DETERMINATION OF WASTE RECEIVING CAPACITY OF IZMIT BAY

A MASTER'S THESIS

IN

ENVIRONMENTAL ENGINEERING DEPARTMENT

MIDDLE EAST TECHNICAL UNIVERSITY

by

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To my Mother and Father

Approval of Graduate School of Natural and Applied Sciences.

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ABSTRACT

DETERMINATION OF WASTE RECEIVING CAPACITY OF IZMIT BAY

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In this study the major sources that cause pollution in Izmit Bay and their pollutional loads are investigated. And it is intensified on Eastern Part of the Bay that receives the major part of the industrial and the domestic waste waters.

The main reasons that cause pollution in the eastern bay (as a polluted-eutrophic lake) are investigated by taking care of the oceanographical, topographical and hydrographical situation in the Bay. And also the critical pollutional parameters are determined. In this study toxic materials and suspended solids are not investigated, since they require measurements in sediments and also due to the lack of information. The studies are intensified on BOD_5, and nutrients (nitrogen and phosphorus). And the waste receiving capacity of the bay is determined according to these parameters.

Besides the settlements around the bay, SEKA pulp and paper factory that give the major part of the organic load to the bay is investigated. And appropriate alternatives for preventing the pollution caused by industries and settlements are proposed.

Key Words : Izmit Bay, Eastern Bay, wastewater, marine pollution, assimilation capacity, pollutional load, pollution control.

ÖZET

İZMİT KÖRFEZİNİN ÖZÜMLEME

KAPASİTESİNİN TAHMİNİ

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Bu tez çalışmasında İzmit Körfezinde kirliliğe neden olan başlıca kirletici kaynaklar ve bunların körfeze verdikleri yükleri incelenmiştir.

Bu incelemeler sonucunda körfezde endüstri ve nüfus yoğunluğunun en fazla olduğu doğu körfez ele alınmıştır.

Şu anda kirli-ötrofik bir göl niteliğinde olan doğu körfezde kirlenmenin nedenleri, körfezin oşinografik, topografik ve hidrografik durumu göz önüne alınarak araştırılmış, kritik kirleticiler belirlenmiştir. Körfez suyunun yanında taban sedimanında da ölçümler gerektiği ve yeterli bilgi edinilemediği için, bu çalışmada toksik metaller ve askıda katı maddeler dikkate alınmamıştır. Çalışmalar körfezde kritik olan BOD_5 ve besin maddeleri (azot ve fosfor) üzerinde yoğunlaştırılmış ve bu parametrelere bağlı olarak körfezin özümleme kapasitesi hesaplanmıştır.

Körfezde yerleşimlerin dışında körfeze en fazla kirlilik yükü veren ve doğu körfezde bulunan SEKA kağıt fabrikası atıksularının taşıdığı

kirlilik yükleri incelenmiş olup evsel ve endüstrilerin yarattığı kirliliğin önlenmesi için alternatifler getirilmiştir.

Anahtar kelimeler : İzmit Körfezi, doğu körfez, atıksu, deniz kirliliği, özümleme kapasitesi, kirlilik yükü, kirlilik kontrolu.

A C K N O W L E D G E M E N T S

I would like to express my deepest gratitude to my thesis supervisor Prof.Dr.Turgut Balkaş for his invaluable supervision throughout this thesis.

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LIST OF ABBREVIATIONS

BOD_5	Five Days Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
N	Nitrogen
NH_3-N	Ammonia Nitrogen
NO_2-N	Nitrite
NO_3-N	Nitrate
P	Phosphorus
PO_4^{-3}	Ortho Phosphate
Q	Discharge Rate
S	Salinity
T	Temperature
TSS	Total Suspended Solids

CHAPTER 1

INTRODUCTION

1.1. General

The use of coastal waters around the world is increasing. This is not only the increase of traditional human activities (fishing, marine transport, disposal of wastes) but also sites for industrial operations. In addition to these activities, coastal waters provide a sink for wastes from land based activities. These wastes enter a specified coastal water region through; the inflow of rivers, direct discharge of liquids and solids, sea currents and atmospheric deposition which effect assimilation capacity.

In the most developing countries as well as the developed countries in the last 10 to 20 years especially the need has been felt to struggle marine pollution. Marine pollution is defined by GESAMP Working Group (1 , 2) as, "directly and indirectly introduction of substances or energy by man into the marine environment resulting in such deleterious effect as harm to living resources, to be a hazard to human health, a hindrance to marine activities including fish, impairment of quality for use of sea water and a reduction of amenities". And as a heavy industrialization of developing countries, pollution problem of the marine environment have increased enormously due to inadequate legislation.

In Turkey as a developing country, the environmental pollution problems have particularly increased since 1960, due to rapid growth of industry and widespread increase of population (3). The wastes of settlements and the industries have been mostly discharged to the environment without any pretreatment. The coastal pollution in Turkey is becoming serious, where in Sea of Marmara, particularly in Izmit Bay the pollution is most serious.

Izmit Bay is the most polluted and the most industrialized region in Turkey. A widespread growth of large spectrum of industrial activities ranging from pulp and paper to petrochemical, from food to metal processing and fertilizer industries have increased the pollution problems arising from their wastewaters with high pollution potential. In the area surrounding the Bay, more than 140 large industrial plants have been established since 1965 (4). The total number of industries that cause pollution in the bay is around 186 (4, 5, 6). Their solid and liquid wastes are directly discharged into the bay without any pretreatment. Besides the industrial waste water discharges, domestic wastewaters discharging directly into the bay also cause pollution in the region.

This great volume of unpurified industrial and domestic wastewaters discharged, have brought the bay in a state that the biological self purification capacity of the bay is no longer sufficient to restore the equilibrium to its normal state. Because of the bottlenecks and bottom topography of the bay, which resembles that of fjords, the capacity of the bay for receiving wastewaters, is limited (7).

1.2. Definitions

The waste receiving capacity of the environment is a property of the environment that can be defined as its ability to accomodate a particular activity or rate of activity (e.g. volume of waste discharge per unit time etc.) without unacceptable impact (1). The waste receiving capacity of a body is partially related to the process that control oxygen balance of that water. Environmental capacity will have to be assessed on the basis of the environmental standards selected, boundary conditions and removal processes.

In order to preserve quality of the water resources and prevent and control pollution of the bay, discharge standards should be set for organic matter, nutrients and other toxic substances. Before setting these standards it is necessary to assess the assimilative capacity of the bay. This process must take into account; physical processes, biochemical processes, biological processes which lead to degradation or removal from the impacted area by which a contaminant or an activity loses its potential for unacceptable impact.

GESAMP Working Group on Methodologies and Guidelines for the Assesment of the Impact of Pollutants on Marine Environment has established a guideline for the evaluation of Environmental Capacity (Waste Receiving Capacity) which has already been applied to some places in the world to evaluate the acceptable level of pollutional input to the marine environment (13, 14).

According to this guideline qualification and derivation of environmental capacity involves the following main contaminants,

- characteristics of the contaminants,
- environmental distribution of the contaminants- concentration of various substances in the water,
- discharges from various sources (rivers, sea currents, coastal outfalls, dumping of industrial wastes and marine transport, etc.)
- oceanographical and hydrographical characteristics of the system,
- definition of the impacted ecosystem (1, 2).

So it is necessary to obtain required data (adequate and reliable) on oceanography and pollutional feature of the ecosystem.

Waste Receiving Capacity of an ecosystem can be calculated using the information listed above. Starting from a simple steady state box model a preliminary calculation can be made and progressively refined by the inclusion of more parameters and variables.

Simple mass balance model such as those using the mean residence time (the ratio between the amount of the chemical species in a given closed system and its rate of disappearence in this system) concept may provide a good insight.

For a closed system, the Waste Receiving Capacity is given by the total load, which is the volume of the system multiplied by the difference between the maximum allowable concentration and the existing concentration in the system. This input will bring the system up to the maximum allowable concentration after which any further input would be unacceptable.

Therefore, in a steady state condition, when the maximum allowable concentration is reached the remaining Waste Receiving Capacity becomes a function of main residence time.

1.3. Scope and Objectives of the Thesis

In this thesis the pollutional data obtained since 1971 are used. In the calculations, the year of 1980 is taken as a base.

Izmit Bay as the most critical region in Turkey interms of its pollution level, it is necessary to evaluate maximum allowable concentrations of selected parameters (which are the most critical) after which any further input would be unacceptable. The objective of this thesis is to evaluate the Waste Receiving Capacity of the eastern part of the bay in the light of the following Chapter that includes the following items;

- the characteristics of the selected parameters, their distribution in the bay and their concentrations,

- oceanographical and hydrographical characteristics of the Bay,
- the definition of the impacted area in the Bay,
- the nature of the pollution problem in Izmit Bay.

CHAPTER 2

GENERAL PROPERTIES OF IZMIT BAY

2.1. General

Izmit Bay is located on the northeastern part of the Sea of Marmara. It is a semi-enclosed water body with approximately 53 km in length. Total surface area is 310 square kilometer. The width of the bay varies from 2 to 10 km. According to the topoghraphy and the oceanographical characteristics, the bay is separated into three distinct regions connected to each other with narrow opening.

REGION / PROPERTIES	EASTERN	CENTRAL	WESTERN
Length (km)	16	20	17
Width (km)	2-5	3-10	3-5.5
Max.Depth (m)	35	180	1000
Surface Area (km^2)	44	166	100
Volume (km^3)	0.850	12.42	-

Table 2.1. Characteristics of the reagions of Izmit Bay (1-17).

Inner Region(Eastern) constitutes the smallest component of the system. It is about 16 km in length and relatively shallow, having maxi-

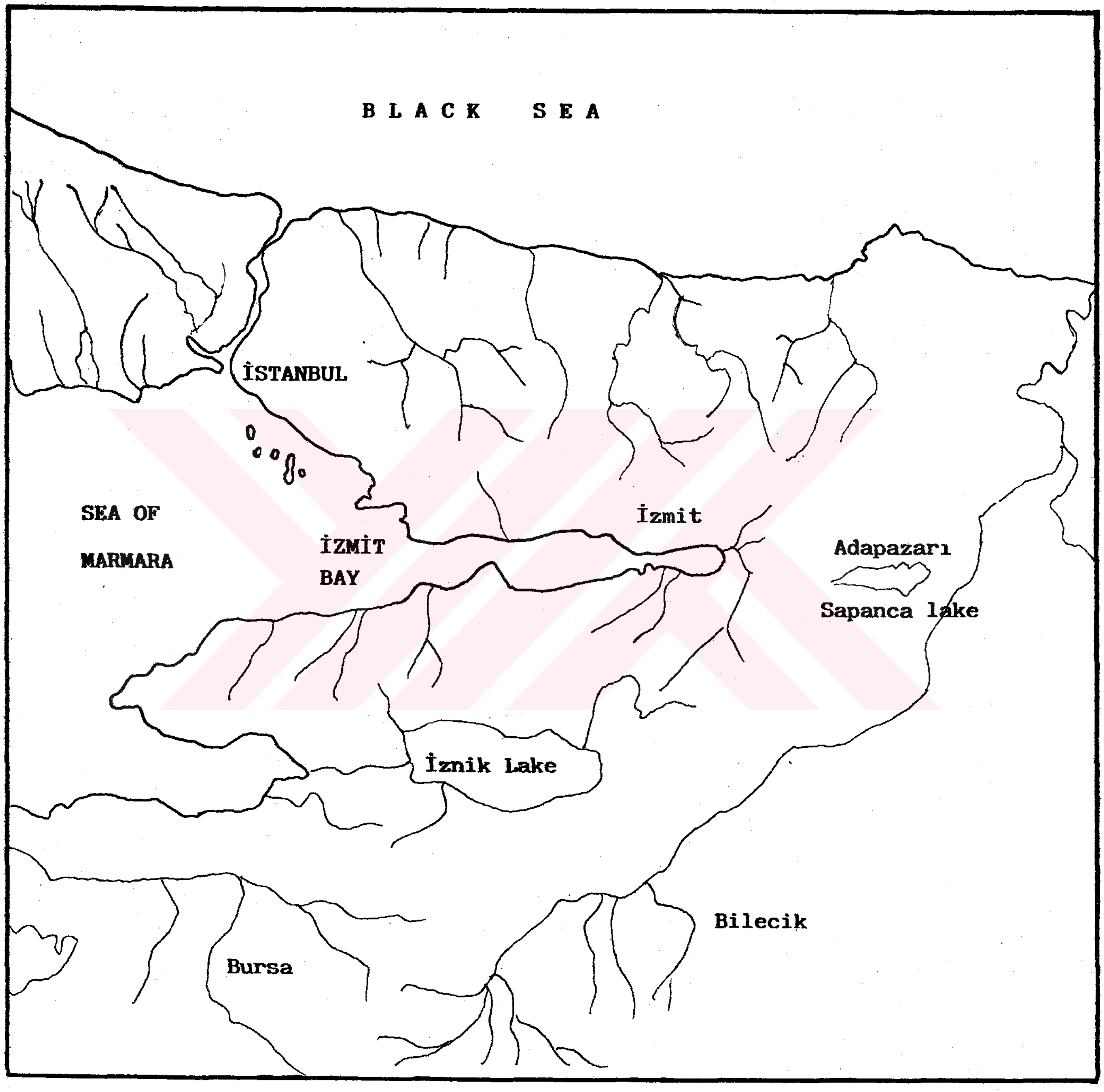

Figure 2.1. Location of the Izmit Bay on the Sea of Marmara.

mum depth of around 35 m. It is connected to the central region by a 2 km wide opening.

Middle Region(Central) is the largest component of the system with a length of about 20 km. The bottom topography varies to a considerable extent along the north-south direction. While the northern part is shallower with an average depth of about 60 m, the depth reaches to approximately 180 m in the southern section. It is separeted from western region with a narrow opening of 3 km width and 55 m sill depth around Dil Burnu.

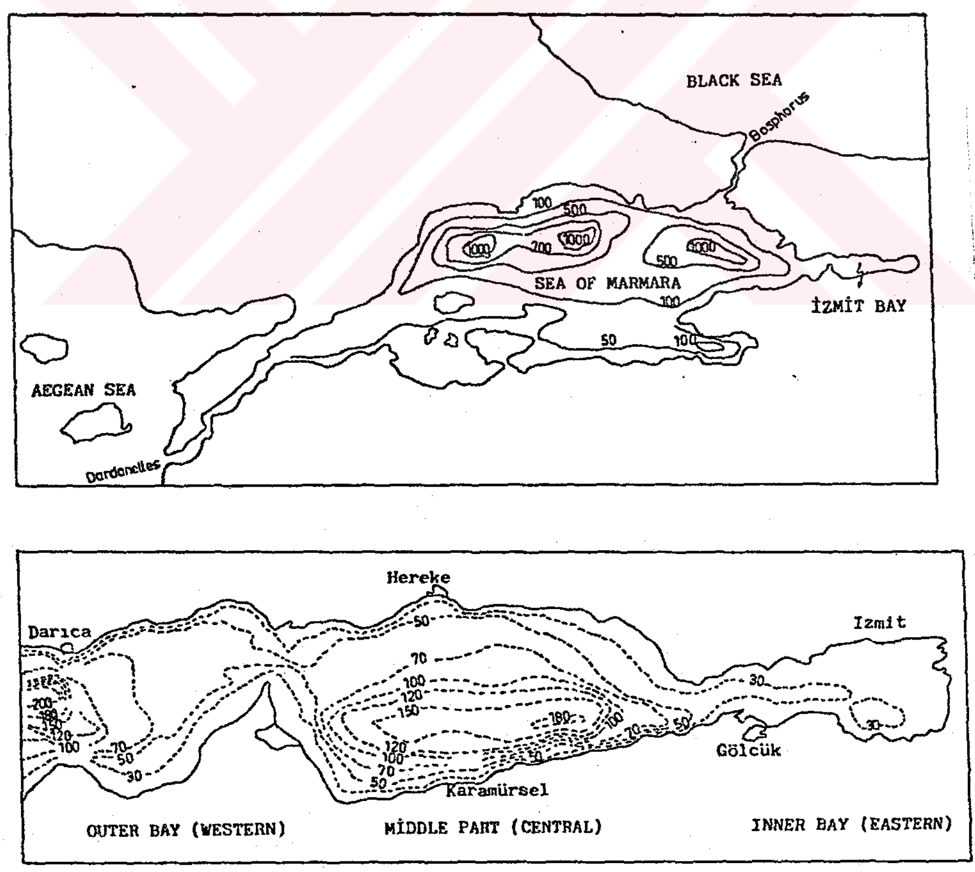

Figure 2.2. Location map and the bathymetry in the bay.

Outer Region(Western) is relatively deeper than the inner section of the bay and the bottom topography slopes downward in westerly direction. The depth near the end of the bay where it is bounded to Northeastern Marmara Basin, reaches 200 m . It is connected to Marmara Basin with a 5.5 km wide opening. In terms of oceanographical characteristics, this region may be treated as a part of the eastern Marmara Basin.

The total drainage area of Izmit Bay for its central and eastern sections is about 1205 km^2, excluding the area of the bay itself. The drainage area of the eastern part is about 230 km^2 and that of central section is about 975 square kilometers.

Western section is under direct influence of Sea of Marmara through deep, wide channel. There is no large industrial activity with high polluting potential. Consequently it is the least polluted part in the bay.

Central part communicates through a 3 km wide sill with western section. It has two parts; Site-I, Site-2 representing western and eastern sections of central region, respectively. Site-2 is higly influenced by the heavy industries located on the north eastern part of the region and by the polluted waters flowing from the surface of the eastern part of the bay. Site-I is comperatively less influenced from sources effecting Site-2.

Eastern section, although it is the smallest part of the bay, it receives most of the pollution load and it is the highly polluted section of the bay.

The pollution is caused mainly by industrial and domestic wastes originated from urban and sub-urban areas.

Determination of the exchange rates between the bay and Sea of Marmara, as well as vertical and horizontal exchanges between the three sections are of primary importance. In addition to amount, the extend of the industrial and domestic wastes discharged into the bay is also the part of the main characteristics to be determined. Besides the investigations of such interactions, through physical, chemical and bio-chemical measurements, other factors affecting the hydrodynamic behaviour of the bay, such as wind driven density currents, should be determined to achieve a representative model of the Bay (6).

The physical parameters to be considered in this study are; temperature, salinity, current speed, direction in the upper and lower layers, sea and atmospheric conditions. Chemical parameters to be considered are; Dissolved Oxygen, Biochemical Oxygen Demand, Nutrients (nitrate, nitrite, ammonia, kjeldahl nitrogen, total and orthophosphate).

2.2. Hydrology and Meteorology in the Bay

The data about hydrological and meteorological regime in/around the bay are taken from General Directorate of State Meteorological Works.

The average annual precipitation is about 700 mm within the bay

(7, 8). Two thirds of the total precipitation is received between October to March.

And the annual evaporation is about 600 mm, about two thirds of this amount occurs between April to November. During this period evaporation is greater than precipitation (7).

The estimated river input through several cracks into the eastern and central regions is approximately about 15 cm. The total fresh water input to the bay comprising the precipitation, evaporation and river inputs can, therefore, be neglected as compared with the total volume of the bay (6).

The ground water reserves can be assumed as constant in the catchment area of the eastern and central part of the bay. So the total fresh water (river) input is equal to the difference between the amounts of precipitation and evaporation. According to the above data (700 mm precipitation and 600 mm evaporation) total fresh water input to the central bay is about 3 m^3/sec and the inner bay is about 0.7 m^3/sec. If we compare these values with the other effects that influence the water circulation in the bay, it has a very minor effect. So the total fresh water input to the bay comprising the precipitation, evaporation and river inputs can, therefore be neglected as compared with the total volume of the bay (6).

The regional wind conditions influencing the Izmit Bay are dominated by northeasterlies from Black Sea throughout the year. Occasionally, prounounced southwesterly winds from Sea of Marmara are also the characteristic feature of the bay, particularly during the winter months. The southeasterly winds may be as high as 15-20 m/sec. But they last within one or two days at most and produce frequently storm waves and surges within the bay (7). The maximum daily mean wind speeds of each month are relatively strong and about 5-7 m/sec.

2.3. Oceanographical Characteristics of the Bay

Since 1967 many studies have carried out in the bay. Most of the studies (1968-1973) comprise mostly the measurements carried out on the eastern section of the bay and on the coastal areas which are influenced directly by the wastewaters. More detailed observations are conducted later, during 1975 for the Izmit Sewerage Project by SWECO and BMB. And long term oceanographical and pollutional data are complied in relation with the on going research studies for the NATO-TU waters project during May 1984-May 1985. The spatial and temporal characteristics of the main hydrographical features related with the water masses, stratification, vertical mixing and circulation occured in the bay and also pollutional studies are given by using those reports.

2.3.1. Temperature and Salinity Variations in the Bay

There are two essential factors affecting the density of sea water;

temperature and salinity. The density gradients explain a number of large scale oceanic circulation and it is only on the basis of systematical measurements of temperature and salinity (thus density) that is possible to discover and explain these circulations (7).

In order to determine density and the circulation pattern in the bay there were long term measurements of salinity and temperature. Salinity distribution within the Izmit Bay shows a similar character to temperature distribution. The Black Sea waters are mixed in some proportions within the Aegean Sea waters as it passes through the Bosphorus, and covers the upper 20 meters of the Sea of Marmara. Aegean Sea waters are present below 25-30 m.

Aegean Sea waters present at depths below 50 m in June, rise up to around 30 m in July and remain there through August. The depth of upper mixed layer in June is higher than in July and it is due to increased input of Black Sea waters in spring.

The monthly variations of typical surface temperature and salinity are shown in Figure 2.4 and 2.5.

The hydrological regime of the bay is to a large extent, governed by the exchange of water between the Black Sea and the Aegean Sea. More specifically, the bay exchanges its water with the Sea of Marmara through its opening to the northeastern Marmara Basin. Although the bay dictates a permanent two layer stratification throughout the year, the degree

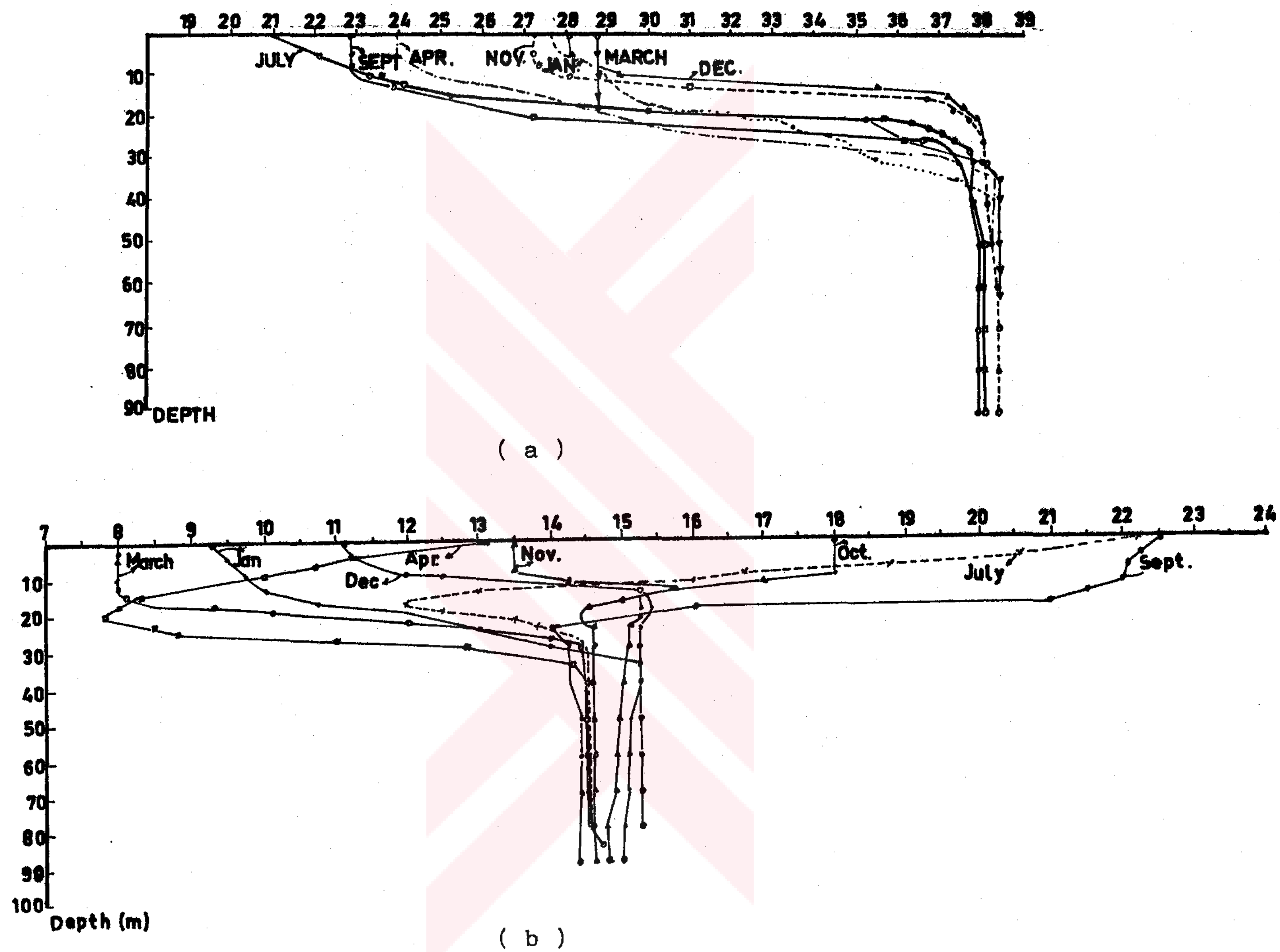

Figure 2.3. Typical monthly variations of temperature and salinity stratification during 1984-1985 (7).

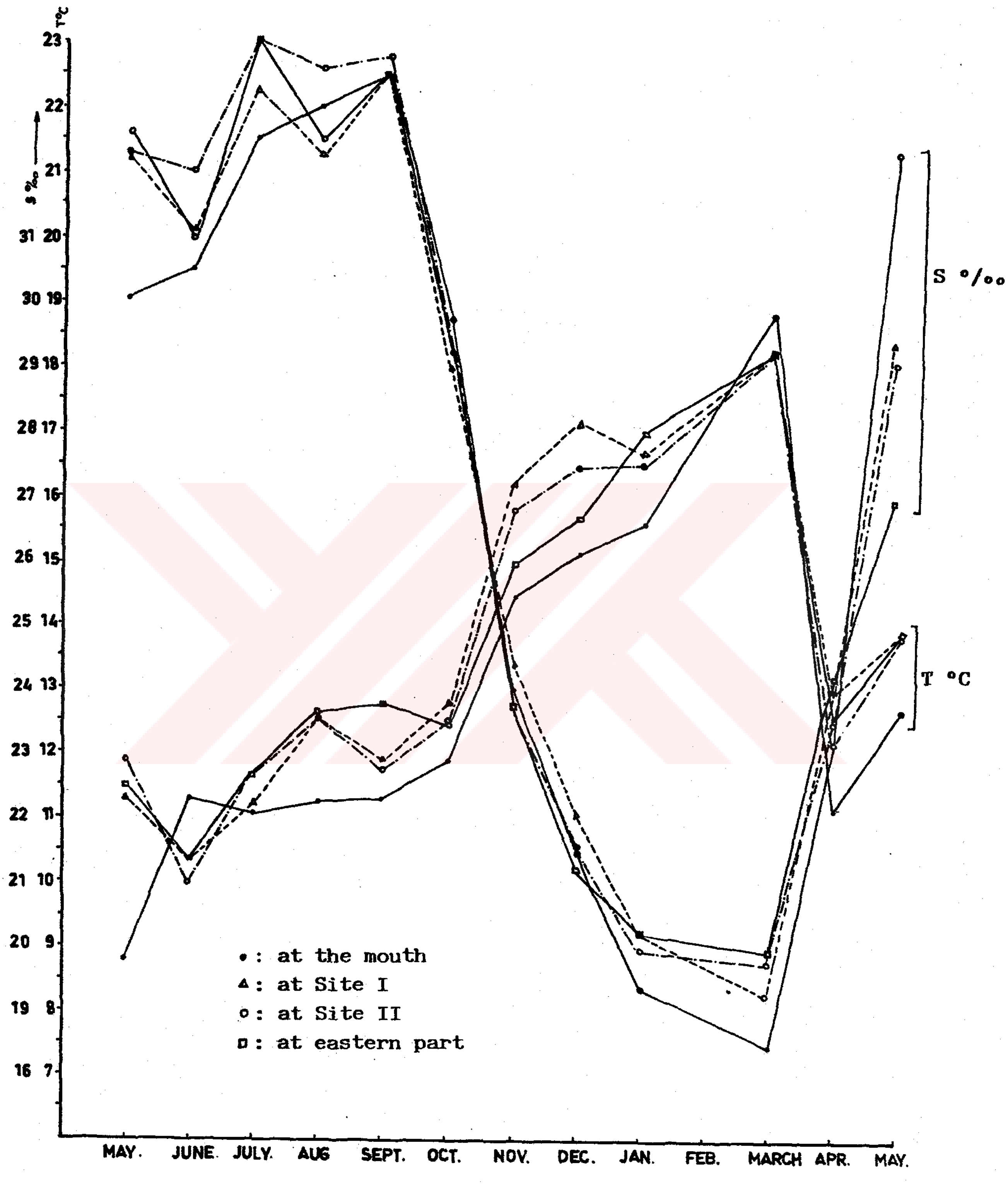

Figure 2.4. Monthly variations of surface temperature and salinity at different sections of the bay (7).

of stratification and the characteristics of water masses show considerable interannual variations, particularly in the upper layers (7). In spring and summer seasons there is an inflow of the low saline waters of Black Sea origin with 21-24 ppt salinity over the high saline waters of the Aegean origin. This period corresponds to times in which precipitation and fresh water flow into the Black Sea increases substantially.

In November surface salinity of the bay waters rises to 26-28 ppt due to inflow of high saline bottom waters into the bay.

In March, the increase in the surface salinity continues during the winter months and reaches 30-32 ppt in March, which also corresponds to minimum temperature values as 7-8 °C.

In April, surface salinity decreases and surface temperatures increase. The change occurs due to the inflow of new brackish surface waters of the Black Sea origin into the bay. The surface salinity data indicates that the replacement of the surface waters in the bay starts in April. The surface water temperature in the bay stays almost constant during the summer months.

In October, surface water temperature starts to decrease, it reaches 11°C in January and 7.5°C in March. The winter season is characterized by the inflow of bottom waters of northeastern Marmara Basin into the bay and subsequent increase in surface salinity. Thus, the layer of high saline bottom waters, which have 38-38.5 ppt salinity and 14.5-15.0 °C temperature, rises inside the bay.

Monthly changes in the vertical structure of the temperature and salinity;

According to salinity, there is always a stable stratification at all seasons. The degree of stratification changes to some extent within a year. Surface and bottom waters having a fairly uniform structure are separated by a sharp hallocline* whose position and slope change seasonally.

Late spring and summer period (from April to September);

This period corresponds to presence of the lowest salinities (21-24 ppt) (**7**), caused by the inflow of Black Sea waters into the bay. The halocline is located about 20-30 m depths below which the lower layer waters attain about 38 ppt salinity values. And the thickness of the transition zone is very limited.

In November and afterwards (during winter months);

The interface rises upwards to approximately 10-15 m depths and becomes more slanted as compared to summer situations. Almost 5-7 ppt

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* The separation between two layers of sea water of different salinity gradients is never a clear interface as is the case with two immiscible liquids. There is always a transition zone whose thickness tends toincrease under the influence of currents and turbulence. This interference is called "hallocline" (19).

increase observed in the winter surface salinities is related with diminishing of the brackish water supply from the Marmara waters as well as increased action of wind induced mixing taking place across the hallocline and due to this strong turbulent mixing across the interface the thickness of the transition zone becomes larger.

The vertical structure of temperature also shows drastic changes. The winter season is characterized by almost uniform and cold surface waters of 8-13°C placed on top of relatively warmer bottom waters with about 15°C temperature. As having 14.5°C temperature during winter months indicates the inflow of Marmara Sea waters in deeper levels.

The longitudional salinity and temperature variations;

Black sea waters with about 21 ppt salinity enters into the bay from its opening to the eastern Marmara Basin and proceeds eastwards along the surface salinity increases to 22 ppt and inner section has a salinity of 23-24 ppt (7). Stratification then weakens gradually towards to interior. The bottom waters have typically 38 ppt salinity values in the western and central regions where the salinity of the deep waters of inner bay is 37.5 ppt. The surface layer waters extent to deepest levels in the eastern region, and the upper layer is only 25-30 m in the western region.

Marmara waters with having 38 ppt salinity and 14.5°C temperature values are only observed in the western and central part, where the salinity and temperature is reduced to 37.5 ppt and 14°C, respectively, within the eastern region. This reduction is due to vertical mixing. During winter especially in the inner part the stratification is weak and there are stronger vertical mixing. As a result of weakening of stratification, upper layers are easily mixed by the northeasterly winds dominating in the winter season. Thus peak values of surface salinity may appear within a short period of time because of strong wind episodes in winter months. Inner part has higher surface salinities then rest of the bay as about 30 ppt.

However, there exists sharp temperature and salinity stratifications throughout the year with the exeption of the eastern region during the winter months. Some short term peaks in the surface salinity can appear due to strong wind episodes in the winter months. Almost a 5 ppt increase in the surface salinity occurs due to the 10 m/sec northeasterly blowing wind in February.

As a conclusion, the stratification of the bay indicates that there are two different types of water structure during the two different periods of the year. The April-September period is characterized by inflow of Black Sea waters along the surface layer. The November-March period, saline Marmara Sea waters inflow to the bay and drive the movement of the water masses.

PERIOD	THE DEPTH OF THE TRANSITION LAYER(m)
MAY-SEPTEMBER	20-25
OCTOBER	15-20
NOVEMBER	10(minimum of the year)
JANUARY	30-40
APRIL	20

Table 2.2. The change of transition layer throughout the year(7).

In Tables 2.3. and 2.4., the summary of the salinity and temperature variations are given.

PERIOD	S%	T°C	COMMENTS
SPRING-SUMMER	21-24	14.5	Inflow of low saline waters of Black Sea origin(times of increased precipitation and fresh water flow into the Black Sea), stratification weakers and vertical mixing is stronger
NOVEMBER	26-28	11	Due to high saline bottom waters inflowing from Aegean Sea. Negative thermocline occurs due to surface cooling
MARCH	30-32	7-8	Increase in surface salinity continues, uniform, homogeneous upper layer is formed because of the turbulent mixing
APRIL	21-24	14	Surface salinity decreases and surface temperature increases due to inflow of Black Sea origin waters into the bay, water exchange starts
WINTER	28-30	7-13	Inflow of saline Aegean Sea waters and replacement of anoxic bottom layer waters with new Aegean Sea waters, drives the movement of water masses

Table 2.3. Salinity and temperature variations through the year (7).

SECTION	PERIOD	COMMENTS
EASTERN	OCTOBER-NOVEMBER	Surface temperature decreases with a simultaneous increase in salinity
	DECEMBER	Surface salinities increase suddenly from about 26 ppt to 32 ppt without any change in temperature
	JANUARY	Surface temperature keeps going down, whereas surface salinity decreases
	MARCH	Surface salinity increases to its original value
CENTRAL SITE I-II	OCTOBER DECEMBER	Surface salinity increase correlate with the decrease in the surface temperature-keeps cooling/mixing character
SITE I	DECEMBER-MARCH	Surface salinity continues to increase and temperature goes further down
SITE II	DECEMBER-JANUARY	Surface layers cool down without any further increase in salinity
SITE II	JANUARY MARCH	Increase in surface salinity
WESTERN	NOVEMBER-DECEMBER	Surface salinity decreases as temperature continues decreasing due to inflow of less saline surface waters from the open sea
	DECEMBER-MARCH	Temperature decreases and salinity increase

Table 2.4. Salinity and temperature variations in the sections of the Bay (7).

2.3.2. Water Circulation Pattern in the Bay

Between Izmit Bay and Marmara Sea, a water circulation, which is the major factor that affect the water quality in the bay, exists to some extent. Therefore the circulation rate of the water in the bay should be determined. The exchange presumably, has a considerable variation throughout the year, eventhough inflow and outflow rates and their temporal variations are not known precisely.(3).

The main factors affecting water circulation in the bay are; amplitudes and periods of wind induced seiches in the transition zone, salinity variations at different depths in the Sea of Marmara, surface currents induced locally by wind in the bay. The minor factors affecting water circulation in the bay are; water level variations due to wind, tidal effects, changes in barometric pressure, turbulent mixing across the transition zone, fresh water discharges into the bay.

The turbulent mixing in the transition zone is estimated from the density difference between the upper and lower layers and the energy produced by the wind motions. As it is mentioned before the fresh water discharges has a very little effect on circulation in the bay (8, 11) (See section 2.2.).

2.3.2.1. Wind Induced Seiches

These measurements were carried out by SWECO-BMB in 1976 between

8-33 m depths (salinity and temperature). It is understood that the main factor that affect internal seiches in eastern part is the wind. For example,it is seen that the level of transition zone is 7 m reduced in 24 hrs due to the storm (in March) that push the surface waters to the central part. The difference between the minimum and maximum levels of the transition zone is average 6.2 m (15-18). The rate of exchange of bottom waters is found as to be 21 x 10^6 m^3/day. The volume of the bottom layers (below transition zone) is 170 x 10^6 m^3, then the retention time for the bottom waters can be found as about 8 days.

On the basis of the hydrographical observations as well as the current measurements, the Izmit Bay shows a two layer current system throughout a year. According to SWECO-BMB (8, 11), the water circulation is basically due to internal seiches, that can be measured by the changes in the thickness of the surface layer within the bay and adjasent Marmara Basin. During the late spring and summer periods, due to inflow of colder and less saline surface waters of Black Sea, the transition zone shows an upward tilting towards the interior where the surface waters mix with those found in deeper levels. A westerly outflow than takes place at the transition zone below which some inflow of less saline Marmara waters penetrate into the bay.

Although SWECO-BMB has found that the water exchange between various sections of the bay is a result of the internal seiches which are found as being the most dominant mechanism responsible for the water movements within the bay , but the internal seiche event has been observed during the extreme conditions (when the winds having magnitudes of about 10-15 m/sec (where monthly mean is 2-3 m/sec) and affected the bay waters with an easterly surface currents of 10-20 cm/sec.

The wind speeds observed later on are smaller than those used in SWECO-BMB computations. The maximum current speed in the bay at 23 m depth is 0.17 m/sec and at 26 m depth is 0.20 m/sec. So the internal seiches, in general, do not have any contribution to seasonal circulation of the Izmit Bay for long term dispersion of the pollutants (7).

The internal seiches with characteristics oscillation period of 40 hours are the major factors that affect short term water circulation pattern also control the water circulation through the bay. Besides these factors, the annual salinity changes in the deep waters of the central part (below the sills at 60 m depth at the entrance of the bay).

2.3.2.2. Wind Induced Currents

The topography of the Izmit Bay shows that the prevailing current direction is from east to west (proved by SWECO-BMB) (8 -11). Water masses that are not affected by wind motions, the current speeds are very low.

In SWECO-BMB report, the results are based on rather limited observations and are representing rather extreme conditions. The maximum daily wind speeds observed in 1986 by TUBITAK (7) within each month during the two years observation are much smaller than those used in SWECO-BMB computations.

According to SWECO, the largest exchange takes place at the surface waters across the Dilburnu between the western and central regions.

The flow proceeds towards Dilburnu, some part of it turn cyclonically and finally leaves the bay along the northern coast. The feature is found to be consistent with transverse summer salinity transects (13). The flow entering into the central region reaches eventually to the eastern region and forms a cyclonic circulation in its innermost section. The surface currents are in westwards and eastwards directions on the northern and southern sections, respectively. On the other hand the current measurements indicate a presence of vertical flow structure within the deeper levels during the summer months. The westerly currents observed at about 20-30 m depths across Dilburnu section are associated with the interfacial zone and the upper parts of the lower layer. The measurements taken at southern part of the bay mouth (50 m depth) reveal inflow of deep Marmara waters into the bay. While some part of the flow undergoes a lateral circulation and eventually leaves the bay along the northern section of the outer region, some part of the saline

Marmara waters are expected to cross Dilburnu section and enter the central region below the levels where the westerly flow takes place (see Figure 2.2, 2.3- Temperature and Salinity variations). Consequently, summer circulation taking place within the bay comprises an inflow of Black Sea waters along the surface levels and a net compensatory outflow within the intermediate levels together with an inflow of deep Marmara waters at near bottom levels influencing particularly the western an central regions.

There is always weak currents not exceeding 5 cm/sec at deeper layers of the bay. Since October corresponds to a transitional period therefore there is weak flow patterns. The salty waters of Sea of Marmara enter to the bay along the southern coast of the western region. During the late autumn and winter periods the transition zone slopes downward in the easterly direction. An outflow occurs at a thin surface layer as well as the near bottom levels. The deep layer in which there is an outflow from the bay is separated by a transition zone tilting upward towards the inner sections. This situation prevails until seasonal circulation patterns, the wind stress exerted on the free surface and associated internal seiches further cause short-term motions of the interfaces which may contribute, to a certain extent, to the seasonal mean circulations of the bay.

The current speeds measured in south entrance point is 15 cm/sec which is three times of those at the same level in the north entrance.

2.3.2.3 Summary of the Circulation Pattern Throughout the Bay

The circulation pattern has mentioned previously depending on the observations made by TUBITAK(3, 5, 6, 7, 18, 19), ITU(4,14,15), and SWECO-BMB(8- 11). There is always a two layer circulation pattern in the bay due to strong stratification.

A. Summer Circulation

The surface layer currents having speeds of maximally about 10-15 cm/sec enter into the western region of the bay through its southern coastline. A similar but weaker feature is also present in the lower layer. The flow enters along the southern coast rather than the northern coast due to the control of the flow by the topographical property of the outer region. And the horizontal circulation within the outer region can be related to sharp stratification and associated somewhat weak vertical mixing taking place between the layers within the outer region during the summer months. The inner sections of the bay are not sensitive to the variations in the flow conditions taking place within the western region.

While there exists clockwise circulation patterns in the deep southern basin, cyclonic circulations form on the northern section. The magnitude of currents are about 5 cm/sec within the central region

(7). The lower layer waters flow in the westerly direction towards the central region where the flow pattern follows closely to that given in the surface layer. These waters cross Dilburnu section and finally joins to the open sea along the northern coast of the outer region together with those entered from the southern coast (7).

The 32% of the surface flow entering the bay undergoes interfacial mixing with the lower layer waters in the western region where 67 % of it enters into the central region and approximately 14 % reaches to the eastern region.

Average current speed of the surface layer is about 7 cm/sec at an average depth of about 9 m. The current speeds, having the maximum at the surface, decrease gradually with depth. And also surface layer speed is 9 cm/sec around Dilburnu section and it is 4 cm/sec around Derince-Gölcük region (7).

B. <u>Winter Circulation</u>

It is found that (7) there is an inflow of deep Marmara waters at about 10 m level whereas an outflow of the deep bay waters taking place at near bottom levels within the central and eastern regions and about 50 m depths near the mouth of the bay. The outflowing waters return to open sea near bottom levels together with the thin surface level.

Deep Marmara waters enter into the bay across Dilburnu section with an average speed of about 4 cm/sec. Then, they are directed towards south with an average current speed less than 5 cm/sec.

The lower layer waters proceeding eastward along the bay also undergo interfacial mixing and corresponding return flow is developed on the outer surface layer. The magnitude of the surface currents double the magnitude of those in the lower layer. At Dilburnu section, surface of the intermediate layer have average current speeds of 8 cm/sec. The currents measured at the near bottom levels, have an average speed of 5 cm/sec, where the average current speeds are about 5 cm/sec and 3 cm/sec respectively, for the intermediate and bottom layers of the Derince-Gölcük section.

Consequently highly polluted surface waters within the interior of the bay are transported to the outer region so that the bay may flush itself to a certain extent during the winter months. The amount of waters reaching to the central and eastern regions along the lower layer constitute, about 60 % and 19 % of the net inflow rate, respectively.

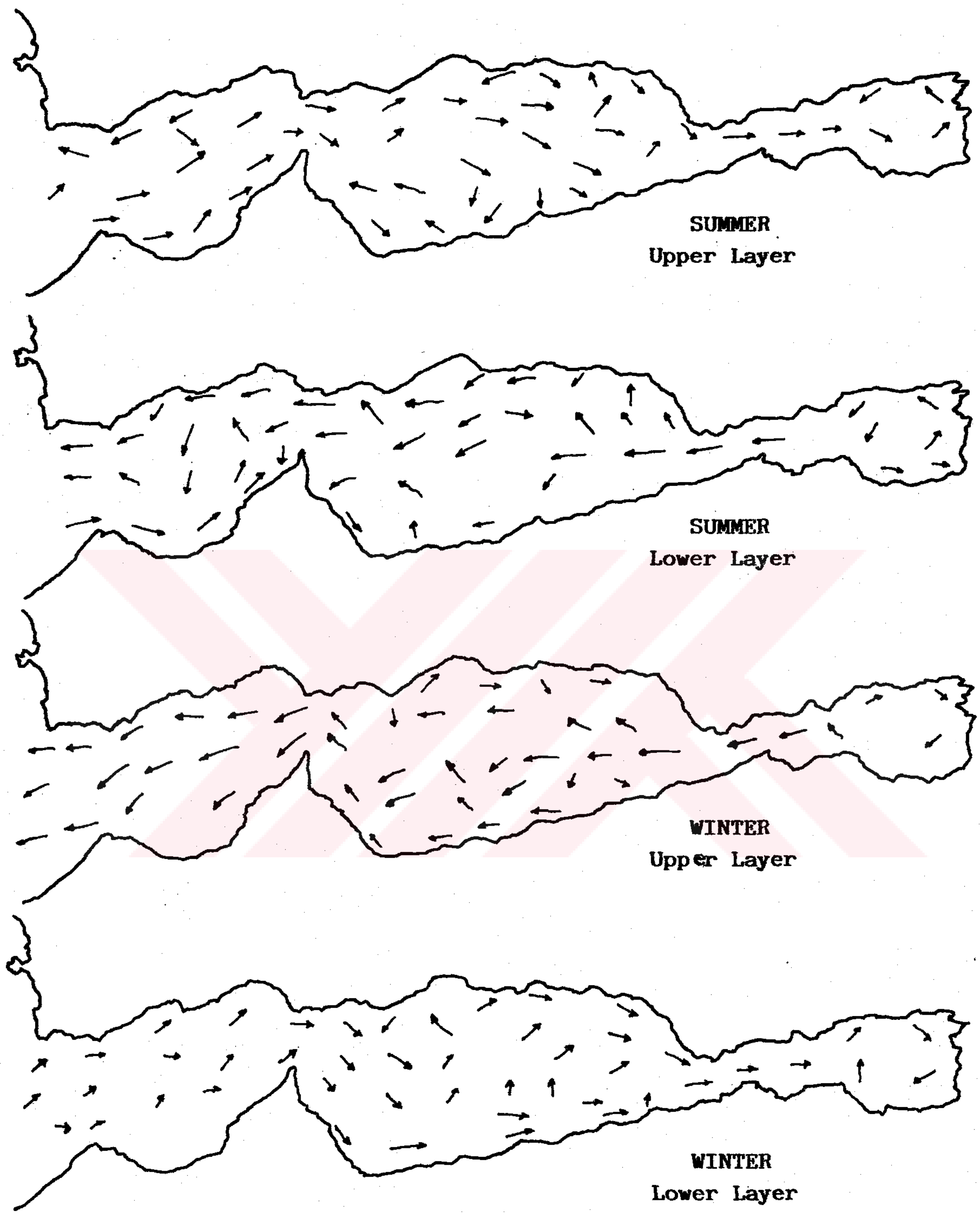


Figure 2.5. Direction of the currents in winter and summer (7).

PERIOD	COMMENTS	
	LOWER	UPPER
SUMMER	Clockwise circulation in the southern basin, cyclonic circulations on the northern section Current speed = 5 cm/sec (Center)	Flow enters along the southhern coast due to topographic property of the outer region Current Speeds (cm/sec); Around Dilburnu region= 9.0 Around Derince-Gölcük = 4.0
WINTER	Deep Marmara waters at about 10 m level enter where deep bay waters outflow Current Speeds(cm/sec); Around Dilburnu Region= 4.0 Central Region = 5.0 Around Derince-Gölcük = 3.0	Undergo interfacial mixing and corresponding return flow is developed on the outer surface layer has twice of the lower layer current speed Highly polluted surface waters within the interior of the bay are transported to the outer region So; The bay flush itself to a certain extent Current speeds(cm/sec); Around Dilburnu region= 8.0 Around Derince-Gölcük = 5.0

Table 2.5. Circulation pattern in the Izmit Bay.

2.4. Beneficial Uses of the Bay

When the pollution level of a marine environment is to be evaluated and the quality criteria to be set, it is necessary to know the beneficial uses of that environment, and the cautions to protect the environment can be taken afterwards.

So it is necessary to define the beneficial uses of the Izmit Bay in order to be able to evaluate the pollutinol level and to set quality criteria. The criteria should be developed according to most suitable beneficial uses of the bay, after the evaluation of waste receiving capacity of the bay for these usages.

According to literature and considering the properties of the bay, the alternate beneficial uses of the bay can be given as;

1) Fish or shell-fish production and fishing;

The purpose of this beneficial use is the assurance of the suitable environment for the growth of fishes and various other living bodies that constitute their food chain in the bay. And also to provide suitable conditions for fishing. But one must take in mind that the various types of fishes and other organisms have different necessities that the required water quality will also change. So in this case the water quality must be developed with regarding the properties of the bay, according to the kind of organisms which are more suitable to produce.

2) Swimming and other water sports (recreational purposes);

For swimming and other sports that can be done by direct contact with water, it is necessary to provide aesthetically attractive marine environment. Besides aesthetics, water must have no health risk. So there should be no disease causing organisms in the marine environment.

3) Transportation;

Transportation includes the tour of various sizes of vessels, and their use of harbours. The marine environment should be in a quality that the bay water does not attack the ship structure and does not constrain transport in the bay.

4) Industrial usage;

Industries abstract water to use in their various proçesses. Sea water is mostly used by industries for cooling and during production, so mainly used for the processes where the salty water does not have any effect on the process.

5) Wastewater disposal-aesthetic sight;

A marine environment can assimilate wastewaters. However the treatment process in marine environment progress slower than a treatment plant. A marine environment which is used for wastewater disposal should not create any health risk and distrub the environment, this must be taken as a minimum quality level.

The most important use among the five classes mentioned above is the production of fish or shell-fish and fishing. If it is listed from more critical to less; second one is swimming and other water sports, third one is industrial usage, fourth one is transportation and finally aesthetic purposes.

According to the quality criteria of Seawater for fish or shell-fish production, aesthetical usage and recreational usage are given in Tables 2.6, 2.7, 2.8, respectively and also the general quality criteria of sea water quality is given in Table 2.9.

Any decision to be taken on the most suitable beneficial usage will decide the permissible pollutional level of the Izmit Bay. Because of this reason, during the selection of the most beneficial usage of the bay it is necessary to increase the quality. But to set higher water standards (choosing the beneficial use as fish or shell-fish production) may cause the closing up of some industries. And it will take so many years for Izmit Bay to renew itself.

To use the bay for recreational and aesthetical usages, the evaluation of the waste receiving capacity of the bay will done accordingly.

PARAMETER	UNIT	TRESHOLD LEVEL
Temperature(max)	°C	34
pH	mg/l	6.5-8.5
Dissolved Oxygen	mg/l	5.0
Floating Oil and Grease	mg/l	0.0
Emulsified Oil and Grease	mg/l	10
Alkylbenzenesulphonate(ABS)	mg/l	2.0
Arsenic,As	mg/l	1.0
NH_3-N	mg/l	0.5
Cadmium, Cd	mg/l	0.01
Free Chloride	mg/l	0.02
Chromium VI	mg/l	0.05
Copper, Cu	mg/l	0.05
Cyanide, CN	mg/l	0.02
Fluoride, F	mg/l	1.5
Lead, Pb	mg/l	0.1
Mercury, Hg	mg/l	0.01
Phenols	mg/l	1.0
Sulfate	mg/l	0.5

Table 2.6. Water Quality Criteria for fish or shell-fish production (21).

PARAMETER	STANDARDS	REMARKS
Color	natural	aesthetically should not be different from the natural color of sea water
Taste and Odor	natural	should not be different from the natural taste and odor
Turbidity (TU)	natural	aesthetically, should not be different from the natural turbidity, and should be below 20 TU
pH	7.5-8.5	
Suspended Solids(mg/l)	3.0	
Oil and Grease(mg/l)	-	should be too low when measured by n-Hexane extraction method, no visible oil film in surface present
Total no.of Coliforms (100 ml MPN)	100	should not exceed the 90 % of the most probable number (MPN) at any time interval

Table 2.7. Standards for recreational usages (21).

PARAMETER	TRESHOLD VALUE	MAXIMUM LEVEL
Sewage and garbage based on visible solid matter	none	none
Suspended Solids(mg/l)	20	100
Emulsified Oil and Grease(mg/l)	10	20
ABS	1	5
pH	6.5-9.0	6.5-9.0

Table 2.8. Sea water quality criteria for aesthetical usages (21).

PARAMETER	CRITERION	REMARKS
pH	7.0-9.0	
Color and Turbidity	natural	The value of photosynthetic activities of aquatic life at any depth should not be affected by more than 90 %
Floating Matter	-	Floating liquid i.e. oil. and solid i.e. garbage matter should not be present
Suspended solids(mg/l)	30	-
Dissolved Oxygen(mg/l)	more than 90% of saturation at any depth	Dissolved oxygen values should be observed at any depth
Degradeable organic pollutants	-	It should not be of an amount that reduces the level of dissolved oxygen given after degredation
Crude oil and Petroleum Derivatives(mg/l)	0.003	Should be evaluated for seawater biota and sediments, preferable none should be observed
Radioactivity	-	natural radioactivity type and levels should not be exceeded
Productivity	-	Seasonal productivity related to the marine environment in question should be observed
Toxicity	none	
Phenols	0.001	
Copper(mg/l)	0.01	
Cadmium(mg/l)	0.01	
Chromium(mg/l)	0.1	
Lead(mg/l)	0.1	
Nickel(mg/l)	0.1	
Zinc(mg/l)	0.1	
Mercury(mg/l)	0.004	
Arsenic(mg/l)	0.1	
Ammonia(mg/l)	0.02	

Table 2.9. Seawater Quality Criteria(21).

2.5. Present Situation of the Bay

Present pollutional level of the bay are examined according to following parameters; BOD_5, N, P.

The reasons for choosing of this parameters are;

- they are mostly used in determination of the pollutional level in the marine environment,
- they are found as the critical parameters for the bay,
- there are more or less enough data about these parameters.

If the eastern part of the Gölcük and Tütünçiftlik section is concerned, organic matters in high concentrations (higher around discharge points) are found. This concentrations vary between 25-330 mg/l for BOD_5 (see Table 2.11). If it is compared with the domestic wastewater of medium strength having about 220 mg/l BOD_5 (26) (see Table 2.10), it can be easily understood that how polluted this region.

CONSTITUENT	CONCENTRATION		
	STRONG	MEDIUM	WEAK
BOD_5(mg/l)	400	220	110
Nitrogen(mg/l)	85	40	20
Phosphorus(mg/l)	15	8	4

Table 2.10. Typical composition of untreated wastewater (Metcalf and Eddy (26)).

PARAMETER	SAMPLING POINTS					
	OFF THE SHORE OF SEKA	ON THE SHORE OF TARIM KOR.	OFF THE SHORE OF IGSAS-PETKIM	OFF THE SHORE PETKIM	ON THE SHORE OF DIL DERESI	BETWEEN GOLCUK-KARAMURSEL
pH	7	7	7	8	7	7
Temperature(°C)	21	21	22	23	23	22
COD(mg/l)	153	141	196	127	170	189
BOD_5(mg/l)	47	40	60	57	18	25
Suspended Solids(mg/l)	81	90	66	106	92	85
Total Dissolved Solids (mg/l)	34000	38000	45000	53000	44000	42000
NH_4-N (mg/l)	0.8	0.6	1.2	0.6	0.6	0.3
Phenol(mg/l)	0.5	0.5	0.5	0.5	0.5	0.5
Detergents(mg/l)	4	4.2	2.3	3.2	3.7	2.1
Grease(mg/l)	2	16	9	7	31	10
Toxicity L_{50}(%)		50				

Table 2.11. The results of the measurement taken in July 28, 1982 (ITU, (7)).

PARAMETER	SAMPLING POINTS						
	OFF THE SHORE OF SEKA	ON THE SHORE OF TARIM KOR.	OFF THE SHORE OF IGSAS	OFF THE SHORE OF PETKIM	ON THE SHORE OF HEREKE	ON THE SHORE OF HALLAC ST.	OFF THE SHORE OF DİL DERESI
pH	7.5	7	7	7	7.5	7	7
Temperature(°C)	13.5	14	14.5	15	14	14	14
COD(mg/l)	413	318	92	113	113	557	299
BOD_5(mg/l)	330	160	55	60	50	220	130
Suspended Matter(mg/l)	320	204	15	42	5	22	37
Total Disolved Matter (mg/l)	31090	31771	38273	45123	42603	35170	31234
NH_4-N(mg/l)	1.7	1.0	1.3	1.7	0.6	0.9	0.9
Phenol(mg/l)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Detergents(mg/l)	3.5	1.25	0.5	0.6	1.0	0.9	0.7
Grease(mg/l)	40	37	36	27	105	85	90
PO_4-P(mg/l)	0.08	0.08	0.1	0.1	0.14	0.22	0.28
Toxicity, LD_{50}(%)	75		78		82		

Table 2.12. The results of the measurements taken in October 17, 1982 (ITU, (7)).

PARAMETER	SAMPLING POINTS			
	OFF THE SHORE OF GOLCUK DOCKYARD	OFF THE SHORE OF KARAMURSEL	OFF THE SHORE OF DEGIRMENDERE	OFF THE SHORE OF CITY OF IZMIT
pH	7	7	6.5	6.5
Temperature(°C)	10	10	10	9
COD(mg/l)	104	176	176	160
BOD_5(mg/l)	25	13	15	27
Suspended matter(mg/l)	1.2	7	15	26
Total Dissolved Solids (mg/l)	33230	29160	30930	30410
NH_4-N(mg/l)	0.8	0.1	0.1	0.3
Detergents(mg/l)	1.8	1.3	1.2	1.2
Grease(mg/l)	74	150	120	76
PO_4-P(mg/l)	0.95	0.08	0.08	
Toxicity, LD_{50}(%)	73	73	75	71

Table 2.13. The results of the measurements taken in December 14, 1982 (ITU, (7)).

PARAMETER	PRESENT SITUATION IN THE EASTERN BAY	QUALITY CRITERIA FOR AESTHETICAL PURPOSES		QUALITY CRITERIA FOR RECREATIONAL PURPOSES		QUALITY CRITERIA FOR FISH LIFE	
		TRESHOLD VALUE	MAXIMUM	TRESHOLD VALUE	MAXIMUM	TRESHOLD VALUE	MAXIMUM
VISIBLE SEWAGE AND GARBAGE SOURCED SOLIDS	Present	None	None	None	None	-	-
SUSPENDED SOLIDS(mg/l)	106-320	20	100	20	100	-	-
EMULSIFIED OIL AND GREASE(mg/l)	40-76	10	20	10	20	10	-
ABS	3.5-4.2	1.0	5.0	1.0	2.0	2.0	-
pH	6.5-8.0	6.5-9.0	6.0-10.0	6.5-9.0	6.0-10.0	-	-
NH_3-N(mg/l)	0.8-1.7	-	-	-	-	0.5	
PHENOL(mg/l)	0.5	-	-	-	-	0.2	

Table 2.14. Comparison of the quality criteria for various uses with the present situation in the Eastern Part of the bay (not includes all the parameters)(ITU, (14)).

The range for NH_4-N is 0.1-1.7 mg/l and for PO_4-P is 0.08-0.95 mg/l in the eastern part. With the other polluting parameters measured in the eastern part show that this part is polluted highly and it is in a way, in the quality of domestic wastewater. The concentrations of various parameters measured at different points in the eastern part of the bay are given in the Tables 2.11, 2.12, 2.13. As it can be seen from there, this part is not suitable for any beneficial uses.

The comparison of the standards for various beneficial uses and the present condition of the eastern part of the bay is given in Table 2.14.

1) Aesthetical usage;

As it can be seen in the Table, the bay is not suitable for aesthetical usage.

2) Recreational usage;

Except pH, all the concentration of the pollutional parameters exceeded the maximum values. So the bay is not in a suitable condition for recreational purposes.

3) Fish or shell-fish production;

The concentrations of all the parameters are exceeded the treshold values in a great extent but Mercury. Mercury has accumulation property through food chain of the fishes. The concentration measured shows the presence of mercury in the bay water (22).

As a result it is seen that the usage of the bay in commercial fishing is limited in a great extent. If the present conditions will prevail in the future, the fishing seems to be impossible during these years.

2.5.1. Distribution of Biochemical Parameters

According to their oceanographic characteristics and the degree of pollution, the bay is divided into four sections for the ease of the evaluation of the measurements and giving the regional averages of the measured parameters of interest. And also for the ease of the comparison of the regions interms of their pollutional levels.

2.5.1.1. Dissolved Oxygen Distribution in the Bay

Intrusion of the Black Sea waters into the surface layer during the summer period and the replacement of anoxic bottom layer waters with new Marmara waters during the winter period may also be supported by the dissolved oxygen (DO) data.

As it can be seen from DO data, the upper layer waters of Black Sea origin have oxygen concentrations mostly at their saturation levels throughout the year. The dissolved oxygen level, which is the basic and critical parameter to be monitored, generally varies between 1.5-

2.5 ppm within the bottom layers of the Sea of Marmara (7).

The November-March period is the mixing period of the upper layers with the bottom layers. Because of the outflow of upper mixed layers from the bay, bottom waters of north-eastern Marmara Basin enter into the bay through the sill of about 55 m depth, separating the western section from the rest of the bay. This entrance of bottom layers of Sea of Marmara is the unique phenomena responsible for the renewal of the dissolved oxygen content of the bottom layers of the bay (7). It is utilized completely during summer months. DO concentrations of the bottom layers reach the values of 1.6-2.0 and 1.0 ppm for the central and eastern regions of the bay in November. So that the DO concentrations reach to their peak values during November.

The DO concentrations of bottom waters remain constant during the winter months. The cold surface water levels have always higher DO concentrations due to minimum microbial activity so that the oxygen consumption rate stays at a minimum level.

During April-May period the upper layer concentrations are increased everywhere within the bay due to intrusion of the oxygen rich cold Black Sea waters into the bay. And due to strong stratification DO content of bottom layers is decreased.

During June-July period the surface layer average DO content decreases due to warming up and weak mixing period started. Consequently,

MONTH	WESTERN		CENTRAL (SITE I)		CENTRAL (SITE II)		EASTERN	
	U	B	U	B	U	B	U	B
May, 1984	9.1	1.7	8.4	1.5	9.0	0.9	8.7	0.5
June	7.5	1.8	7.0	1.4	6.2	0.9	4.9	0.7
July	5.9	1.8	6.4	1.1	4.6	0.7	3.8	0.4
August	8.7	1.7	6.9	1.0	6.5	0.7	3.3	0.4
September	7.6	1.6	7.7	0.6	8.5	0.6	9.8	0.5
October	9.9	0.2	9.6	(0-0.8)	11.3	(0-0.6)	7.3	0.0
November	9.1	3.0	9.0	1.6	9.4	2.0	8.7	1.0
December	7.8	2.0	7.8	1.2	8.4	1.2	6.2	0.9
January,1985	8.6	1.6	8.1	1.1	7.6	1.3	7.7	1.0
March	8.7	3.4	8.3	2.7	7.9	2.0	8.6	2.1
April	9.3	1.6	9.3	1.3	9.2	1.3	8.5	1.0
May	9.6	1.8	9.6	1.6	9.4	1.4	8.0	0.7

Table 2.15. Monthly variations of dissolved oxygen (mg/l) in the Izmit Bay (3).

U : Upper layer (20-30 ppt salinity)

B : Bottom layer(37-37.5 ppt salinity)

Site I : Western part of central region

Site II: Eastern part of the central region

PERIOD	COMMENTS ON 'DO' DATA
WINTER	Characterized by fairly saturated values related with the presence of cold surface layer waters which have always higher DO levels and restricts the microbial activity so that oxygen consumption rate stays at a minimum level
OCTOBER	Due to vertical mixing DO content of surface waters increases, but DO of lower layer decreases because of the high oxygen consumption by biochemical decomposition of organic matter penetrating fromthe productive layer
NOVEMBER	Anoxic bottom waters appeared in October is replaced by oxygenated water masses. Bottom layers DO concentrations increase to about 1.6-2.0 and 1 ppm for central and eastern sections and 3 ppm increase in western section
MARCH	The least productive time of the year, corresponding to maximum values of DO in surface waters
APRIL	The DO content of the bottom waters starts to decrease with development of new stronger summer stratification associated with weak vertical mixing which cause difficult oxygen diffusion through the interface
JUNE-JULY	Warming up and weak mixing period, oxygen consumption rate increases as a result of intense microbiological activities in upper layer waters. DO depletion is more effective
AUGUST-SEPTEMBER	DO concentration rises within the uppermost 5 m's depths due to primary production reaching its maximum level while below this zone DO concentrations reduce sharply

Table 2.16. Dissolved oxygen variation throughout the year.

oxygen consumption rate increases as a result of microbial activities taking place within the upper layer waters intensively. This reduction is more evident in the eastern region.

During August-September period, primary production reaches its maximum level within the uppermost 5 m depths, where the DO concentrations decrease sharply below this zone. Furthermore, surface cooling which starts to be effective during October as well as intensification of vertical mixing result in increase in surface average DO content (7). But the lower layer average DO values are reduced, caused by extra oxygen deplation associated with the penetration of higher amount of organic matters from the upper layer waters.

2.5.1.2. Biochemical Oxygen Demand (BOD) Distribution

The biodegradable organic matter content of the surface layer in-terms of BOD_5, originated from man-made sources and primary production in the photic zone, shows spatial and temporal variations. The highest BOD_5 values are reached during summer in the eastern part (3).

During December-March period the BOD_5 distribution in the surface waters are at about the same levels due to the transport of surface waters towards the mouth of the bay by local surface currents. Before the renewal of the Bay water during September and October, there is an increase in the BOD_5 values towards the eastern section. In November inflow of water through the bottom layer into the bay causes a current system in the surface layer during winter period. This system carries the pollutants towards the outside of the bay, so BOD_5 values decrease in September and in winter.

Although there is no significant monthly difference in BOD values in the surface waters through the bay other than the eastern section in which major part of the pollutants are discharged directly into the surface layers.

Bottom waters become anoxic due to the limited water exchange rate with open Marmara Sea waters and then degredable organic matter settles from the surface waters and exceeds the oxygen supply rate.

In Table 2.17 the BOD_5 distribution of the Bay in the surface water is given, since the maximum value of BOD_5 is present in the surface.

MONTH	WESTERN	CENTRAL (SITE I)	CENTRAL (SITE II)	EASTERN
September, 1984	0.3	0.8	2.4	5.1
October	1.2	1.2	2.7	5.0
November	2.0	2.0	1.4	4.1
December	0.8	1.4	1.1	1.1
January, 1985	0.7	0.9	1.0	2.7
March	1.2	1.1	0.7	1.3
May	1.4	2.1	2.7	3.1

Table 2.17. Seasonal variation of BOD_5 of upper layers of Izmit Bay (7).

2.5.1.3. Nutrient Concentrations in the Bay

A. Ortho Phosphate Concentrations

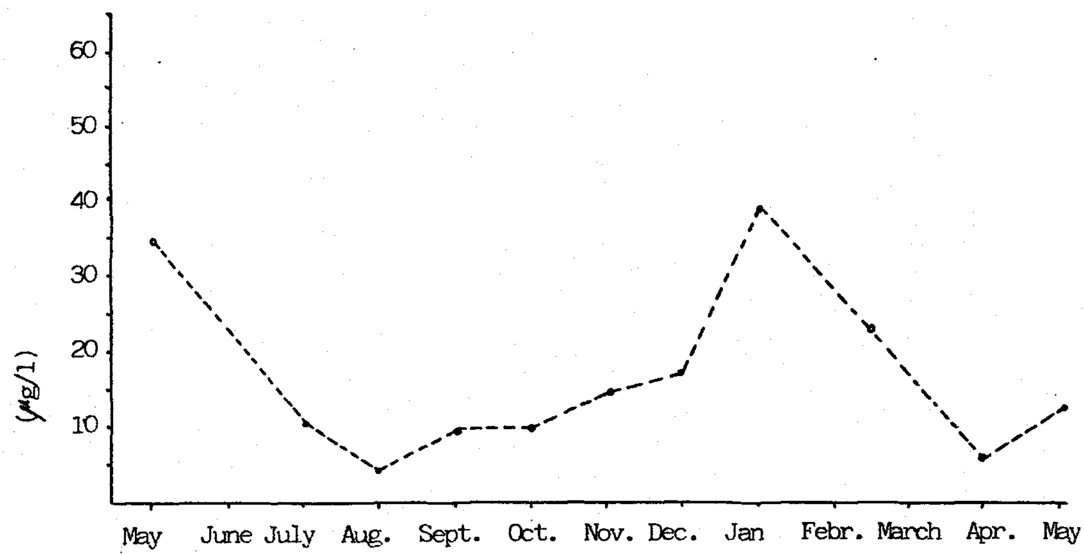
Ortho phosphate concentrations in the surface layers of eastern part decrease continuously from May to August and reach their minimum levels in March and August. It decreases from about 35 μg/l in May to less than 5 μg/l in August. In lower layers the concentration decreases continuously from about 35 μg/l in May to 30 μg/l in June and then increases to about 40 μg/l in August at 40 m depth.

In August, the primary production within the bay is considered to be a phosphate dependent production. Since the nitrogen to phosphorus ratio (N/P) in weight it much higher than 7 which is the natural ratio, o-phosphate is the limiting parameter in spring bloom.

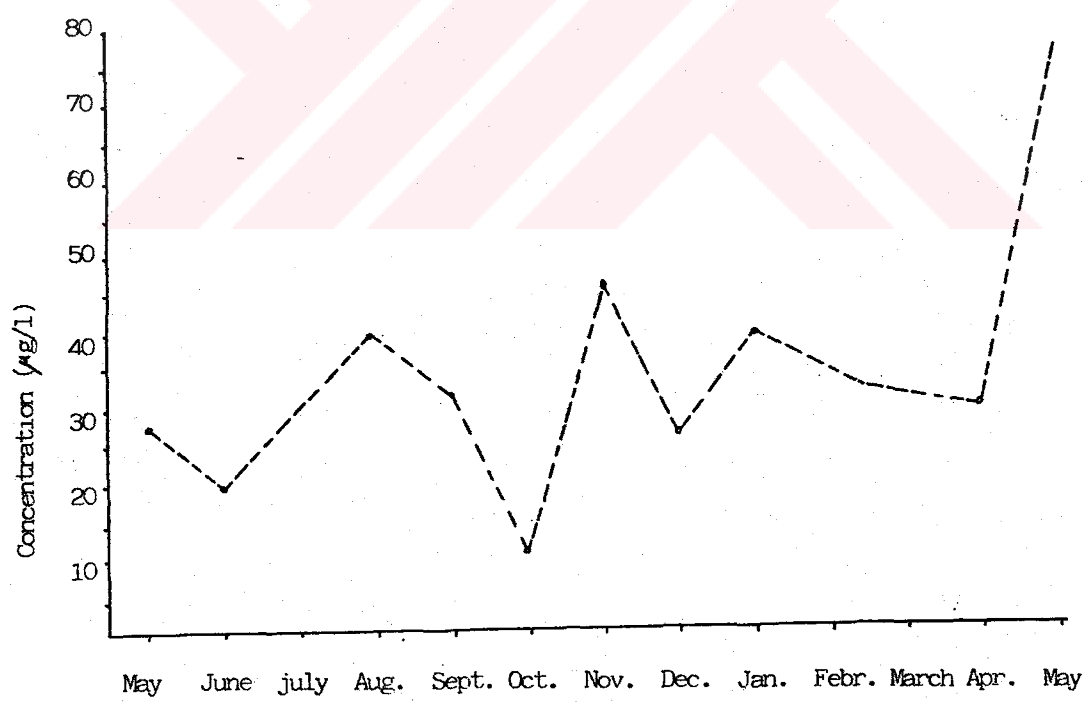
Then there is a continuous increase in concentration from September to December after which it reaches its maximum value in January corresponding to period of entrance of phosphate rich bottom waters of Sea of Marmara (see section 2.3.2.).

During March, low phosphate level is due to fast deposition and incomplete decomposition of organic matter. In April o-phosphate level increase again.

In Figure 2.6. the monthly variation of ortho phosphate levels in the upper and lower layers are given. And in Table 2.18., the data about seasonal variations of ortho phosphate and total phosphate are given.



a) Upper Layer



b) Lower layer

Figure 2.6. Variation of ortho phosphate levels in the upper and lower layer of Eastern Part of Izmit Bay (3).

MONTH	WESTERN		CENTRAL (SITE I)		CENTRAL (SITE II)		EASTERN	
	U	B	U	B	U	B	U	B
Ortho-phosphate								
May, 1984	32.5	30.0	-	31.3	-	33.5	-	-
June	20.7	25.7	23.1	27.8	24.4	30.0	19.7	
July	12.0	35.6	10.9	38.8	22.5	42.1	15.5	30.1
August	0.5	8.5	3.9	11.8	3.5	18.4	13.4	39.1
September	13.4	24.7	10.1	39.4	30.2	38.9	20.1	31.5
October	10.1	17.7	10.0	23.5	28.4	25.9	8.8	11.0
November	15.5	28.3	14.9	46.3	20.8	42.5	26.3	46.7
December	15.5	20.5	17.5	28.2	16.7	25.5	21.6	26.3
January, 1985	35.4	49.5	38.9	52.7	42.1	60.3	42.0	39.6
March	7.7	18.8	6.4	27.6	9.0	34.4	22.8	32.0
April	6.9	30.2	6.4	32.2	7.7	33.6	6.2	31.0
May	10.0	48.5	12.0	80.0	12.7	78.0	12.5	76.0
Total Phosphate								
February, 1975	95	110	81	104	68	102	104	188
March	58	60	47	67	46	73	82	85
April	20	67	36	83	27	71	33	75
May	52	39	61	91	53	73	77	165
June	33	101	67	107	38	96	71	138
August	26	82	46	91	59	144	77	136
May, 1984	182	258	115	136	92	180	145	342
June	26	29	29	32	28	39	24	-
July	57	59	66	65	56	59	62	79
August	50	65	46	48	54	58	35	55
September	28	38	42	69	43	54	49	45
October	38	39	30	58	45	55	35	-
April	27	62	30	72	68	86	43	109

Table 2.18. Seasonal variations of ortho phosphate and total phosphate in the bay waters (μg P/l) (3, 6).

U= Upper Layer

B= Bottom layer

B. Nitrogen Concentrations

Nitrite concentrations of the eastern section is comperatively higher than the western sections during May to October. Nitrite level starts to decrease in January and reaches its minimum value in March.

In April it starts to increase and the concentration is less than 20 ppb in the surface layers and as high as 83-108 ppb in the bottom layers. during May, surface layers have 240-280 ppb ammonia concentration and 380-460 ppb in the bottom layers (3, 9).

The maximum values of nitrite both in surface and bottom layers is reached in June (3).

In Figure 2.7, the variation of Nitrite and Nitrate concentrations in eastern part of the bay is shown. As it can be seen in Table 2.19, nitrate concentration approaches to its minimum value in March, where the nitrate enrichments in the bay waters appears in April after the nutrient rich Black Sea water entersed the bay.

The nutrients, ortho phosphate and Nitrate are always available in the bay and keep the photosynthetic reaction of the bay over the natural level of the marine environment. Thus, organic loads from man-made sources and high organic matter produced in the bay create anoxic conditions in the bottom waters and transition zone during the stagnant period of the bay, particularly between August-October.(23). The change in nutrient concentrations in the eastern bay is given in Table 2.22.

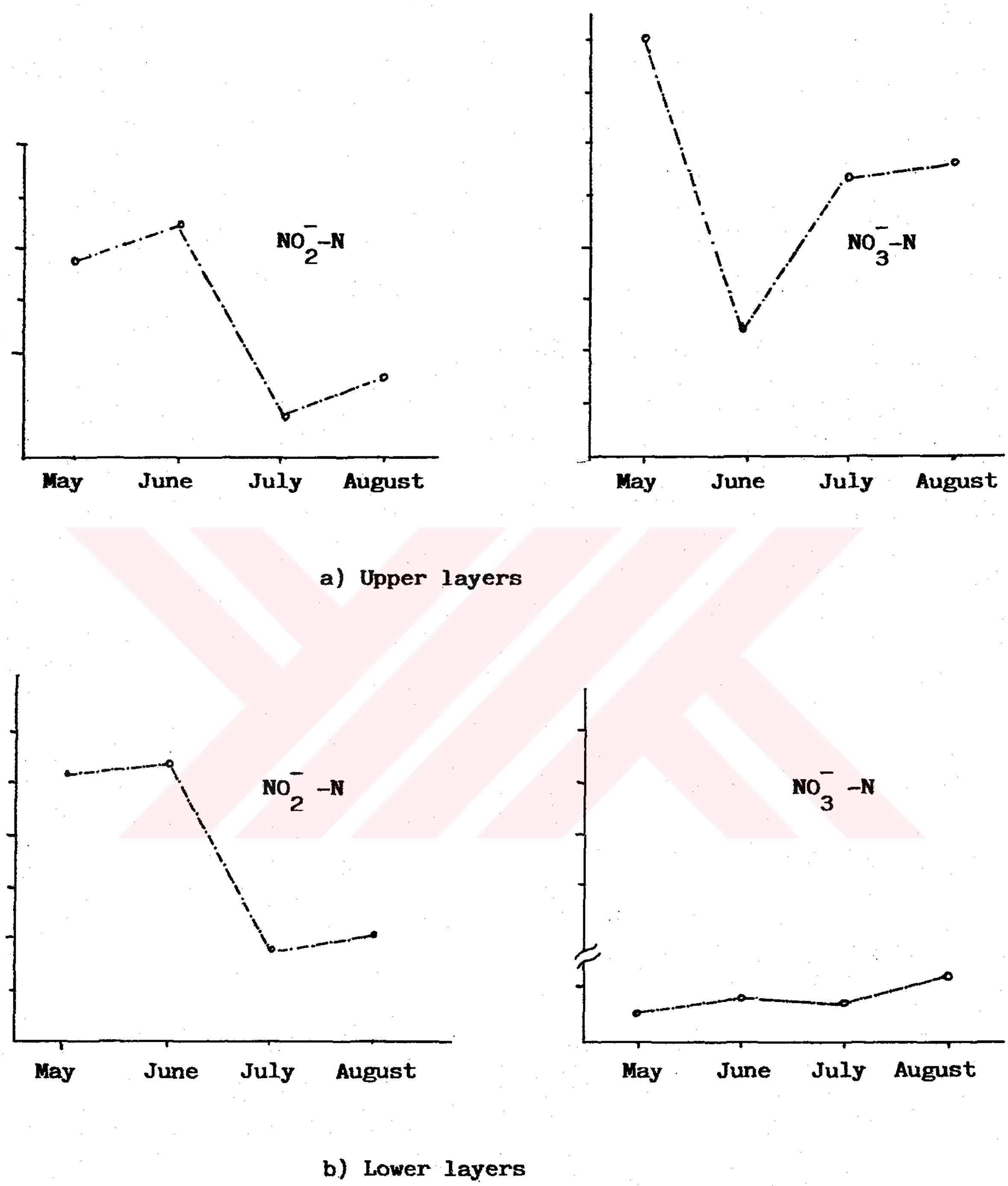


Figure 2.7. Variation of Nitrite and Nitrate concentrations of eastern part of the Izmit Bay (3).

MONTH	WESTERN		CENTRAL (SITE I)		CENTRAL (SITE II)		EASTERN	
	U	B	U	B	U	B	U	B
Nitrate								
May, 1984	10.1	135	4.9	123	2.2	114	20.6	5.2
June	3.0	108	2.9	160	5.2	126	6.0	6.8
July	5.9	141	12.4	143	15.5	121	13.5	6.7
August	14.9	124	20.6	119	9.8	130	14.2	11.9
September	5.0	84	4.0	81	5.1	81	11.9	-
October	2.5	49	2.1	40.2	2.3	41.6	2.3	3.0
November	34.3	118	32.4	104	40.8	95.0	32.4	92
December	4.3	17.3	3.4	18.3	4.0	16.9	5.5	20.6
January, 1985	3.7	7.2	4.7	5.2	5.0	5.3	5.3	5.0
March	1.2	1.4	1.1	2.6	1.3	1.5	1.2	1.3
April	5.6	110	6.8	113	7.3	97	9.7	91
May	15	163	43	158	22	139	20	134
Nitrite								
May, 1984	8.2	9.4	2.1	11.4	1.2	14.1	9.6	-
June	11.3	12.3	12.6	11.7	10.3	16	10.3	13.2
July	1.3	2.7	2.3	3.1	1.9	7.3	1.8	4.3
August	2.8	3.2	2.7	3.6	3.2	5.8	3.7	5.1
September	2.0	2.8	2.6	2.7	3.0	14.2	3.5	4.0
October	4.7	6.8	4.3	6.8	6.2	7.4	6.5	6.0
November	3.9	3.7	4.3	2.5	2.0	1.5	4.3	3.7
December	6.4	6.7	7.3	7.0	6.5	6.9	7.4	7.9
January, 1985	2.9	3.2	4.6	5.5	8.0	6.6	8.1	9.8
March	3.7	3.8	4.1	4.4	5.5	4.7	5.2	7.1
April	3.6	2.9	4.5	3.1	4.5	5.8	4.6	7.5
May	2.0	2.8	2.6	2.6	2.6	2.8	3.1	3.2
Ammonia								
April	17	87	19	83	23	103	43	108
May	246	460	272	437	290	411	250	383

Table 2.19. Seasonal variations of Nitrite and Nitrate in the bay waters (μg/l) (3).

U= Upper Layer
B= Bottom Layer

PERIOD	ORTHO PHOSPHATE CONCENTRATION	COMMENTS
MARCH-APRIL	Reaches its lowest value	The primary production within the Bay is considered to be a phosphate dependent-o-phosphate is limiting factor in August, because nitrogen to phosphorus ratio (N/P) in weight is much higher than 7, the natural value
SEPTEMBER-DECEMBER	Continues to increase in concentration	These high concentrations corresponds to the period of entrance of phosphate rich bottom waters of Marmara Sea waters
JANUARY	Reaches its maximum value	

Table 2.20. Ortho phosphate concentration in the eastern bay (3).

PERIOD	NITRATE CONCENTRATION	COMMENTS
NOVEMBER	Increases	Corresponds to the time of entrance of Marmara Sea water
JANUARY	Starts to decrease	
MARCH	Reaches its minimum value	Bottom waters of the bay are oxygenated due to mixing fast decomposition of organic matter
APRIL-JUNE	Starts to increase again reaches its maximum(both in surface and bottom)	Due to primary production and subsequent decomposition of organic matter

Table 2.21. Nitrate concentration in the eastern bay (3).

PARAMETER	1984								1985			
	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	MARCH	APRIL	MAY
$o\text{-}PO_4$ (U)		19.7	15.5	13.4	31.5	8.8	26.3	21.6	42.0	22.8	6.2	12.5
(B)		-	30.1	39.1	31.5	11.0	46.7	26.3	39.6	32.8	31.0	76.0
NITRATE(U)	20.6	6.0	13.5	14.2	11.9	2.3	32.4	5.5	5.3	1.2	9.7	20.0
(B)	5.2	6.8	6.7	11.9	-	3.0	92.0	20.6	5.0	1.3	91.0	134.0
NITRITE(U)	9.6	10.3	1.8	3.7	3.5	6.5	4.3	7.4	8.1	5.2	4.6	3.1
(B)	-	13.2	4.3	5.1	4.0	6.0	3.7	7.9	9.8	7.1	7.5	3.2

Table 2.22. Seasonal variations in nutrient concentrations in the eastern bay waters (μg-P/l) and (μg-N/l) (3).

2.6. Main Polluting Sources of the Bay

2.6.1. General

The main polluting sources of the bay can be divided into two as point sources and non-point sources. Point sources are; industries, settlements, rivers, partly drainage waters, ballast wastewaters of ships. Non-point sources are; drainage waters from agricultural areas.

This classification becomes more complicated with;

- the septic tanks of industries and domestic wastewaters and seepage of them to land and rivers,
- drainage of waters from agricultural areas and settlements to river.

The Main Polluting Sources of the Bay;

1. Erosion problem around the catchment area of the bay; soil is carried out by surface waters and settle to the bay bottom.
2. Widespread settlements and more than 200 industries (40 of them located around the inner bay).
3. Non-point pollution; as a result of agricultural activities, artificial fertilizers and insecticides are carried out to the bay by storm waters.
4. Transportation in the bay that is used for different purposes.

The certain boundaries of the interested area around the Izmit

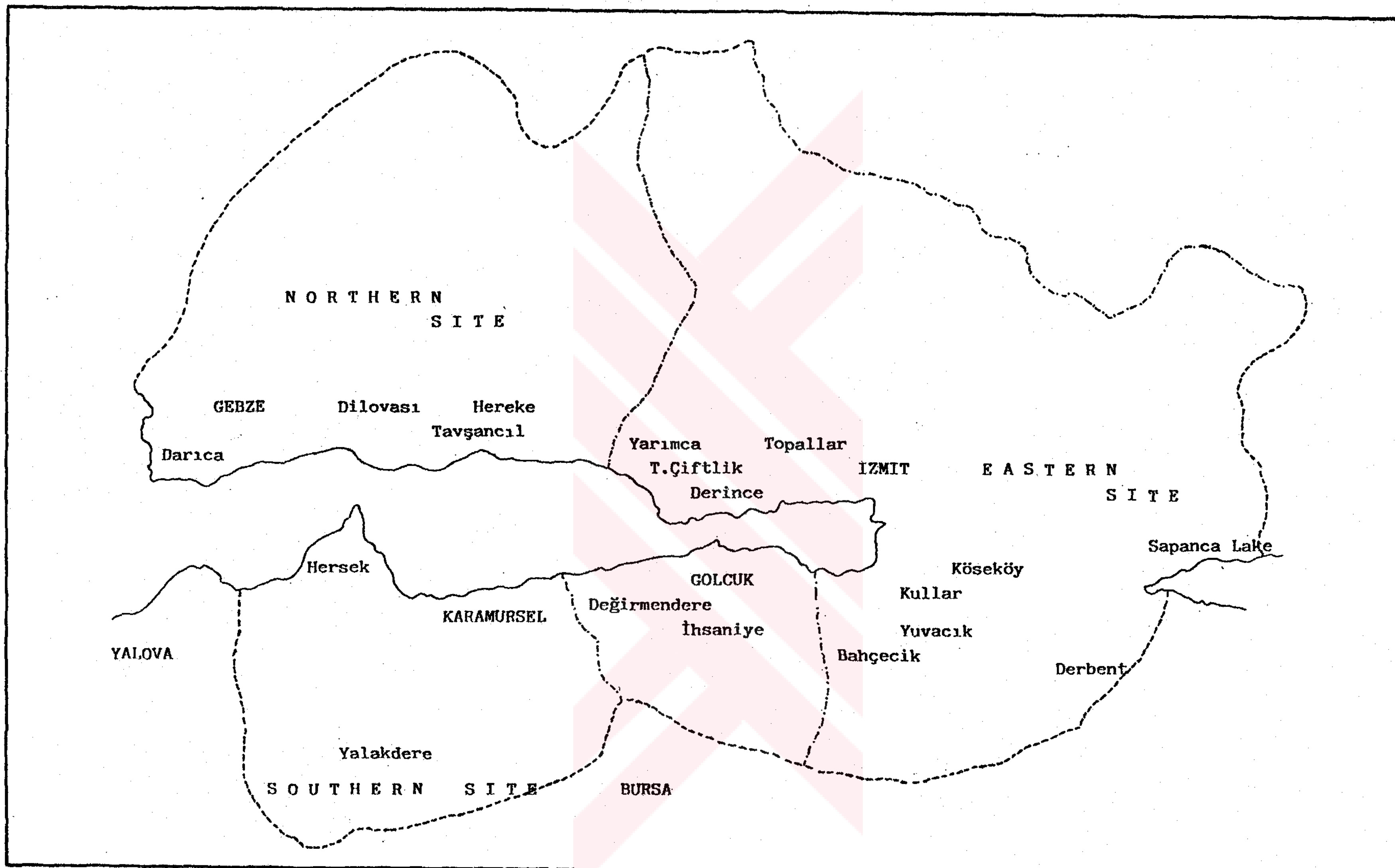


Figure 2.8. Boundaries of ınterested area in Izmit Bay.

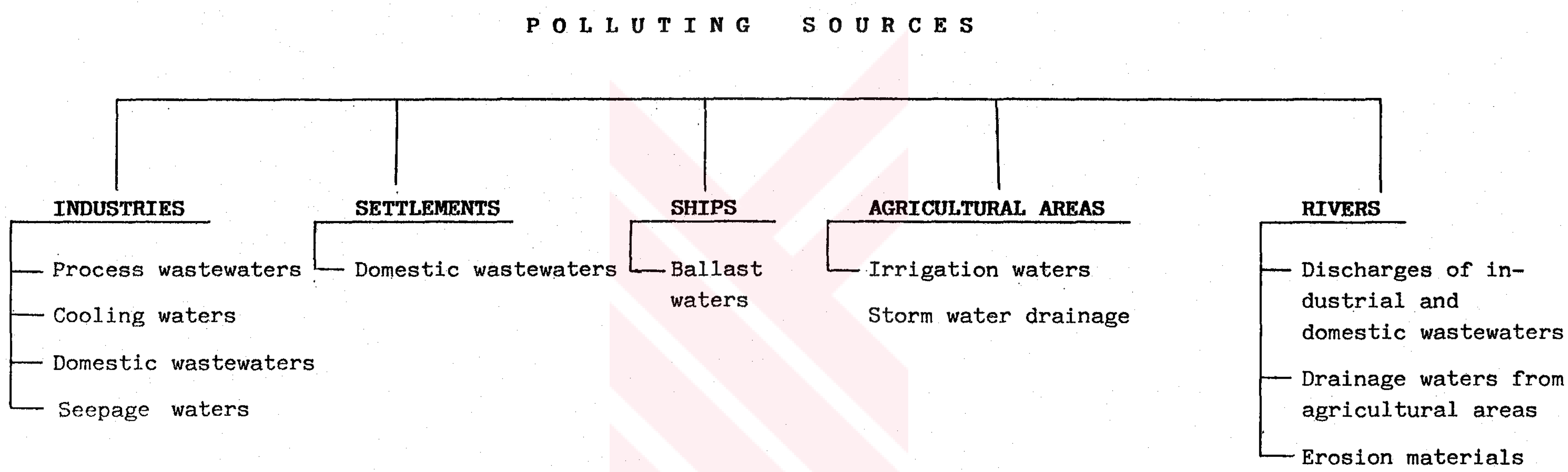


Figure 2.9. Polluting sources of Izmit Bay.

Bay are shown in Figure 2.8. As it can be seen from there, the boundaries are as follows;

Eastern: Uzunbey-Mandıra line

Western: Balyanoz Burnu-Orman Kulübesi line

Northern: Balyanoz Burnu-Gebze-Uzunbey line

Southern: Çiftlikköy-Dereköy-Mandıra line.

2.6.2. Domestic Wastewater Discharges

Population Distribution;

The total population around the bay is about 525500 in 1980 (27). The 56 % of this population is living in the urban site and 44 % is living in the rural site. According to the population point of view, the distribution around the bay is as follows;

Northern coast: 70 % of the population living on.

Southern coast: 20 % of the population living on.

Eastern coast : 10 % of the total population living on (3).

Since the settlements along northern coast of Izmit Bay is severely limited due to sharp topography, most of the residental and commercial settlements are in east-west direction along the transportation routes. There are four major urban centers around the bay;

- Gebze (on the north)
- Izmit (on the north eastern)

- Gölcük (on the southern)

- Karamürsel (on the southern)

The population distribution of the eastern part of the bay(inner) in 1980 is given as follows (27).

PLACE	POPULATION	PLACE	POPULATION
Tütünçiftlik	17.000	Yuvacık	4.500
Topallar	7.000	Bahçecik	8.000
Derince	67.000	Ihsaniye	7.000
Izmit	192.000	Gölcük	46.000
Kullar	5.000	Others	10.000
Köseköy	5.500	Eastern Total	370.000

Table 2.23. Population distribution along eastern part of the Izmit Bay (27) in 1980.

Pollutional Load of Domestic Wastewater Discharges;

The per capita water consumption for domestic wastewaters is taken as 375 l/day and the unit waste loads as 60 g BOD_5/day, 12 g N/day, and 3 g P/day for 1980 are taken in the calculations of domestic wastewater loads (8).

Then the total domestic wastewater load is found as 32 ton BOD_5/day, 6.3 ton N/day, and 1.6 ton P/day.

- 59 % of this amount is discharged from Izmit region (including Derince, Kullar, Köseköy, Yuvacık, Derbent)
- 16 % of the waste load is discharged from Gebze region (including Çayırova, Darıca, Dilovası)
- 11 % is from Gölcük (including Bahçecik, Değirmendere)
- 7 % is from Yarımca region (including Tütünçiftlik)
- 5 % is from Karamürsel
- 2 % of the waste load is discharged from Hereke.

As it can be understood, the major part of the pollutional load of the bay is discharged from eastern part of the bay.

The pollutional loads of the eastern bay originated from domestic sources, with having 1.39 x 10^5 m^3/day average flow rate are; 22.2 ton BOD_5, 4.45 ton N, and 1.11 ton P per day.

2.6.3. Industrial Waste Loads

The industrial pollution in the eastern part and the eastern site of the central part of the Izmit Bay is the most critical. Industrial pollution is mostly generated by Izmit, Kullar, Yarımca settling areas.

According to industrial Categories;

- the major part of the BOD_5 load is coming from "pulp and paper and food industry",
- the major part of the TSS load is from "pulp and paper and sand and gravel production plants",

- the major part of the N load is from "chemical and food industries",
- the major part of the P load is from "chemical and food industries".

The total area of the industrial settlements around the bay is 565 ha. The 285 ha of this area is covered by eastern part of the bay.

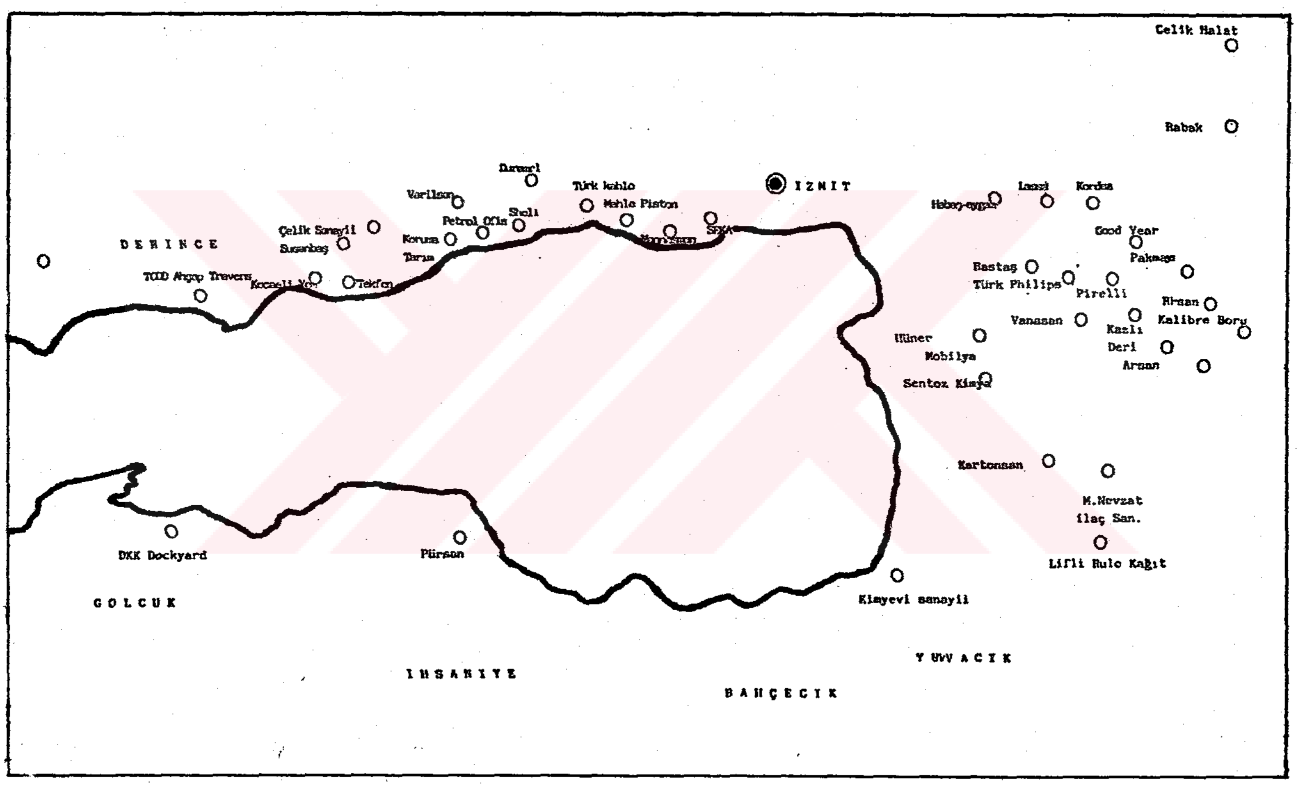


Figure 2.10. Location of the industries around eastern part of the bay.

There are about 186 industries around the Izmit Bay. 140 of them are located around the eastern part of the bay. The largest industries with high pollution potential of eastern bay are shown in Figure 2.10.

INDUSTRY	LOAD	%
*SEKA Cellulose	59700	59
*PAKMAYA	12760	12
PETKIM	11700	11
*FURSAN	6500	6
IPRAS	3000	3
ANSA	1618	1.5
YARIMCA GUBRE	792	1
PETROL OFISI	928	0.8
MARSHALL	640	0.6
*KARTONSAN	624	0.6
*DKK DOCKYARD	600	0.6
*MANNESMAN	597	0.3
NASAS	320	0.2
*KORUMA TARIM	308	0.2
*KAZLI DERI	255	0.2
YARIMCA PORCELAIN	180	0.1
IPEK KAGIT	180	0.1
*KORDSA	140	
*PIRELLI	128	
*MUSTAFA NEVZAT	125	
HEREKE SUMERBANK	120	
BASF	108	
OTHERS	724	
TOTAL	102047	100
EASTERN TOTAL	83255	82

Table 2.24. Organic load of industries (according to importance and priority) (kg/day) (4,15).

*Located on eastern part of the bay.

INDUSTRY	LOAD	%
IGSAS	7920	72
YARIMCA GUBRE	400	4
ANSA	1250	11
PAKMAYA	464	4
FURSAN	416	4
PETKIM	234	2
IPRAS	180	2
YARIMCA PORCELAIN	25	
OTHERS	68	
TOTAL	10957	100
EASTERN TOTAL	1098	10

Table 2.25. Nitrogen load of industries (kg/day)(15).

INDUSTRY	LOAD	%
YARIMCA GUBRE	400	88
PAKMAYA	116	6
FURSAN	52	3
MANNESMAN	16	0.9
ANSA	13	0.7
PETKIM	12	0.6
CELIK HALAT	2	0.1
ARCELIK	2	0.1
NASAS	1	
DKK DOCKYARD	1	
RABAK	1	
TOTAL	619	100
EASTERN TOTAL	191	31

Table 2.26. Phosphorus load of industries (kg/day)(15).

As it is shown in Table 2.24, the organic load of the industries is found as 102.047 ton/day. The 82 % of this amount is discharging into the eastern part of the bay (15). And also the pulp and paper industrial complexes (SEKA) have enormous pollutional potential interms of its BOD_5. About 60 % of the organic load reaching the bay is discharged from this plant And the BOD_5 load of 6 plants around the bay, including SEKA, Fürsan, Pakmaya, Ipraş, Ansa, covers the 92 % of the grand total of the BOD_5 entering the bay. The population equivalent of the industries interms of their organic load is found as 1.3×10^6, which is more than the estimated population of Izmit Bay in 2000, 1.25×10^6 (15).

The nitrogen load of the industries is given in Table 2.25. As can be seen from there, the total nitrogen load of the bay is about 11 ton/day. The 80 % of the nitrogen load of the industries is originated from two fertilizer plants.

The phosphorus load of the industries is given in TAble 2.26. And the total load is found as 0.619 ton/day. About 90 % of this load is discharged by fertilizer plants.

The total volume of the wastewaters of these industries directly discharging into the bay is about 1.8×10^5 m^3/day. The 73 % of this wastewater discharges is given by SEKA, Ipraş, and Petkim; 27 % of the total wastewater discharge is from remaining industries.

INDUSTRY	Q (m^3/day)	%
SEKA CELLULOSE	95000	53
PETKIM	23400	13
IPRAS	12000	7
IGSAS	6600	4
PAKMAYA	5800	3
KARTONSAN	5200	3
YARIMCA GUBRE	3960	2
MANNESMAN	2640	1.5
FURSAN	2600	1.5
SEKA CHLOR ALKALIE	2500	1.5
KORUMA TARIM	2250	1
PIRELLI	1830	1
YARIMCA PORSELEN	1800	1
OTHERS	13320	
TOTAL	178900	100
EASTERN TOTAL	124100	69

Table 2.27. Wastewater discharge rate of industries (15)

Domestic Wastewaters of Industries ;

As the number of the workers being 26668 (15), the domestic wastewater discharge of the industries is 13343 m^3/day, and BOD_5 load is 0.20 ton/day, N load is 0.02 ton/day, and P load is 0.004 ton/day (15).

In Tables 2.28 and 2.29 the comparison of the observed waste composition of the industries with the literature values are given. As can be seen, most of the characteristics of the wastewaters of the industries are in the range of literature values except SEKA wastewaters.

NAME	INDUSTRY	Parameter	ITU (13)	SWECO (8)	TUBITAK (29-30)	TUBITAK (16)	ITU (15)	LITERATURE
SEKA	Pulp and Paper	Q (m^3/day)	125000					
		BOD_5(mg/l)	2250	117-2160		388		300-3000
FURSAN	Fermentation	Q (m^3/day)		2200				
		BOD_5(mg/l)		1710	2400-5810	2150	690	
		Total P(mg/l)		0.2		1-36		
PAKMAYA	Fermentation	Q (m^3/day)			7000	5830		
		BOD_5(mg/l)		1050	2000-4230	2200		3000-4500
		Total P(mg/l)		0.6		2-12		4-35
KORDSA	Plastic	BOD_5(mg/l)			67-360	25		65-400
		NH_4-N(mg/l)				7.1-7.9		
ANSA	Chemical	BOD_5(mg/l)	20-400	54-1050		1240		15-8460
		P (mg/l)		0.1-0.6		7-30		

Table 2.28. Comparison of the measurements carried in different periods with the Literature values for selected components and Industries (15).

NAME	INDUSTRY	PARAMETER	ITU (13)	SWECO (8)	TUBITAK (29-30)	TUBITAK (16)	ITU (15)	LITERATURE
KAZLI DERI	Leather	Q (m^3/day)			500	880		
		BOD_5(mg/l)		1140	138-985	290		349-1620
		NH_4-N(mg/l)						13-104
GOODYEAR	Rubber	Q (m^3/day)		1200	1800	620		
		BOD_5(mg/l)	25-51		40-60	31-77		0.2-31
		NH_4-N(mg/l)				0.15-4.6		
IGSAS	Fertilizer	NH_4-N(mg/l)			24-3315	87-3960		20-4000
M.NEVZAT	Pharmaceutical	BOD_5 (mg/l)			15-2130			50-27000
		NH_4-N(mg/l)			0.6-3.4			
PETKIM	Petrochemical	Q (m^3/day)		8640				
		BOD_5(mg/l)	24-260	0-250	185-770		500-910	225-1950
		NH_4-N(mg/l)				2.0-2.5		

Table 2.28. Comparison of the measurements carried in different periods with the literature values for selected components and Industries (15).

INDUSTRY	WASTEWATER RATE (m^3/ton product)		BOD (kg/ton product)		N (kg/ton product)		P (kg/ton product)	
	OBSERVED	LITERATURE	OBSERVED	LITERATURE	OBSERVED	LITERATURE	OBSERVED	LITERATURE
FURSAN	390		636		47.2		7.79	
PAKMAYA	82	15-80	595-1488	300-420	6.56		1.64	
SEKA-Cellulose	200-220	90-150*	23-39	15-24	0.6-240			
KARTONSAN	51	18**-106***	15.2	10-25.1				

* The range is for the pulp and paper factories with new technologies

** For waste paper

*** Unintegrated cardboard

Table 2.29. Actual industrial composition and literature values for some selected components and industries (15, 31).

The industries that cause the major part of the pollutional load are;

INTERMS OF BOD	INTERMS OF N	INTERMS OF P
SEKA Pulp and Paper	Ansa	Pakmaya
Pakmaya	Pakmaya	Fürsan
Fürsan	Fürsan	Mannesman
Ansa		Ansa
Petrol ofis		

2.6.4. Drainage Waters Pollutional Load

The drainage waters of the settlements(rain water) and the agricultural areas are also discharging into the Izmit Bay. The wastewaters drained from agricultural areas include N, P, BOD_5 and TSS, due to the usage of fertilizers. In Table 2.28, the pollutional load of the drainage waters as kg per hectar per day is given.Then daily pollutional loads of the drainage waters are found as 1 ton BOD_5, 193 ton TSS, 0.4 ton N, and 0.034 ton P (4).

The most important polluting parameter is Total Suspended Solids. The 26 % of TSS is coming from Karamürsel, 23 % is from Gebze, 23 % is from Kullar-Köseköy, 18 % is from Gölcük, 5 % is from Yarımca and 1 % is coming from other areas.

The percentage distribution of the pollution parameters around the bay carried by drainage waters are given as follows (4);

	NORTH	EAST	SOUTH
BOD	11	1	88
TSS	17	2	81
N	16	1	83
P	13	2	85

PARAMETER	FROM SETTLEMENTS	AGRICULTURAL AREAS	OTHERS
BOD	0.160	0.0060	0.0030
TSS	1.600	2.6900	1.3450
N	0.012	0.0050	0.0025
P	0.003	0.0030	0.0002

Table 2.30. Pollutional load of drainage waters (kg/na/day) (4).

The waste loads carried to the eastern by drainage waters are given in Table 2.29. As it can be seen, the total BOD_5 load is about 0.240 ton/day, TSS load is about 27 ton/day, N load is about 0.061 ton/day and P load is 0.0315 ton/day.

PARAMETER	FROM SETTLEMENTS	AGRICULTURAL AREAS	TOTAL
Drainage area (ha)	1153	9324	
BOD_5 (kg/day)	184.5	56	240.5
TSS (kg/day)	1845	25082	26927
N (kg/day)	14	46.6	60.60
P (kg/day)	3.5	28	31.50

Table 2.31. Pollutional load of drainage waters to eastern part of the bay (15).

It can be concluded that the major polluting sources in the bay interms of BOD_5, P, and N is industries, where drainage waters discharge the major part of TSS load (63 %). All the polluting parameters, except TSS, discharged into the northern ands eastern coasts are from industries, where settlements are more important interms of their waste load except TSS through the southern coast. And the 86 % of the total wastewater discharge is given by industries, only 24 % of the total wastewater discharge is given by settlements.

2.5.6. Pollutional Load of Rivers

There are many rivers in the catchment area of Izmit Bay. And the rivers discharging into the eastern part of the bay are shown in Figure 2.11.

RIVER	Q Min	Q Max	Q Avg
Çınarlı Dere	0.212	1.9.9	0.983
Kurt Dere	0.154	14.038	2.231
Seymenli Dere	0.067	1.015	0.428
Bıçkı Dere	0.106	0.511	0.252
Hisar Dere	0.399	6.673	2.732
Yalak Dere	0.272	5.992	2.118
Kiraz Dere	0.898	25.030	9.155

Table 2.32. The characteristics of the rivers discharging into the Izmit Bay (m^3/sec) (28).

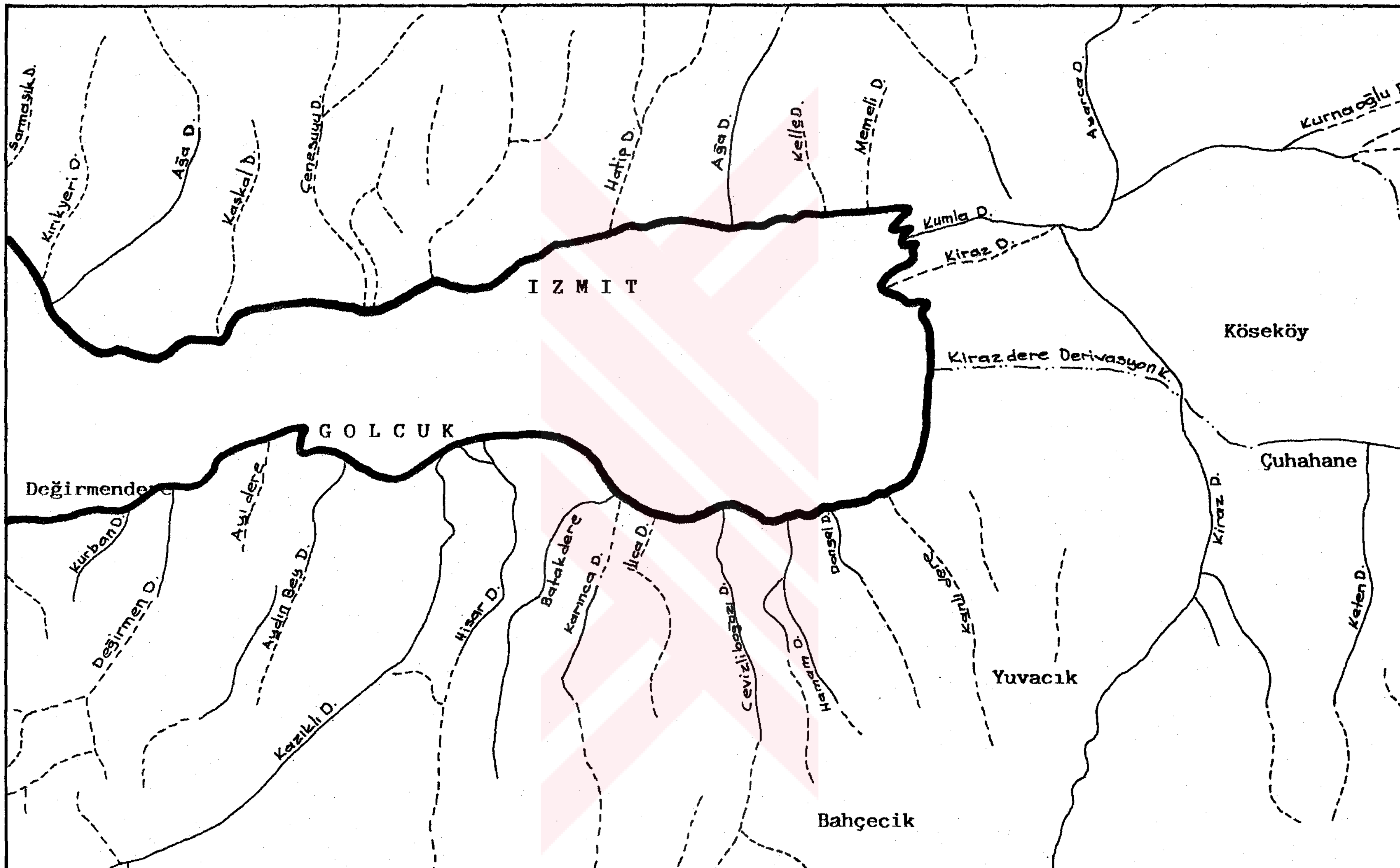


Figure 2.11. The rivers discharging into the eastern part of the bay.

RIVER	BOD_5	N	P
Cuhahane Deresi	15-24	0.8-24	0.1
Kiraz Dere	5	5.4-10	0.1
Kullar Deresi	5	2.7-170	0.1-0.8

Table 2.33. The pollutional data of the rivers (SWECO-BMB measurements) (mg/l) (9).

RIVER	BOD_5	N	P
Dil Deresi (US)	5	1	0.01
(DS)	1100	1.7	0.80
Kiraz Dere	28	-	0.01
Kumla-Akarca Dere	610	-	0.01

Table 2.34. The pollutional data of the rivers discharging into the eastern bay (ITU measurements) (mg/l) (5).

The flow rates of the important rivers discharging into the bay are given in Table 2.32. There are many studies on the quality of the rivers discharging into the Izmit Bay (13, 29, 30). These rivers receive the wastewaters of industries, and some of the settlements as Gebze. And also the seepages from agricultural areas are dragged into rivers. The pollutional load of the selected rivers are given in Tables 2.33, and 2.34.

When compared with the industrial and domestic loads, the loads of the rivers are neglected inthis Thesis.

2.6.6. Pollution Caused by Ships

Rubbish, ballast water and bilge water disposed of from the ships supplying the factories with oil and other raw materials and also the naval base at Gölcük are also important sources of pollution and must be considered in the total environmental control programme for Izmit Bay. In this Thesis these pollutional load is negliged interms of their organic and nutrient load.

The total pollutional load of Izmit Bay and the eastern part of the bay are summarized in Table 2.35. According to the evaluations, the BOD_5 load the eastern part is 79 % of the total load of the bay, where N load is 31 % and P load is 56 % of the total load. Organic load of the industrial activities and nitrogen content of the industries are much higher than that of domestic wastes, where the phosphorus load ow domestic wastewaters is about twice that of industrial origin in the bay.

	BAY LOAD	EASTERN LOAD
DOMESTIC		
BOD_5	31.530	22.400
N	6.300	4.450
P	1.600	1.110
INDUSTRIAL		
BOD_5	102.000	83.300
N	11.000	1.200
P	0.600	0.200
DRAINAGE		
BOD_5	1.000	0.240
N	1.200	0.060
P	0.200	0.032
RIVERS		
BOD_5		0.035
N		0.015
P		0.001
TOTAL		
BOD_5	134.530	105.975
N	18.500	5.725
P	2.400	1.343

Table 2.35. Pollutional loads of Izmit Bay and Eastern Part of the Bay (tons/day).

2.6.7. Evaluation of Maximum Allowable Loads

In this Thesis the assimilative capacity of Izmit Bay is evaluated by taking into consideration the oxygen and the nutrient concentrations, thus the consequences of floatables and other visible pollution of bacterial pollution, and of discharge of toxic material are ignored . These parameters have to be dealt separately.

As it is mentioned before, there are two layer current system during two periods of the year. During summer, due to the capacity of the water transferred to the lower layer by vertical turbulent exchanges are limited, the bottom layer circulation is weaker. And the net flow in the eastern region at Derince-Gölcük region at upper layer (thickness is 10 m) is 1000 m^3/sec during summer. And during winter the upper layer flow is 1500 m^3/sec, and the lower layer flow is 1500 m^3/sec through this region.

	Thickness* (m)	Area** (mill m^2)	Volume** (km^3)	t (day)	Flow* (km^3/day)
SUMMER (Upper Layer)	10	44	0.440	5	0.088
WINTER (Upper Layer)	15	44	0.660	5	0.132
(Lower Layer)	8	24	0.195	4	0.049

* Ref.7 , ** Ref. 8

In the light of the circulation data, summarized above, and the pollutional loads discharging into the bay, the waste receiving capacity of the eastern part of the bay will be calculated. In this calculation the guideline which is prepared by GESAMP (See section 1.2.) will be used.

The main residence time for this part of the bay is between 4-7 days in winter, and about 5-8 days in summer (8).

It is found that the total BOD_5 load to the eastern part of the bay should be limited to about 10-30 ton/day. During the evaluation of this figure, the Wastewater Discharge Quality Standards for Izmit Bay (prepared by ITU and TUBITAK in 1984 (18)) is used. In Table 2.36, the discharge quality standards for the selected industries and domestic wastewaters are given.

Besides the organic load, also there is a need for a reduction of nutrients; phosphate and nitrates. Because the eutrophication in the eastern part of the bay has started and phosphorus and in some cases nitrogen are recognized as primary elements responsible for eutrophication in natural bodies of water. Therefore the nutrient discharge has to be limited.

The quality criteria for Nitrogen concentration in sea water (for survival of fishes) is 0.2 mg/l, according to Water Quality Control Regulation. In order to meet this quality criteria the maximum allowable load is found as about 1750 kg/day ((0.44 m^3 / 5 day)x 0.02 mg/l) with bay.

NAME OF THE POLLUTING BODY	MONTHLY AVERAGE	DAILY MAXIMUM
Petrol Ofisi	200	400
Kazlı Deri	100	200
Fürsan	150	375
Pakmaya	150	375
Kartonsan	50	100
SEKA	40	80
*Domestic Wastewaters	20	40

Table 2.36. BOD_5 discharge quality standards for various sources located around eastern part of the Izmit Bay (6).

*Valid for urban and rural residences where sewerage system exists.

a main residence time of about 5 days during summer period, which is the most critical period in Izmit Bay. And the maximum allowable concentration for winter pariod is calculated for upper and lower layer. Then the total allowable load for winter is about 3700 kg/day.

According to the quality criteria for the prevention of eutrophication is given as 0.0051 mg/l for winter period and, 0.0034 mg/l for summer period (20). Then the maximum allowable load for phosphorus is found as 950 kg/day for winter period and 300 kg/day for summer period in the eastern part of the bay.

So if this maximum allowable loads are compared with the present pollutional load of the bay (see Table 2.35), the assimilation capacity of the bay is exceeded in a greater extend. And when the removal processes are applied, it is necessary to consider the two important periods in the bay.

CHAPTER 3

DISCUSSION

Izmit Bay, an elongated semi-enclosed water body located on the northeastern part of the Sea of Marmara, is the region that is the most polluted and the most industrialized region in Turkey. So that the local and the national authorities have great interest on this bay and carried many studies since 1977. In this thesis, BOD_5,N and P are taken into consideration and the pollutional loads of these parameters are calculated.

When the results of the measurements compared with the quality standards for various beneficial uses, it is found that the eastern part of the bay is entireley polluted state and can not be used for any beneficial use, and the quality of the eastern bay waters can be characterized as sewage.

While controlling the organic matter effects on water bodies, it is recommended to keep the oxygen content of the bottom waters more than 0.0 ppm and the surface layers around 80 % of the saturation concentration of oxygen. But dissolved oxygen concentrations of the bottom layers of the eastern regions decreases to 0.0 ppm during October, and the dissolved oxygen concentration of the upper layers decreases to 3.8 to 3.3 ppm in the eastern region. So dissolved oxygen concentration shows how pollution is critical in this region.

Nutrient measurements have given a general picture of the eutrophication level of Izmit Bay, possibly indicating phosphorus to be the limiting factor for algal growth. The nutrients, which are always available in the bay in amounts over the natural levels valid for oceans, keep the primary production over natural levels of marine environment. Thus anoxic conditions occur in the bottom layers, during August and September that is the period of weak circulation in the bay. The N/P ratio is always higher than the natural value, 7. So phosphate is a limiting factor that requires discharge quality standards for nitrogen and phosphorus. Therefore the nutrient discharge has to be limited.

The inner parts of the Izmit Bay are closed to the effect of the Sea of Marmara. Because it is a semi-enclosed water body. There is always a two layer current system throughout the year. This two layer current system is the result of high rate of inflow from Black Sea during late spring and summer periods and the inflow of high saline waters of Sea of Marmara at near bottom levels during winter. The largest exchange occurs at the surface. The bottom layer circulation is weaker because the capacity of the water transferred to the lower layer by vertical turbulent exchanges are limited due to sharp stratification. Where there is an outflow occurs at the surface layer during summer period, an outflow occurs at a thin surface layer as well as the near bottom levels during autumn and winter.

As a consequence, highly polluted surface waters within the interior of the bay are transported to the outer region so that the bay may flush itself to a certain extent during the winter months. And also it is found that, the bottom layer waters of the bay changes every year. And together with the other effects that cause water exchange, the retention time of the bottom waters in the central part is less than one year.

The major pollutant sources of the bay are industrial and domestic wastewaters discharging into the bay directly or dragged by storm run-off. Other sources are storm run-off of dainage areas (rural, urban and agricultural areas), rivers and ballast wastewaters of ships used for transportation purposes in the bay.

Currently, densely populated settlements are directly discharging their wastewaters into the bay. The total population around the Izmit Bay is about 525500 in 1980. Approximately 70 % of this population is living in the eastern part of the Izmit Bay. The biggest settlements, city of Izmit, is discharging the major part of the domestic waste load of the eastern bay. The total population in the eastern bay with the other important settlements (Derince, Gölcük, Tütünçiftlik, Bahçecik, Topallar, Ihsaniye, Kullar, Köseköy, Yuvacık) is 370000 in 1980. The organic load of domestic wastewaters is 22.4 ton/day (together with the industrial domestic discharges), that covers the 21 % of the total organic load of eastern bay. The P load is 1.11 ton/day, 83 % of the eastern total, and the N load is 4.45 ton/day, 78 % of the eastern total.

Although the organic and nitrogen load of the industrial activities are much higher than that of domestic wastewaters, the phosphorus load of domestic wastewaters is five times more than that of industrial origin in the eastern bay.

At the moment, there exists no sewerage facility around the bay. Although construction of the sewerage network of eastern and central regions has been started in 1977, the work has not yet reached to the stage of wastewater treatment. This work is carried out by Iller Bankası according to the Izmit Sewerage Master Plan prepared by SWECO-BMB in 1976. It is not expected that the treatment in the area would start before 1992. Besides, the project does not include all of the urban and industrial areas. The treatment plant of Izmit is planned to be in operation in 1992, and the treatment plant of eastern part of city of Izmit (including Köseköy, Kullar, Yuvacık) is still under planning stage.

The domestic discharges are very important in terms of their pollutional load with increasing population. However, the pollution around the bay is mostly of industrial origin. Industrial waste loads cover 76 % of the organic load and 60 % of the nitrogen load in the bay, and industrial organic load is three times that of the domestic origin, where the nitrogen load is twice times that of domestic load.

The contribution of pollutional loads in the bay are unevenly distributed between the 186 pollutant discharging industrial plants. Out of the 140 plants, 40 of them discharging their wastewaters into the eastern bay and make-up about 80 % of the industrial loads in all pollutant categories. Almost none of these plants have established wastewater treatment facilities of any kind by 1983 (24). The present situation of the effluent treatment of the industries are shown in Table 3.1. The industries are discharging 83.3 ton BOD_5, 1.2 ton N, and 0.2 ton P per day into the eastern part of the bay.

The most important pollution sources in the eastern part of the bay are the city of Izmit, the biggest settlement around this

Name of the Industry	Waste water			Receiving Body					Exist any Treatment Plant		The type of the existing treatment				Receiving Body for the Treatment Plant effluents					
	Average discharge (m^3/day)	Industrial Fraction	Domestic Fraction	Municipal Channel	Izmit Bay	River	Treatment Plant	Land	Yes	No	Physical	Chemical	Biological	Sludge	Izmit Bay	River	Water Channel	Land	Municipal Chan.	Others
TCDD Ahşap Travers Fabrikası	90	11	89				x		x		x									x
Petrol Ofis Madeni Yağ ve Gres	232	91	9							x										
Shell Yağ Gres	40	20	80		x				x		x				x					
Habaş Sınai ve tıbbi İstihsal E.									x		x	x		x						
Tarım Koruma ilaç.	3790	98.2	1.8		x	x			x		x	x			x	x				
Lassa Lastik Fab.	300	25	75	x			x		x		x	x	x				x			
Duramel Kimya ve P.*																				
Kordsa	150		100	x					x			x	x				x			
Pirelli	1830	85	15				x		x		x					x				
Goodyear Las.TAŞ.	620	52	43		x				x		x	x				x				

Table 3.1. Discharge conditions of the wastewaters of industries located around the eastern part of the bay (14).

Name of the Industry	Waste water			Receiving Body					Exist any Treatment Plant		The type of the existing treatment				Receiving Body for the Treatment Plant effluents					
	Average discharge (m^3/day)	Industrial Fraction	Domestic Fraction	Municipal Channel	Izmit Bay	River	Treatment Plant	Land	Yes	No	Physical	Chemical	Biological	Sludge	Izmit Bay	River	Water Channel	Land	Municipal Chan.	Others
Mannesman	2638	95	5			x				x										
Derince Varil Fact.	13	92.3	7.7		x				x											
Çelik Sanayi	50	–	100				x		x		x				x					
Istanbul Mahle Pist.	34	6	94		x				x		x				x					
Arçelik A.Ş.	360	44	56				x		x		x	x				x				
Kalibre Boru San.	2.8	20	80	x			x		x		x								x	
Tekfen	2.75		100			x			x		x				x					
Türk Kablo	90	75	25		x				x		x				x					
Rabak									x		x									
Baştaş										x										
Philips										x										
Hüner Mobilya	5		100																	

Table 3.1. Discharge conditions of the wastewaters of the industries located around the eastern part of the bay. contin.

Name of the Industry	Waste water			Receiving Body					Exist any Treatment Plant		The type of the existing treatment				Receiving Body for the Treatment Plant effluents					
	Average discharge (m^3/day)	Industrial Fraction	Domestic Fraction	Municipal Channel	Izmit Bay	River	Treatment Plant	Land	Yes	No	Physical	Chemical	Biological	Sludge	Izmit Bay	River	Water Channel	Land	Municipal Chan.	Others
Lifli Rulo	1429	99.7	0.3			x	x		x		x					x				
Kazlı Deri San.	1000	90.0	10						x		x						x			
Kartonsan	4200	99.8	0.2			x			*								x			
SEKA																				
Cellulose																				
Chlor-Alkalie	108060	99.0	1.0							x					x					
Fürsan	2600	97.0	3.0			x			**											
Gölcük-Dockyard	600				x															
Mustafa N.Ilaç San.	1250	99.0	1.0							x										
Pak Gıda A.Ş.	5800									x										

* Septhic tank

* Although have a treatment plant (anaerobic), the effluent still have 10000mg organic load/day.

Table 3.1. Discharge conditions of the wastewaters of the industries located around the eastern part of the bay.(Contin.)

region, and industries especially SEKA pulp and paper industry. SEKA is located within the area between Derince and Izmit, and discharges enormous pollutional load interms of its BOD_5. It constitutes the 60 % of the total organic load of industries. If SEKA cellulose plant discharges no wastewater, the pollution caused by organic matters will be reduced by 50 %, and TSS by 50 %. The average wastewater flow rate is 95000 m^3 /day. Sulfite-cellulose plant is the main source for various organic and inorganic matters present in this wastewaters, and also HSO_3^- ions that cause oxygen deplation in the receiving bodies. The suspended solids present in the wastewaters are generally of organic origin and have a property of accumulation in the receiving bodies due to their slow degradation rate, and consequently cause anoxic zones in these bodies.

According to information from SEKA, the sulphite-cellulose factory is quite old and worn out. This system is not able to hold the paper fibres in the system, and this fibres are discharged into the bay with the process wastewaters by constituting the major part of the organic load of the plant. Recently the construction of wastewater treatment plant of SEKA has been tendered. But this treatment plant will treat only 50 % of the total organic load. And still 30 tons of organic load remains to be discharged into the bay (present load as being 59.7 (4,15)).

Some of the wastewaters are discharging into the bay indirectly are dragged by surface run-off and by rivers. Drainage waters give the bay approximately 65 % of the total TSS load. The rivers discharging into the bay are polluted with the direct discharges of industries and settlements and also with the seepage from the agricultural areas. But the pollutional load of the rivers is neglected as compared with the loads of industries and settlements.

It is found that the total BOD discharge into the eastern part of the bay should be limited to about 30 ton/day, but that figure may be changed depending on tne changes in the water quality of the bay. Then approximately 70 % total BOD removal is required to meet the required quality criteria.

Phosphorus and in some cases nitrogen are recognized as primary elements responsible for eutrophication in natural bodies of water. Therefore the nutrient discharges has to be limited. The phosphorus can be reduced by chemical cougulation and sedimentation, but it is also possible to precipitate phosphorus by adding coagulant to the aeration tank in activated sludge plant. The nitrogen removal is more complicated and expensive neverthless it is possible by means of nitrification and denitrification or by ion exchange. Then the nutrient discharges must be controlled and limited to 3.7-1.7 ton N/day and 1-0.3 ton P/day in the bay.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

The objective of this study is to obtain results based on the necessities for improving the water quality of the eastern region of the bay to the level for preserving the aquatic life. In order to prevent and control pollution and improve water quality of the bay, it is necessary to limit the quantities of organic matter, and nutrients discharging into the bay. In order to decide what restrictions must be placed upon the discharges and what concentrations are acceptable by the receiving body, the maximum allowable loads for these parameters are calculated. The results of these evaluations show that the assimilation capacity of the bay has exceeded the limit, especially in the most critical period, in summer.

According to the hydrodynamic features in the bay, the water quality can not be improved by partial treatment and other preliminary treatment alternatives. It is necessary to apply tertiary treatment processes to reach the discharge quality standards and to provide maximum allowable limits. And also organic matter must be mainly discharged into the surface layer, where there is a substantial oxygen supply due to algal production and take up from atmosphere.

At the same time large nutrient discharges should be made below the transition zone, where there is lack of light and avoids strong algal blooms in the surface level. And also it is recommended that nitrogen is not discharged as ammonia since it causes additional oxygen deplation. As the pollutional data of the Izmit Bay show, the assimilative capacity of the bottom water of the eastern part of the bay is fully utilized. Then it is better to pump the sewage to the central part of the bay, especilly to the western region of this part.

At present lack of adequate data makes it difficult to make accurate determinations about limiting parameter for the control of eutrophication. According to the actual ratio between nitrogen and phosphorus, phosphorus seems to be the limiting parameter but there should be investigations carried for the other parameters that cause eutrophication, such as diatoms, SiO_2, SO_4^{-2}, trace metals, Cu^{++}, Co^{++}, Fe^{++} and others.

After the investments have been done on construction of sewerage and treatment facilities to meet the required standards, it is not possible to determine when the eastern bay will reach the quality of the uses for the fish or shell-fish production. And when it is chosen as the target to be reached as the beneficial usage, then this will require the closing down of some industries located around this region, since this quality requires highest degree of water quality.

The SEKA pulp and paper industry gives the major part of the organic load to the bay and accounts 56 % of the BOD_5 load to the eastern part of the bay. Today it is impossible to satisfy the limits given for SEKA wastewaters for BOD_5 and TSS with the process currently in use. As one alternative, to make some changes in pulp and paper production process and to make modifications in the system will reduce the organic matter content by recovering the sulfite-cellulose wastes (methanol, acetic acid, cymen, etc.). But for economic reasons it can not be rebuilt inorder to decrease the BOD_5 discharge, nor is it economical to built a treatment plant for BOD_5 reduction. Consequently, the intention is to close the absolute sulphite pulp mill immidiately and to replace this plant with a modern pulp mill in a more suitable place. And than the papermaking facilities can be phased out gradually. This is best for the prevention of pollution caused by SEKA wastewaters. By this way the volume of the wastewaters to be treated will be reduced and hence the treatment cost.

Besides SEKA, there are many industries that require solutions to their wastewaters. There are some small industries that can not built and operate their individual treatment plants, because of their economic situation. The alternative to accept their wastewaters after a preliminary treatment to an acceptable level to sewerage systems of cities or to city treatment plant, will be the best choice for their problems. If this alternative will be applied, then the authorities must take in mind the discharge rates from these industries during the design of city treatment systems together with the sewerage systems.

There are some large industries that must solve their wastewater problem by themselves. For the individual treatment of the major industries, it is necessary for the government to encourage them for example by giving credits to built their own treatment plants. And also it is necessary for the government to reduce the electricity cost used in treatment plants. Because there are still some industries having their individual treatment plants that could not operate them due to the high operation cost. For example the yearly operation cost of the SEKA treatment plant is expected to be 35 billion (with the prices of 1988) and more than 90 % of this cost will be expanded for electricity, where its construction cost is 16.7 billion.

Local administrative authorities for pollution control (e.g. provincial governors, municipalities and local agencies of central governments) can take up responsibilities in some parts, but unable to monitor the whole. A pollution control commission under the General Directorate of Environment seems to be a necessity in order to monitor and to streamline the activities of pollution in Izmit Bay.

And also it is necessary to rise the charges of the penalties for environmental offences and to set them according to the polluting categories.

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