoke and odors, but its is also a breeder of flies and rodents, capable of carrying diseases. The country is littered with solid waste and present conditions have an adverse impact on public health and environment. If corrective measures are not undertaken, the future situation will become worse.

Ayoub and Akra (1994) have discussed the daily refuse generated per capita, followed by, specifying the types and places of disposal sites and their capacities. Due to the lack of statistical data on population in Lebanon, it is difficult to obtain correct figures throughout the country. However, some estimates have been done by several institutions which elicit some data about domestic waste generation. According to CDR (1993), the estimate of refuse generation range from 1200-1500 tons per day, at an average generation rate of 1.12 kg per person per day for a population of one million. Other than local street and hill sides dumping and burning, there are three major sites for refuse disposal in Beirut area which are the Quarantina composting plant, Amroussieh incineration plant and the open dump of Bourj Hammoud. Refuse generated is distributed as follow:

- ~ 500 tons per day to Quarantina compost plant
- ~ 250 tons per day to Amroussieh incineration plant
- ~ 450 at Bourj Hammoud open dump

Personal contact with people in the government have shown that there are plans for increasing the capacity of both plants. This will certainly solve the problem of waste management in Lebanon and allow the closing of the open dump.

1.3.1.3-Toxic Wastes

Toxic waste materials will inevitably move toward areas of least political and economic power to refuse it. In industrialized countries, poorer neighborhoods or rural areas have most often been chosen as sites for proposed toxic waste landfills or incinerators. Residents have been lured into accepting the waste with the promise of revenue, jobs or electricity (Green Peace, 1989).

The same situation had been repeating itself, but on a much more freightening scale in Lebanon. Since 1988 Lebanon has been a victim of illegal traffic by transboundary movements of industrial hazardous wastes. Most of the waste trade scandals of recent years involved shipments sailing on the Mediterranean sea. At least ten ships departed Italian harbours between 1987-1988 bound for Lebanon, Rumania, Nigeria, Djibouti, Syria, Turkey, and Venezuela. According to Green Peace (1989), the Italian Ministry of Environment has declared that it is only able to manage 10% of its industrial waste. Thus the remainder is exported or illegally dumped. Nearly, 300,000 tons of waste were exported during 1988, 20% by ships. However, many other shipments go unreported by the government, making such figures unrealistically low.

Malychef (1994), reported that 16,000 barrels and 20 containers of toxic waste are known to have been dumped on war-torn Lebanon. European wastes have been discovered in and around Beirut. They were located in unsafe conditions, on natural hills and seashores resulting in pollution of the environment. When attempts were made to sell the poisons as raw materials for various commercial uses, the scandal of the dumping was revealed. Many innocent victims were injured, prompting analysis of the various substances. (Picture I,II).

Approximately 3000 barrels were found in different places. Until today, thousands of these toxic wastes are still located in unsafe conditions. Their location has never been detected. Among the barrels were found such extremely dangerous compounds as PCB's, herbicides with high levels of toxic chemicals such as dioxins, methylisocyanate.

One of the concerns of scientists about marine pollution relates to the discharge of radioactive materials resulting from toxic wastes or any other sources. There are three forms of radioactivity that are introduced by man into the marine environment.

1- Nuclear fuels, such as Uranium 235, Platinium 238 which may be introduced from nuclear ships, aircraft and satellites.

2- Fission products from nuclear detonations and energy production, such as Strontium-90, Cesium 137, and Barium 40

3- Activation products such as Zinc 65, and Iron 55 resulting from neutron bombardment of components of nuclear reactors, weapons and natural constituents in the environment. Small quantities of radionucleides are also introduced into the ecosystem from laboratories and medical sources.

Like other pollutants, radioactive materials are persistent in the environment due to their long half-lives, for example Strontium-90 has a half life of 27.7 yrs. Thus radioactive materials accumulate in bottom sediments and organisms (Goldberg, 1972).


1.3.1.4- Protective Laws

The rapid urbanisation and industrial growth that the Republic of Lebanon has experienced before the civil war, and will continue to experience now that this war is over, affect to a significant extent its socio-economic, environmental, and living conditions particularly in major cities, as well as in major areas which have been classified for industrial zoning.

This growth has definitely placed a considerable burden on the Lebanese government and local authorities to keep pace with the rising demand for the protection of the environment, particularly in cases where industrial waste management plans have not been devised yet by the regulatory agencies.

The Ministry of Environment together with other regulatory agencies, recognize the fact that the severity and complexity of the environmental and community problems that could be generated, would become evident and intolerable if industrial wastes, including liquid, solid, or airborn contaminants, remain to be disposed of in an unmanageable manner.

It is a well known fact that the exsisting laws on pollution of the marine environment in Lebanon are old and inadequate. This, in addition to the inability of the government to enforce the law for various reasons, has helped in creating a chaotic situation which has become increasingly difficult to control.

In view of the mentioned problems, the recommendations for halting pollution of the marine environment in Lebanon should include the followings:

1- Revising and updating environmental laws.

2- Introducing new regulations that dictate the planning process and the implementation of environmental protection related projects, keeping in mind the future development of the country.

3- Enforcing these laws.

4- preparing campaigns to protect the marine environment.

5- Providing support to researchers.

6- Preparation of a well defined set of rules and regulations for managing the discharge of industrial wastes into the environment or public sewer systems.

1.4- Objectives

This study aimed primarily at evaluating the recreational water quality along the Lebanese coast. Thus physical, biological and chemical analysis were conducted in order to determine the degree of contamination.

More specifically, the long term goals of this study was to:

- 1) Help identify areas where waste management needs to be improved
- 2) Identify areas where human can be affected through activities.

1.5- Scope

The results of this study are limited in scope with respect to the following:

- 1) Chemical analysis of mercury and cadmium
- 2) Biological analysis of fecal coliforms: E.coli and Streptococcus Feacalis
- 3) Physical analysis of dissolved oxygen (DO), pH, temperature and salinity.

Chapter 2- Contaminants and The Marine Environment- A Literature Review

2.1- Introduction

The world's ever growing population and its progressive adoption of an industrially-based lifestyle has inevitably led to an increased anthropogenic impact on the biosphere. The types and sources of pollutant are as diverse as their potential effects and fates within the environment (Freedman, 1989).

Pollutants may be of numerous types, including certain metals, a diverse range of organic compounds and some gases. These substances may be a synthetic compound or a naturally occurring element whose concentration is elevated by anthropogenic activity to levels which are either toxic or capable of disrupting the ecology of an area. The importance attributed to a particular pollutant is normally linked to its perceived toxicity to humans (Nelson et al., 1996).

2.2- Sources and Transport Paths

Metal pollution is invisible. However like organochloride pesticides and even worse, once metals are added into the marine environment, they are there for ever. Major sources of metal pollution in the Mediterranean are the industrial effluents and mining areas. The disposition of waste either through dumping, pipelines and rivers directly into the sea or through atmospheric pollution, in such large quantities may increase their natural concentration levels. Besides these, ports and estuaries also contribute to the increased metal content of the sea.

The routes of entry of inorganic pollutant into the marine environment are unknown in many cases, and the paths indicated in Table 2.2 can only be regarded as a rough evaluation. Atmospheric pollution may give rise to a world wide contamination of the seas, while dumping, rivers, pipelines have mainly local or regional effects however serious they may be (Shiber, 1979).

Table 2.2- Entry routes of pollutants.

1: Ma an in pi disj dire a n	d use of dustrial roduct- posal via ct outfalls d rivers	Domestic waste via the same as 1:	Agriculture forestry public health via runoff from canals	Deliberate dumping from ships	Operational discharge from ships in course from ships in course	Accidental release from ships pipeline	Military activity transfer from atmost
Domestic sewage	i		0	i	i	0	0
Pesticides	i	i	ü	7	o	o	ü
Inorganic	ü	i	i	i	o	o	i
oil/oil dispersent	i	o	o	i	i	o	i
organic waste	ii	i	i	i	o	o	o
solid objects	i	0	ü	ü	i	ii	0

Source: Ahmad (1972)

(?) Uncertain (ii) important

(i) significant (o) negligible

2.2.1- Sources and Controls: Lebanon's case

Lebanese industries have always had the tendency to dominate the planning structure of the areas where they are located, and therefore, the activities of these industries will attempt to exhibit a greater tendency for generating and disposing ever growing volumes of different types of industrial wastes. The characteristics of the geographical location of Lebanon and of major Lebanese cities, together with their continuing prospect for future economic growth and diversification, seem to be very promising and yielding positive results. As such, a study should be carried out in developing the most appropriate treatment facilities, and also in securing the greatest environmental benefit.

Because of the variable nature of wastes that have to be dealt with in the development of a treatment plan, the number of solutions to the management, handling, treatment, storage, and disposal of the various types of industrial wastes is quite numerous and as such the need for developing these solutions should be fully investigated to select and conclude the most viable solution. Whatever the origin of the discharge, control has to be exercised at source.

2.2.2- Types of Pollutants

A variety of compounds can cause water pollution; They can all be classified roughly into three categories (Goldberg, 1972).

1- Organic pollutants: These are compounds containing substances which originated from living material.

2-Inorganic pollutants: These are various compounds which are not carbon compounds and which, in fact, may even be insoluble in water.

3-Other pollutants: These types of chemicals will include physical and radioactive pollution.

2.2.3- Inorganic Pollutants

Inorganic pollutants are the clearly toxic materials which get into the water through their use in agriculture or industry. These chemicals may induce changes in many biologically active organisms. The chemical, toxicity and environmental fate of these is closely related to their position in the periodic table. The term 'heavy metals' has been variously used to refer to the metallic elements low in the periodic table with high atomic weights (>100), or a relative density greater than five. Some 38 elements have a density greater than five. Many inorganic pollutants are abundant within the earth's crust and considered as essential nutrients; elements such as Fe, Zn, Mn, Cu. Others which are normally present in low concentrations are classified as highly toxic compounds. Such elements, e.g. Cd, Ag, Hg, and Pb. The requirement for, and potential toxicity of, heavy metals results from the fact that they are transitional elements, able to form stable coordinated compounds with a range of both organic and inorganic ligands.(Doudoroff and Katz, 1953; Fergusson, 1990; Morgan and Stumm, 1991)

2.3- Composition of Sea Water

Sea water around the world may vary in chemical composition, salinity, total dissolved solids and many other characteristics. The major parameters considered to define standard sea water are salinity and pH. These parameters are assumed to be 8.1(pH) and 35g/kg (Salinity) respectively.

Chemically, sea water is a complex but concentrated electrolytic aquatic system consisting of many ionic and molecular species (Sadiq,1992). The chemical composition of sea water consists of two fractions: dissolved (particles $< 0.45 \mu$ m) and undissolved (particles>0.45 μ m).

1- Undissolved fractions : (such as Al, Fe, Mn)

2- Dissolved fractions : These are classified into three constituents

- a) Major constituents (such as Na, K, Cl, Mg, Ca)
- b) Minor constituents (such as B, F, N, P, Li)
- c) Trace constituents (such as Cd, Hg, Pb, As, Se).

Because of their high toxicity to aquatic organisms and health significance to humans, trace elements are the most frequently determined elements in sea water. These chemicals are mainly present in extremely low concentrations, generally in ppm (Riley and Skirrow, 1975; Drever, 1982; Parker, 1972).

Sadiq (1992) has defined standards for chemical composition of trace elements in sea water. For example, the concentrations of cadmium (Cd) and mercury (Hg) in sea water should not exceed 0.05 and 0.03 ppb respectively.

2.4- Transport in the Environment

The important influences exercised by the presence of certain metals on the growth of living matters, foodstuffs for human consumption, and environment have elicited public concern about the amount of elements present and if they exist within the limits from a regulatory stand point. Nevertheless, deficiencies and excesses of known trace elements could impair human health.

Society is only concerned about heavy metals that have received increased attention as widespread environmental and accidental food contaminants. Opportunities exist for the release of potentially environmentally hazardous compounds at every stage of product manufacture, use and disposal. In addition to the manufacturing industries, pollutants may routinely enter the environment as a result of agricultural practices, food processing and transport, hence, finding their way into the air, food chain, and water sources (Fennema, 1985).

2.5- Contamination of the Atmosphere

The majority of metals present in the atmosphere are associated with particulate material. Because this material is largely inert in nature and hydroscopic, metals present there occur predominately in the liquid phase. Major soluble metals are being present as ionic species, however, other metals mainly mercury (Hg) occurs in the gaseous phase (Morgon and Stumm, 1991; Puxbaum, 1991). The release of mercury (Hg) vapor into the atmosphere may also occur whenever metallic mercury (Hg) is used. In Canada, for instance, an estimated annual amount of 6,400 kg of mercury (Hg) is accidentally

released into the environment through the breakage of some 4 million thermometers in hospitals and homes would ultimately volatilize into the atmosphere (Friberg and Vostal, 1972).

The presence of metals in the atmosphere reflects the geographic distribution and concentration of industrial sources. High concentrations are associated with densely populated industrial regions and air masses which originate in such regions, such as the city of Beirut. Very low concentrations have been found over an altitude of 400 m from sea level, such as on Mount Lebanon (Malychef, 1994).

The major source of atmospheric metals is associated with the combustion of fossil fuels, such as: 1) the thermal electric station at Zouk, emitting Cobalt (Co), Selenium (Se), and furans, 2) the operation of smelters and metal refineries where Arsenic (As), Zinc (Zn), Cadmium (Cd), and Cupper (Cu) which are released from secondary production plants, 3) the iron and steel industries, located at the industrial zone in the suburbs of Beirut, releasing Chromium (Cr) and Magnesium (Mn). Lead emissions are dominated by releases through the combustion of petrollium which contains lead additives.

The relation of air pollution to water pollution is clear. Experiments conducted in the U.S.A have shown that each 200 L of gasoline burned in automobiles, releases in the air 1.5 m.t of carbon monoxide, 0.1 to 0.2 m.t of hydrocarbons and 20 to 70 Kg of nitrogen oxide plus significant quantities of aldehydes, sulfur compounds, organic acids, ammonia, lead and other metallic oxides. Rain washes appreciable amounts of these

materials into water sources to become water pollutants. Yet, the importance of materials washed from polluted air into water must still be assessed (U.S.Senate, 1963).

2.6- Elements in the Aquatic Environment

Metals occur naturally, but large-scale release to the aquatic environment requires human intervention. Industrial waste waters are obviously major sources of metal discharges. In addition, there are more diffuse sources of urban runoff and leachate from solid waste disposal sites, both of which may be rich in metals (Martin and Whitfield, 1981).

Organic and inorganic particulate matters are commonly transported from inland sources and consequently discharged into the coastal waters. Examples of such mechanisms include: transport by air, rivers and municipal sewage or refuses, and chemical or biological precipitation of soluble dissolved substances. The heavier particles tend to settle close to the point of discharge, while the lighter ones may be dispersed over a wide area. Organic particles, being lighter than the inorganic ones, tend to remain in suspension or float on the surfaces. The damage inflicted upon the marine ecosystem would depend largely on the nature and the physico chemical properties of the particulate matter.

The interaction between recipient waters, aquatic organisms and discharged foreign materials were described by Gross (1971). According to Gross (1971), soluble substances associated with the particles are released into the surrounding water, and subsequently subjected to ion exchange reactions, precipitation and gravitational settling

or biological processes. Any insoluble products resulting from these processes may become available for ingestion by aquatic organisms.

2.7-Trace Elements in Waste Waters

It is well known that the Mediterranean is one of the most polluted bodies of water in the world and its future is, at best, dubious unless a great deal is done to remedy the situation. Waste water discharge remains the major aspect of pollution in Lebanon (Emery and George, 1963). Along the Lebanese coast, untreated domestic sewage, garbage and great amounts of toxic waste from industrial plants, together with pesticides, weed-killers, fertilizers and other domestic toxic substances (such as paints, solvents, batteries) find their way directly into the sea, not only from the coastal towns and villages, but also from inland areas via rivers (Ahmad, 1972; Shiber, 1979). The waste water input along the Lebanese coast is particularly heavy because the volume of sewage discharged directly or indirectly into the sea, is of the order of 178 500 m³ on a daily basis (Ahmad, 1972). No up-to-date figures are available, but it would probably be safe to assume that the volume of wastes entering the Mediterranean from Lebanon has increased from year to year, particularly around Beirut (Shiber, 1979).

Many types of industrial waste waters contain heavy metals. In Lebanon, during the wet season, stormwater runoff is very heavy. The metal content of the marine ecosystem could be affected either by atmospheric fallout, stormwater runoff, river discharge, or all three (Shiber, 1979). The impact of trace metals contained in discharge waste waters forms one of the major areas of concern to environmentalists, ecologists, controlling agencies, and the general public because of the possible injurious effects entailed. Many

29

investigators directed their research activities towards the content and sources of trace metals (Klein et al., 1974; Chen et al., 1974). Others became more involved in studies on the effectiveness of waste water treatment in the removal of the metal constituents (Argo, 1972; Nilsson, 1971).

Shiber (1979) conducted experiments on metal concentrations in marine sediments from Lebanon and reported that the highest level of metals occur at the closest point of sewer outfalls. Klein et al. (1974) investigated the sources of metals in New York city, and assessed the degree of pollution of the harbor waters with such metals as Cu, Cr, Ni, Zn, Cd, Hg, and Pb. The highest levels of metal recieved at the harbor came from three different sources:

a) waste water treatment plant effluents

b) storm water, and

c) untreated waste water.

The amount reported is 150 times greater than those reported in the literature for the Atlantic ocean. The high degree of metal pollution does not only result from industries (Table 2.7.1 and 2.7.2).

Sources	Cu	Cr	Ni	Zn	Cd	Hg	Pb
				mg/L			
Residential area	0.212	0.023	0.073	0.212	0.002	-	-
Surface runoff	0.46	0.16	0.15	1.6	0.025	-	-
Treated w.w.	0.15	0.08	0.10	0.26	0.01	0.006	-
Sludge	60	38	9.1	85	3.1	-	-
Harbor waters	0.09	<0.002	0.015	0.15	0.0025	<0.004	0.308
Atlantic waters	0.09	0.0005	0.010	0.125	0.0023	0.0005	0.23
(near shore)							
River waters	0.089	<0.0029	0.0154	0.151	0.0027	<0.0048	-
Source: (Klein et al., 1974)							

Table 2.7.1- Trace metals in New York city waste waters and harbour.

31

Metal Source	% total quantities					
	Cu	Cr	Ni	Zn	Cd	
Water supply	20	0	0	7	0	
Surface runoff	14	9	10	31	12	
Residential area	47	28	25	42	49	
Unknown	0	11	0	0	0	
% Removed	45	48	17	36	41	

Table 2.7.2- Contribution of trace metals from waste water treatment plant

Source: (klein et al., 1974)

2.8- Characteristics of Heavy Metals

Metals in the form of salts occur in a variety of effluents which enter natural bodies of water (Meinck et al., 1960). Among the sources of such effluents are mines, metal processing factories, chemical industries and the brine from oil wells. True metallic elements, such as Cadmium (Cd), Copper (Cu), Lead (Pb), and Zinc (Zn), are good conductors of electricity, have a lustrous appearance and tend to enter reactions as positively charged cation (Marshal, 1991). A total of 108 elements have these properties and are considered to be true metals. A further seven are referred to as semi-metals. Finally, Arsenic (As), Selenium (Se) and Thallium (Te), have the physical properties of metals but chemically behave more like non-metal elements.

Recently, concerns about pollutants in the marine environment has increased considerably due to the observed effects of these substances on the ecosystem. When dealing with polluted waters, Mercury (Hg) and Cadmium (Cd) are considered to be the most threatening of the inorganic pollutants. Each of these elements will be discussed in greater detail.

2.8.1- Mercury (Hg)

Mercury (Hg, atomic weight of 200.59) occurs in its +I and +II oxidation states. Mercury (II) forms stable, water soluble, halide complexes (Marczenko, 1976).

Mercury (Hg) in poisonous amounts can enter natural bodies of water from industrial effluents originating in factories which produce mercury- containing compounds or which use mercury in their processes. Jensen and Jernelov (1969) defined mercury as one of the

most toxic elements. Mercury is known to undergo methylation and dimethylation to form organic compounds. The divalent form of mercury, Hg²+, is converted to much more toxic organomercurial compounds.

 $\begin{array}{c} CH_{3}CO \\ \uparrow \\ Hg^{2}+ + 2CH_{3}CO \longrightarrow Hg + CH_{3} \longrightarrow Hg (CH_{3})_{2} \end{array}$

The methyl donor involved in the methylation of Hg²⁺ is methyl cobalamin, which is usually associated with the conversion of homocystein and methionin. The resultant organomercurial compounds are volatile and toxic (Sadiq, 1992). In marine environment, Hg exists in several forms. Because of its strong affinity for halogens, it can form chloro complexes. Both methylation and dimethylation are mainly biological processes involving bacteria. Because of bacterial involvement in dimethylation, methylmercural compounds are unstable in sea water. This is probably why limited information is found on organic Hg compounds in seawater. Many investigators reported that concentrations of methylmercury in sea water range between 0.3 and 6% of the total dissolved Hg in sea water (Egawa et al., 1982; Yamamoto et al., 1983). Another reason for the limitation of organic Hg in sea water is the similarities of charges on Hg and organics. Mercury and organic molecules are negatively charged in sea water. Thus, organic complexes of mercury do not contribute appreciably to the total dissolved Hg in sea water. It is assumed that total dissolved Hg and total inorganic Hg, in practical purposes, are synonymous. Jensen and Jernelov (1969), described mercury in the marine environment. They reported that, most of the mercury compounds in sea water decompose to the

inorganic form: Hg , HgS, HgCl₂. The latter then gradually changes to methyl mercury which is highly toxic. Methyl mercury and total mercury are often analyzed for their content in fish in order to get a correct understanding and evaluation of the situation. As, for instance, the presence of methyl mercury differs in properties from those of inorganic mercury compounds.

Generally, the effects of pollutant on the environment and organisms fall into one of the major categories described here under.

2.8.1.1- Health Effect

The effects of pollutants on human health can be either on a short or long term basis. The marine pollutants, such as trace elements, usually affect human health on a long term basis because of their low intake into the body through foods.

One good example of a pollutant which has a long term effect on human health is mercury. A large-scale poisoning occured in Japan as a result of water polluted with mercury. An industrial plant on the shores of Minamata bay, Kyushu, Japan, used mercury chloride as a catalyzer in the production of vinyl chloride. Effluent from the factory loaded with waste mercury salt was poured into Minamata Bay. Fish and shellfish caught in the Bay had very large amounts of mercury in their tissues. It is interesting to note that inorganic mercury salts, originating in an industrial effluent, was transformed with time into organic mercury compounds. The mechanism by which the inorganic form of mercury was changed to an organic form is unknown. The human consumption of fish was followed by severe illness and even death. Minamata disease was responsible for the death of about 41 persons and the neurological disorders of about 111 persons between 1953 and 1960 (Irukayama, 1966; Ui, 1969).

In this case, it took at least 4 years for a pollutant to affect a human population. Radiation, on the other hand, which is known to cause both somatic and genetic abnormalities in man, will take a relatively shorter time. The other pollutants constituting the bulk of hazardous pollutants to man in the marine environment, include sewage, DDT, and heavy metals such as Cd, Hg, Zn.

It's known that DDT, together with heavy metals, tends to accumulate in the fatty tissues of animals.

2.8.1.2- Occurrence

Mercury is a reactive and dynamic element in marine environments. It is probably the most ubiquitous of all the heavy metals. This is because Hg is the only metal that can exist as both a liquid and as a volatile form at ambient temperatures. Mercury is present in nature in very small amounts estimated at 50 to 80 ppb of the earths content (Laxen, 1983). Due to easy transformation of physical forms, Hg cycles readily and continuously in nature. As a free metal, it is found in the form of glodes of liquid Hg in Spain and as impregnated schist or slate in India and Yugoslavia.

In certain parts of the world, mercuric salts are found chiefly as red sulfide (HgS), commonly known as cinnabar ore having an average mercury content of 0.1 to 0.4 %. This ore has been found in almost all types of rocks (igneous, metamorphic, and sedimentary) in concentrations ranging from 50 to 500 ppb. But, the common host rocks

are limestone, calcareous shales, sand stone, serpentine, chert, basalt and rhyolite (Friberg and Vostal, 1972; Ilo, 1972; Patty, 1962). Spain, Italy, Mexico, and the USSR are the chief world producers, but Chile, Peru, Yougoslavia, Philipine, China, USA, Canada and Turkey are important sources of Hg. The total amount generated annually is about 200,000 tons, half of which occur in Spain (Friberg and Vostal, 1972; Ilo, 1972; GESAMP, 1974).

The Hg ore is generally extracted by underground mining. The Hg metal is then separated from the Ore by roasting, or by reduction with iron or calcium oxide.

2.8.2- Cadmium (Cd)

Cadmium (Cd, atomic weight of 112.40) occurs in the divalent form (+II oxidation state) in the marine environment and it is not directly affected by oxidation-reduction transformations. Insoluble in excess NaOH, it can form ammine, cyanide, halide, and EDTA complexes (Marczenko,1976). It is a soft, silver white, blue-tinged, lustrous metal, with a melting of 321°C, a boiling point of 765°C and a density of 8.65g/cm³ at 20°C (Nriagu 1980).

Cadmium is a pollutant of significance of human health and one of the most frequently determined trace element in sea water. Concentrations of Cadmium (Cd) in sea water are extremely low and the lack of sufficiently sensitive and reliable analytical techniques, make the direct measurement of cadmium in sea water very difficult (Sadiq, 1992).

Cadmium (Cd) enters the environment via atmospheric deposition and through effluent discharges from point sources near-shore areas. In general, relatively high concentrations of Cadmium (Cd) in coastal waters may result from human activities. CEPA (1994) indicated that an estimate total of 159 tons of cadmium are released annually to the Canadian environment. Approximately, 12 tons enter into the aquatic environments as hydrated cadmium ion or in ionic complexes, and 147 tons are released via atmospheric deposition as particulate Cadmium oxides. Cadmium and cadmium compounds may find their way into the environment through many pathways. In this century, these compounds have been used increasingly by industries in alkaline accumulators, alloys, paints and plastics, causing a sharp increase in environmental contamination. Cadmium is emitted to air and water by mines, metal smelters, the use in agriculture of fertilizers, either as chemicals or as sludge from sewage plants, and the use of cadmium containing pesticides. These are the major sources that may be due to the contamination of the environment (Yamagata and Shigematsu,1970; Schroeder et al.,1967).

2.8.2.1- Health Effect

As a 'free ion', cadmium is probably the most bioavailable and toxic chemical species prior to mercury. This element is regarded as a priority pollutant because of its toxicity to humans. There have been numerous investigations to identify the occupational hazards around some factories within one industrial zone in the suburbs of Beirut. Nuwayhid (1994) reported that half of the establishments studied were located at street level while the other half underground or above street level. The host buildings were mostly in poor condition, and more than 80% of the establishments lacked proper ventilation, illumination, and housekeeping. Safety and health hazards, whether chemical or physical, were frequent with minimal use of general or personal safety rules. The study showed that 30 to 90 % of workers were exposed to hazardous materials that could be a potential hazard to health. Epidemiological and clinical studies showed that cadmium plays an important role as the etiological factor in many diseases. Nephrotoxic effects of cadmium in exposed workers were investigated by Kjellstrom, (1985). Many deaths from 'Kidney disease' or from 'niphritis/nephrosis' had been reported among workers employed in cadmium smelters, cadmium-copper alloy smelters, and other cadmium related industries. The clinical course of the 'Itai-itai' disease was described by Hagino and Yoshioka (1968). It was noted that the disease had a relationship with the water of the Jintsu River in Japan. The carcinogenic effect of cadmium causing lung cancer and prostate cancer, following prolonged inhalation exposure to cadmium were also reported by Ades and Kazantzis, (1988).

Numerous case studies of acute poisoning in humans as well as skin and eye irritation, have been reported following inhalation or ingestion of unspecified concentrations of cadmium (EPA,1985; WHO,1992). Moreover, exposure of Cadmium via food is the most important. It is estimated that most foodstuffs should not exceed 0.05 ppm of Cadmium, wet weight, and that the daily intake lies wilthin the range of 50µg.

2.8.2.2- Occurrence

Cadmium is a relatively rare earth element distributed with an average concentration of 0.15-0.2 mg/kg. Chemically, cadmium is known as sulfophilic being slightly concentrated in sulfide ores, mainly in association with zinc.

Cadmium is obtained as a by-product in the refining of zinc and other metals such as lead and copper. A typical zinc concentrate would contain between 0.2 and 5 % cadmium.. The significance of this small percentage is well understood when the world production of Zinc is known to be about 7 million tons (Brooks, 1978; Fleischer et al, 1970).

The natural occurrence of cadmium in air has been reported to be approximately 0.002μ g/m³. However, higher values reaching up to 5.4 µg/m³ have been found in areas where cadmium-emitting factories are situated (Friberg et al, 1976). Most fresh waters contain less than 1µg/l of cadmium, whereas the cadmium content of sea water is about 0.02μ g/l (Fleischer et al, 1970). Soils and oceanic sediments, on the other hand, contain approximately 0.4 ppm and 0.2 ppm, respectively (Aston, 1972; Schroeder and Balassa, 1973). The content of cadmium is apparently low in limestones and sandstones, but is appreciably concentrated in shales, oceanic and lacustrine sediments, oceanic manganese oxide nodules and in phosphorites (Fleischer et al., 1970). It is reported that the occurrence of cadmium is also associated with organic matter (Gulbrandsen, 1966). The cadmium production of the world comes mainly from sphalerite ore (zinc sulphide).

Cadmium metal is recovered from the blue powder collected during the distillation of zinc, the cadmium fraction from zinc distillation units, and the copper-cadmium filtrate deposited from sulfate solution. Significant amount are also obtained from the dusts from

roasters, sintering machines, and fuming furnaces used in zinc, lead and copper production (Fleischer et al., 1970). About 74 % of the annual production of cadmium is supplied by Canada, Japan, U.S.A, U.S.S.R and Zaire. Other countries producing significant amounts of cadmium include, Poland, Australia, Germany, France, Italy, Spain and Yougoslavia (IARC, 1976).

2.9- The Biological Aspect of Pollution

2.9.1- General Characteristics of the Sea

Approximately 70 percent of the earth's surface is salt water made up of the oceans, seas, and inland lakes. Most of this water is 3.5 percent salt. Sodium and chloride ions constitute about 85 percent of the salt in sea water. The next five elements, in order of concentrations, are magnesium, sulfure, calcium, potassium and bromine. Lyman and Fleming (1940), stated that the major constituents of sea water consists of the components presented in Table 2.9.

Table 2.9- Major constituents of sea water.

<u>Constituents</u>	<u>¢∕k</u> g
NaCl	23.477 gr
Mg Cl	4.981
Na2SO4	3.917
CaCl2	1.102
Kcl	0.664
NaHCO3	0.192
Kbr	0.096
H3BO3	0.026
SrCl2	0.024
NaF	0.003
H2O	1000.000

Source: (Lyman and Fleming, 1940).

In addition to these salts, sea water is known to contain a large number of trace elements. The sum of these elements does not exceed 0.025 % of the major constituents. A number of these elements are more concentrated in certain marine plants or biota than in sea water. The salinity of sea water samples, away from any considerable dilution factors such as large river or land drainage, is approximately 3.5 %. The pH value ranges between 7.5-8.5 (Harvey, 1955).

2.10- Sea Water Quality: Bacteriological Quality of Coastal Waters

The oceans are an important habitat for microorganims. Most of the bacterial community is primarily gram negative and only marginally aerobic. They are found naturally in salt water. Others gain entrance to these waters from natural sources such as air or soil or from industrial or domestic processes. Sea water contains sufficient nutrient material to provide a satisfactory medium for the growth and proliferation of microorganisms. A rapid depletion of dissolved oxygen (O_2) can occur when nutrients contaminate the water, often leading to the massive development of photosynthetic microorganisms.

Among the greatest threats to the marine ecosystem is the direct discharge of organic waste, such as sewage with none or limited treatment. These discharges bring about a process known as eutrophication whereby excessive nutrient input causes the development of huge phytoplankton masses that greatly increase water turbidity and a large number of bacteria including pathogens or disease type microorganisms (AbiSaab and Atallah, 1996).

2.10.1- Case Study: Lebanon

Regardless of solid waste pollution in marine environment, waste water discharge, through very short sewer outfalls, remains the major aspect of pollution in Lebanon. These type of pollutants are responsible for the general unhygienic conditions observed in beaches. The discharge of untreated municipal sewage has resulted in the disfiguration of beaches, production of noxious odors, discoloration of sea water, and the presence of slicks of scum as well as fecal and other solid matter floating on the surface. The foregoing, organic matter in domestic sewage presents the most serious health hazard, since human wastes contain large number of bacteria. The disease-causing bacteria (pathogens) are released to the plumbing system and are conveyed by the sewer system to the disposal system and to the sea. This is one of the chains of transmission of disease from sick persons to healthy persons. In the summer of 1970, such conditions associated with heavy pollution have resulted in the closure of Beirut beaches as a preventive measure against the transmission of Cholera (Ahmad, 1972). This was later found to be an unnecessary and excessively stringent measure.

2.10.2- Determination of Water Quality

Reinhold (1991), stated that measurement and expression of a polluted water quality are important factors in controlling pollution. However, these factors are expressed by several parameters such as temperature, pH, dissolve oxygen (DO), bacterial count and so on. A study within the context of the UNEP Mediterranean action plan on the recreational water quality, shows satisfactory bacteriological quality in most of the stations sampled. WHO/UNEP (1977) expert consultation recommends that "highly satisfactory bathing areas should show E.coli counts of consistently less than 100 per 100 ml, and to be considered acceptable no more than 10 % of at least 10 consecutive samples collected during the bathing season should exceed 1000 E.coli per 100 ml".

2.11- Bacterial Contamination of the Lebanese Coast

The rapid rise in the population of Lebanon is causing an increase in the pollution of coastal and river waters by human and industrial wastes. The common practice of disposing of these wastes in the Mediterranean sea is of growing concern nowadays as it may result in the contamination of shellfish areas and bathing beaches.

The presence of pathogenic agents in coastal waters may be a sign of recent or constant contamination. These agents can survive sufficiently long in sea water to be transmitted to man and the risk of infection may persist for several days. However, the relatively low incidence of disease among swimmers in polluted areas indicates a process of self-purification. As a result a combination of physical, chemical and biological factors takes place in sea water.

2.11.1- Bacterial Flora of Sea Water

Bacteria, yeasts and other microorganisms are presumably as important in the oceans as they are in terrestrial habitats. However, information about their occurrence and activities, which is essential for full understanding of the chemical and biological processes taking place in the marine environment, is as yet important. The open ocean is relatively high in osmotic pressure, low in nutrients, and quite cold in great depths. Bacterial population in such waters tend to be much lower than in estuaries and in small freshwater bodies fed by rivers and streams. Most of bacteria are found in the superficial layers of the sea water. In the littoral zone, where biological activity is usually more active, the total plate count indicates the presence of $\sim 10^2$ to 10^3 bacteria/ml of water. The lowest count is encountered in the open ocean particularly at a depth greater than 1000 m (Zobell, 1963).

Large numbers of microorganisms in a body of water generally indicate high nutrient levels in the water. Water contaminated by inflows from sewage systems or from biodegradable industrial organic wastes is relatively high in bacterial counts. Sea water contains bacteria, some of which are freely suspended in the water, other may be attached to living organisms or particles of organic debris. In water with low nutrient concentrations, microorganisms tend to grow on stationary surfaces and on particulate matter (Malychef, 1994).

2.11.2- Species of Microorganisms Found in Sea Water

The primary interest of sea water contamination is microbial pollution, especially pathogenic and viral organisms. The most dangerous form of water pollution occurs when significant amount of wastes is introduced into the marine environment. Many diseases are perpetuated by the fecal- one chain of transmission of diseases, in which pathogens shed in human feaces contaminates the water. The contaminated water used for recreational purposes such as swimming or boating may be ingested accidentally. Typical of these diseases are typhoid fever, cholera and hepatitis A transmitted by bacteria and viruses. The most common pathogenic organisms, that are introduced into the marine environment from human activities are mainly the strains of *Salmonella*, *Shigella*, *Vibrio*, *Clostridium*, *Escherichia coli*, *Streptococcus feacalis*, *Mycobacterium*, *Endamoeba hystolytica* and hookworm larvae. Not all pathogens must be ingested to

cause disease. For instance, some diseases are spread among persons who swim in waters contaminated by human feces. These types of pathogens are not usually ingested, but they bore through the skin. Table 2.11 summarizes the major diseases caused by different strains of bacteria (Bishop, 1983).

Table 2.11- Marine fish and shellfish diseases born from bacteria, viruses, and parasites

Disease agent	Disease in humans	Principal aquatic animal involved	Mode of trans- mission to human		
Bacterial:	Diarrhea,	Fish or Shellfish	Ingestion of fish		
Clostridium	abdominal pain		or shellfish that		
			has not been		
			refrigerated		
Clostridium:	Botulism	Fermented, salted,	Ingestion of		
botulinum		and smoked lish	improperly pro-		
			cessed fish		
Salmonella	Typoid and	Fish or shellfish	Ingestion of raw		
	paratyphoid		or insufficiently		
	fever		cooked fish or		
			shellfish		
Vibrio	Diarrhea,	Fish or shellfish	Ingestion of raw		
	abdominal pain		or insufficiently		
			cooked fish or		
			shellfish		
Viral:					
Virus of	Infectious	Shellfish	Ingestion of raw		
infectious	hepatitis		or inadequately		
hepatitis			cooked contaminated		
			shellfish		
Parasitic					
Nematodes	Enteritis	Cod, herring,	Ingestion of raw		
		mackeral	or partially cooked		
			pickled or smoked		
			herring		

Source: Bishop (1983).

2.11.3- Disease-Causing Bacteria

The release of these human wastes into the environment sometimes causes serious health problems. The importance to public health of a clean sea water requires objective test methods to establish high standards of water safety and to evaluate the effectiveness of treatment procedures to monitor waste discharge in the marine system. For the disposal of sewage the use depends on the careful management of the amounts of wastes entering the ecosystem and the level of pathogenic microorganisms associated with their release.

Increasing population densities and urbanization during the last 10 years were initially not accompanied by adequate sanitation practices. Fecal contamination, through untreated or inadequately treated sewage effluents entering the marine environment, creates conditions for rapid dissemination of pathogens. This situation revealed conditions for devastating epidemics caused by enteropathogenic microorganisms. Matossian (1984) described the epidemiological and clinical conditions, followed by the principal means by which individuals may be exposed to pathogens in the sea. The likelihood of infection in recreational waters depends upon the presence of a pathogen, its number, its ability to survive, its infectious dose, and the degree of its dispersal. The presence of pathogens, as a result of a continuous flow of sewage into the marine system, continues to be a major cause of sickness and death in undeveloped regions. However, the risk of acquiring an infection while swimming is associated with the degree of sewage contamination. Matossian (1982) has pointed out that infections are transmitted to humans by direct or indirect routes. The primary route of infection is accidental ingestion. However, bacteria may gain access to the blood stream through skin abrasions which may lead to anaerobic infections that could incite tetanic convulsions followed by death. Most studies have found that swimming in polluted sea water may result in cutaneous infections due to certain microorganisms such as *Staphylococcal, Streptococcal* and other bacterial skin conditions. In addition, enteropathogenic microorganisms such as *Vibrio cholerae* (cholera), *Salmonella typhi* (typhoid fever), various other *Salmonella* and *Shigella* strains (causing gastrointestinal infections of varying severity), and *Entamoeba histolytica* (the causative agent of amoebic dysentery) are also of public health concern. Many investigators reported epidemiological and clinical cases associated with the consumption of sea food. A major outbreak of typhoid fever oysters and mussels. Following that occurrence, many disease outbreaks stemming from bacterial and viral contamination were reported around the world (Bishop, 1983).

2.12- Indicators of Water Pollution

The most frequently used indicator organisms for fecal contamination are strains of *Streptococcus feacalis* and *Escherichia coli*. One of their important characteristics is their consistently high densities and exclusive presence in the fecal wastes of man. They do not survive well in water, therefore, their presence indicate recent pollution (Slanetz and Bartley, 1965). Many other microorganisms have been seriously considered as recreational water quality indicators. Bishop (1983) and Orlob (1956) have reported that

microorganisms such as Salmonella, Clostridium perfringens, and fecal coliforms have also been used as useful indicator organisms for fecal contamination.

2.12.1- Escherichia Coli

2.12.1.1- Ecology

Escherichia coli, are types of coliform bacteria which are normal inhabitants of the colon or intestines of warm-blooded animals, humans and birds. Thus, sewage consistently carries large numbers of these microorganisms in a suspension state, in the order of 10 to 100 million coliforms per 100 ml of sewage. *E.coli* are normally not considered to be pathogenic themselves, but are 'indicators' of the presence of sewage contamination. In the marine environment, *E. Coli* bacteria have a short survival time unlike other microorganisms such as *Salmonella*. (Moselio, 1992).

2.12.1.2- General Characteristics

E.coli is a gram-negative, facultative anaerobic, non-spore forming, motile rod. It is one of the most common inhabitants of the intestinal tract and is probably the most familiar to microbiologists. The species belongs to the family Enterobacteriaceae, or enterics, as they are commonly called. As most of enteric bacteria, E.coli, include peritrichous flagella, usually endowed with only four to eight flagella per cell. As typical bacterial flagella, they are composed of a long filament, a hook, and a basal body. Different E.coli strains carry one or two kinds of pili (sex pili), that help them adhere to surfaces of mucous membranes. Specialized sex pili aid in the exchange of genetic information between cells. which often includes antibiotic resistance.

The *Escherichia coli* cell (Figure 3) is composed of a cytoplasmic membrane made up of about 200 different proteins and four kinds of phospholipids. Over 20 proteins are involved in various aspects of peptoglycan biosynthesis, cell wall elongation, and cell division. Approximately half of these proteins, known as the penicillin-binding proteins, may be directly involved in cell wall synthesis. The outer membrane of *E.coli* is covered by a polysaccharide capsule, whereas, the cell wall consists of a peptidoglycan layer responsible for cell shape and rigidity. Most of the biochemical activities necessary for growth occur in the cytoplasm. These activities are divided into those concerned with metabolic fueling such as providing the energy required for cellular maturation. Figure 3 summarizes the structure and cell functions of *E.coli* (Moselio, 1992).

2.12.2- Streptococcus Feacalis

2.12.2.1- Ecology

The fecal *Streptococci* are consistently present in the intestinal tract of the warmblooded animals and they are commonly monitored as an indicator of recent fecal contamination. They do not multiply in water. According to several scientists (Burman, 1961; Hanes and Fragala, 1967), these species have a shorter life span in water than that of *Escherichia coli* and other Enterobacteriaceae, thus making them useful indicator organisms in water subject to remote fecal contamination.
2.12.2.2- General Characteristics

Streptococcus feacalis species, now referred to as Enterococcus feacalis, are classified into Lancefield group D (Rebecca Lancefield was first to initiate research in this area). They belong to the family Streptococcaceae, which also includes the genera Aerococcus, Gemella, Leuconostoc, and Pediococcus. The Enterococci are gram positive, normally considered to be facultatively anaerobic organisms having a preference for anaerobic conditions. Few species are pigmented or motile. Being widely distributed in nature, Enterococci species appear mostly in chains of varying length (Devriese et al., 1989).



Figure-3- Drawing of E. Coli: cell structure

54

f

Chapter 3- Methodology

3.1-The Study Area

The coastal area included in this study stretches from Akkar in the north to Saida in the south, over a distance of 155 km. It comprises almost 70 % of the entire length of the Lebanese coast. Exclusion of the rest of the coastal area was dictated by the prevailing political situation which made it unsafe to work along the entire coast. However, the area covered is considered to be an adequate representation of the Lebanese coastal area, and is therefore able to meet the objectives of this study.

The study area is known to receive pollutants from numerous sources. Some of the major sources include refineries, powerplants and factories for the production of cement (north), fertilizers, plastics and paints (Figure A & B indicate the geographic distribution of industries situated along the coast and the population density). In addition, direct discharges of waste waters and refuse from coastal towns along with pollutants carried by stream and rivers from inland sources are also considered to be of importance in relation to marine pollution. Such conditions would have varying impacts on the marine ecosystem along the Lebanese coast. However, no attempt was made to divide the study area into sub-areas. This was mainly due to the distribution pattern of pollution sources which does not provide a justifiable basis for such an action.



Soure: Khatib & Alami Beirut - Lebanon



leirut	455400.00	19375910.000	235.03
lekan	470511.00	4.1619440+09	1.13
ount Lebenon	1537585.00	51.9864750+09	7.74
Sabatieh	297639.00	1.1015030+09	2.70
forth	883107.00	2.008425e+09	4.40
South	366477.00	9.2987184+08	3.94

3.2- Sample Collection and Preparation

Sea water, sediments and biota are the three components of the marine ecosystem and are in continuous interaction with each other. Marine sediments serve as an important sink or reservoir for dissolved cadmium (Cd) or mercury (Hg) in sea water and therefore play a pivotal role in regulating the concentrations of the above mentioned elements. For example, excess cadmium in sea water is adsorbed on the sediment surfaces and if the sea water is depleted, the adsorbed cadmium may dissolve in order to reestablish an equilibrium. Like cadmium, sediments are the reservoir for mercury. This compound can either be present as a solid phase or adsorbed on marine sediments. Most of the data on cadmium and mercury concentrations in marine sediments are generally collected from industrialized areas. However, higher concentrations can be found in the coastal areas affected by human activities (Boyden, 1975; Katz and Kaplan, 1981). In any metal study, it is important that all three components are analyzed for their metal contents. However, due to financial constraints, only sea water samples will be analyzed in this study for their metal content, namely cadmium and mercury. Cadmium and mercury were selected because, among all heavy metals, they are highly toxic at very low concentrations. The samples of sea water for cadmium analysis were personnally collected, but the fish samples for mercury analysis were purchased at each sampling station.

3.2.1- Collection of Cadmium Samples

From July to September 1994, 125 water samples used for cadmium analysis were collected from 20 locations extending from Akkar (S1) in the north to Saida (S20) in the south. Sea water samples were collected at irregular intervals at 20 sampling stations over all (six replicates per sampling station; Figure 4). The intervals were reduced in the area facing Beirut harbor and the Quarantine (S17), where marine pollution is found to be comparatively higher than in other places. The increased degree of pollution in that specific area is a result of the heavy discharges of domestic refuse.

Using a motor boat, the samples were collected at a distance of about 500 m off the coast and at a depth up to 1 m. Precleaned polyethylene (with polyethylene cap) bottles, were hand-plunged, opened below surface and allowed to be filled at each collection site. An overall average of six samples were collected at each sampling station. After collection, the samples were immediately acidified with concentrated nitric acid (2 ml of HNO3). The addition of acid will lower the pH to nearly 2 but no lower than 1.75, as recommended by ASTM (1973). Samples were then brought to the laboratory and stored in a refrigerated room at approximately 4°C until required for cadmium analysis, in order to prevent any changes in volume due to evaporation.

3.2.2- Collection of Mercury Samples

Over a period of 2 months (August to September), 60 samples of fish were analyzed for their mercury content. Fifteen samples of each of the four local species, *Sparisoma cretense* (Zullaik), *Mugil cephalus* (Bouri), *Epinephelus aeneus* (Loukos Ramli), and *Boops boops* (Ghobous), were purchased along the coast of Mount Lebanon (Kesrouane area- S12 to S15-), immediately after being caught by local fishermen. The fish samples, considered to be representative for the whole coast, were then transported to the laboratory in pre-cleaned plastic bags containing crushed ice for processing.

3.2.3- Collection of Sea Water Samples: Physical Analysis

From August to October 1994, 9 sampling stations were selected to undergo the physical analysis of water (Figure 5). 3 off-shore sampling stations (0.5-1 km from the shore) were located between Tripoli and Jbeil in the north. 3 were located in the near shore stations (near sewer outfalls) covering the area between Kesrouan (Tabarja) and Beirut (Ramlet Al-Baida), and off-shore sampling stations stretched from El-Chouf to Saida in the south (0.5 - 1 km from the coast). One sample of sea water was collected at each sampling station for each parameter. During this period and at the 9 sampling stations, an overall of 36 samples were collected in sterilized bottles made of borosilicate glass and analyzed for the following parameters: salinity, pH, temperature, dissolved oxygen.

3.2.4- Sample Collection: Bacteriological Analysis

Over a period of 3 months (July to September 1994), 128 samples were collected in sterile flasks from 16 sampling stations (S1 - S16 in Figure 6). The sampling design was performed at different areas frequently visited by swimmers and bathers during the summer months. The sampling stations stretch from Akkar in the north to Saida in the south. For each station, sea water samples were collected from near shore (30 m) and at a distance of 500m off shore. Each study site was sampled in duplicate on a basis of 2 samples for each microorganisms. Most of the samples were collected in the morning just below the water surface in the area of greatest bather density. The bottles were placed in plastic cooler containers packed with ice and brought to the laboratory for processing. All experiments were performed within 1 to 2 hours of collection. Samples situated between stations S9 - S13 were collected close to a sewer outfall, while others were sampled from a distance.







Beirut - Lebanon

3.3- Analysis of Sea Water Samples

3.3.1- A- Heavy Metals

3.3.1.1- Preliminary Treatment of Samples

Samples containing particulates or organic materials required pretreatment before analysis. Care was taken not to introduce metals into samples during preliminary treatment, particularly during digestion, in order to prevent any sample contamination. Accordingly, containers and other materials were soaked in HNO₃ and rinsed with deionized water for several days before being used. All reagent-grade acids used for the preservation and digestion were checked for purity.

3.3.1.2- Analysis of Trace Elements: Cadmium (Cd) and Mercury (Hg)

Prior to any analysis of sampled material, the analyst decides what fraction is to be analyzed (dissolved, suspended, total, or acid extractable metals). This decision will determine in part whether the sample is acidified with or without filtration, and the type of digestion needed. SMEWW (1981), defined the following terms:

Dissolved metals: Those constituents (metals) of an unacidified sample that pass through a 0.45 µm Membrane Filtration.

Suspended metals: Those constituents (metals) of an unacidified sample that are retained by a 0.45µm Membrane Filtration

Total metals: The concentrations of metals determined on an unfiltered sample after vigorous digestion, or the sum of the concentrations of metals in both dissolved and suspended fractions.

Acid extractable metals: The concentration of metals in solution after treatment of an unfiltered sample with hot dilute mineral acid.

3.3.1.3- Cadmium Analysis

In order to reduce interference by organic matter and to convert metal associated with particulates to a usually free-metal form which can be determined by atomic absorption spectrometry, the use of a digestion technique is required. This procedure is mainly used when analyzing cadmium in sediments and biota. However, this study is only restricted to the analysis of cadmium concentration in sea water. The extraction method with specific reagents was used in order to bring the concentrations of cadmium samples within the working range of the atomic absorption spectrometry. Determination of low concentrations of cadmium was prepared by chelation with ammonium pyrrolidine dithiocarbamate (ADPC), extraction into methyl isobutyl ketone (MIBK) and aspirated directly into an air-acetylene flame. The concentration method proposed by Lindgren (1975) was used in the present study. According to Lingred (1975), each 100 ml of sea water samples were extracted with 5 ml of 1 % APDC solution, prepared in 10 ml MIBK solvent. The pH was adjusted to 3 with the addition of a mineral acid (HCL) and the solution was then transferred to individual 200 ml volumetric flasks. After addition of the proper volumes of APDC solution and MIBK, samples were shaken vigorously for 3

minutes and let to separate into aqueous and organic layers. Distilled-deionized water was added down the sides of the flask to bring the organic layer into the neck and accessible to the aspiration tube. The organic extracts were directly aspirated into the flame (Zeroing instrument on a water-saturated MIBK blank) and absorbance was then recorded. Standards and blank solution were also prepared using the same procedure. This extraction technique was conducted in order to minimize the slight inefficiencies which might have occurred during sample extraction. Chester and Stoner (1974) discussed other extraction methods also employed for cadmium determination by the atomic absorption spectrometry such as using different chelating resins.

3.3.1.4- Mercury Analysis

There is limited data available on the distribution and determination of mercury in the aquatic environment. However, several studies conducted in Lebanon have discussed the various analytical techniques for mercury determination. The most commonly used method for determining total mercury in fish and sea water samples is cold vapor atomic absorption spectrometry. This method involves sample digestion with strong acids followed by reduction to elemental mercury, aeration and measurement of mercury absorption. Other methods include colorimetric techniques and atomic absorption spectrometry (Shiber et al. 1978). The levels of mercury in sea water is extremely low and its accurate determination is still a major problem. The analytical procedure applied to fish samples for the determination of total mercury was adopted by the FAO Research Center, Lebanon. It is generally known that almost all fish contain at least trace amounts

of mercury mainly in the form of methylmercury. So far, research has focused on how the methylmercury is accumulated in biota and where it comes from (Grieb et al., 1990; Bloom, 1992). Total mercury levels in various sea water samples has also been reported by many countries (Shiber et al. 1978).

For the accurate analysis of total mercury, complete digestion of organic materials in the sample is essential. The choice of digestion method is still largely a matter of personal preferences. In the present study, a sulphuric acid and peroxide digestion was used (FAO, Research Center, Lebanon). A fish sample of known weight, between 0.2 to 1 g was mixed with 3 ml of H_2SO_4 in 0.2 ml of H_2O_2 and digested for 1 - 2 hours in a bath heated at 95°C until the appearance of a clear solution. This wet oxidation step at this specific temperature has converted all mercury to the mercuric ion. The mixture was then treated with 2 ml KMnO₄ and allowed to cool for 24 hours. Afterwards, 10 % of hydroxylamine solution was added to reduce the excess KMnO₄. The sample was then directly subjected to the atomic absorption spectrometry and the readings were recorded at 253.7 nm. A series of standards and blanks of mercury solutions were prepared in an identical manner as the samples.

3.3.1.5- Equipment and Reagent Used

In the present study, cadmium and mercury content in water samples were determined using the atomic absorption spectrometry (AAS) model 210VGP. This method is the most widely used because of its relative simplicity, speed and sensitivity. The detection limit of the instrument (AAS) is 0.002 ppm for cadmium (range from 0.2 to 1.8 ppm), and 0.1 ppm for mercury (range from 73 to 290).

All the experiments were conducted in a clean environment. Extreme precautions were taken to avoid any contamination of the samples of sea water before, during and after the analysis. Free mercury reagents, used during the analysis were supplied by Merck and Biolab.

3.3.2- B- Indicator Microorganisms

The microbiological experiments were conducted to assess the relative safety of bathing and swimming beaches along the coast of Lebanon. For this purpose, *Streptococcus feacalis* and *E.coli* were analyzed over a period of 3 months (July to September 1994) since these two microorganisms are used routinely to check the pollution level of waters (APHA, 1992: Bordner and Winter, 1985). The Lebanese coastal waters have been for centuries the recipients of most of the refuse of human society. This includes not only industrial wastes but also enormous quantities of domestic sewage and animal wastes. Hence, the reason for detecting *E.coli* and *Streptococcus feacalis* is that the presence of these two microorganisms in water is a sure indication of contamination by human or animal feces. Epidemiological investigations reported by Matossian (1984) on sea water quality show a correlation between public health risk and a high level of fecal contamination from indicators such as *E.coli* and *Enterococci*. According to Matossian (1994), the sea water contains sufficient nutrient materials to provide a satisfactory medium for the growth and multiplication of a large

number of fecal coliforms and pathogenic bacteria that are of concern to the public health. The presence of these microorganisms results from the heavy loading of untreated or partially treated municipal sewage.

Microbiological investigations of sea water samples undertaken on an international scale show that genito-urinary infections such as cystitis and conjunctival infections are mainly caused by *E.coli*, *Staphylococcus* and other pathogenic bacteria (Matossian, 1984). The occurrence of bacteria and hepatitis A virus in swimming waters has been occasionally associated with human outbreaks of illness (Winslow and Moxon 1928). Gastroenteritis outbreaks causing enteric fever, vomiting, diarrhea, associated with swimming in polluted marine waters were also discussed by Cabelli et al. (1982).

3.3.2.1- Bacteriological Analysis

Fecal coliform analysis is a more definitive test for recent fecal pollution since these microorganisms do not survive long in water. Several techniques were used for determining coliforms in water. However, counts of fecal coliform bacterial were determined using the membrane filter technique. This method is highly reproducible, precise, and can be used to test relatively large volumes of samples in approximately 24 hours, as compared to other methods such as the standard fermentation tube method. The use of the membrane filter technique (MF) has been approved by the National training center of the U.S Environmental Protection Agency (EPA, 1977).

Fecal coliforms (E. Coli) and fecal streptococci (Streptococcus feacalis) counts were determined using the membrane filtration technique. All sterilized membranes used for

the bacterial counts had a pore size of 0.45µm and a white gridd for counting (ASTM, 1979). Different volumes of water samples were used depending on the pollution present. The water samples were filtered through the sterile membrane, and the membrane filter was immediately removed, using flame sterilized forceps, and transfered directly to a selective agar medium in petri dish. Petri dishes were incubated up side down and in plastic bags to prevent drying out.

For *(E.coli)*, petri dishes containing mFC agar medium were incubated for 24 hours at $44.5^{\circ}C \pm 0.2$. This higher incubation temperature used with mFC allows solely coliforms of fecal origin to grow into visible colonies and prevents the growth of non-fecal coliforms. As the fecal coliforms grow at this temperature, they ferment lactose present in the medium producing acid which reacts with the aniline dye to produce a blue color (Figure 7). For *(Streptococcus feacalis)*, petri dishes containing KF agar medium were incubated for 48 hours at $35^{\circ}C \pm 0.5$. The KF medium is selective for fecal streptococcus colonies and colours the colonies dark red to pink. However, few non-fecal streptococcus colonies were observed.



Fecal Coliform

Figure 7: Fecal coliform culture (E. Coli) on m-FC media

3.3.3- Physical Analysis

3.3.3.1- Dissolved Oxygen (DO)

Aquatic environments are dominated by the liquid phase. And, the only oxygen available is that which can be dissolved in water. In oceans, organic matter from the surface can sink to great depths, creating nutrient-rich zones where microorganisms can quickly use the dissolved oxygen, creating anaerobic conditions. Hence, biological decomposition of organic substances takes place (Tortora et al, 1989).

Dissolved oxygen in waters depends on the physical, chemical, and biochemical activities in water body. The analysis of dissolved oxygen is the key test in water pollution control (Grasshoff, 1976).

The Hach model 160 46 portable (DO) meter was used to measure DO in water at the laboratory as well as in the field. The instrument uses an electrode, oxygen sensor, that can measure the DO in the ranges of 0-10 and 0-20 mg/l. The DO probe method is desirable when testing polluted, turbid, or colored water. However, for sea water analysis, the sensitivity of the electrode varies with the salt content of the test solution. As a result it is necessary to know the salt concentration for a given temperature and atmospheric pressure in order to accurately measure the (DO) content.

The samples brought to the lab, were stored at -4°C for 24 hours. During the analytical process, the temperature was set to 21°C under atmospheric pressure (760 mmHg = 1 atm). Readings were taken in mg/L, after calibrating the sensor.

3.3.3.2- Salinity, Temperature and pH

Temperature and pH readings were taken by a portable pH meter. The model 3150 portable pH meter is designed with an incorporated sensor unit to provide a direct readout of temperature in °C. The salt concentration in the sea water samples was measured using a Beckman salinometer.

3.3.4- Statistical Analysis

The statistical analysis was the mean average and the standard deviation were calculated for each experiment. Physical and chemical results were expressed in mg/L, μ g/L and mg/Kg.

Chapter 4- Results and Discussion

The recreational water quality along the coast of Lebanon was studied. The corresponding detailed data are presented in Appendices A to E. Physical, chemical, and microbiological analysis were conducted in relation to the sampling locations stretching from Akkar (in the north) to Saida (in the south), a distance of about 155 Km.

4.1- Cadmium

Cadmium content in sea water along the Lebanese coast ranged between 0.21 to 1.96 $\mu g/L$ with an overall mean value of 0.7694 \pm 0.0470 $\mu g/L$, from August to September 1994 (Table 4.1.1). The corresponding detailed data are given in the Appendix A. Moreover, these results agreed with those of previous studies. Cadmium concentrations ranging from 0.94 µg/L and 1µg/L respectively were found in coastal waters of the Eastern Mediterranean basin of Haifa, Israel (Roth and Hornung, 1977), and Alexandria, Egypt (Ibragim and Patin, 1976). In contrast, various regions of the Western Mediterranean basin such as 'La spezia gulf waters (Italy)', Ligurian sea, in addition to coastal waters in France, have reported distinctly lower results ranging from 0.1 - 0.6 µg/L (Capelli et al., 1978; Frache et al., 1974; Benon et al., 1978). However, the cadmium content of the Northwestern region of the Mediterranean were found to be of 0.23µg/L and 0.77µg/L respectively (Fukai and Huynh, 1976). Limited data on cadmium levels along the Lebanese coast were available. Shiber (1979) has pointed out that the cadmium concentration in most of the samples collected from the coast of Ras Beirut (Lebanon) in the summer and fall of 1977 and the spring of 1978, was very high. The mean cadmium concentration in sea water was found to be 30µg/L. However, in the

present study, the highest values of cadmium content in sea water were only found in samples a few collected from certain sampling stations (table 4.1.2).

Location	Station	Industry	[Cd]µg/L
			Mean	Std.dev
Tripoli	S3-S4	Oil Refineries	1.90	0.052
Chekka	S5	Cement Industry	1.83	0.065
Kaslik	S13	Metal Industry	0.79	0.046
Beirut	S16	Ni-Cd battery factory	1.19	0.213
R.A.B*	S17	Paint factory	1.77	0.056

Table 4.1.2- Highest Cadmium levels along the Lebanese coast.

* Ramlet Al-Bayda (Khalde)

Samples collected from most stations had distinctly lower values of cadmium concentrations ranging from 0.2 to 0.5μ g/L. The stations with high Cadmium levels (S3, S4, S5, S13, S16, S17) are all located close to an industrial zone. The cadmium- level profiles lead to the conclusion that the contamination of the seashore is primarily attributed to the discharge of industrial effluents from the city's many factories .Table 4.1.3 summarizes the factories that are prime contributors of cadmium in the aquatic system, in addition to the oily wastes from the tapline oil terminal and refinery. The high levels of such contaminants could also originate from the discharges of municipal waste water from Kaslik, Beirut and suburbs (S13, S16 and S17), as well as from river discharges and stormwater runoff. Water pollutants could find their way into the sea either through direct waste disposal of these industries located on the coast, or from the atmosphere. It should be noted that for each station, these samples were

collected at 500 m from the shore. One could assume that higher results, particularly in the neighbourhood of waste discharge, are obtained. Nevertheless, a relative low cadmium profile occurs in the regions extending between El-Batroun and Tabarja (S7-S12) and between Chouf and Saida (S18- S20). Apparently, these locations lack significant industrial waste water discharges.

According to the E O A (1977), the degree of cadmium contamination is classified into three categories:

Category 1- Non polluted sea water = $0.01-0.1 \ \mu g/L$

Category 2- Sea water undergoing pollution = $0.1 - 0.5 \mu g/L$

Category 3- Polluted sea water = $0.5 - 2.5 \mu g/L$.

In confirmation to these categories, the Lebanese recreational water analyzed for cadmium content and holding a mean of 0.7694 μ g/L, can therefore be classified into the third category depicting a progressive state of water pollution.

			[Cd]	ug/L
Date	Station	Location	Mean	Std.dev
July	S1	Akkar	0.42	0.036
July	S2	Akkar	0.54	0.129
July	S3	Tripoli	1.83	0.129
July	S4	Tripoli	1.90	0.052
July	S5	Chekka	1.83	0.065
July	S6	El- koura	0.53	0.112
July	S7	El-Batroun	0.40	0.034
August	S8	Aamchit	0.36	0.044
August	S9	Jbeil	0.46	0.039
August	S10	Bouar	0.39	0.032
August	S11	Safra	0.40	0.036
August	S12	Tabarja	0.37	0.035
August	S13	Kaslik	0.79	0.046
August	S14	Jounieh	0.56	0.037
September	S15	Antelias	0.49	0.040
September	S16	Beirut	1.19	0.214
September	S17	Ramlet Al-Bayda	1.77	0.056
September	S18	Chouf	0.44	0.035
September	S19	Saida	0.48	0.065

Table 4.1.1- Cadmium levels in Lebanon's coastal waters

Note: 125 samples were collected at each sampling station and over a distance of 0.5 to 1 Km.

Table 4.1.3 Major industries located on the coast

Location	Production	Cadmium level (ug/L)
Chekka	Cement factory/Food indutries	1.83 (0.129)
Selaata	Phosphate fertilizer factory	0.52 (0.111)
Dora	Nickel-Cadmium battery factory	1.19 (0.213)
Tripoli	Soap and perfumeries factory	1.89 (0.052)
Khalde	Paint factory	1.77 (0.056)
Jounieh	metal factory	0.56 (0.036)

4.2- Mercury

Mercury concentrations along the coast of Lebanon are summarized in Table 4.2. The mean values and standard deviations for total mercury content of the edible muscle tissues for each of the 4 species of fish are also included. Mercury levels are an average of August and September of 1994. The corresponding detailed data are given in the appendix (B). The results of this study showed that the mercury content of the edible muscle tissues range between 0.02 mg/Kg to 0.102 mg/Kg with an overall mean value of 0.0606 ± 0.0130 mg/Kg (wet weight).

Species		No. of	Wei	ight a	Len	gth ь
		Samples	Mean	Std.dev	Mean	Std.dev
Sparisoma creten (Zullaik)	se	15	69.65	10.493	13.1	1.172
<i>Mugil cephalus</i> (Bouri)		15	98.95	10.073	20.01	1.858
<i>Boops boops</i> (Ghoubous)	15	37.23	12.525	13.47	1.496
Epinephelus aene (Loukous Ramli	eus)	15	297.54	158.861	22.4	2.582
a : Weight in (gm) b : Length in (cm) c: wet weight	Total Std.dev	125.84 117.208	17.25 4.680			0.06 0.013

Table 4.2- Mean values for weight, length, and total mercury in

81

General results obtained showed that the reported values for mercury are below the accepted tolerance limit of 0.5 mg/Kg (PAHO, 1973). A careful study of the results reveal some indication that the mercury content of the muscle tissues varies widely with fish species. Many investigators described a relationship between mercury levels and body weight, length or age (Suzuki et al,. 1973; Barber et al,.1972; Friberg and Vostal, 1972; Bache et al,.1971). This is in conformity with the findings of the present study that the low mercury levels may be attributed to the small size of the collected samples.

In addition, comparative results show that the edible fish from the Lebanese coastal waters are, at present, less contaminated with mercury than those from the European countries of the Mediterranean sea. Caviglia and Cugurra (1978) reported higher values of mercury in 365 samples of marine fish and molluscs from the Ligurian sea. The mean value obtained with 53 species was 0.201 mg/kg (wet weight). Similarly, high concentrations of mercury ranging from 0.222 to 0.297 mg/kg (wet weight) were found in some fish species from the Adriatic sea (Buggiani and Vannuchi, 1980; Carracciolo et al., 1974). In any case, the Mediterranean sea is known to be more highly polluted by human wastes. The continuous discharge of pollutants into the sea would become increasingly augmented in some areas as they are tranported by the current which picks up more pollutants along its path. The distributions of these nutrients are significantly influenced by hydrological and meteorological conditions (Kibar and Sokolov, 1988). This would probably have yielded higher concentrations indicating a serious risk to health.

4.3- Fecal coliforms

Fecal coliforms (*E.coli* and *Streptococcus*) determined in the present study are summarized in tables 4.3.1 and 4.3.2 along with average means and standard deviations. The corresponding detailed data are given in the appendix C and D. Microbiological analysis are the average for July, August and September of 1994.

The results of this study revealed that fecal coliforms along the coast of Lebanon ranged from 50 to more than 500 colonies per 100ml of sea water sample for *E.coli* with an overall mean value of 172 ± 110.3996 (near shore or at 30m) and 137 ± 99.1021 (offshore or at 500 m), respectively. However, *Streptococcus feacalis* along the coast ranged from 47 to more than 500 colonies per 100 ml with an overall mean value of 173 \pm 115.1517 (near shore or at 30m) and 124 \pm 88.1695 (off shore or at 500m) respectively.

Most of the reported results did not exceed the limits recommended by WHO/UNEP (1977) on safety of swimming in recreational sea water. Approximately 50 % of the sampling stations (S1, S2, S5, S6, S9 and S16) showed satisfactory results (<100 colonies/100 ml). Sampling stations extending from S12 to S14 indicate an unsatisfactory water quality. The high counts of fecal coliforms (over 500 colonies/100ml) reveal a poor quality and a public health hazards to swimmers and fishermen . These values exceed the limits approved by WHO/UNEP (1977) recommendations that "highly satisfactory bathing areas should show *E. Coli* counts of consistently less than 100 per 100ml, and to be considered acceptable no more than 10 %

of the samples during the bathing season should exceed 1000 *E.coli* per 100 ml". Values ranging between 100 and 500 fecal coliforms per 100 ml represent a low risk.

If appropriate protective measures are not taken, these values will probably increase causing detrimental effects on the marine environment. It appears that an overall mean value of 160 colonies/100 ml obtained in this study is moderately high. This results from the fact that the sampling stations S3, S4, S11 and S15 are subjected to a heavy flow of municipal waste water, being close to a sewer outfall from an area subjected to the sudden influx of people (50 persons /year /100 m of coastal distance) (Kouyoumjian and and Belian 1985). Another observation that deserves attention relates to the high levels of fecal coliforms in the regions of Antelias. Dora, and Ramlet Al-Bayda (S12, S13, S14) because the sewage discharged in these areas were sewage and is not readily purged out of the area.

Comparison between the 30 and 500 m off shore results indicate that the near shore waters are more subject to microbial contamination. Yet, identical results were observed for the sampling stations S12, S13, S14 for both the 30 and 500 m off - shore sampling sites. The constant discharge of untreated sewage as well as industrial and agricultural wastes presents the most serious health hazard to swimmers, bathers and fishermen. In the light of the results in the present study, tables 4.3.3 and 4.3.4 summarize the microbial standards for bathing beaches in Lebanon. In any case, the results obtained are acceptable in the sense that they closely represent the conditions of the recreational water quality.

Date	Station	ation Location		Coliform counts (CFU/100ml)			
·			Near s	hore (30m)	Off sh	ore (500m)	
			Mean	Std.dev	Mean	Std.dev	
July	S1	Akkar	90	2.828	80	2.828	
July	S2	Akkar	100	2.828	82	2.828	
July	S3	Tripoli	434	5.657	383	4.243	
July	S4	Chekka	187	4.243	165	2.828	
July	S5	El-koura	76	2.828	66	2.828	
August	S6	El-Batroun	85	1.414	61	4.243	
August	S7	Jbeil	107	7.071	96	2.828	
August	S 8	Aamchit	121	4.243	97	1.414	
August	S 9	Safra	97	1.414	61	4,243	
August	S10	Tabaria	122	2,828	109	4.243	
August	S11	Kaslik	354	2.828	301	4.243	
September	S12	Antelias	>500		>500		
September	S13	Dora	>500		>500		
September	S14	R.AI.B*	>500		>500		
September	S15	Khalde	235	4 243	162	2 828	
September	S16	Saida	76	2 828	50	2.020	
		Total	160.21		424 77	2.020	
			100.31		131.//		
		Std.dev	114.399		101.228		

Table 4.3.1- Number of Fecal coliforms (*E.coli*)in the
recreational
waters of the sixteen study beaches.

*: Ramlet Al-Bayda

Date	Station	Location			Coliform counts (C	FU/100ml)
			Near shore (30m)		Off sho	re (500m)
		-	Mean	Std.dev	Mean	Std.dev
July	S1	Akkar	76	2.828	39	4.243
July	S2	Akkar	89	1.414	45	4.243
July	S3	Tripoli	335	4.243	254	2.828
July	S4	Chekka	289	4.243	184	2.828
July	S5	El-koura	50	2.828	34	2.828
August	S6	El-Batroun	50	2.828	35	1.414
August	S7	Jbeil	126	2.828	98	2.828
August	S8	Aamchit	116	2.828	85	1.414
August	S9	Safra	99	1.414	67	1.414
August	S10	Tabarja	119	1.414	86	2.828
August	S11	Kaslik	423	4.243	322	2.828
September	S12	Antelias	>500		>500	
September	S13	Dora	>500		>500	
September	S14	R.AI.B*	>500		>500	
September	S15	Khalde	245	1.414	190	2.828
September	S16	Saida	74	2.828	47	1.414
		Total	160.85		114.31	
		Std.dev	121.050		93.606	

Table 4.3.2- Number of Fecal coliforms(Streptococcus Feacalis)in the recreational waters of the sixteen study beaches.

*: Ramlet Al-Bayda

			E.coli	** CFU/100 mi	
Location	Station	Suitabilitya for bathing	Satisfactory FC<100	Low risk 100 <fc<500< th=""><th>High risk FC>500</th></fc<500<>	High risk FC>500
El-Koura	S5	Suitable	76		
Saida	S16	Suitable	76		
El-Batroun	S6	Suitable	85		
Akkar	S1	Suitable	90		
Safra	S9	Suitable	97		
Akkar	S2	Suitable	100		
Jbeil	S7	Suitable		107	
Aamchit	S8	Suitable		121	
Tabaria	S10	Suitable		122	
Chekka	S4	Suitable		187	
Khalde	S15	Suitable		235	
Kaslik	S11	Suitable		354	
Tripoli	S3	Suitable		434	
Antelias	S12	Unsuitable			>500
Dora	S13	Unsuitable			>500
R.A.B*	S14	Unsuitable			>500

Table 4.3.3 - Microbial standards for bathing beaches in Lebanon

al based on bacterial standards for marine waters in the state of Maine (USA)

*: Ramlet Al-Bayda

**: 30m from seashore

			Streptococcus feacalis * CFU/100ml			
Location	Station	Suitabilitya for bathing	Satisfactory FC<100	Low risk 100 <fc<500< th=""><th>High risk FC>500</th></fc<500<>	High risk FC>500	
El-Koura	S5	Suitable	50			
El-Batroun	S6	Suitable	50			
Saida	S16	Suitable	74			
Akkar	S1	Suitable	76			
Akkar	S2	Suitable	89			
Safra	S9	Suitable	98			
Aamchit	S8	Suitable		116		
Tabaria	S10	Suitable		119		
Jbeil	S7	Suitable		126		
Khalde	S15	Suitable		245		
Chekka	S4	Suitable		289		
Tripoli	S3	Suitable		335		
Kaslik	S11	Suitable		423 **		
Antelias	S12	Unsuitable			>500	
Dora	S13	Unsuitable			>500	
R.A.B	S14	Unsuitable			>500	

Table 4.3.4 - Microbial standards for bathing beaches in Lebanon

a based on bacterial standards for marine waters in the state of Maine (USA)

* 30m from seashore

** Undergoing progressive pollution
4.4 - Physical Parameters

Variation of concentrations along with the average mean and standard deviations of each measured parameter are summarized in table 4.4. The corresponding detailed data are given in the appendix (E).

	Date	Station	Salinity (ppt)	рН	DO (mg/L)	Temp. deg.C
Mean	Aug-Sep	S1-S9*	38.78	7.98	4.03	27.9
Std.dev			0.187	0.179	1.284	0.579

Table 4.4- Physical parameters: Variation of concentrations in sampling stations

*: The corresponding detailed data are given in the appendix (E)

4.4.1- Dissolved Oxygen

The results of this experiment revealed that the oxygen content in sea water along the coast of Lebanon ranged from 1.7 - 5.2 mg/L with an overall mean value of 4.0333 \pm 0.1787. These samples were collected at 0.5 to 1 km off the shore. One can assume that samples collected near shore, particularly close to a sewer outfall, might probably have vielded lower oxygen concentrations. The highest mean value of dissolved oxygen (5.2 mg/L) was found in stations S2 (north) and S9 (south) away from sewer outfall, whereas the lower value (1.7 - 2.2 mg/L) was found in stations S5 and S6 in the coastal water outside Beirut harbour and the Quarantine area (Bourj-Hammoud/Dora). The water within this area itself is known to be more highly polluted by human wastes than any other area along the coast. Low dissolved oxygen levels in water, is an indication that microorganisms are using oxygen more rapidly that it can be replenished because of the presence of organic matter. This results in cyclic changes in dissolved oxygen or even in the complete depletion of oxygen. Lakkis and Zeidane (1987) have pointed out that the low concentrations of dissolved oxygen reveal the presence of high concentration of organic matters and of pollution. If nutrients are available, microorganisms can quickly use the dissolved oxygen creating anaerobic conditions.

4.4.2- Salinity, Temperature and pH

The salinity values found in this study show an overall mean of 38.7791 ± 0.1873 . Temperature and pH represent an overall mean of 27.9 ± 0.5788 and 7.9778 ± 0.1783 , respectively. The coastal water of Lebanon is typically characterized by high temperatures and salinity during August and September. However, low salinity and pH values were reported during winter and early spring (Kouyoumjian, 1985). Many investigators have studied the effect of salinity on the toxicity of metals. CEPA (1994), Rainbow (1990) and Mance (1987) have pointed out that cadmium is more toxic to aquatic organisms at low pH and salinity. It appears that salinity has a major effect on microbial counts. Malychef (1994) found no linear correlation between salinity and the number of fecal coliforms in Antelias (Beirut).

Chapter 5- Conclusion

A study was undertaken to investigate the recreational water quality along the coast of Lebanon. Samples were collected along a coastal area stretching from Akkar in the north to Saida in the south, thus covering a distance of about 155 Km.

The analysis was divided into three categories:

Physical (Dissolved oxygen, Salinity, Temperature and pH)

Chemical (Cadmium and Mercury)

Biological (Fecal coliforms - E.coli and Streptococcus feacalis)

For each sampling session, 16 to 20 sampling stations were established for the sample collection throughout the summer of 1994. Samples were collected near shore close to a sewer outfall and dumping sites as well as off shore at a distance of 0.5 - 1 Km away from any sewer outfall. These regions are assumed to be highly contaminated by marine pollutants finding their routes into the aquatic system.

The entire analysis was performed and reported according to North American and European standards. The data was used to describe the situation of the marine environment and to classify the degree of contamination within Lebanese coastal waters.

From the data obtained, several conclusions can be drawn:

1- On the basis of the classification established, cadmium content in sea water exceeded the limits, with an overall mean of 0.7694 μ g/L ± 0.0470, as recommended by the European Oceanic Association (EOA). The Lebanese coast is therefore undergoing progressive pollution and corrective actions are necessary.

2- The mercury level in fish was found to hold an overall mean value of 0.0606 ± 0.0130 , has met the international standard (tolerance limit 0.5 mg/kg). The marine fish caught along the coast are considered safe for human consumption from the standpoint of mercury contamination.

3- Sea water samples were subjected to bacteriological examination. For this purpose, fecal coliform (*E*.coli) and fecal streptococci (*Streptococcus feacalis*) were monitored, since these two groups of bacteria are considered to be the best single indicators of marine pollution. The bacterial water quality in most of the regions showed satisfactory results. The overall mean value for *E.coli* was found to be 160 colonies/100ml \pm 114.3981 close to the shores and 132 \pm 101.2584 away from the shore. Whereas, 160 \pm 121.0502 and 114 \pm 93.6059 colonies of *Streptococcus feacalis* were detected respectively. The continuous dumping of wastes into the sea will pose a major public health concern by increasing the number of fecal coliforms and other pathogenic bacteria. It will also be detrimental to marine life.

4- The high concentration of organic matter resulting from sewage disposal into the sea is a good indication of oxygen depletion. Rapid depletion of dissolved oxygen can occur when nutrients contaminate the water and often leads to the massive development of microbial groups. The lebanon shore waters were found to have a low concentrations of dissolved oxygen (1.7-2.2 mg/l) which indicates a high load of organic matter resulting from the continuous flow of sewage.

5.1- Recommendations

1- More safety controls and regulations on environmental pollutants should be enforced to maintain their concentrations below the limit, so that there are no adverse effect on organisms except in the case of rare accidental releases.

2- The implementation of a proper monitoring program to evaluate the level of mercury in the marine environment is required as soon as possible. Additional measurements are needed to make more general conclusions about trace metal contamination.

3- There is a great need to establish a national plan for the control and monitoring of industrial and municipal waste discharges into the environment taking into account regional and interregional linkages. This would obviously minimize contamination of the seashore.

4- There is a need for a properly funded marine research center involving the use of appropriate methods for sampling and analysis, which should be universally accepted in order to evaluate and classify the existing sources of pollutants in respect to their potentiality for toxicity.

6- References

- Abi Saab, M., and Atallah, A., 1996: Impact de plusieurs sources de pollution sur les populations microplanctoniques des eaux cotieres de Batroun. Centre de Recherches Marines, Conseil National de la Recherche Scientifiques, Beyrouth, Liban.Vol. I, No.1,(1)
- Ades, A.E., and G. Kazantzis, 1988: "Lung cancer in a Non-ferrous Smelter: The role of cadmium", Brit. J. Ind. Med., 45: 435-442.
- Ahmad M.I, 1971: Marine pollution by oil and municipal wastes along the coast of Lebanon 239 pp M.S. Thesis American University of Beirut
- APCL, 1994: Association de la protection du consommateur Libanais. Personal communication. Dr Abi Nader, M. Dr Malychef, P. Beirut, Lebanon
- APHA, 1992: Compendium of methods for the microbiological examination of foods. Compiled by the American Public Health Association's Technical committee on microbiological methods for foods; Vanderzant, D. F. Splittstoesser ed. 3rd. Ed. Washigton D.C.
- Aston, S.R., 1972: Distribution of cadmium in norht Atlantic deep sea sediments, Nature 239, pp 393-395.
- Ayoub, G. Akra, A. 1978: American University of Beirut. Department of Civil Enginnering "The state of solid waste in Lebanon". Personal communication
- Argo, D.G., 1972: Heavy metals removal in waste water treatment processess. Part I water and sewage works. Water and sewage Works magazine. 119:62-65
- ASTM, 1973: Annual book of ASTM standards. Part 23- water; atmospheric analysis, American Society for Testing Materials, Philadelphia, Pa, p346.
- ASTM, 1979: "Tentative Method for Evaluating Water Testing Membrane Filters forFecal Coliform Recovery". American Society for Testing Material Standard. D 3508-76T. Washington, D.C.
- Bache, C.A., Gutenmann, W.H., and Lish, D.J., 1971: Residues of total mercury and methylmercuric salts in lake trout as a function of age. Sci., 172: 951-952.
- Barber, R.T., Vijayakumar, A., and Cross, F.A., 1972: Mercury concentrations in recent and ninety-year-old benthopelagic fish. Sci., 178: 636-639

- Benon, P., Blanc, F., Bourgade, B., David, P., Kantin, R., Leveau, M., Romano, J.C., and Santiot, D., 1978: Distribution of some heavy metals in the Gulf. Mar. Poll. Bull. 9: 71-75
- Bishop, P.L., 1983: Marine pollution and its control. Mc Graw Hill series, in water resources and Environmental Engineering. NY.U.S.A., pp 59-79.
- Bloom, N.S., 1992: On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 46: 1131-1140.
- Bordner, R., and Winter, J., (eds) 1985: Microbiological methods for monitoring the environment. EPA 600/ 8-78-017. Washington, D.C. USA
- Boutin, C. 1987: Domestic waste water treatment in tanks planted with rooted mycrophytes: Case study; description of the system; design criteria; and efficiency. Wat. Sci. Tech. 19: 29-40.
- Boyden, C.R., 1975: Distribution of some trace elements in Poole Harbour, Dorset. Mar. Poll. Bull. 6:180-187
- Brooks, R.R., 1978: Pollution through trace elements In: Environmental chemistry. J. O'M.(ed.) Bockris. Plenum Press.429-476 pp. N.Y. U.S.A
- Buggiani, S.S., and Vannuchi, C., 1980: Mercury and lead concentrations in some species of fish from the Tuscan coast (Italy). Environ. Contam. Toxicol. Bull., 25: 90-92
- Burman, N.P., 1961: Some observations on coli-aerogenes bacteria and streptococci in water. J. Appl. Bacteriol. 24: 368-376
- Chen, K.Y., Young, C.S., and Rohatji, N., 1974: trace element in waste water effluents. J. Water Poll. Contr. Fed. 46:2663-2675
- Cabelli, V.J., Dufour, A.P., Mc Cabe, L.J., and Levin, M.A., 1982: Swimming- associated gastroenteritis and water quality. Am. J. Epidem., 115: 606.
- Capelli, R., Contardi, V., Fassone, B., and Zanicchi, G., 1978: Heavy metals in mussels (*Mytillus galloprovincialis*) from the Gulf of La spezia, and from the promontory of portofino, Italy. Mar. Chem. 6:179-185.
- Carracciolo, S., di Silvestro, C., and Cieri, B., 1974: Total mercury content of some species of fish and shellfish taken from central Adriatic sea off the Abruzzi coast. I- Resultsof experiments effected during 1974. Atti. Soc. Ital. Sci. Vet., 28: 668-672
- Caviglia, A., and Cuggurra, F. 1978: Further studies on the mercury contents in some species of marine fish and molluscs. Environ. Contam. Toxicol. Bull., 19: 528-537

- CDR 1994: "Conseil du development et de la construction "- Beirut- Liban. Personal communication.
- CEPA, 1994: Cadmium and its compounds. Government of Canada, Canadian Environmental Protection Agency. Ministry of Health and Welfare .pp, 5-47
- Chen, K.Y., Young, C.S., and Rohatgi, N., 1974: Trace element in waste water effluents. J.Water.Poll.Contr.Fed. 46:2663-2675
- Chester, R., and Stoner, J.H., 1974: The distribution of zinc, nickel, magnesium, cadmium, iron, in some surface waters from the world ocean. Mar. Chem. 2: 17-32
- Cooper, P.F., J.A. Hobson, and S.Jones 1989: Sewage treatment by reed bed systems J. IWEM. 3: 60-74.
- Dalu, R. 1978: Evaluation of waste water treatment plants in Lebanon. Master of science thesis. Faculty of Engineering and Architecture. American University of Beirut, Lebanon, pp. 131
- Devriese, L.A., Collins, M.D., and Wirth, R., 1989: "The Genus Enterococcus". The Prokarytes second ed. A handbook on the biology of bacteria: Ecophysiology, Isolation, Identification, Applications. Vol. II, Springer-Verlag, NY, Inc., pp. 1465-1477.

Doudoroff, P., and Katz, M., 1953: Sewage Indust. Wastes, 25:802-839.

Drever, J.I., 1982: The geochemistry of Natural waters. Printice-Hall, Englewood Cliffs, New Jersey., p 239.

Emery, K.O., and George, C.J., 1963: The shores of Lebanon, Beirut, Catholic Press.,

- Egawa, H., Kuroda, T., and Shiraishi, N., 1982: Determination of the trace amount of "methylmercury" in sea water using chelating resins. Nippon kagaku kaishi 4:685-691
- EOA (European Oceanic Association) 1977: Metallic effluents of industrial origin in the marine environment. Graham and Trotman Ltd. 216 pp. London.
- EPA, 1988: Constructed wetlands and aquatic plant systems for municipal waste water treatment. Report 625/1-88/022. Environmental Protection Agency, Cincinnati, Ohio. USA.
- EPA, 1977: Manual for the Interim Certification of Laboratories Involved in Analyzing Public Drinking Water Supplies: Criteria and Procedures. Prepared by the Water Supply Quality Assurance Work Group, Environmental Protection Agency, Washington, D.C. 20460.

FAO, 1971 An International problems for fisheries. FAO, Rome. 49 pp.

- Fawaz, M., and H. Mallat. 1992: L'etat et la gestion de l'environment au Liban. UNDP LEB/90/ENV/DSS.
- Fennema, O.R., 1985: Food Chemistry. Marcell Dekker, Inc. N.Y. USA
- Fergusson, J.E., 1990: The Heavy Elements. Chemistry, Environmental Impact and Health Effects. Pergamon Press, Oxford
- Fleischer, M., Sarofim, A.F., Fassett, D.W., Hammond, P., Shacklette, H.T., Nisbet, I.C.T., and Esptein, S., 1970: Environmental impact of cadmium: a review by the panel on. Hazardous Trace Substances. Environ. Health Perspect. 7: 253-317
- Frache, R., Baffi, F., Dadone, A., and Zanicchi, G., 1974: The determination of heavy metals in the Ligurian sea. I- The distribution of Cu, Co, Ni, and Cd in surface waters. Mar. Chem. 4: 365-375
- Freedman, B., 1989: Evironmental ecology. The Impacts of Pollution and Other Stresses on Ecosystem Structure and Function. Academic Press, San Diego
- Friberg, L., and Vostal, J. 1972: Mercury in the environment. An epidemiological and toxicological appraisal. Chemical Rubber Co, Cleveland, Ohio, pp 211-215
- Friberg, L., Picator, M., Nordberg, G.F., and Kjellstrom, T., 1976: Cadmium in the environment, Cleveland, OH: CRC Press, Inc. 248 pp.
- Fukai, R., and Huynh, L., 1976: Copper, Zinc, and Cadmium in the coastal waters of the N.W. Mediterranean. Mar. Poll. Bull. 7: 9-13
- Gerges, M.A. 1976: The Damming of the Nile and its effects on the hydrographic conditions and circulation pattern in the Southeastern Mediterranean and the Suez Canal, in: Symposium on the Mediterranean IBP/PM UNESCO, pp. 177-191.
- GESAMP, 1974: Joint group of experts on the scientific aspects of marine pollution. Review of harmful substances. Provisional version GESAMP VI/10/supp. London, England
- GFCM, 1972: The state of marine pollution in the Mediterranean and legistlative controls pp.66. Rome, FAO (1972).
- Goldberg, E.D., 1972: A guide to marine pollution. Gordon and Breach Science Publishers Inc., NY, USA., pp 41-129.

Grasshoff, K., 1976: Methods of sea water analysis. Velag Chemi-Weiheim Publishers, NY.

Green peace, 1994: Update of waste trade in the Mediterranean regions. Ams. Bull. Holland.

- Green Peace, 1989: The Mediterranean project. Green Peace International, Ams.Bull. Holland.
- Grieb, T.M., Driscoll, C.T., Gloss, S.P., Schofield, C.L., Bowie, G.L., and Porcella, D.B., 1990: Factors affecting mercury accumulation in fish in the upper Michigan peninsula. Environ. Toxicol. Chem. 9: 919-930.
- Gross, M.G. 1971: Waste removal and recycling by sedimentary processes, FAO. Report of the FAO technical conference on marine pollution and its effects on living resources and fishing, Rome, 8-19. Dec. 1970. FAO fisheries reports, No 99, FAO, Rome, p, 104
- Gulbrandsen, R.A., 1966: Chemical composition of phosphorites of the phosphoria formation. Geochim- Cosmochim. Acta 30, pp 769-772.
- Hafez. M, and W.K. Shenouda, 1977: The environmental impacts of the Aswan high Dam. Water quality. Bull. 2, 8-10
- Hagino, N., and Yoshioka, K., 1968: A study on the cause of the Itai-itai disease, J. Jap. Orthop Ass, (Nihon Seikeigeka Gakkaishi).35, 818,1961. (In Japanese; cited in Kato and Kawano (1968).

Hanes, N.B., and Fragala, R., 1967: J. Water. Poll. Contr. Fed. 39: 97.

- Harvey, H.W., 1955: The chemistry and fertility of sea waters. Cambridge University Press, London. England
- IARC, 1976: Monograph on the evaluation of carcinogenic risk of chemicals to man, Vol.11, International Agency for research on cancer, pp 125, Lyon, IARC.
- Ibragim, A.M., and Patin, S.A., 1976: Effect of mercury, lead, cadmium, and copper on primary production and phytoplankton in some coastal regions of the Mediterranean and Red seas. Okeonologia, 15: 589-591

I.L.O: 1972 : Encyclopedia of occupational health and safety, Vol.II, I.L.O, Geneva, p. 1261.

- Irukayama, K., 1966: The pollution of Minamata bay and Minamata disease, Advances in water pollution research, 3: 153-166.
- Jensen, S., and Jernelov, A., 1969: Biological methylation of mercury in aquatic organisms. Nature. 223: 5207.

- Katz, A., and Kaplan, I.R.1981: Heavy metal behavior in coastal sediments of southern California; a critical review and synthesis. Mar. Chem. 10:261-299
- Kibar, N., and Sokolov, C., 1988: Temporal and spatial variability of current speeds in the Mediterranean Sea near the Lebanese coast, Okeanologiya, 28(4), pp.561-570.
- Kimor, H. 1991: Changes and stress signs in plankton communities as a result of Man-Induced Perturbations in Enclosed coastal Seas (Mediterranean, Baltic). Marine pollution Bull. Vol.23, pp. 171-174..
- Kjellstrom, T., 1985: "Renal Effects", in cadmium and health: A toxicological and Epidemiological Appraisal. Volume II. In: Effects and response, L.Friberg, C.G. Elinder, T. Kjellstrom, and G.F. Nordberg (eds), CRC Press Inc., Boca Raton, FL, Chap.9, pp. 21-109.
- Klein, L.A., Lang, M., Nash . M., and Kirchner.S.L., 1974: Sources of metals in New york. Waste water, J. Water. Poll. Contr. Fed., 46:2653-2662.
- Kouyoumjian, H.H., and Belian, J., 1985: Recreational Water Quality in Jounieh Bay Lebanon. Marine Research centre; National Council for Scientific Research, Jounieh, Lebanon. Leb. Sci. Bull., Vol. I, 1:59-64.
- Lakkis, S., and Zeidane, R., 1987: Modifications de l'ecosystem planctonique par la pollution des eaux cotieres Libanaises, FAO Fishing Report. N'352 Supplement, pp. 123-159.
- Laxen, D.P.H., 1983: The chemistry of metal pollutants in water. In pollution: causes, effects and control, Harrison, R.M., (ed) Royal Soc. Chem., special Publ. No. 44, p. 104-123.
- Lindgren, O., 1975: Heavy metal analysis by Atomic Absorption Spectrometry and flame emission spect. FAO fishing technical paper. No.137, Rome. 55-60 pp
- Lyman, J., and Fleming, R.H., 1940: Composition of sea water. J. Mar. Res. 3: 134-146
- Lyons, W.B., and Fitzgerald, W.F., 1980: Trace metal fluxes to nearshore long Island sound sediments. Mar. Poll. Bull. 11 (6):157-161
- Malychef, P. 1994: Ecologist, Pharmacist. Beirut, Lebanon. Personal communication.
- Mance, G., 1987: Pollution threat of heavy metals in aquatic environments. Brit. Libr. Catalog. In Publ. Data. Elsevier Applied Science Publishers Ltd., N.Y. pp 132-241

- Marczenko, Z., 1976: Spectrophotometric determination of elements. Ellis Horwood Ltd; col.House, Wetegrate, Chichester, England.
- Marshall, W., 1991: Analytical chemistry I. Department of Food Science and Agricultural Chemistry, Mc Gill University, Montreal, Ca.
- Martin, J.M., and Whitfield, M., 1981: The significance of the river input of chemical elements to the ocean. In Wong, C.S., Boyle, E., Bruland, K.W., Buton, J.D., and Goldberg, E.D., (eds), Trace metals in sea water. Plenum Press, NY, pp. 265-296
- Matossian, R.M., 1982: Infectious diseases of Lebanon: Past, present and future. American University of Beirut. Lebanon
- Matossian, R.M., 1984: Infective hazards of bathing on Lebanon's beaches. Leb.Med. J., 34:2.
- Meink, F., Stoof, H., and Kohlschuetter, H., 1960: Industrie Abwasser. Stuttgart, Gustave Fisher Verlag, pp 560.
- Metcalf and Eddy, Inc. 1991: Waste water engineering treatment, disposal, and reuse. 3rd edition. Mc Graw-Hill, Inc, pp. 1334.
- Morgon, J.J., and Stumm, W., 1991: Chemical processes in the environment, relevance of chemical speciation. In Merian, E. (Ed.), Metals and their compounds in the environment, pp 69-103. VCH, Weinheim
- Moselio Schaechler 1992: Encyclopedia of Microbiology V(2). Wiley and Sons Publishers Ltd., N.Y. p 115-124
- Nelson, B., Heinz, H.C., and Redmon-Norwood, A., 1996: Environmental contaminants in wildlife, CRC. Press, Inc, pp 5-40
- Nilsson, R., 1971: Removal of metals by chemical treatment of municipal waste water. Water.Res. 5:51-60.
- Nriagu, J.O., 1980: The biogeochemistry of mercury in the environment. Elsevier/ North holland, Amesterdam.
- Nuwayhid, I., 1994: A survey on industrial wastes and occupational hazards in an industrial zonein the suburbs of Beirut. Department of Environmental Health, Faculty of Health Sciences, American University of Beirut, Lebanon. Environ. Sci. D-24,

Orlob, C.T., 1956: Sewage indust. Waste 28, 1147.

- PAHO (Pan American Health Organization), 1973: Normas sanitarias de alimentos, Apropada por el consejo de ministros de salud publica de centro America y Panama, 1964-1966, Guatemala, p.4.
- Parker, C.R., 1972: Water analysis by Atomic Absorption Varian Techtron, Pty.Ltd.Australia, pp 26
- Pathan, M.D., 1977: Pollutional aspects of water resources in Lebanon, vol.I: Development, quality and treatment of water supplies: 1964-1975, pp. 325, M.S. thesis American University of Beirut.
- Patty, F.A., 1962: Industrial Hygiene and toxicology. Vol.II (2nd. Ed.), John Wiley and Sons, NY, p.2377.
- Pescod, M.B. 1992: Waste water treatment and use in agriculture. F.A.O. Irrigation and Drainage paper, number 47. Food and Agriculture Organization of the United Nations, Rome, Italy, pp.123.
- Puxbaum, H., 1991: Metal compounds in the atmosphere. In Merian, E. (Ed). Metals and their compounds in the environment. Vett weiheim. VCH Publishers Inc. N.Y. pp. 257-277
- Rainbow, P.S., 1990: Heavy metal levels in marine invertebrates, in: Heavy metals in the marine environment, R.W. Furness and P.S. Rainbow (eds.), CRC Press, Boca Raton, Florida, pp. 67-80.
- Reddy, K.R., and W.F. de Busk. 1985: Nutrient removal potential of selected aquatic macrophytes. J. Environ. Qual. 14: 459-462.
- Reinhold V.N., 1985: Stream, lake, estuary, and ocean pollution. Lib. Of Cong. NY.USA. pp. 240
- Riley, J.P., and Skirrow, S., 1975: Chemical oceanography. Academic Press, London, pp 606
- Roth, I., and Hornung, H., 1977: Heavy metal concentrations in water, sediments, and fish from Mediterranean coastal areas, Israel. Mar. Pollu. Bull. 11: 265-269
- Ruivo, M., 1972: Marine pollution and sea life. Fishing News (Books) Ltd, FAO, London, England, pp. 29-36
- Sadiq, M., 1992: Toxic metal chemistry in marine environments. Marcell Dekker, Inc, NY. pp 106-145

- Schierup, H.H., and H.Brix 1990: Danish experience with emergent hydrophyte treatment system (EHTS) and prospects in the light of future requirements on outlet water quality Wat. Sci. Tech. 22: 65-72.
- Schroeder, H.A., and Balassa, J.J., 1973: Cadmium: uptake by vegetables from super phosphate in soil. Sci. 140, pp 189-192.
- Schroeder, H.A., Nason, A.P., Tipton, I.H., and Balassa, J.J., 1967: Essential trace metals in man: Zinc, relation to environmental cadmium. J. Chronic. Dis. 20, 179,1967
- Shiber, J.G., Washburn, E., and Saliba, A., 1978: Lead and Mercury concentrations in the coastal waters of north and south Lebanon. Mar. Poll. Bull., Vol.9, pp 109-111.
- Shiber, J.G., 1979: Heavy metals in Ras Beirut Prawns and Sea Urchin eggs. Departmentof Biology, American University of Beirut, Lebanon, J. Environ. Sci. Health, B14 (1), 73-95.
- Shiber, J.G., 1979: Metal concentrations in marine sediments from Lebanon. Wat. Air, and Soil Poll. 13: 35-43.
- Slanetz, L.W., and Bartley, C.M., 1965: Health Lab.Sci. (2): 142
- SMEWW, 1981: Standard methods for the examination of water and waste water. 15th. Ed. Prepared and published jointly by APHA, AWWA, WPCF. Washington D.C. Standard Methods for the Examination of Water and Waste Water. USA, pp. 85-146
- Suzuki, T., Miyama, T., and Toyama, C., 1973: The chemical form and bodily distribution of mercury in marine fish. Environ. Contam. Toxicol. Bull., 10: 347-345
- Thacher, P.S. 1978: The Mediterranean action plan. Am. Bio. 6:308-312.
- Tortora, G.J., Funke, B.R., Case, C.L., 1989: Microbiology an introduction 3rd. Ed. Benjamin/cummings Publ. Comp. Inc. 665-691 pp
- Tripathi, B.D, and S.C Shukla. 1991: Biological treatment of waste water by selected aquatic plants. Environ. Pollut. 69:69-78.
- Ui, J.K., 1969: Minamata disease water pollution by industrial waste. J. Rev. Int. Oceanogr. Med., 13/14, p. 37-44.
- U.S.EPA (United States Environmental Protection Agency), 1985: "Drinking water criteria document for cadmium (Final Draft)", prepared by life systems, Inc. Cleveland, OH, NTIS PB86-117934.

- U.S. Senate, 1963: 86th Congress: Hearings Spec. Subcom. Air and water poll. Sept. 9, 10, 11., p. 502
- WHO, 1992: "Environmental Health Criteria 135: Cadmium- Environmental Aspects", World Health Organization Geneva, Switzerland, p. 156
- WHO/UNEP, 1977: Health criteria and epidemiological studies related to coastal water pollution. Report of a group of experts jointly convened by WHO and UNEP. WHO regional office for Europe, Copenhagen. Denmark
- Winslow, C.E.A., and Moxon, D., 1928: Bacterial pollution of bathing beach waters in new haven harbor. Am. J. Hyg. 8: 299.
- Yamamoto, J., Kaneda, Y., and Hikasa, Y., 1983: Picogram determination of methylmercury in sea water by gold amalgamatia and atomic absorption spectrophotometry. Int. J. Environ. Anal. Chem. 16: 1-16
- Yamagata, N., and Shigematsu, I., 1970: Cadmium pollution in perspective, Bull. Inst. Pub. Health.19:1-4
- Zobell C.E., 1963: Domain of the marine microbiologist symposium on marine microbiology pp 3-25. Thomas C.C publisher, Springfield, Illinois. USA

Appendix - A-

Experiment	No. 1- (Cadmium	sample data	
------------	----------	---------	-------------	--

Date	Station	Location	[Cd] ug/L
July	S1	Akkar	0.38
•			0.45
			0.47
			0.41
			0.39
			0.4
lean average		···· _··· ··· -·· -	0.4167
standard deviation			0.0356
γl	S2	Akkar	0.46
•			0.51
			0.74
			0.42
			0.44
			0.65
lean average		· · · ·	0.5367
tandard deviation			0.1294
ıly	S3	Tripoli	1.92
		•	1.7
			1.95
			1.64
			1.86
			1.91
ean average		<u> </u>	1.83
landard deviation		<u> </u>	0.1287
Jly	S4	Tripoli	1.96
		•	1.93
			1.91
			1.87
			1.9
			1.81
ean average			1.8967
andard deviation			0.0520

July	S5	Chekka	1.86 1.84 1.8 1.78 1.76
Mean average Standard deviation			1.83 0.0654
July	S6	El-Koura	0.45 0.61 0.52 0.42 0.46 0.71
Mean average Standard deviation	·		0.5283 0.1116
July	S7	El-Batroun	0.37 0.45 0.42 0.4 0.38 0.36
Mean average Standard deviation			0.3967 0.0339
August	S8	Aamchit	0.36 0.29 0.34 0.4 0.41 0.38
Mean average Standard deviation			0.3633 0.0441
August	S9	Jbeil	0.46 0.45 0.4 0.44 0.52 0.46
Mean average Standard deviation			0.455 0.0389

.

August	S10	Bouar	0.35 0.38 0.41 0.44 0.37 0.4
Mean average Standard deviation	·		0.3917 0.0319
August	S11	Safra	0.42 0.37 0.39 0.45 0.43 0.36
Mean average Standard deviation			0.4033 0.0356
August	S12	Tabarja	0.32 0.4 0.37 0.35 0.41 0.34
Mean average Standard deviation	·····		0.365 0.0351
August	S13	Kaslik	0.73 0.86 0.78 0.76 0.82 0.8
Mean average Standard deviation			0.7917 0.0458
August	S14	Jounieh	0.52 0.56 0.61 0.55 0.53 0.6
Mean average Standard deviation			0.5617 0.0366

September	S15	Antelias	0.47 0.51 0.48 0.42 0.54 0.49
Mean average Standard deviation			0.485 0.0404
September	S16	Beirut	0.91 0.96 1.2 1.41 1.3 1.38
Mean average Standard deviation	- <u> </u>		1.1933 0.2135
September	S17	Ramlet Al-Bayda	1.72 1.7 1.76 1.84 1.82 1.8
Mean average Standard deviation			1.7733 0.0561
September	S18	Chouf	0.4 0.46 0.39 0.44 0.45 0.48
Mean average Standard deviation			0.4367 0.0350
September	S19	Saida	0.53 0.57 0.43 0.48 0.4 0.44
Mean average Standard deviation	·····	······	0.475 0.0647

September	S20	Saida	0.21
			0.25
			0.24
			0.26
			0.28
			0.31
Mean average			0.2583
Standard deviation	on		0.0343

Appendix - B -

	Zullaik a			B	ourri a
	Weight (gm)	Length (cm)	[Hg] (mg/Kg)	[Hg] We (mg/Kg)	eight Length (gm) (cm)
	77.5	14.1	0.07	0.07	85.2 17.8
	86.2	15.3	0.06	0.09	100.5 22.3
	70.4	11.6	0.04	0.06	92.7 20.1
	54.5	11.5	0.04	0.09	120.6 23.4
	62.5	12.6	0.04	0.07	95.7 18.1
	77.8	12.7	0.05	0.03	86.5 17.6
	84.2	14.3	0.09	0.07	110 21.3
	76.1	11.8	0.04	0.07	107.5 20.6
	60.5	12.7	0.06	0.02	90.5 19.7
	52.5	14.5	0.05	0.07	96.8 21.2
	61.6	12.5	0.05	0.07	104 20.1
	65.5	12.8	0.04	0.06	98 20
	70.5	13.2	0.03	0.06	89.4 17.3
	64.5	12.4	0.04	0.06	95.5 18.6
	80.5	14.5	0.08	0.10	11.4 22.1
Mean	69.65	13.1	0.05	0.07	98.95 20.01
Std.dev	10.493	1.172	0.018	0.021	10.073 1.858
			_		

Experiment No.2 - Mercury sample data

a- Arabic local name

.

					Goubous a		
	Weight (gm)	Length (cm)	[Hg] (mg/Kg)	[Hg] (mg/Kg)	Weight (gm)	Length (cm)	
	300	23.6	0.08	0.03	19.5	12.7	
	250	22.1	0.06	0.05	23.5	13.9	
	470	20.7	0.09	0.04	34.6	14.2	
	260.5	18.5	0.08	0.09	46.5	15.1	
	86.5	19	0.04	0.07	58	15.3	
	94.7	22.5	0.08	0.08	52.5	15.5	
	106	24	0.05	0.06	37.5	12.3	
	122	22	0.08	0.04	38	11.8	
	476.5	24.6	0.08	0.04	26.5	11.3	
	423.4	22.5	0.06	0.03	24	11.1	
	372.5	20.4	0.09	0.05	23.5	14.1	
	500.7	27.5	0.09	0.03	32	12.5	
	546.5	26.8	0.10	0.03	45	13.8	
	223.2	20.3	0.09	0.04	41.3	13	
	230.6	21.5	0.09	0.05	56	15.4	
Mean	297.54	22.40	0.08	0.05	37.23	3 13.47	
Std.dev	158.860	2.582	0.018	0.019	12.52	5 1.496	

a- Arabic local name

Appendix - C-

Date	Station	Locatio	n Coliform counts(CFU/100ml)			
			Near s	shore (10m)	Off shore (500m)	
July	S1	Akkar		88	78	
·				92	82	
			Mean Std.dev	90 2.8284	80 2.8284	
July	S2	Akkar		102	84	
			Maan	90		
			Std.dev	2.8284	2.8284	
July	S3	Tripoli		430	380	
				438	386	
			Mean	434	383	
			Sta.aev	5.6569	4.2420	
July	S4	Chekka		190	167	
			, <u> </u>	184	163	
			Mean Std.dev	187 4.2426	165 2.8284	
July	S5	El-Koura		78	64	
				74	68	
			Mean Std.dov	76	66 2 8284	
			Stu.dev	2.0204	2.0204	
August	S6	El-Batrour	ı	84	64	
				86	58	
			Mean Std.dev	85 1.4142	61 4.2426	
August	S7	Jbeil		112	98	
				102	94	
			Mean Std.dev	107 7.0711	96 2.8284	
August	S8	Aamchit		124	96	
				118	98	
			Mean Std.dev	121 4.2426	97 1. 4142	

Experiment No.3 - Fecal coliform data- E.coli

August	S9	Safra		96		64
				98	, 	58
			Mean	9 7		61
			Std.dev	1.4142	· ·	4.2426
August	S10	Tabarja		120		112
				124		106
			Mean	122		109
			Std.dev	2.8284		4.2426
August	S11	Kaslik		356		304
Ū				352		298
			Mean	354		301
			Std.dev	2.8284	<u></u>	4.2426
Septembe	s S12	Antelias		>500		>500
Septembe	s S13	Dora		>500		>500
Septembe	er S14	Ramlet El	-Bayda	>500		>500
Septembe	S15	Khalde		238		164
				232		160
			Mean	235		162
			Std.dev	4.2426		2.8284
Septembe	S16	Saida		78		52
				74		48
			Mean	76		50
			Std.dev	2.8284		2.8284

Appendix - D -

Date	Station	Locatio	n Coliform counts(CFU/100ml)			
			Near	shore (10m)	Off shore (500m)	
July	S1	Akkar		78	36	
,				74	42	
			Mean	76	39	
			Std.dev	2.8284	4.2426	
July	S2	Akkar		88	42	
				90	48	
			Mean	89	45	
			Std.dev	1.4142	4.2426	
July	S3	Tripoli		332	256	
				338	252	
			Mean	335	254	
			Std.dev	4.2426	2.8284	
July	S4	Chekka		292	182	
				286	186	
			Mean	289	184	
			Std.dev	4.2426	2.8284	
July	S5	El-Koura		48	36	
				52	32	
			Mean	50	34	
			Std.dev	2.8284	2.8284	
August	S6	El-Batrour	ı	52	34	
				48	36	
			Mean	50	35	
			Std.dev	2.8284	1.4142	
August	S7	Jbeil		124	100	
				128	96	
			Mean	126	98	
			Std.dev	2.8284	2.8284	
August	S8	Aamchit		118	86	
				114		
			Mean	116	85	
			Std.dev	2.8284	1.4142	

Experiment No.4 - Fecal coliform data- Streptococcus Feacalis

August	S9	Safra		98	3	66
				100)	68
			Mean	99		67
			Std.dev	1.4142	2	1.4142
August	S10	Tabarja		120)	84
				118	3	88
			Mean	119	9	86
			Std.dev	1.4142	2	2.8284
August	S11	Kaslik		420)	320
				426	5	324
			Mean	423	3	322
			Std.dev	4.2426	<u>}</u>	2.8284
Septembe S12		Antelias		>500		>500
				>500		>500
Septembe S13		Dora		>500		>500
				>500		>500
September S14		Ramlet El-Bayda		>500		>500
				>500		>500
Septembe	S15	Khalde		246	5	188
				244	l i	192
			Mean	245	5	190
			Std.dev	1.4142	2	2.8284
Septembe	S16	Saida		76	5	48
·				72	2	46
			Mean	74	••••••••••••••••••••••••••••••••••••••	47
			Std.dev	2.8284	L	1.4142

•

Appendix - E -

Experiment No. 5 - P	nysical analy	/sis- Salinity	, pH, DO ,	Temperature
----------------------	---------------	----------------	-------------------	-------------

Date	Station	Salinity (ppt)	рН	DO (mg/L)	Temp. degC
August	S1	38.757	7.8	4.5	28.3
	S2	38. 9 67	8.2	5.2	28
	S3	38.645	7.8	4.8	27 7
Septembe	S4	38.924	8	3.6	26.8
	S5	38.924	78	2.2	28.7
	S6	39 01	8.3	1.7	27.4
October	S7	38 667	8	43	27 8
	S8	38.664	7.9	4.8	28.5
	S9	38 454	8	5.2	27.9
Mean		38.78	7.98	4.03	27.9
Std.dev		0.187	0.179	1.284	0.579

.









IMAGE EVALUATION TEST TARGET (QA-3)









C 1993, Applied Image, Inc., All Rights Reserved