THE IZMIT BAY CASE STUDY

S. Tuğrul, M. Sunay, Ö. Baştürk and T.I. Balkaş

TUBITAK, Marmara Research Institute
P.O.Box 21 Gebze-Kocaeli,
TURKEY.

The polluted waters of Izmit Bay were studied to measure the variations of biochemical and physical characteristics monthly. The spatial and temporal changes of nutrients (nitrate, nitrite, ammonia and o-phosphate), chlorophyll-a, BOD_5 , total coliform, total mercury, dissolved petroleum hydrocarbon (PAH), secchi disc depth, temperature and salinity in the bay were monitored during the period of May 1984 - April 1985. Also, some reliable data obtained from previous studies is included. The total amounts of wastes discharged into the bay and types of polluting sources were identified, as well as governmental regulations on discharges of industries being discussed. The evaluated results were compared with the results obtained from the relatively unpolluted waters of Marmara Sea. The degree of pollution in the bay was assessed.

INTRODUCTION

In recent decades, the remarkable technological progress of industries in developed countries have accelerated the transfer of technical knowledge to developing countries. As a consequence of heavy investments in the industrialization of developing countries, pollution problems of the 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. The large volumes of wastes from domestic and industrial sources have been mostly discharged to the environment without any pre-treatment. Along with the land and the atmosphere, the coastal waters of Turkey have been receiving the majority of these wastes. Accordingly, the pollution of the Marmara Sea, particularly of Izmit Bay, has caused great concern to local and

G. Kullenberg (ed.), The Role of the Oceans as a Waste Disposal Option, 243–274.

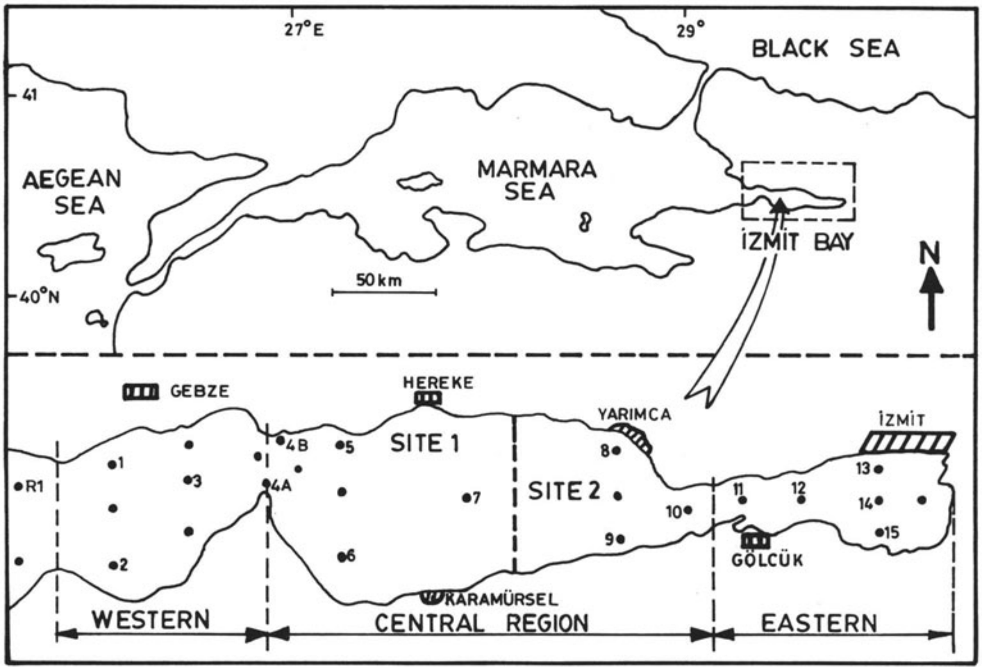

Figure 1. Sampling locations in İzmit Bay

national authorities due to the environmental deterioration which this area has undergone. Up till the present time, it was assumed that dumping waste water into the bay was a practical solution. In the area surrounding the bay, more than 140 large industrial plants have arisen since 1965. Their solid and liquid wastes mostly find their way directly into the bay without any pretreatment *(1-5)*. The volume of unpurified waste waters, both domestic sewage and industrial, is now so great that the biological self-purification capacity of the bay is no longer sufficient to restore the equilibrium to its normal state. It is well known that the self-purification capacity of bay water is directly related to the processes that control the oxygen balance of that water.

In order to improve water resources and prevent and control pullution of the bay, it is necessary to limit the quantities of organic matter, nutrients, and other toxic substances discharged into the bay. Before deciding what restriction must be placed upon the discharges and what concentrations are acceptable by the receiving water, it is necessary to assess the assimilative capacity of the bay. The selection of treatment methods and the extent of treatment are also firmly related to the assimilative capacity of the receiving water. This can be achieved by obtaining adequate and reliable oceanographic and pollutional data about Izmit Bay.

Although, so far, many studies have been accomplished on the characterization and treatment alternatives of waste effluents *(1-5)*, very limited work has been performed on measuring the oceanographic characteristics of the bay systematically *(6-8)*. Without having knowledge of the physical, chemical and biological properties of the bay, finding a reasonable solution to the pollution is unlikely. Therefore, reliable temporal and spatial measurements of oceanographic parameters in the bay water are of vital importance to assess the assimilative capacity of the bay. It has been suggested that the Bay of Izmit is in an entirely polluted state *(4-8)*. However, all of these previous studies have been focused on the coastal areas, which are influenced directly by waste waters. After obtaining the systematic reliable data for physico-chemical parameters which control the bioassimilation capacity of the bay, the mathematical model being developed for the two-layer water masses of the bay would say the amount of biodegradable organic matter that can be assimilated by the water body. Then, the comparison of the volume of waste waters to be treated with the estimated allowable load of the model study would make a beneficial usage programme for the bay possible to initiate.

In order to assess the degree of pollution and the assimilative capacity of Izmit Bay, a monthly measurement programme was carried out during the period May 1984 - April 1985. The preliminary results obtained will also be submitted in detail *(9)*, to the NATO Scientific Affairs Division, which has provided financial support for this work.

EXPERIMENTAL

Sampling stations. The measurements of physical and biochemical parameters were carried out at the points given in Figure 1. The numbered stations represent biochemical measurement points while dissolved oxygen, temperature and conductivity measurements were also done at the additional points marked on the map.

Temperature and conductivity. Temperature and conductivity were measured, in situ, by a Kahlsico Surveyor Model 6D probe.

Sampling. The water samples were collected by Hydro-Bios model nansen bottles.

Sample preservation. The water samples taken for nutrient analyses are preserved as given in standard methods *(10)*. The samples for Hg-analysis were preserved by adding HSO_4 + $K_2Cr_2O_7$ to the samples *(11)*.

Chlorophyll-a and total coliform. The water samples collected from different depths were filtered on board and frozen following the addition of $MgCO_3$ solution *(12)*. The filter papers were homogenized and the absorptions at different wavelengths were measured using a Varian Model UV/VIS spectrophotometer. The water samples for total coliform were collected by the special sterilized glass bottles. Treatments of the samples were completed on board by using a Millipore Model incubation system.

Nutrient analysis. Phosphate, nitrite, nitrate, ammonia and silicate analyses were accomplished by a Technicon Model autoanalyzer system *(13)*.

Total mercury. The samples digested with NHO_3 + $KMnO_4$ were analyzed by cold vapour-AA technique after concentrating the inorganic mercury in a 8 ml of dilute $KMnO_4$ solution *(11)*.

Dissolved petroleum hydrocarbon (PAH). PAH extracted into the CCl_4 was dried and dissolved in hexane again. The measurements were achieved using a fluorescent module of the UV/VIS spectrophotometer at 310 nm of excitation, e.g. characteristics excitation max. of chrysene *(14)*.

RESULTS AND DISCUSSION

Before discussing the oceanographic results of the bay, a brief summary of the population distribution around the bay is given to indicate the expected population increase in the future and to allow the comparison of amounts of pollutants entering the bay originating from domestic, industrial and surface run-off of drainage areas (rural, urban and agricultural areas) are given to evaluate the annual pollutional loads reaching the bay waters. The basic polluting industries are defined with their contributions to the pollutional load in terms of BOD_5, nitrogen, phosphorus and other toxic substances. Finally, the present pollutional level of the bay water is estimated and the oceanographic parameters of the area are evaluated to assess the assimilative capacity of the bay and the limiting nutrient element in these waters.

Population Distribution Around The Bay

The settlement area along the northern coast of Izmit Bay is severely limited becasue of the sharp topography of the steep coastal hills to the north and south. Most of the residential and commercial settlements are in the east-west direction along the transportation routes. There are four major urban centers around the bay namely; Gebze area on the north, Izmit metropolitan area on the northeastern part, Gölcük and Karamürsel areas on the southern banks of the bay. About 70% of the population live on the northern, 20% on the southern and 10% on the eastern banks of the bay area (Table-1). 56% of the total population live close to the industrial areas *(5)*. Rural areas, which are mostly inhibited by workers and their families, are in the neighbourhood of the metropolitan areas. The estimated population growth rates of major urban centers are given in Table-2 *(5)*. It is evident that the most drastic population growth is observed in the Gebze area, which acts a buffer-zone against the migration from rural areas to the Istanbul metropolitan area. The projections of the population distributions illustrated in Table-1 were obtained by the logistic and geometric extrapolation methods *(5)*. As is seen in the table, the expected population of the northern part of the bay will be more than two-fold of the present population in 20 years. About 10% of the present population are working in 140 major industries.

Sources And Amounts Of Pollutants Entering The Bay

The amounts and types of wastes discharged into the bay waters from both domestic and industrial sources within the area have been well documented (Tables 3-7), whereas those from agricultural areas and surface

Table 1. Expected populations (x1000) around Izmit Bay

LOCATION	1980	1985	1990	1996	2000	2005
NORTHERN PART						
Gebze	84.5	116.0	170.0	227.0	280.0	321.0
Izmit	192.5	230.0	261.0	286.0	305.0	319.0
Yarımca	19.0	29.0	39.0	48.0	56.0	61.0
Derince	67.0	117.0	164.0	204.0	232.0	248.0
Other small towns	36.0	52.0	73.0	94.0	120.0	149.0
SUB-TOTAL	399.0	544.0	707.0	859.0	993.0	1098.0
SOUTHERN PART						
Gölcük	46.0	57.0	64.0	69.0	73.0	75.0
Karamürsel	28.0	31.0	36.0	40.0	45.0	49.0
Other small towns	28.0	34.0	40.0	45.0	54.0	70.0
SUB-TOTAL	102.0	122.0	140.0	154.0	172.0	189.0
EASTERN PART (Total)	23.0	31.0	42.0	59.0	84.0	123.0
OVERALL TOTAL	524.0	697.0	889.0	1072.0	1249.0	1410.0

Table 2. Population growth rates of major urban areas around the bay (%)

YEARS	GEBZE	IZMIT	GÖLCÜK	KARAMÜRSEL
1945-50	2.5	3.2	2.9	2.3
1950-55	2.1	3.9	5.1	2.3
1955-60	3.7	3.8	3.9	2.8
1960-65	2.1	3.0	1.9	2.0
1965-70	6.9	4.6	5.5	1.2
1970-75	8.3	5.4	1.5	0.2
1975-80	19.5	3.5	6.0	3.5

run-off from urban and rural areas are not well known *(5)*. However some figures have been estimated for surface run-off (Table 7). The estimated domestic waste water discharged into the bay and their pollutional loads are given in Tables 3 and 4, respectively.

As can be seen from Table 4, a major part of domestic wastes discharged into the bay waters are along the northern coasts. Contributions of industrial wastes to the pollutional profile of the bay are depicted in Tables 5 and 6. The pulp and paper industry complexes (SEKA), which are located within the area between Derince and Izmit, have enormous pollutional pontential in terms of its BOD_5(biodegradable organic load).

Table 3. Expected domestic waste water discharges into the Bay of Izmit (x 10^3 m^3/day)

LOCATION	YEARS 1980	1985	1990	1995	2000
Northern part	75	110	150	195	240
Eastern part	4.4	6.5	9	14	20
Southern part	17	22	27	61	37
TOTAL	92.4	138.5	186	270	297

Table 4. Pollutional loads of domestic waste water sources (tons/day)

LOCATION and PARAMETER	YEARS 1980	1985	1990	1995	2000
Northern part					
BOD_5	24	33	42	52	60
TSS	36	49	64	77	90
T-N	4.8	6.6	8.5	10.3	11.9
T-P	1.2	1.6	2.1	2.6	3.0
Eastern part					
BOD_5	1.4	1.9	2.6	3.6	5.1
TSS	2.1	2.8	3.8	5.3	7.6
T-N	0.28	0.39	0.52	0.71	1.0
T-P	0.074	0.096	0.13	0.18	0.26
Southern part					
BOD_5	6.2	7.4	8.4	9.3	10.4
TSS	9.2	11.0	12.6	13.9	15.5
T-N	1.2	1.5	1.7	1.9	2.1
T-P	0.31	0.37	0.42	0.46	0.52
GRAND TOTAL					
BOD_5	31.6	42.3	53	64.9	75.5
TSS	47.3	62.8	80.4	96.2	112.6
T-N	6.3	8.5	10.7	12.9	15.0
T-P	1.6	2.2	2.7	3.2	3.8

BOD_5 : Biochemical oxygen demand ; TSS : Total suspended solid
T-N : Total nitrogen ; T-P : Total phosphorus

About 50% of the organic load reaching the bay are discharged from SEKA. The total BOD_5 loads of 6 plants around the bay are 92% of the grand total entering the bay waters *(5)*. The biodegradable organic load of industrial discharges is equivalent to 105 tons of dissolved oxygen per day as BOD. The 80% of nitrogen loads from industries originate from two fertilizer plants *(5)*. The total volume of waste waters of industries directly discharged into the bay is about 1.9 x 10^5 m^3/day. Three industries, SEKA (pulp and paper industry), PETKIM (petrochemical industrial complexes) and IPRAS (a rafinery) contribute 58% of the total industrial waste water discharges.

Table 5. Estimated pollutional loads of industrial waste waters (tons/day)

TYPE OF INDUSTRY	TOTAL FLOW (m^3/d)	BOD_5	TSS	T-N*	NH_3	T-P	OIL AND GREASE
Food	9320	20.3	1.4	0.94	-	0.18	0.4
Textile	555	0.30	0.19	0.001	0.007	-	-
Leather	1479	0.30	0.23	-	0.006	0.40	-
Pulp and paper	102628	61.7	42.4	-	-	-	-
Chemicals	51019	17.5	10.9	4.3	9.8	1.66	3.3
Rafineries	13765	3.4	1.1	-	0.21	-	0.84
Cement, glass and ceramics	2870	0.34	18.8	-	0.042	-	0.09
Metal finishing and machinery	5472	1.7	1.2	-	0.026	0.021	1.44
TOTAL	187108	105.5	76.9	4.24	10.1	2.26	6.07

* T-N : Total organic nitrogen

Table 6. Toxic dissolved substance discharges of industrial origin into the Bay.

PARAMETER	kg/day	PARAMETER	kg/day
Lead	6.6	Nickel	2.2
Copper	11.9	Mercury	5.1
Zinc	43.2	Cynide	0.74
Chromium	209	Phenol	200
Cadmium	1.8	Fluoride	2000

The estimated pollutional loads of different industrial settlements and urban areas are complied in Table 7. As can be seen from the results, organic loads of industrial activities, 105 tons of BOD per day, are much higher than that of domestic wastes. A similar pattern is seen in the nitrogen content of industrial wastes as the phosphorus load of domestic waters is two-fold that of industrial origin.

Currently, There exists no sewerage facility in the concerned area. Domestic and industrial waste waters are mostly discharged directly into the bay or dragged by storm run-off. The projected sewerage system was prepared by SWECO and BUE in 1975 *(8)*. The proposed system does not involve all of the urban and industrial areas. Although the sewerage pro-

Table 7 . Estimated pollutional loads of domestic and industrial wastewaters and surface run-off waters of drainage area reaching the bay waters (tons/day)[a]

LOCATION and SOURCES	BOD_5	TSS	T-N	T-P
Northern Part				
Industrial	83	70	11.4	0.61
Domestic	24	36	4.8	1.2
Run-off	0.1	42	0.08	0.005
Eastern Part				
Industrial	21.7	5.6	2.2	0.19
Domestic	1.4	2.1	0.29	0.07
Run-off	0.1	43.6	0.08	0.005
Southern Part				
Industrial	0.78	1.26	0.9	-
Domestic	6.1	9.2	1.23	0.31
Run-off	0.8	85.9	0.2	0.02
Industrial Total	105.5	76.9	14.5	0.80
Domestic Total	31.5	47.3	6.3	1.58
Run-off Total	1.0	171.5	0.36	0.03
OVERALL TOTAL	138.0	295.7	21.16	2.41

(a) : Data from reference 5.
T-N : Total kjeldahl nitrogen (organic-N + NH_3)

ject has been authorized, no attempt at construction has been made so far. The studies performed up to 1984 defined the chemical compositions of industrial wastes with their daily flow rates and applicable treatment systems for the most polluting industries *(5)*. Following that project, some discharge standards were developed for major polluting plants *(14)*. According to these standards, non-hazardous waste waters of the industries can be discharged into the domestic sewerage system to be constructed after the pretreatment of industrial waste waters in the areas of the plants. Then, the collected wastes will be discharged into defined points in the bay by following the physico-chemical and biological treatment.

Physical And Meteorological Properties Of The Bay

Izmit Bay, located on the northeastern part of the Sea of Marmara has a surface area of approximately 310 km^2. It is an elongated semi-enclosed body of water, about 50 km in length and 2 - 10 km in width, and has considerable depth except for the eastern part. Topographically and in terms of its oceanographic characteristics, Izmit Bay may be separated into three distinct regions; briefly western, central and eastern regions which are connected to each other through narrow openings *(5, 8)*. The bottom of the western section slopes upward in an easterly direction from about 100 meter-depth contour which bounds the bay to the northeastern Marmara Basin. As seen from Table 8, the surface area of this section is about 100 km^2 and it is connected to the northeastern Marmara Basin through a 5.5 km wide opening. Continuing in an easterly direction, there exists a sill about 55 meters in depth and 3 km in width, which separates the western region from the central part of the bay. The central region, which has about 170 km^2 surface area, constitutes the largest part of the bay. The eastern part of the bay is the smallest section of the system (44 km^2) and is connected to the central region by a 2 km wide opening. It is relatively shallow with a maximum depth of about 35 m. Although this section of the bay is small in area and shallow in depth, it receives the majority of domestic and industrial wastes. This portion also receives some inflow of fresh water from several creaks which are mostly polluted by industrial wastes.

Table 8. Basic physical properties of hydrographic regions of Izmit Bay *(5-8)*

REGION	LENGTH(km)	WIDTH(km)	MAX.DEPTH(m)	SURFACE AREA(km^2)	VOLUME (km^3)
Eastern	16	2-5	35	44	850
Central	20	3-10	180	166	12420
Western	17	3-5.5	1000	100	?

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 whereas that of the central section is about 975 km^2. The annual precipitation is about 700 mm, as the evaporation from the surface of the bay is about 600 mm annually. Estimated fresh water inputs into the eastern and central sections are about 12 and 3 m^3/ sec, respectively. The total input of the fresh water can be ignored when compared with the volume of the bay.

The regional wind regimes influencing Izmit Bay are dominated by northerlies from the Black and occasional southeasterly winds from the Aegean Sea. The prevailing wind from the north known as Etesian winds are particularly pronounced in July and August. Cold northerly outbreaks are also effective in the winter. The winter season is further characterized by the occasionally pronounced southerly winds with the local name of Lodos. They frequently produce storm waves and surges within the bay, and bring warmer and humid weather to the region. Long-term mean air temperatures around the area vary from about 3°C in winter to about 26°C in summer *(5)*.

Temperature And Salinity Variations In The Bay

As a part of the Turkish Straight System, the hydrological regime of the bay is, to a large extent, governed by the exchange of water between the Black Sea and the Mediterranean (Figure 1). More specifically, the bay exchanges its water with the Sea of Marmara through its opening to the northern Marmara Basin. This exchange has, presumably, a considerable variation throughout the year, even though inflow and outflow rates and their temporal variations are not known precisely. In terms of flow and stratification characteristics, the basic nature of İzmit Bay is the existance of a two-layer current system associated with two-layer stratification held throughout the year *(T.Oğuz, per.comm.)*. In general, spring and summer seasons are characterized by the inflow of the low saline waters of Black Sea origin with 21 - 24 ppt salinity over the high saline waters of the Mediterranean origin (Figure 2). This period corresponds to times in which precipitation and fresh water flow into the Black Sea increase substantially. As seen in Figure 2, the surface salinity of the bay waters rises 26 → 28 ppt in November due to inflow of high saline bottom waters into the bay. The increase in the surface salinity continues during the winter months and reaches 30 ppt in March. The subsequent decrease in the surface salinity appeared in April due to inflow of the low saline waters of Black Sea origin into the bay again. The surface salinity distribution 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. It starts decreasing in October, reaching 11°C in January and 7.5°C by March. On the other hand, the winter season is characterized by the inflow of bottom waters of the northeastern Marmara Basin into the bay and the subsequent increase in surface layer salinity. Thus, the layer of the high saline waters, which have 38 - 38.5 ppt salinity and 14.4 - 15.0°C temperature, rises inside the bay. Also in relation with bottom water, it was concluded that, while the surface water inflow is seen in April (Figure 2) the high saline waters of the northeastern Marmara Basin enter the bay from bottom during the same period. Consequently, as the surface salinity decreases the 38 ppt salinity contour along the bay rises more than 10 meters with respect to the depth of that contour in March.

Typical seasonal variations of salinity and temperature within the bay showing the permanent existence of two-layer stratification are illustrated in Figure 2, at a station located in the central region of the bay. The longitudinal variations of salinity with depth in summer and winter months are depicted in Figure 3, which show the temporal variations of water masses of different densities within the different regions of the bay, the times of exchange of the bay water masses with the northeastern Marmara waters and the extent of the vertical mixing in the bay. As seen in Figure 3, the thickness of the transition zone between two water masses of different salinity during the summer months is very limited as it becomes larger in the winter months due to the strong turbulent mixing across the interface. However, there exists sharp temperature and salinity stratifications throughout the year with the exception 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. A typical example is shown in Figure 4, indicating an almost 5 ppt increase in the surface salinity value due to the 10 m/sec northeasterly wind blown in February *(7)*. It is proposed that this type of wind episode could be the major factor

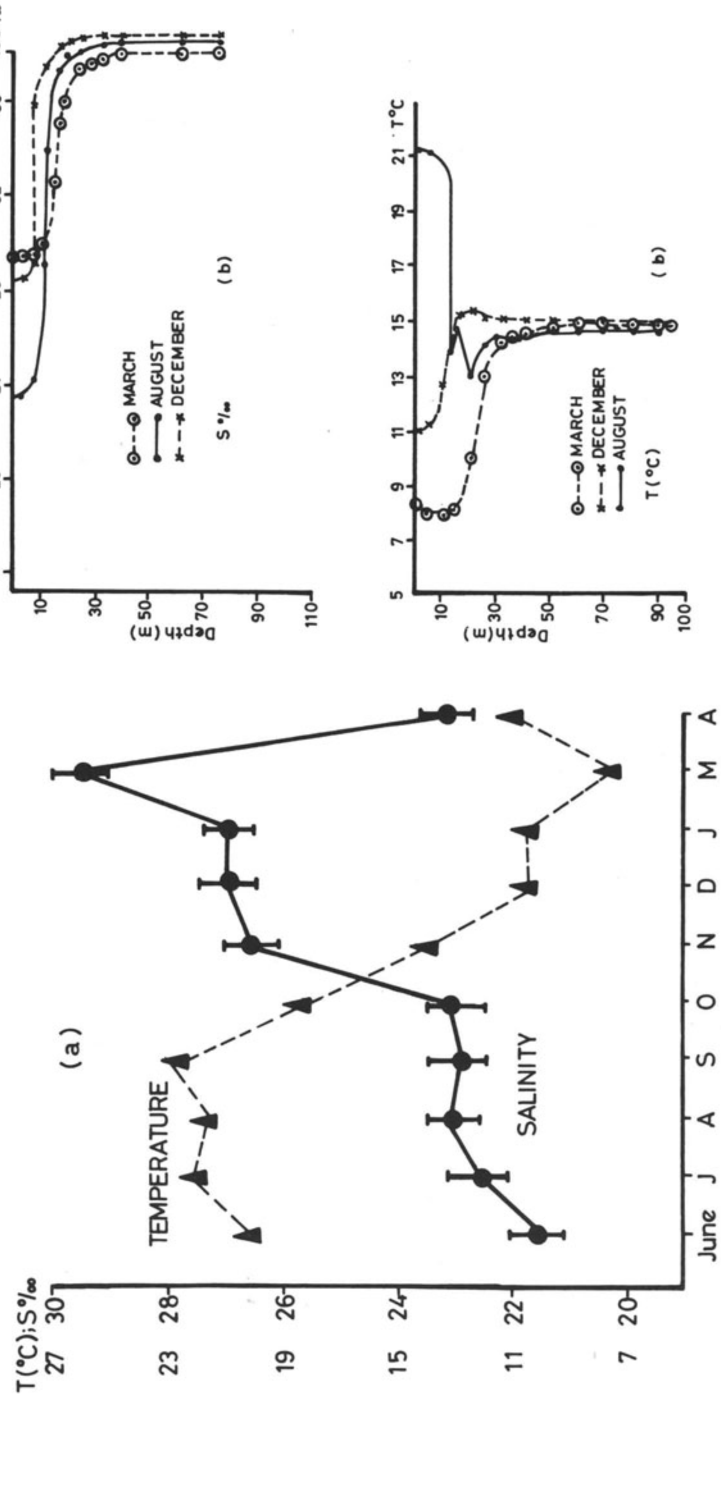

Figure 2. Variations of temperature and salinity ;(a) at the surface waters of the bay and (b) at Station 7.

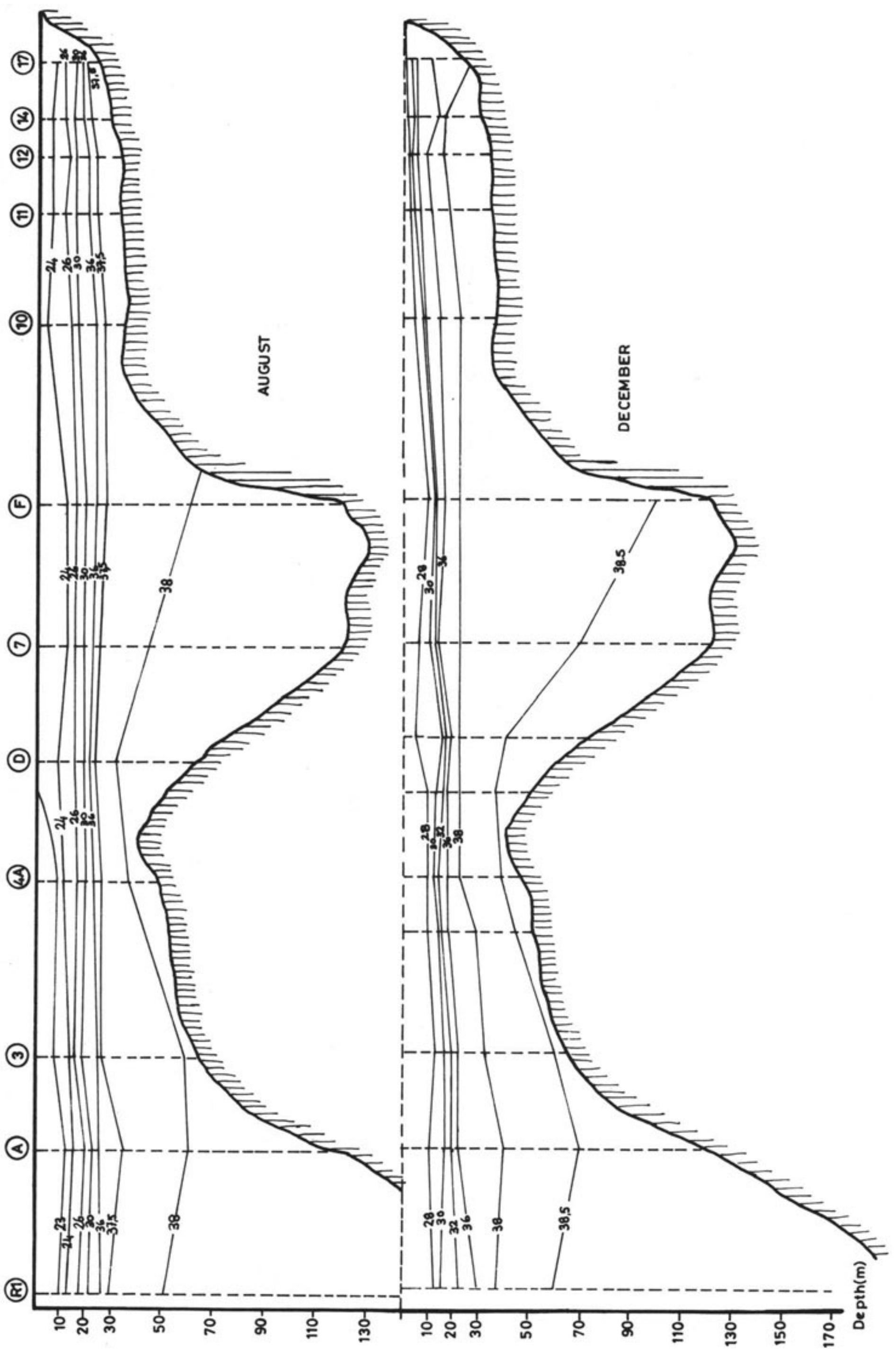

Figure 3 . Longitudinal variations of salinity in İzmit Bay.

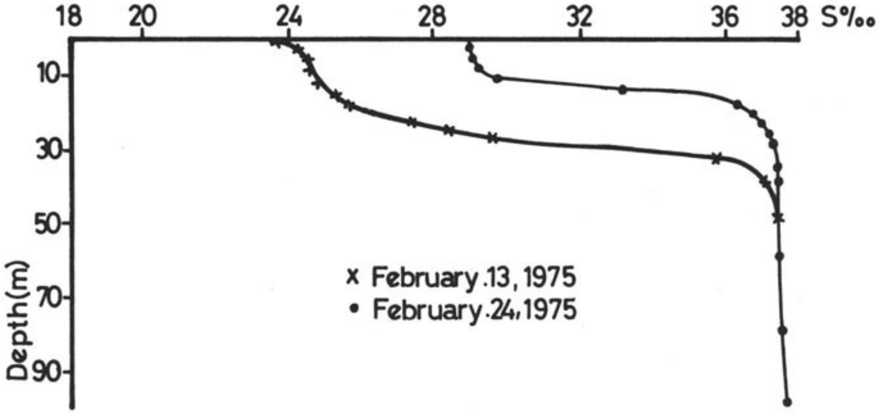

Figure 4. Effect of northeasterly wind episode on the salinity distribution (7).

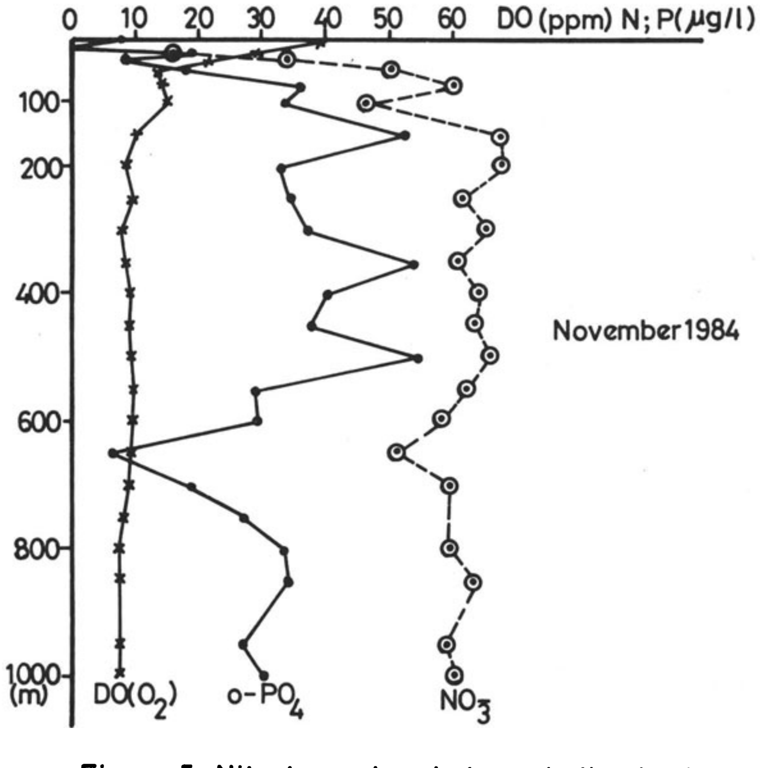

Figure 5. Nitrate, o-phosphate and dissolved oxygen distributions in the Marmara Sea.

affecting water exchanges between the bay sections and with the northeastern Marmara Basin *(16)*. The results of chemical parameters show that this type of event could affect the water circulation in three different sections, but not affect the water exchange with open water to a great extent. The field measurements carried out at the end of October and on 8th of November, 1984, evidently show that the water masses in the bottom were replaced by the northeastern Marmara Sea waters containing dissolved oxygen over 2 ppm. 38‰ S contour was at 35 m in October and was seen at 20 m inside the bay in November.

Distributions Of Biochemical Parameters

In order to obtain the regional averages of the measured parameters the bay is divided into four sections, depending upon its oceanographic characteristics and the degree of pollution in the sites (Figure 1). The western region of the bay is the least polluted site in the area, since it is under the direct influence of the Marmara Sea through a wide and deep channel, and in addition in the region, there is no industry with high polluting potential. The central part of the bay is divided into two sections. Sites 1 and 2 represent the western and the eastern sections of the central region of the bay. Site 2 of the central region is highly influenced by the heavy industries located on the northeastern part of the region and by the polluted waters flowing from the surface of the eastern part of the bay, while site 1 is comparatively less influenced from those sources affecting site 1. The fourth column in the tables represent the results of the eastern (inner) part of the bay.

The results of nutrients, chll-a, BOD_5, total coliform, dissolved petroleum hydrocarbon, heavy metals and secchi disc depth obtained in this work and previous studies are given in Tables 9 - 18. The graphical representations of some tabulated data are also illustrated in Figures 5 - 11. Before discussing the results, one must take into account nutrient levels in the Black Sea and open waters of the Marmara, in order to assess the levels and spatial and temporal changes of the parameters. The distributions of some parameters in the Black Sea and the Marmara Sea are compiled in Table 12. Also, the vertical profiles of dissolved oxygen, nitrate and o-phosphate in the Marmara Sea obtained in November are illustrated in Figure 5. The surface waters of the Black Sea have a dissolved nitrogen value (nitrate + nitrite + ammonia) less than 5 ppb while ortho-phosphate level, ranges between 1 and 8 ppb *(17)*. In the Marmara Sea the nitrate and o-PO_4 concentrations in deep waters are 60 - 70 ppb and 25 - 55 ppb in November, respectively. The chll-a values of both sea waters measured in November are consistently higher than 1 mg/m^3 in the productive zone. As seen from Table 12, the ratio of N/P (in weight) is less than 1 in the surface waters of the Marmara and of the Black Sea. In the deep waters of the Marmara this ratio is about 2. In other words, dissolved nitrogen in the form of nitrate is the limiting nutrient elements in these waters in November.

As the dissolved oxygen (DO) values of Izmit Bay waters are examined (Table 9 and Figure 6), it is seen that the upper layer waters of Black Sea origin (21 - 30 ppt salinity) have oxygen concentrations mostly at their saturation levels throughout the year. However, there is a net

Table 9. Seasonal variations of dissolved oxygen and BOD_5 in the Izmit Bay waters (mg/l)

MONTH/LOCATION	WESTERN		CENTRAL (Site 1)		CENTRAL (Site 2)		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
BOD_5								
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	-

(*) : Range values of the bottom waters; (-) : not measured
U : Upper layer (20-30 ppt salinity) ; B : Bottom layer (37-38.5 ppt salinity)

decrease in the DO levels of surface waters up to 3.8 ppm in the eastern region of the bay in July. In August, it increases again, except in the eastern part. In October, there is a remarkable increase in the surface water values of DO as the opposite is seen in the bottom waters in which all available DO was consumed by the biochemical decomposition of organic matter falling down from the productive upper layer. The anoxic bottom waters appeared in October and were replaced in November by the oxygenated water masses. Consequently, the DO concentrations of the bottom layers reach the values of 1.6 - 2.0 and 1 ppm for the central and eastern regions of the bay (Table 9). The DO levels of the bottom waters stay constant during the winter months, and tend to increase in March, which corresponds to the least productive time of the year (Table 10), and in addition, the transition zone between the two layers is significantly larger to allow the diffusion of dissolved oxygen in the overlying waters to the bottom waters. Then, in April, the DO values of bottom layers start to decrease due to the strong stratification in the bay which render difficult oxygen diffusion through the interface. This situation was created by the inflows of low saline waters of Black Sea

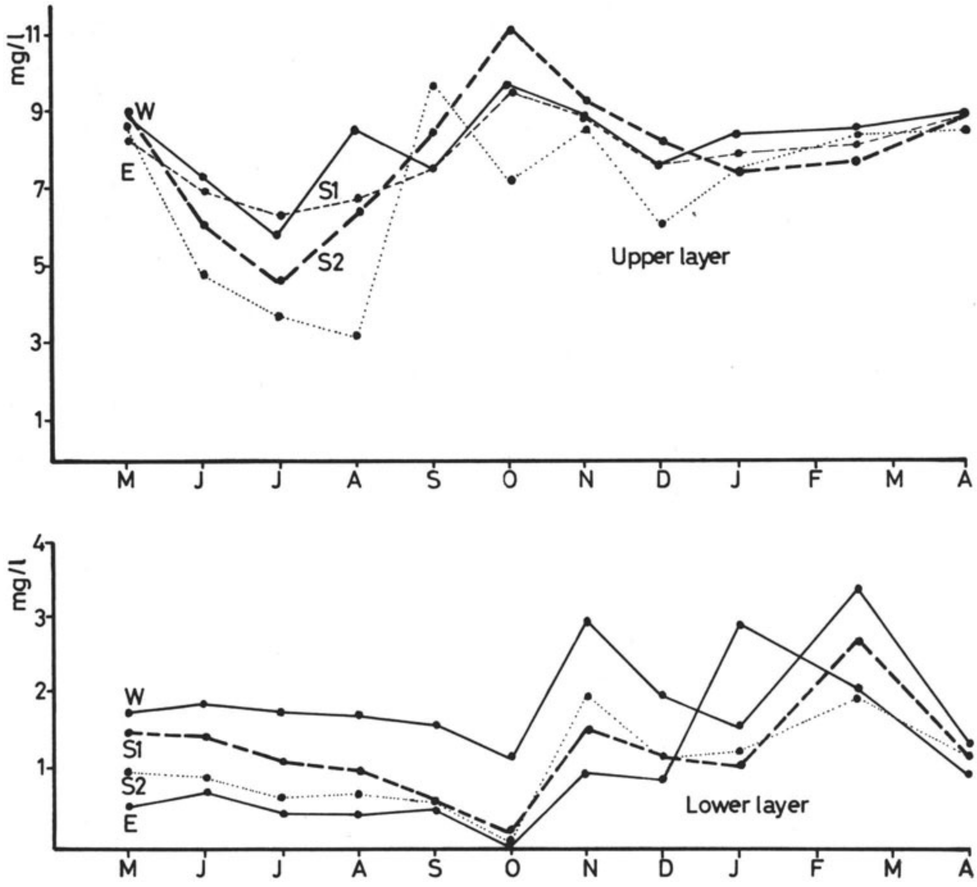

Figure 6. Dissolved oxygen variation in İzmit Bay

Table 10. Longitudinal variations of chlorophyll-a (mg/m^3) and secchi disc depth (m) in the Bay.

MONTH/LOCATION	WESTERN	CENTRAL (Site 1)	CENTRAL (Site 2)	EASTERN
Chll-a				
May, 1984	2.6	5.3	12.7	10.7
June	2.2	5.0	7.4	5.6
July	1.7	13.8	24.2	9.1
August	1.0	2.4	2.3	5.0
September	0.85	2.2	6.3	21.7
October	2.9	3.3	0.9	6.5
November	1.2	5.4	12.4	11.5
December	1.8	2.5	3.5	4.0
January, 1985	2.6	1.9	0.35	0.63
March	0.66	0.55	0.85	1.0
April	2.2	4.5	5.0	5.3
S.Disc Depth				
May, 1984	3.5	2.7	1.9	1.5
June	3.5	3.2	2.7	2.0
July	5.5	2.5	1.5	1.1
August	10.0	5.8	3.6	3.0
September	9.5	7.2	3.7	2.5
October	4.7	3.6	3.2	2.0
November	3.5	2.8	2.7	1.8
December	3.9	4.0	2.4	1.8
January, 1985	5.0	3.6	3.6	3.0
March	4.5	4.0	4.2	1.7
April	3.0	1.8	2.0	2.2
December, 1969[(a)]	10.0	6.0	-	4.5
January, 1970[(a)]	11.0	5.5	-	3.5
August, 1970[(a)]	12.0	9.0	-	6.0

(a) : Data from reference 7.

origin (22 - 24 ppt) and high saline waters (38 - 38.5 ppt) into the bay in April.

The biodegradable organic matter contents of the productive layer (0 - 10 meters) of the bay water in terms of BOD_5 shows spatial and temporal variations. The highest values during the summer months were observed in the eastern part (Table 9). This coincides with the DO variation pattern in the same region. In March and November, BOD values of the western region are almost at the same level with those measured in the Site 1, and higher than those observed in the Site 2 of the central region. Before renewal of the bay water, there exists an increasing pattern in BOD values toward the eastern part. In November , the inflow of water from the bottom into the bay creates an opposite current system

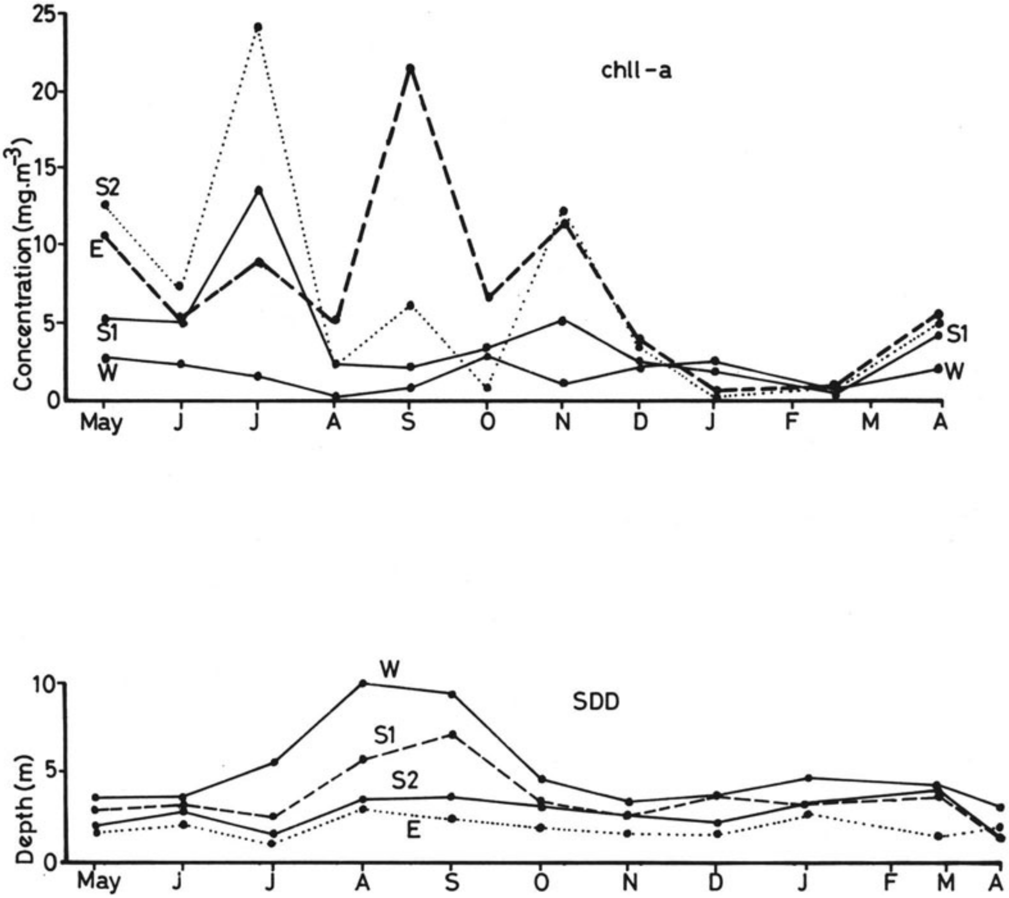

Figure 7. Chlorophyll-a and secchi disc depth variations in İzmit Bay

in the surface layer, which carries the pollutants at the surface waters towards the outside of the bay. For this reason, no significant difference in the BOD results of the western and central regions was detected.

As expected, the light transparency in the bay (secchi disc depth) decreases towards the inside of the bay depending on the productivity and the amount of terrestrial solid materials in the water (Table 10 and Figure 7). It reaches 10 meters in the western region in August and start to decrease in October as results of increase in the primary productivity. As can be seen from the chll-a results in Table 10, the August - September period is the less productive time of the year in the area. There is also a correlation between BOD and Secchi disc depth (SDD) results of the western and the central regions. SDD increases in the regions as BOD_5 (biodegradable organic matter) drops in September and the winter months, December-January. As Black Sea waters enter the bay in April, some remarkable decreases in the SDD values were seen and significant increases in the chll-a (productivity) values. As can be seen in Figure 7, the SDD, one of the indicators of primary production and pollutional levels in the aquatic environment, was comparatively high in 1970 and independent of the season in the western region of the bay. The comparison of the results of 1970 and 1984 - 1985 appear in the 10 year - pollutional level in the bay, particularly in site 2 of the central and eastern regions.

The primary production in the bay shows seasonal and regional difference (Table 10). In general, during the May - December period the chll-a values of the western region are always lower than those found inside the bay waters, although an opposite trend is seen in the winter months. There exists three major chll-a peaks for the regions, which appear in different months (Figure 7). In the western part, the maxima values are seen in May, October and January as the peaks of the central part appear in May, July and November. When the November data of the bay is compared with the chll-a results of the Marmara Sea and the Black Sea obtained in November, the productivity is four-fold in site 1 and ten-fold in the open waters in site 2 of the central region. In the eastern part of the bay, no correlation has been found between chll-a and secchi disc depth due to the large amounts of terrestrial input of suspended solid wastes to this shallow area. The chll-a and BOD_5 results measured in the same sites do not show a positive correlation due most probably to the biodegradable organic matter of anthropogenic origin in the surface layer. The primary production values of May 1984 calculated from the results of chlorophyll-a are 0.08, 0.24 and 0.38 g-C/m^2-day in the western, central and eastern regions of the bay, respectively. In August, 0.16, 0.35 and 0.43 g-C/m^2-day were found in the same regions, respectively *(19)*. These calculated figures just allow us to compare the productivity level with other seas, rather than to use the data in the calculation of annual primary production of the system.

The total coliform numbers per 100 ml of water are found to be below the swimming standards, which is accepted by many countries, in the western and central (site 1) regions during June 1984 - March 1985 (Table 11). But, the central (site 2) and eastern parts of the bay mostly have such large numbers of coli that swimming is prohibited. The lowest numbers of coli in the site 1 and eastern part were observed in November which corresponds to the renewal time of the bay water as pointed out in the

Table 11. Total coliform distribution in the bay waters(number/100 ml).

Month/Location	Western		Central (Site 1)		Central (Site 2)		Eastern	
	S	5m	S	5m	S	5m	S	5m
June,1984	215	87	535	555	1980	1360	6800	5610
July	150	105	1530	970	$>10^4$	$>10^4$	$>10^4$	$>10^4$
August	905	560	85	95	3680	1040	375	330
September	90	195	190	115	4370	1230	-	6040
October	500	162	390	325	275	165	7665	5235
November	925	292	155	245	-	140	-	350
December	367	345	435	385	250	175	1435	1025
March, 1985	20	30	35	80	1-500	20-1000	$>10^4$	$>10^4$
April	136	110	113	625	10^3-10^4	100-10^4	3500	1950

Table 12. The levels of some parameters in the Black Sea and the Marmara Sea.

Parameter	Black Sea(a)	Marmara Sea	
Nitrate (μg-N/l)	<1-4 (0-100 m)	<2	(surface, Nov.1984)
		60-75	(75-1000 m,Nov.1984)
O-PO_4(μg-P/l)	2-40 (0-100 m)	1-8	(surface, Nov.1984)
		20-55	(75-1000 m,Nov.1984)
		10-40	(200-1000m,June 1984)
Silicate (μg/l)	10-150(0-800 m)	1300-1750	(200-1000m,June 1984)
Chll-a (mg/m^3)	1.1-1.6(Nov.1984)	1.3-1.7	(Nov.1984)
pH	8.5-7.5	8.45-7.95	

(a): Some of the Black Sea data are from reference 17.

discussion of the dissolved oxygen results. In July, the transport of dissolved nutrient elements of the bottom waters to the surface layer by strong physical events, increased the chll-a level in the bay. Similar increases in the coli concentrations of the surface waters were seen due presumably to the strong currents carrying the waste waters from coast to off-shore. In July, as seen in Figure 2a, the surface salinity inside the bay rises 1 ppt and it was also observed that there exists a water flow inside the bay from the bottom,which is easily followed from the salinity variations of the bottom waters. The coliform distributions in different parts of the bay can help us to understand the current system affecting the surface waters. If one looks at the March result, it easily be understood that the surface currents in site 2 and the eastern part of the bay are not strong enough to carry the pollutants of the inner waters towards the bay entrance. This event occured in November. The inflow of the Marmara waters from the bottom created a current system strong enough to carry the pollutants far from their sources.

The reactive silicate in the surface waters of the bay is generally high enough not to limit primary productivity throughout the year(Table 13). However, as seen from the results, the surface water levels in May, June and September are so significantly low that this could be a critical constituent of the photosynthetical production in the photic zone of the bay, particularly of the central region. The lowest values of silicate in the bottom waters were observed in October which corresponds to the oxygen deficiency time in the bay (Figure 8). In other words, the exchange of water masses between different sections of the bay, the bay and the northeastern Marmara are very restricted. So, although the chll-a is significant inside the bay in October, the organic matter settles down before it is decomposed within the water column. In November, silicate rich bottom waters of the northeastern Marmara Basin enter the bay. Consequently DO, chll-a and silicate contents of the bottom waters of the bay increased. Some of the nutrients are carried to the surface waters by vertical mixing in the bay. The silicate distribution with depth always shows a uniformly increasing pattern in the bay water and the Marmara Sea. The silicate concentrations of the Marmara are much higher than of the Black Sea.

The nutrient elements, phosphorus and nitrogen in the forms of o-PO_4, NO_3, NO_2 and NH_3, show seasonal changes in the bay waters (Tables 14 - 16, Figures 9 - 11). Ortho-phosphate concentration in the surface waters of the central and western regions reaches its lowest levels in August and March (Figure 9). The maxima in the regions appear in May and January. These high concentrations correspond to the times in which the nutrient rich waters of Black Sea origin flow into the bay from the surface and the phosphate rich bottom waters entered the bay during November -December period mix vertically inside the bay and as a consequence of the continuous vertical mixing, some of the dissolved phosphorus is transported to the surface waters. As seen in Table 14, o-PO_4 becomes the limiting parameter in the productive layer of the western region in August. However, it is high enough not to be a limiting factor upon the photosynthesis in the inner regions of the bay throughout the year. If the nitrate values are compared with the results of o-PO_4 in the surface waters, it is obvious that the N/P ratio never approaches the natural value, 7, in weight. In the bottom waters of the bay, nitrate and orthophosphate do not show similar seasonal distribution patterns. Nitrate in the western region is comparatively lower than those of the inner parts during the May - October period as the changes of o-PO_4 shows fluctuation during this period. In November, which corresponds to the inflow of the Marmara bottom waters, NO_3 and o-PO_4 concentrations increase in the bay waters. In January, o-PO_4 is at its maximum levels in the western and central regions while the NO_3 concentration approaches its minimum value in March. The expected nitrate enrichment in the bay water appeared in April after the nutrient rich Black Sea waters entered the bay (Figures 2 and 10). The nitrate measurements recorded in 1976 by *Artüz and Kor(7)* are in agreement with the values of this study with the exception of the winter results. Although both seasonal changes have the same pattern, the magnitutes of the concentrations are different in the winter data. The nitrate concentrations are within the ranges of 40-50 and 1 - 10 μg at/l for measurements in 1975 and 1985, respectively. The nitrite distributions in the bay are depicted in Figure 11. No re-

Table 13. The distribution of reactive silicate in the Bay Waters(μg/l).

MONTH/LOCATION	WESTERN		CENTRAL (Site 1)		CENTRAL (Site 2)		EASTERN	
	U	B[(a)]	U	B	U	B	U	B
May,1984	8.6	729	<1	496	9.8	796	6.9	64
June	11.8	1060	7.0	1097	6.7	1306	78	690
July	42	1008	51	1003	12.2	1071	22	888
August	32	709	28	741	45	757	77	764
September	4.4	942	4.9	1007	1.0	1007	33	141
October	24	562	34	619	60	626	91	560
November	275	968	142	1010	209	878	212	918
December	142	768	193	810	186	783	178	776
January,1985	181	955	295	974	397	944	502	544
March	31	807	43	841	46	923	66	959
April	88	981	72	954	127	974	127	971

(a) : This column represents the average silicate results of the bottom waters up to 200 meters.

markable change was observed in the nitrite concentrations of the western regions. The ammonia formation, particularly in the surface layers, was only seen in the winter season. It was found as 6.7 and 8.3 - 28 ppb for the western and central regions in December. In January, it ranges between 10 - 15 ppb in both upper and lower layers of the regions. No absolute data exists for March month due to contamination problems encountered in the analytical method. In April, the ammonia concentrations are as high as 83 - 108 ppb in the bottom waters of the bay as the surface values range between 17 and 43 ppb (Table 16).

The nutrients, o-PO_4 and NO_3, 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 between two layers during the stagnant period of the bay, particularly between August - October.

Petroleum Hydrocarbons (PAH), particularly polynuclear aromatic hydrocarbon in surface waters of different seas, are tabulated in Table 17. The PAH concentration in Izmit Bay ranges between 3 and 32 μg/l depending on the location and sampling times. The average values of five months in the bay are comparatively higher than in the open waters of Marmara and the northeastern Mediterranean. Such relatively higher values might be attributed to the dense ship and tanker traffic in the bay. However the average PAH concentrations were generally far from being critical. For a better evaluation of the distribution and effects of petroleum hydrocarbons in Izmit Bay, the PAH's in sediment and organisms should also be analysed as a further study.

The toxic metals, Hg, Cd and Pb, were measured in the water, sediment

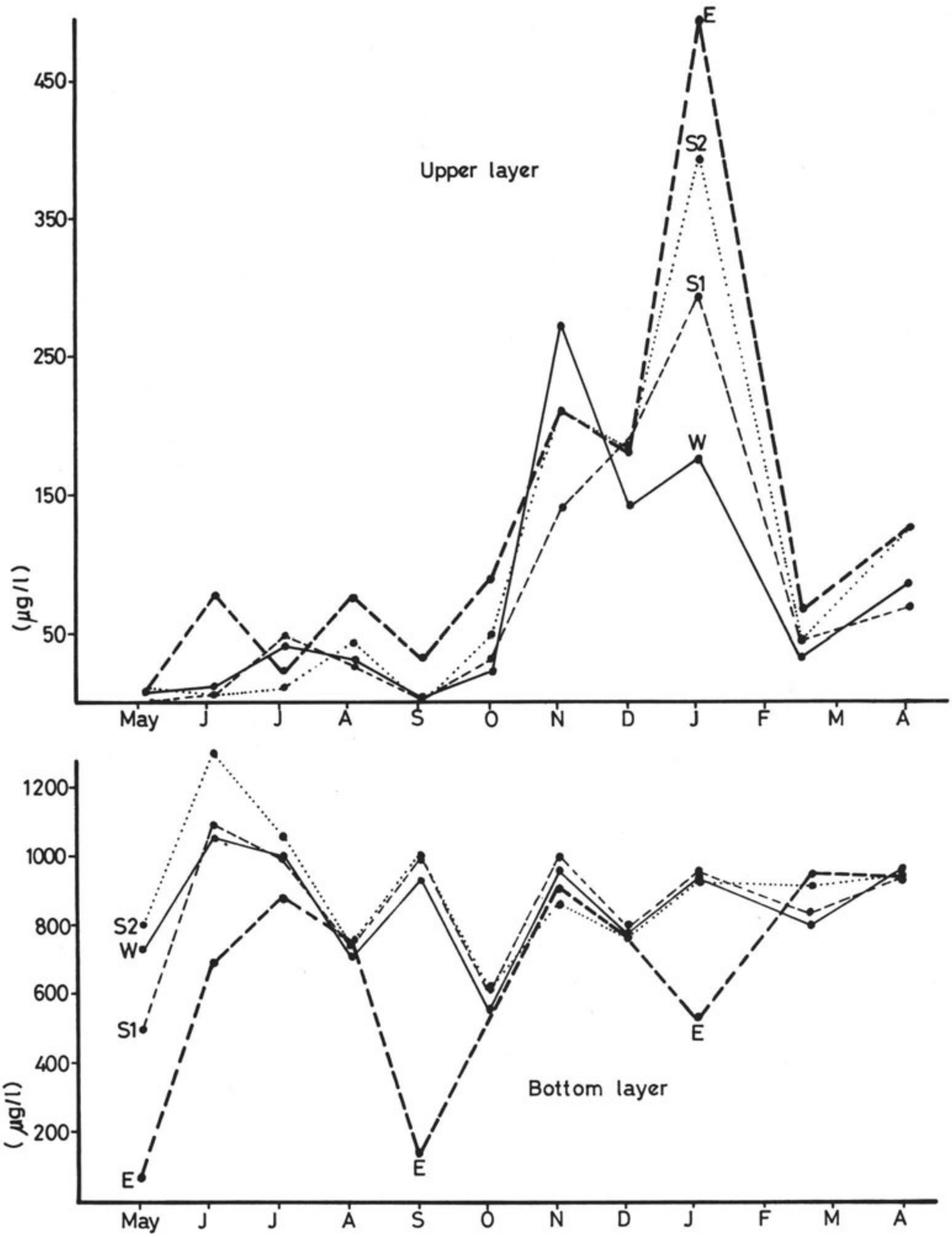

Figure 8. Silicate variation in the bay waters.

Table 14. Seasonal variations of o-PO_4 and t-PO_4 in the bay waters (μg-P/l).

MONTH/LOCATION	WESTERN		CENTRAL (Site 1)		CENTRAL (Site 2)		EASTERN	
	U	B	U	B	U	B	U	B
o-PO_4								
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
t-PO_4								
February, 1975[a]	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

(a) : Data from reference 7

and fish samples of the bay by *Taymaz et al. (19)* in June, July and October 1980. We also measured T-Hg in the surface waters sampled in June 1984. The results obtained are given in Table 18. As seen from the table, the nearshore water samples, particularly in the areas which are still influenced by Hg-containing wastes, have high values of total mercury. Also, the lead contents of these waters are surprisingly high. The total mercury in the inner sites of the bay are unexpectedly low, compared to the nearshore samples.

CONCLUSIONS

The Bay of Izmit has a permanent salinity stratification created by the low saline waters of the Black Sea origin overlying the high saline Mediterranean waters. The thicknesses of the layers change seasonally depending upon the current systems in the area, i.e., the inflow times

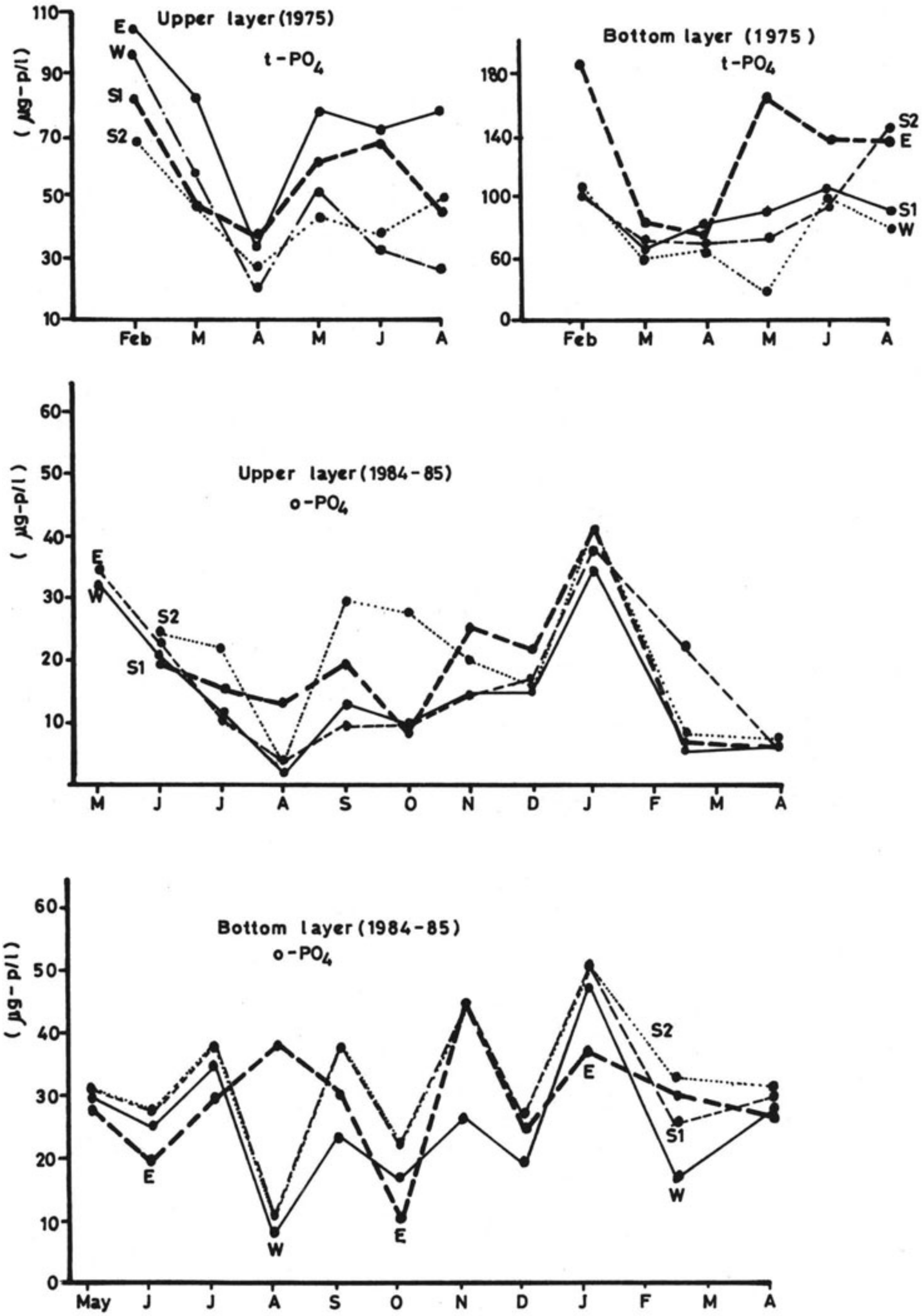

Figure 9. Phosphate distribution in İzmit Bay.

Table 15. Seasonal variations of nitrate and nitrite (µg-N/l) in the bay waters (7).

MONTH/LOCATION	WESTERN		SITE 1		SITE 2		EASTERN	
	U	B	U	B	U	B	U	B
Nitrate								
February, 1975	12	55	4.0	51	5.6	55	11	41
March	24	47	13	43	20	45	15	41
April	12	84	10	43	14	46	19	54
May	20	108	38	102	11	113	13	120
June	11	89	11	86	9.4	117	18	100
August	11	137	11	151	11	147	24	98
Nitrite								
February, 1975	1.7	2.0	1.0	1.7	0.6	1.6	1.5	1.7
March	1.3	4.0	2.8	2.8	1.6	2.3	1.9	3.4
April	2.8	4.0	2.8	3.6	3.1	4.0	4.1	4.8
May	1.6	3.1	1.9	4.3	1.0	4.5	4.5	7.3
June	2.6	3.8	0.7	4.3	1.3	3.5	3.1	5.8
August	0.1	3.0	0.6	3.8	1.0	3.7	2.5	4.7

of both low and high saline waters into the bay.

The Black Sea waters enter the bay from the surface in April while the bottom waters of the northeastern Marmara Basin replace relatively less saline bottom waters of the bay in November and to some extent in April. This situation predicts that the pollutants discharged into the surface waters of the bay are confined in the central and the eastern parts of the bay due to the major surface currents towards the inside the bay. Thus, in addition to organic loads discharged into the bay, the nutrient rich surface waters entering the bay raise the available nutrient levels. Both factors increasing the primary production in the area create the anoxic condition which appeared in October. However, the residence time of the bottom water is not long enough to complete the nitrate reduction in the water column. It was found that the nitrate concentrations of the bottom waters are higher than 40 µg-N/l in October.

The nutrients are generally high enough not to be limiting factor upon the photosynthetic reaction in the surface layers of the bay. In August, the ortho-phosphate concentration is too low to be the limiting parameter in the photic zone of the bay. The decrease in the nitrate concentrations of the bottom waters it becomes more apparent in the winter months as a consequence of rapid sedimentation of the solid organic matters and diffusion of ammonia toward the surface through the weak halocline as well as of the denitrification reaction proceeding in the water column. The rate of (nitrate + nitrite + ammonia) to orthophosphate, N/P in weight, is always less than 7 in the surface waters throughout the year, with the exception of the western region in August. In other words, the rate of biochemical synthesis is mostly limited by the dissolved nitrogen ions in the surface waters while o-phosphate becomes the limiting factor upon the primary production occasionally between July and October. However, in order to see the consistency of the temporal changes of the measured parameters and to have more reliable

Table 16. Seasonal variations of nitrate, nitrite and ammonia in İzmit Bay (μg-N/l).

Month/Location	Western		Central (Site 1)		Central (Site 2)		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	32.8	104	40.8	95	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
Nitrite								
May, 1984	8.2	9.9	2.1	11.4	1.2	14.1	9.6	-
June	11.3	12.3	12.6	11.7	10.3	16.0	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
Ammonia								
September	<1-14	<1	<1	<1	<1	<1-14	12	-
October	12	<1	<1	<1	9	15	<1	-
November	<1-10	<1	4	<1	18	<1	42	3.2
December	6.7	<1	8.3	<1	28	<1	15	<1
January	12.5	10.7	12	9.5	15	10	27	32
April	17	87	19	83	23	103	43	108

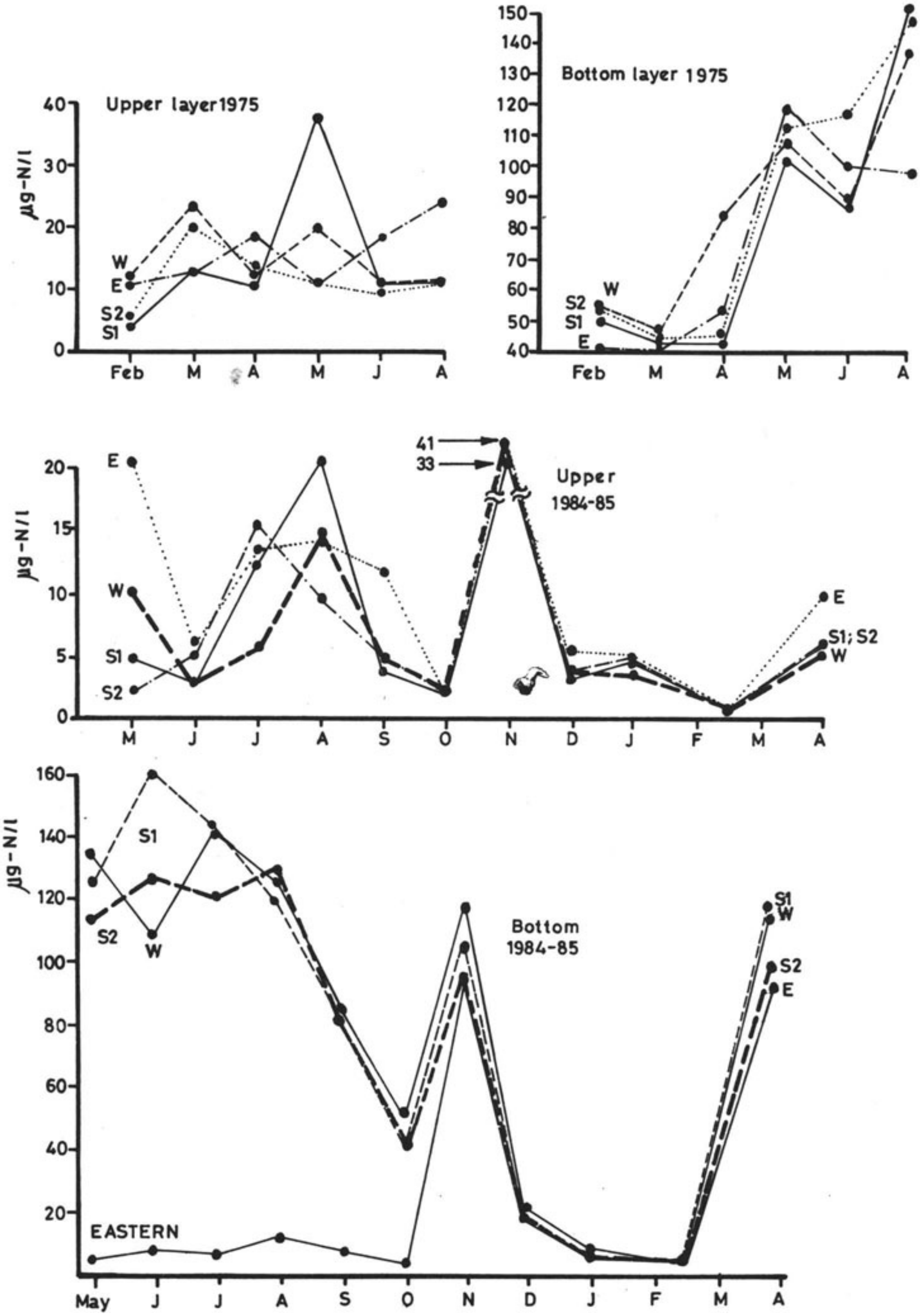

Figure 10. Nitrate distribution in İzmit Bay

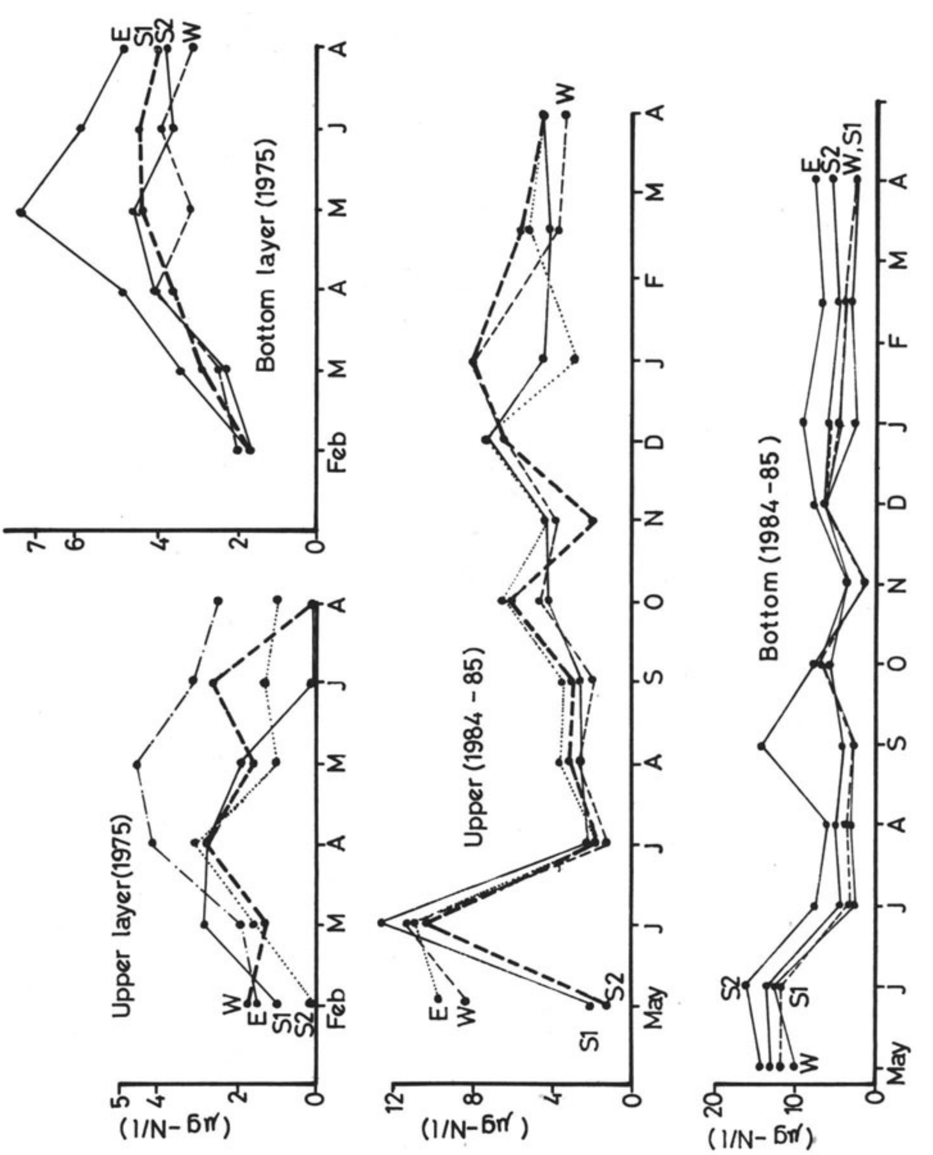

Figure 11. Nitrite distribution in İzmit Bay .

Table 17. Dissolved petroleum hydrocarbons in the surface waters of Izmit Bay and the northeastern Mediterranean.

Location	PAH (µg/l)	
Izmit Bay	3.0 - 32 (5.9)	(May 1984)
Izmit Bay	2.8 - 7.5 (6.6)	(June 1984)
Izmit Bay	4.3 -27.5 (10.7)	(July 1984)
Izmit Bay	0.9 -10.0 (5.0)	(October 1984)
Izmit Bay	6.2 -11.9 (9.3)	(November 1984)
Izmit Bay	0.9 - 7.4 (3.6)	(November 1984)
Northeastern Mediterranean[a]	0.9 - 5.0 (1.5)	

(a) : Data from reference 18.

Table 18. The mercury, cadmium and lead distributions in the water, sediment and fish samples of the Bay.

Location[a]	Hg	Cd	Pb
Water			
Nearshore waters of central P. (October,1980)	3.0 ppb	-	-
Nearshore waters of eastren P. (October,1980)	6.9 ppb	0.02 ppb	1750 ppb
Eastern Part (June-July,1980)	0.34 ppb	0.18 ppb	0.62 ppb
Central Part (June-July,1980)	0.68 ppb	0.39 ppb	20 ppb
Eastern(June, 1984)	0.05 ppb	-	-
Central(June, 1984)	0.04 ppb	-	-
Western(June, 1984)	0.04 ppb	-	-
Sediment			
Eastern Section	5.3 ppm	0.8 ppm	32.6 ppm
Central Section	0.57 ppm	0.31ppm	23.5 ppm
Fish			
	3-40 ppb (16)[b]	60-600ppb (300)[b]	4.4-15.6 ppm (8.5)[b]

(a) : 1980 data, fish and sediment results from reference 20.
(b) : Average results of different fish species

data this work will be conducted seasonally for one year.

Acknowledgements: This work was fully supported by Scientific Affairs Division of NATO within the framework of "Science for Stability Programme". We also thank O.Sağlamer, E.Morkoç and A.Bozyap, Chemistry Department of MRI, who performed the nutrients, chlorophyll-a and total coliform analyses in the water samples.

REFERENCES

1. Timur,A., Kınayyiğit,G., Dumlu,G., Ilhan,R., Çiler,M., Kavaklı,M., Armağan,Z. and Bozyap,A., 1982, *The prevention and removal of the water pollution in Izmit Bay:Determination of technological aspects,* TUBITAK-MRI, Chem.Dept. Publ., 411 pp. (in Turkish).
2. Timur,A., Dumlu,G., Timur,H., Çiler,M., Ilhan,R. and Balkaş,T. 1982, *The prevention and removal of the water pollution in Izmit Bay: Determination of technological aspects,* TUBITAK-MRI, Chem.Dept.Publ. No.106, 383 pp. (in Turkish).
3. Gönenç,E., Tünay,O., Saybay,S. and Orhon,D. 1983, *The prevention and removal of the water pollution in Izmit Bay: Determination of technological aspects,*ITU-Civil Eng.Publ., 374 pp. (in Turkish).
4. DAMOC. 1971, *Istanbul region drinking water and swerage master plan and feasibility studies,* UNDP/WHO project.
5. Orhon,D., Gönenç,E., Tünay,O. and Akkaya,M. 1984, *The prevention and removal of the water pollution in Izmit Bay: Determination of technological aspects,* ITU-Civil Eng.Publ., 373 pp. (in Turkish).
6. Kor,N., (1974), *The control of pollution in Izmit Bay,* TUBITAK Publ., No. MAG 211/A (in Turkish).
7. Artüz,I. and Kor,N. 1971, *A preliminary work on the control of pollution in Izmit Bay,* Hydrobiology Inst. Publ., (in Turkish).
8. SWECO and BUE. 1976, *İzmit swerage project: Master plan,* (in Turkish).
9. TUBITAK-MRI 1985, *Determination of characteristics and assimilative capacity of Izmit Bay,* TUBITAK-MRI, Chem.Dept. (to be published).
10. APWA-AWWA-WPCF 1980, *Standard methods for the examination of water and wastewater,* 15th ed.
11. EPS 1981, *Mercury: Methods for sampling, preservation and analysis,* Economic and Technical Review Report EPS 3-EL-81-4, 108 pp.
12. Yılmaz,A., 1982, *Fluorescence measurements in Marine Environments,* METU-MSI, Master Thesis.
13. TIS 1978, Industrial Methods No: 253-80 E and 100-70 W/B, Technicon Industrial Systems.
14. IOC 1975, *Guide to operational procedures for the IGOSS pilot project on marine pollution (petroleum) monitoring,* UNESCO, Manuals and Guides No:7, pp. 28-31.
15. TUBITAK-MRI 1984, *Wastewater discharge quality standards and application guidelines for Izmit Bay,* TUBITAK-MRI, Chem.Dept. Publ. No.129, 51 pp.
16. Sümer,M. 1983, *Water movements in Izmit Bay,* ITU-Civil Eng. Publ. (in Turkish).

17. Grasshoff,K. 1971, *The hydrochemistry of land-locked basin and fjords,* in Chemical Oceanography, ed. J.P.Riley and G.Skirrow, Academic Press, vol.2.
18. Sunay,M. 1982, *Distribution and source identification of petroleum hydrocarbons in the marine environment,* METU-MSI, Ph.D. Thesis, pp. 99-100.
19. Morkoç,E. 1984, *Primary productivity in Izmit Bay,* IU-MSGI, Master Thesis, pp.44-51.
20. Taymaz,K., Yiğit,V., Özbal,H., Ceritoğlu,A. and Müftügil,N. 1984, *Heavy metal concentrations in water, sediment and fish from Izmit Bay, Turkey,* Intern.J. Env.Anal. Chem., 16, pp.253-265.