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ABSTRACT

Environmental Protection Committee (EPC) is committed to a program that has it's goal as a secure, wholesome environment. One of the objectives of this program is to ensure that environmental effects are assessed. The impact on the marine environment of effluents from 8 major industries were investigated and monitored on a quarterly basis from January to December 1992. 37 physical and chemical parameters were measured for each industrial effluent. The analyses of data over a year showed that most of industries met the proposed effluent guidelines, therefore, do not have a major impact on the overall marine environment. It also indicated that one of the metal treatment industries is the most polluting among all other major industries on the island. It discharge effluent containing high Aluminum, and total suspended solids, into the marine environment.

Table of Contents

1.0 INTRODUCTION

Bahrain has decided to diversify and industrialize the island and it is the responsibility of Environmental Protection Committee (EPC), to ensure that the quality of the environment is taken into consideration in this planning. The Environmental Protection Committee has to prepare adequate legislation integrating environmental consideration into planning and development, proposing means for controlling, ensuring training for professionals and technicians in the environmental field.

Essentially public health programs as well as pollution prevention and control programs include recognition of the problems, collection of information, and selection of appropriate solutions. The use of limited existing information is not sufficient to make accurate waste-load inventories. Therefore a continuous monitoring program is necessary to know the exact composition of the sample at a particular point of time of the sample collection. The results will provide data for the following:

1. Formation and implementation of general policies relating to the protection of the marine environment in all sectors of Bahrain.

2. Preparation of laws and regulations for the protection of the marine environment and enforcement of these laws.

2.0 LITERATURE REVIEW:

2.1 ENVIRONMENTAL SIGNIFICANCE OF EACH PARAMETERS MONITORED

2.1.1. COLOUR & ODOUR

Color in water may result from the presence of natural metallic ions such as Iron and Manganese, humus and peat materials, plankton, weeds and industrial wastes. Colored industrial wastes may require color removal before discharging into a sea. Most of organic and inorganic chemicals contribute odor. These may originate from natural sources from also decomposition of vegetable matter or from associated microbial activity. Odors are caused by volatile substances associated with organic matter, living organisms principally bacteria, algae and gases such as Hydrogen Sulphide (H_2S).

2.1.2. pH

pH is the most important parameter in water chemistry. Practically every phase of water supply, and wastewater treatment e.g. acid-base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control is pH dependent. Acidic or basic nature of water is indicated by pH value. For discharging into sea an effluent pH should be between 6.5 to 8.5.

2.1.3. TEMPERATURE

Temperature of the water that is discharged into sea is important, as different kinds of aquatic organisms are not equally susceptible to changing in temperature. Water temperature determines how efficiently certain unit processes operate in the treatment plant. The rate at which chemical dissolve and react is partially dependent on temperature. Cold water requires more chemicals for efficient coagulation and flocculation, where as warm water requires less chemicals for these processes to be efficient. High water temperature is not suitable for many marine organisms. Water temperatures also determine the speed at which plant and animal life will grow, growth being slow in cold water and rapid in warm one. Temperature measurements are important not only for their own sake but also because they identify the magnitude of the density, viscosity, vapor pressure, and surface tension of water, the saturation values of solids and gases that are or can be dissolved in it, and the rate of chemical, biological, and biological activity, such as corrosion, biological oxygen demand (B.O.D), and growth and decay of microorganisms.

2.1.4. TOTAL SUSPENDED SOLIDS (TSS)

This is a measure of non-filterable residue which in turn measures the physical state of the concentration of water. Total suspended solids and Turbidity are inter-related. Total suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay, whereas the organic fraction includes such materials as grease, oil, tar, animal, vegetable fats, various fibers, saw dust, hair, and various materials from sewers. They adversely affect fisheries by covering the bottom of the sea with a blanket of materials that destroys the fish-food, bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen Sulphide, carbon dioxide, methane, and other noxious gases. Suspended particles also serve as a transport mechanism for pesticides and other substances which are rapidly sorbed or onto clay particles. Solids in suspension are aesthetically displeasing. Total suspended solids can cause adverse conditions for aquatic life by reducing transmittance of light, by choking the gills of fish and smothering benthic organisms. It has been found that no uniform standards have been arrived at for this characteristic in literature. No quantitative limit has therefore been prescribed for it. Usually no visible suspended solids are allowed in effluents while discharging to sea.

2.1.5. TURBIDITY

Clarity of water is a major determinant of the condition and productivity of that system. Turbidity is usually caused by suspended matter such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Correlation of Turbidity with the weight concentration of suspended matter is difficult because the size, shape, and refractive index of the particulates also affect the light scattering properties of the suspension.

2.1.6. SALINITY

Salinity is an important measurement in the analysis of certain industrial wastes and seawater. It is defined as the total solids in water after all carbonate have been converted to oxides, all bromide and iodide have been replaced by chloride, and all organic matter has been oxidized [(6)] is numerically smaller than the total dissolved solids (TDS) and usually is reported as parts per thousand (‰.).

2.1.7. TOTAL DISSOLVED SOLIDS (TDS)

Total dissolved solids (TDS) referred to as total filterable residue in natural waters consists mainly of carbonates, bicarbonates, chloride, sulphate, calcium, magnesium, sodium, and potassium. Total dissolved solids in water tend to change the waters physical and chemical nature, distilled or demonized water has flat taste, whereas water with some dissolved solids is preferred by most consumers (9). Different salts in solution may interact and cause effects that salt alone would not cause. The presence of harmful dissolved compounds or ions such as Arsenic and Mercury can be dangerous in water even where the total solids concentration is relatively low.

2.1.8. CONDUCTIVITY

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valency, and relative concentrations, and on the temperature of measurement (6). Solutions of most inorganic acids, bases, and salts are relatively good conductors. Conversely, molecules of organic compounds that do not dissociate in aqueous solution conduct current very poorly, if at all.

2.1.9. AMMONIA-NITROGEN

Determinations of various forms of nitrogen throw light on the pollutional history of the carrying water. All forms of nitrogen as well as nitrogen gas are biologically interconvertible and are components of the nitrogen cycle. Ammonia naturally is present in surface and wastewater. Its concentration generally is low in ground waters because it absorbs to soil particles and clays, and it is not readily leached from soils. It is produced largely by deamination of organic nitrogen containing compounds and by the hydrolysis of urea. At some water treatment plants ammonia is added to react with chlorine to form a combined chlorine residual. The unionized ammonia is the primary toxic form, and that the ionized species is considerably less toxic. High temperature and high pH values lead to a greater proportion of unionized ammonia and therefore an increase in toxicity. When ammonia is dissolved in water the following equilibrium is established.

$$NH_3 + H_2O \ = NH_4^+ + OH^-$$

The ratio of NH_4 to NH_3 will increase as pH decreases and decreases as pH increases. The lowest lethal (LC 50 96h) concentration of unionized ammonia for young fish is 0.2 mg/l(4). The Environmental Protection Agency of United States of America (USEPA), Water Quality Criteria is 0.02 mg/l of unionized ammonia for fresh water, no criteria is given for seawater. Tolerance limit for water quality after receiving discharges for free ammonia as N is 1 mg/l (4).

2.1.10. ALKALINITY/ACIDITY

Alkalinity of water is a measure of the water's capacity to neutralize an acid, therefore it is related to water's buffering capacity, that its capacity to resist change in pH as acid is added. Alkalinity is important in calculating Langelier index to judge if treated water is corrosive or not. Alkalinity can cause scale formation in distribution mains and plumping system by restricting flow plugging valves and fouling boilers. Acidity can cause corrosion thereby causing premature pipe or equipment failure.

2.1.11. DISSOLVED OXYGEN (DO)

Dissolved Oxygen (DO) in water is not considered as a contaminant. An excess or lack of dissolved oxygen does, however, help in creating unfavorable conditions. Generally a lack of dissolved oxygen in natural waters creates the most problems specially an increase in tastes and odors as a result of anaerobic decomposition. The solubility of dissolved oxygen decreases with decreasing atmospheric pressure (barometric pressure). Solubility of oxygen in water decreases as salinity increases. Seawater has a high salinity and dissolved oxygen concentration at saturation is considerably lower than for fresh water [(2)]. A high dissolved oxygen concentration is detrimental to metal pipes because oxygen helps accelerate corrosion. Oxygen is important as an oxidant in water plant operation. Its primary value is to oxidize Iron and Manganese into forms that will precipitate out of the water. It also removes excess carbon dioxide, provided there is a long enough contact time. It will also help to degrade some organic compounds that cause taste and odor problems. Usually some form of aeration is used to ensure that enough dissolved oxygen is present in water for effective oxidation. In addition to that operators can use dissolved oxygen data from their raw water storage reservoirs to get an indication of the general quality of the water. Based on this data, operators may be able to make treatment changes or alter the manner in which the reservoir releases are made in order to prevent taste, odour, and other problems.

All aerobic treatment processes depend on the presence of sufficient dissolved oxygen, and tests for it are indispensable as a means of controlling the rate of aeration to assure that aerobic conditions are maintained. Dissolved oxygen is important in natural waters because of its key role in biological energy transfers. Although aquatic organisms respire efficiently at oxygen concentrations considerably below saturation values, metabolic rates and efficiencies are dependent on the availability of dissolved oxygen. So dissolved oxygen is a major determinant of the environmental quality of water. When water becomes deoxygenated, the aquatic fauna suffocates.

2.1.12. SULPHIDE (H_2S)

Sulphide is often present in ground water. Its common presence in wastewater comes from the decomposition of organic matter, sometimes from industrial wastes but mostly from the bacterial reduction of sulphate. Hydrogen Sulphide escaping into air from Sulphide containing wastewater causes odor nuisances. Hydrogen Sulphide is very toxic, it attacks metals directly or indirectly causing serious corrosion of concrete sewers because it is oxidized biologically to sulphuric acid on the pipe wall. Sulphate in water provides source of energy for anaerobic sulphate reducing bacteria which release hydrogen Sulphide during the production of energy. Hydrogen Sulphide is highly objectionable and is toxic to human being and fish.

2.1.13. CYANIDE

Cyanide refers to all CN^- groups in cyanide compounds that can be determined as cyanide ion[(6).] Cyanide occurs in water as a result of contamination from industrial or chemical sources. Cyanide may occur in various forms including simple soluble alkali salts, simple insoluble salts, complexed cyanides, cyano-organic compounds, cyanates, and thiocyanates. Simple and alkali salts decompose readily forming toxic cyanate ions, while cyanide complexes are relatively stable and therefore less toxic. In streams at temperature between 10-35 ^oC moderate doses of cyanides can be decomposed by bacterial action. Much of the cyanide in ground water is removed as water percolates through soil, particularly if the soil contain large amounts of organic matter.

The toxicity of cyanide to fish and animal life is due to inhibition of their oxygen transport mechanism. In human being cyanide takes the place of haemoglobin, preventing oxygen from reaching tissues and causing anoxia. Fish that have been poisoned by cyanide exhibit characteristic brightly colored gills due to the inhibition of oxidase, the enzyme responsible for oxygen transfer. The degree of toxicity of cyanide to the fish depends on water quality, temperature, dissolved oxygen, and the concentration of certain minerals such as Zinc and Cadmium which form toxic salts with cyanide. However, the limit of fish tolerance is usually around 0.1 mg/l. In human beings up to 18 mg CN^- per a day can be converted by the liver to less toxic thiocynate that is eliminated slowly in the urine.

2.1.14. CHLORIDE

Chlorides are widely distributed in the nature. They are present in mineral deposits, sea, brackish water, ocean vapors, spray carried inland by wind, and in human excerta. In sea water chloride is very high and there is a direct correlation between chloride and salinity. The relationship between chlorinity and salinity is:

Salinity = 1.806 x Chlorinity[(6)].

2.1.15. NITRATE-NITROGEN (NO_3-N)

Nitrate generally occurs in trace quantities in surface water but may attain high levels in some ground water. Nitrogen in protein is a constituent of all living organisms. Protein is decomposed by biological action to amino acids and then to ammonia which is converted by nitrification to nitrates and nitrites. Synthesis of plant and animal protein on the other hand proceeds with uptake of nitrates and nitrites. The concentrations of the various forms of nitrogen and their rates of interconversion are part of the chemical definition of the environment. With increased population, both human and livestock, the rate of nitrification has increased to about three times that of denitrification. The effect of this imbalance of the environment is still unknown [(1).]

Although nitrates are essential for protein synthesis, high concentrations of nitrates in a body of water may stimulate algal bloom causing oxygen depression. The autotropic conversion of ammonia to nitrate can also account for significant oxygen depression in the receiving body of water and contributes to unfavorable conditions for normal biology.

2.1.16. NITRITE-NITROGEN (NO_2-N)

Nitrite is an oxidation product of ammonia. It is rather rapidly and easily converted to nitrates, and its presence in higher concentrations is indicative of active biological process in the water. Conversion of ammonia to nitrite occurs rapidly in the presence of water, oxygen, and an organism called nitrosomonas. Nitrite is then converted to nitrate by a second organism called nitrobacter. Both of these bacteria are found in soil and water.

2.1.17. PHOSPHOROUS

Phosphorous occurs as phosphates. These are classified as orthophosphates, condensed phosphates, and organically bound phosphates. They occur in solutions, in particles or in the bodies of aquatic organisms. These forms of phosphate arise from a variety of sources. Small amounts of polyphosphates are added to some water supplies during treatment. Phosphates are used extensively in the treatment of boiler waters. Orthophosphates applied to agricultural land as fertilizers are carried into surface waters by storm run-off and other means. Primarily biological processes form organic phosphates. They are contributed to sewage by body wastes, food residues, and also may be formed from orthophosphates in biological treatment processes.

Phosphorous is essential to the growth of organisms and can be the nutrient that limits the primary productivity of a body of water. In instances where phosphate is a growth-limiting nutrient, the discharge of raw or treated waste water, agricultural drainage or certain industrial waste to that water may stimulate the growth of phosphosynthetic aquatic micro- and macro-organisms in nuisance quantities. Phosphate is abundant in plants and it is a constituent of protoplasm. When excess phosphorous enters a body of water one of the limitations on the plant and animal growth is removed. The resulting accelerated enrichment process will result in increased oxygen demand, and thus diminish the capability of a body of water to support an increased diversity of plant and animal life. The amount of phosphorous that can be tolerated by a body of water before disruption of the ecosystem is a function of the complex physical and chemical characteristics of the body of water.

The safe phosphorous level for drinking water is 0.1 mg/l, while a safe phosphorous level for aquatic life is approximately 0.02 mg/l(1).

2.1.18. METHYLENE BLUE ACTIVE SUBSTANCES (M.B.A.S.)/ DETERGENTS

Surfactants, or surface active agents, are soluble organic compounds which alter the surface properties of solutions when present in relatively low concentrations(1). Since they have the properties of wetting, dispersing and emulsifying, surfactants are used as the basic cleaning agents in synthetic detergents. Surfactants have both a hydrophobic and hydrophelic region. The hydrophobic region becomes associated with dirt and grease while the hydrophelic portion becomes associated with water. The surfactant, thus, provides a link between the dirt and water, and the dirt is washed away.

Surfactant are classified according to their ionization properties as anionic, cationic, and nonionic. Anionic surfactants are the type most widely used in synthetic detergents and are most likely to be found in water. Although the effect of anionic surfactants on aquatic life is extremely variable (1).

The most prevalent anionic surfactant found in waste water today and the most widely used, Linear Alkylbenzene Sulfonate (LAS),with a straight-chain alkyl group, is 98% biodegradable(1). Methylene blue active substances indicate LAS in particular, other anionic surfactants in general and many other materials. Many industrial cleaners, however, contain cationic or nonionic surfactants rather than the anionic type.

2.1.19. FLUORIDE

Owing to industrial activity involving the use of so many fluoride-containing substances, fluoride contamination of the environment is ubiquitous (3). Most waters contain less than 1 mg/l fluoride.

2.1.20. BIOLOGICAL OXYGEN DEMAND (BOD)

Biological Oxygen Demand (BOD) determines the relative oxygen requirements of wastewater, effluents, and polluted waters. This test determines the amount of biodegradable organic materials in the wastewater by measuring the oxygen consumed by microorganisms in decomposing organic matter of waste. Biological Oxygen Demand (BOD) is widely used to determine:

1. The pollutional load of waste waters.

2. The degree of pollution in lakes and stream at any time and their self-purification capacity.

3. Efficiency of waste water treatment plants.

2.1.21. CHEMICAL OXYGEN DEMAND (COD)

Chemical Oxygen Demand (COD) is a measure of the oxygen equivalent of the portion of organic matter in the sample that can be oxidized by a strong chemical-oxidizing agent. The COD value is important in industrial waste studies and control of waste water treatment plants. Generally the BOD is 50 to 70 % of the COD. Certain organic compounds are oxidized in this test that normally are not oxidized biologically. So COD gives a measure of total organic matter.

Oxidation of 1000 mg of phenol is an example.

$$C_6H_5\,OH + 7\,0_2 = 6\,CO_2 + 3\,H_2O.$$

$$\text{Theoretical COD} = \frac{1000 \times 224}{94} = 2383 \text{ mg.}$$

2.1.22. TOTAL KJELDAHL NITROGEN (TKN)

KJELDAHL nitrogen includes organic nitrogen and ammonia nitrogen. Organic nitrogen includes such natural materials as proteins and peptide, nucleic acids, urea, and numerous synthetic organic materials.

2.1.23. HYDROCARBONS

Pollution by hydrocarbons emanates from many sources, crude oil or fuel as a consequence of ships discharging their ballast water at sea or from refinery effluents.

The low concentration of water dispersed hydrocarbons adversely affect living organisms.

2.1.24. PHENOLS

Phenols are defined as the hydroxy derivatives of Benzene and may occur in domestic and industrial waste waters, natural waters, and potable water supplies. Although industrial effluents are the major source of environmental pollution, phenolic compounds also occur naturally in water from decay of vegetation and from the urine of several animals. Because phenols are very soluble in water the concentration of phenols in streams and lakes is increased after a rainfall due to plant decomposition products dissolved in the run off. The rate of natural decomposition of phenolic compounds is 3 to 5 mg/l per a day in the presence of earth and aquatic plants (1). The decomposition of phenols causes a decrease in dissolved oxygen in the body of water. Phenolic compounds are quite toxic to fish. Furthermore other toxic substances such as cyanide or ammonia often accompany industrial discharges of phenol and a synergistic toxic effect is likely to occur. Tolerance limit for phenol for discharging into open sea is 0.1 mg/l.

2.1.25. TRACE METALS

Trace metals are elements that occur at low levels. Some of these metals are recognized, as nutrients required for animal and plant life (8). Of these, many are essential at low levels but toxic at higher levels. This is the typical behavior of many substances in the aquatic environment. Lead and Mercury have such toxicological and environmental significance.

Some of heavy metals are among the most harmful of the elemental pollutants. These elements include essential elements like Iron as well as toxic metal like Lead, Mercury, and Cadmium. Most of them have a tremendous affinity for Sulphur and attack Sulphur bonds in enzymes, thus immobilizing the enzymes (8) and causing many diseases to human beings and other organisms. Toxic metals such as Mercury, Cadmium, Lead, and Copper tend to accumulate in bottom sediments from which they may be released by various processes of remobilization and in changing form can move up the biological chain thereby reaching human being where they produce chronic and acute ailments.

2.1.26. BACTERIA

A variety of different microorganisms are found in polluted or untreated water. Most of these organisms do not pose a health hazard to human being (9). The organisms that are concerned are those that cause disease i.e. pathogenic organisms or pathogens, which include bacteria, virus, and protozoa. It is impractical to test water for every known pathogen. Pathogens are difficult to identify and it is not economical to routinely test for specific types. A more practical approach is to examine the water for indicator organisms. An indicator organism should always be present in contaminated water, always be absent when contamination is not present, survive longer than pathogens and be easily identified. The Coliform group of bacteria meets all criteria for an ideal indicator. These bacteria are generally not pathogenic, yet, they are usually present when pathogens are present [(9)]. Additionally Coliform bacteria are more plentiful than pathogens and can often stay alive in the environment for longer period of time. As a rule where Coliforms are found in water it is assumed that pathogens may also be present making the water bacterially unsafe, in particular for drinking and swimming purposes.

3.0 MATERIALS AND METHODS

From January to December 1992, grab samples of industrial effluents were collected covering about 3 industrial effluents a month, however, fourteen industrial effluents were covered on a quarterly basis. Samples were collected in precleaned glass bottles of 2.5L capacity, transported to the laboratory and analyzed immediately. For the determination of trace metals, samples were collected in acid cleaned polyethylene bottles containing 1 ml of conc. Nitric acid. Samples for total hydrocarbons were collected in specially cleaned glass bottles.

3.1. APPARATUS

3.1.1. Laboratory glass wares.
3.1.2. Orion 101. Conductivity meter.
3.1.3. Orion 901. Ionanalyser U.S.A.
3.1.4. Kjeldahl digestion system W. Germany.
3.1.5. Incubator 220V,Fisher Isotemperature Oven 200-series U.S.A.
3.1.6. Airoven - Heraes 220 V W.Germany.
3.1.7. Airoven 215 -Fisher Isotemperature -200 series U.S.A.
3.1.8. Turbidimeter DRT-1000 D.H.F Instrument. U.S.A.
3.1.9. Mettler AE160 Balance Swiss made.
3.1.10. Griffin - Student Bath W.Germany.
3.1.11. Karl Kolb water bath W.Germany.
3.1.12. Karl Kolb fridge and thermomix, W.Germany.
3.1.13. Fisher 182A. Isotemp muffle furnace, U.S.A.
3.1.14. Fisher 310T. Thermomix(R) stirring hot plate, U.S.A.
3.1.15. Karl Kolb shaker, U.S.A.
3.1.16. TDS-water bath, U.S.A.
3.1.17. Millipore - water testing kit - Bacteriological,U.S.A.
3.1.18. Millipore - filter manifold, U.S.A.
3.1.19. Dessicators.
3.1.20. Autoclave 220 V -National, U.S.A.
3.1.21. Refractometer - Salinometer, U.S.A.
3.1.22. COD digester, Jencons Scientific Ltd. England.
3.1.23. Milton Roy -UV- Mercury monitor 1235 - Milton Roy Co.U.S.A.
3.1.24. Corning Mega Pure T.M. system - deioniser, U.S.A.
3.1.25. Spetronic 21 - UVD - Spectrophotometer, Bauch & Lomb.
3.1.26. Shimadzu - RF540 - Spectrofluorophotometer, Japan.
3.1.27. Pye-Unicam Sp9 Atomic Absorption Spectrophotometer,England.

3.2. REAGENTS

All reagents used were of Analytical Reagent grade, from Fisher Scientific and from B.D.H. Pesticide grade solvents from Burdick & Jackson U.S.A. were used for hydrocarbon analysis.

3.3. PROCEDURE

After measuring Total suspended solids, Turbidity, B.O.D. and C.O.D., the samples were filtered through Whatman No.40 filter paper. The filtered samples then were tested for all other parameters, using the standard procedures and methods outlined in APHA/ASTM/and USEPA.

Each sample for metal analysis was digested with Nitric acid (1%) and made up to a suitable volume. Total metals were then analysed using a flame/flameless Atomic Absorption Spectrophotometer. Seawater or highly saline samples were buffered with ammonium acetate and then passed through a chelex-100 resin column at flow rate of 2 ml per minute. Excess ammonium acetate was removed with deionised distilled water and the column was eluted with 20 ml of 2M Nitric acid. Then the elute was analyzed for metals using Atomic Absorption Spectrophotometer.

For hydrocarbon analysis, a water sample (1000 ml) was shaken repeatedly with n-hexane/dichloromethane mixture (7/3 v/v) in a separatory funnel. The organic phase was separated, and made up to a suitable volume (100 ml). Finally hydrocarbon content was measured using Fluorescence Spectrophotometer.

4.0. RESULTS AND DISCUSSION

Results of 9 major industrial effluents are shown in tables 1-10 which include average values, ranges and total load per year in tones. Characteristics of effluents from each industry are discussed below.

4.1. NORTH SITRA SEWAGE TREATMENT PLANT

North Sitra sewage treatment plant is designed for treating industrial effluents from the north Sitra industrial area and Al-Mamir. At present only few industries Like Gulf Aluminum Rolling Mill Company (GARMCO) and sulphuric acid plant are connected to it. The wastewater process incorporated is an extended aeration activated sludge process for secondary treatment. After the secondary treatment the water is chlorinated and discharged into the sea at flow rate of 1000 m^3/day.

The effluent analysis done during 1992,(Table-1) shows that there are no major threats to the marine environment from the plant discharge, except for ammonia-N which varied from (8.42 mg/l to 27.2 mg/l , with an average of 15.43 mg/l, whereas the allowed limit as outlined by Bahrain proposed guidelines is (1 mg/l). As ammonia-N is high, TKN also showed high with an average of 22.45 mg/l, which is showes treatment inefficiently.

It has been noticed that the average of aluminum is 2.873mg/l, because of the GARMCO outfall is connected to the plant. Eventually some heavy metal and inorganic matter are discharged into the marine environment, because the l removal of such chemicals is not applied in the plant. However the pollution load is not that much as the effluent flow is very low. (See Table - 1)

As the flow of industrial wastes into this plant is low, only one balancing tank is in use through which water continuously flows. Efficient treatment is seldom achieved and water is pumped out to the sea without chlorination. (Chlorine plant is not functioning in most of the time).

Bacteriological analysis showed an average of $5.5x10^6$ Coliforms per 100 ml, and varied from $2.5x10^6$ to $10x10^6$ Coliforms/100 ml, Whereas the allowable limit (table-10) is 1000 No/100 ml.

4.2. SITRA POWER AND WATER STATION

Sitra power and water station produces electrical power and supplies more than 60% of Bahrain's total supply of desalinated water, working with Multi-Stage Flash (MSF).

The plant at the present produces 25 million gallon per a day of desalinated water. It discharges about 1.47 million m^3/day of brine containing chemicals from the following:

1- winter feedline which is used in winter for raising temperature.
2- Reject feedline which is used for heat exchange.
3- Brine blowdown which is created from final stages of distillation.

These three lines meet at the outlet culverts located on the East Side of the station that is then discharged directly into the sea.

In 1992 Analysis of the effluent (Table-2) did not show any evidence of harmful chemical substances. Natural light transmittance is reduced by the discharge of brine and there is an aesthetically undesirable discoloration of the sea surface at all time.

In winter due to relative high temperature of the effluent (33.4 ^{o}C) compared with sea water temperature (14.0 ^{o}C), can cause a rise in water temperature and bring about thermal pollution, which could occur in the vicinity of the discharge point, as the sea current velocities are generally low, and the movement towards the offshore is slow. The biological effects of thermal pollution depend upon how much the temperature is raised. This is because the metabolic rate of physiological processes is speeded up by heat. And as each species has its own metabolic rate, most aquatic animals can only exist within a specific temperature range. Plants are less sensitive to temperature changes. However, higher temperature increases the rate of their physiological processes and speed up growth. The resulting rise in water temperature will lower the oxygen saturation percentage and speed up the biodegradation of pollutants organic matter. Both these effects will result in a sharp increase in the oxygen sag, or deficit in the water.

4.3. BALEXCO

BALEXCO discharges treated milky effluent at flow rate of 200 M^3/day; into the sea.

The effluent is generated from the following operations:

1- Overflow of the contaminated rinse tanks during the Aluminum load dipping, either from alkaline or acidic rinses.

2- Dragout during lifting of the loads from tanks, rising, anodising, etching, or, coloring.

3- Cleaning of different tanks when chemicals are used for tanks replenishing.

The wastewater generated from the plant containing undissolved Aluminum (mainly Aluminum hydroxide), and a significant amount of dissolved Aluminum with an average of 867.935 mg/l, which is undesirable for discharge into sea. Moreover, Aluminum hydroxide precipitated around the discharge point is very noticeable, extending out some distance from it, and impairing the quality of the seawater. This has already created anaerobic condition around the area, smothering all the living organisms.

Total Suspended Solids varied from 1270.0 mg/l to 13490.0 mg/l, and this is mainly due to the high content of aluminum hydroxide in the effluent. Total of 380.24 ton/yr of suspended solids are discharged into the sea. This high content of Aluminum has caused high Turbidity (average 1194 NTU). These conditions resulted as a result of:

1- the sedimentation tank is not large enough to efficiently treat the volume of wastewater generated.
2- the pH controller system is not always operational, which is clearly seen from Table-3.

D.O values were always low and this could be due to the high amount of Aluminum and other chemicals used in the plant processes for oxidation/reduction reaction.

High ammonia (average 4.99 mg/l) could be attributed to ammonium hydroxide and other chemicals used in the processes, and also due to the sanitary water connected to the discharge point. Due to this the effluent contained some Hydrogen Sulphide as well.

4.4. R.O.PLANT AT RAS ABU JARJUR

The feed water to the plant is collected from 15 boreholes which is mainly brackish under-ground water. As the plant is designed to use the R.O method where the semipermeable membranes are used for this purpose, the desalination process produces fresh water from brackish water using a pressurized membrane system which utilises relatively few process of chemicals in order to achieve the requirement.

The plant discharges brine at flow rate of 3785 m^3 per a day. The analysis during 1992, (table-4) showed that the effluent did not meet Bahrain's proposed effluent guidelines for the following:

Parameter	Unit	Avange	Average	Proposed Guidelines
Ammonia-N	mg/l	1.71-2.47	2.09	1.00
Sulphide as H_2S	mg/l	15.22-26.10	20.52	.50
D.O.	mg/l	.90-5.00	2.05	>2.00

As can be seen clearly from the above that the very high contents of Hydrogen Sulphide in the effluent is due to the use of ground water. Generally Hydrogen Sulphide is formed in the deep water of stagnant basins, by the reduction of sulphate ions [(10)]. In Carbon regeneration & washing area Sulphide is generated as a result of washing.

Dissolved Oxygen (D.O) values were always low in the effluent. It has been believed that D.O levels in ground water are always low because of consumption of oxygen by terrestrial microorganisms and by chemical reactions with minerals [(10)].

The availability of ammonium contents in the effluent could be attributed to the chemicals being used in the processes of the plant such as $HOCH_2CH_2NH_2$.

4.5. BAHRAIN PETROLEUM COMPANY (BAPCO)

The refinery at Bahrain Petroleum Company (BAPCO) started operation in the 1930s, and is one of the largest in the Middle East area. The complex operation at refinery involve a large Fluid Catalytic Cracking Unit (FCCU),a Sulphur recovery plant, and a large number of process heaters (about 29) .
Oily wastewater treatment processes at the refinery consist of American Petroleum Institute separators (API), a skim pond, and an Induced Air Flotation unit (IAF).

BAPCO Refinery discharges treated effluent at flow rate of 572000 m^3/day. Effluent analysis done during 1992 (Table-5) shows that the effluent met the Bahrain proposed effluent guidelines for all parameters. However temperatures relatively are high (35.5 ^oC) compared to the ambient sea water temperatures (24 ^oC), this could bring about thermal pollution near the vicinity of discharge point, and extending out some distance from the discharge point because the flow rate of the effluent is mild enough to reach some how off the discharge point. In addition to that the Pollution load is very high from BAPCO as the effluent flow rate is too high, (see Table- 5).

BAPCO has also a separate sea discharge from No-6 separator. Analysis of this effluent during 1991 (Table-6) showed that the discharge met the proposed effluent guidelines.

4.6. AL-ZAMIL ALUMINUM

Alzamil is a major manufacture of Aluminum products in Bahrain, The plant is designed for anodising and spry coating of aluminum bars.

The pretreatment of Aluminum bars consists of degreasing, etching, desmut, and Zinc Chromate dipping.

The company incorporated an 'in house' waste treatment facility to convert hexavalent Chromium (toxic) to trivalent state (less toxic). The plant discharges treated effluent at flow rate of 108.7 m^3/day. The plant uses tankers to discharge some of the effluent near BALEXCO effluent discharge point, at Sitra which may aggravate environmental impact in the area around. The analysis during 1992 (Table-7) shows that Alzamil met the Bahrain proposed guidelines for effluent for all parameters even for Aluminum and pH.

4.7. GULF PETROCHEMICALS INDUSTRIES COMPANY (GPIC)

GPIC is the first Bahraini venture into petrochemical field. It started production on 19^{th} may 1985, the company complex is situated at Sitra, on the east coast of Bahrain, at a site of 600,000 m^2 reclaimed from sea to house ammonia & methanol plants, in the capacity of 1200 metric ton per day (MTPD) of each products. GPIC discharges effluent at the flow rate of 552000 m^3/day. The effluent contains cooling water, water from various plants and sanitary water that is treated in the biological treatment unit (capacity 200 m^3/day). In this regard as the flow rate of the effluent is that high (552000 m^3/day, the sanitary water could not influence the whole effluent discharged into the sea.

The effluent analysis done in 1992 (Table-8) shows that the level of pollutant load from the plant is not expected to be high as the concentration of the parameters are low and not exceeding the effluent guidelines. The environmental impact of the discharge of cooling water at 45 ^{o}C was studied by Delft Hydraulics and showed that the heating effect is local within 1500 meters of outfall and no more than +2 to 4 ^{o}C. It may be noted that the heat input into the same area of the sea from summer months considerably exceeds that of the cooling water discharges, so that the incremental effect is small.

4.8. TUBLI SEWAGE TREATMENT PLANT

Tubli Water Pollution Control Center (TWPCC) is designed to treat domestic wastewater from several metropolitan areas including Manama, Muharraq, and Isa town together with the developing areas of Sanabis, Jidhafs, and Al-Khamis.

As biological process is concern, most of industrial wastewater has been rejected to be connected with the plant due to a fear of disturbing the biological condition which may cause inefficient treatment.

Tubli plant discharges treated effluent at flow rate of 100,000 m^3/day to Tubli bay. This effluent is high quality especially after tertiary treatment. But as the secondary system including the chlorination is not operated continuously Coliform bacteria counts are very high in the effluent (1160890 No/100 ml). Analysis done during 1992 (Table - 9) showed that the effluent met the proposed effluent guidelines except for total Coliform bacteria (18560-4200000 No/100 ml), with an average of 1160890 No/100 ml, whereas the permissible limit is 1000 No/100 ml, as outlined in table-11.

4.9. ADDUR DESALINATION PLANT

Ad Dur Desalination plant started up in April 1992. The plant produces 46,000 m^3 per day of fresh water at present. As the plant is designed to use the reverse osmosis method, where the semi- permeable membranes are used for this purpose, the desalination processes use seawater as raw material and few chemicals are used.

The plant discharges brine effluent at a flow rate of 59,125 m^3 per day. The analysis done during 1992 (Table - 10) showed that the plant met the proposed effluent guidelines. However, the Iron (ferric chloride) which is used in the plant processes and discharged along with the effluent precipitated around the discharge point is impairing the quality of the seawater. This has created brownish condition around the area of discharge.

5.0 CONCLUSION

As the sampling was carried out on quarterly basis, it is difficult to make any firm conclusions from this study. However the following points have emerged from the study.

- There are many factors affecting marine water quality. Urban centers along the coast, cause tremendous stress to the vulnerable coastal environment by discharging treated and untreated sewage into the shallow coastal water, together with industrial effluents and other activities such as irrigation drainage water.

- Most of the industrial effluent outlets are located along the East Coast of Sitra (figure - 1) extending some 9 Km. long, the majority being in the upper half.

- Bapco effluents do not contain high levels of contaminants, however, since the flow rate are very high (572000 m^3/day), large quantities of chemicals such as sulphides, heavy metals are discharged into the marine environment, and because the current velocities of the sea are generally low, the effluent discharged near the coastline will move offshore only slowly and suspended matter will settle out rapidly. Therefore, the effluent will cause potential impact in the vicinity of discharge point.

- There are high nutrients loading into Tubli bay, from Tubli effluent (see table-9) and other various sewage discharges in that area. This may enrich the presence of the nutrient in the bay, such enrichment of the sea water by Nitrogen and Phosphorous can disturb the nutrient balance at the site of discharges. And also it can enhance the growth of certain marine organisms such as the algal bloom or red tides.

- Effluent containing high coliform bacteria is discharged to the marine environment. Although the persistence of the coliforms in the marine environment is short, it is possible that amenity use of the beaches for activities such as recreational purposes, bathing, water skiing, and consumption of polluted shellfish may pose health hazards to human beings.

- A point of concern is the proximity of the water desalination plants to major sources of effluent outlets. As figure-1 shows, North Sitra sewage treatment plant and BALEXCO are discharging their effluents near Sitra power and Water Station. This situation can lead to reduced quality of distilled water due to impurities could be associated with intake water.

- The Bahrain Aluminum Extrusion Company (BALEXCO) discharges it's effluent to the sea containing undissolved and 867.935 mg/l dissolved Aluminum Hydroxide, which adds up around 63.4 ton/yr entering the marine environment. This quantity of Aluminum is extremely very high considering the flow rate of 200 m^3/day. The precipitated Aluminum around the discharge points is very noticeable and extending out some distance from it, and impairing the quality of seawater. This has already created anaerobic conditions in the area. Therefore, the living organisms would not be able to adapt or survive in such conditions.

- The relatively high temperature effluents discharged directly into the marine environment from various industries such as Sitra Power & Water Station and BAPCO & GPIC, can cause a rise in water temperature and bring about thermal pollution since the difference in temperature can be more than10 ^{o}C

- It should be pointed that Bahrain's marine environment is naturally stressful. This is due to the fact that the waters surrounding Bahrain are very shallow. This, in combination with local weather patterns and tidal regimes, creates a wide variation in the water temperatures as well as high salinities due to high evaporation rates. Therefore, many marine habitats are surviving on the edge of their tolerance limits. Industrial effluents discharge points located at the east coast are most likely to increase the possibility of changes in the hydrology of the sea, which eventually could cause devastating effects on the marine environment, especially along the high productive east coast.

6.0 RECOMMENDATIONS

1. There is an absolute need for the formulation of legislative backing for Environmental Protection Committee (EPC). Without laws and regulatory legal guidelines, much of the research done by EPC will be of no use, and it is difficult to provide adequate and effective protection to the marine environment.

2. Continuous monitoring of effluent characteristics on quarterly basis are required, for finding yearly pollution load to the marine environment as the data will help EPC to update the status of the Marine Environment Report for Bahrain.

3. Since the waste water generated from BALEXCO is containing a significant amount of aluminum, which is undesirable for discharge into the marine environment especially because of the proximity of the discharge point to the Sitra Power & Water Station intakes, therefore, an improvement in the treatment facilities of the plant have to be introduced, such as upgrading the existing sedimentation pond by enlarging it and to install a second pond next to the existing one ... etc.

4. Although the persistence of the coliforms in the marine environment is short, it is possible that amenity use of the beaches for activities such as recreational purposes, bathing, water skiing, and consumption of polluted shellfish may pose health hazards to human beings. It is important that coastal water be sufficiently free from pathogenic organisms, so that water borne infections do not pose a significant health risk to those who utilize it for recreation and other purpose. Thus, the chlorination of secondary effluent stream of Tubli WPCC is necessary as it is discharged into Tubli bay, otherwise the effluent utilization for agriculture should be implemented.

5. Studies dealing with impact of industrial effluent discharges on marine ecology as well as desalination plant intakes should be encouraged and carried out.

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LIST OF TABLES

Table 2 Effluent Analysis for Sitra Power & Water Station

Table 3 Effluent Analysis for Balexco

Table 4 Effluent Analysis for R.O. Plant

Table 5 ffluent Analysis for BAPCO

Table 6 Effluent Analysis for BAPCO No. 6 sep

Table 7 Effluent Analysis for Al Zamil Aluminium

Table 8 Effluent Analysis for GPIC

Table 9 Effluent Analysis for Tubli WPCC

Table 10 Effluent Analysis for Ad Dur R.O. Plant

Table 11 Proposed Effluent Guidelines for Bahrain

LIST OF FIGURESLIST OF FIGURES