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EUTROPHICATION AND HYDROCHEMICAL CHARACTERISTICS OF THE IZMIT BAY

E. Morkoç[*], S. Tuğrul[**], O. S. Okay[*], T. Legoviç[***]

**Department of Environmental Engineering, TUBITAK-Marmara Research Center, P.O. Box 21, 41470 Gebze-Kocaeli, Turkey.*
***Marine Science Institute, Middle East Technical University, P.O. Box 28, Erdemli-Içel, Turkey.*
****Rudjer Boskovic Institute, P.O. Box 1016, 41001 Zagreb, Croatia.*

ABSTRACT

The elongated Bay of Izmit is one of the heavily polluted semi-enclosed basin in Turkey. Systematic data obtained between 1984 and 1988 demonstrate that two distinct water masses are present throughout the year. The brackish waters of Black Sea origin form the surface layer (10-15 m) with salinities and temparatures varying respectively from 22-24 ppt and 20-24°C in summer to 26-30 ppt and 6-7°C in winter. Salty waters of the Mediterranean origin underly the permanent pycnocline and possess much more stable properties: salinity and temparature vary between 38-38.5 ppt and 14-15°C, respectively.

Since the plant production is limited to the upper layer including the halocline in late summer, nutrients, having low surface values in the productive seasons but with higher winter concentrations, exhibited a sharp increase in the holocline but stay almost constant in the lower layer. Algal biomass, in terms of chlorophyll-a concentration, was as large as 33 μg/l in the polluted inner bay in the spring. In March, production reached to a peak value of 3300 mg C/m^2/day; the annual rate at least 2-4 times larger than in the Marmara and Black Seas. Dissolved oxygen concentrations exhibiting a decreasing trend in the pycnocline, vary seasonally between 0.5-2.0 mg/l in the subhalocline waters of the inner bay. Though phosphate and nitrate occasionally limit the plant production in the bay, reactive silicate was observed to be major limiting nutrient due to large inputs of N and P relative to silicate content of the polluted waters. This preliminary finding suggests that the removal of phosphate from wastes helps to recover the damaged ecosystem of the bay.

KEYWORDS

Nutrients; eutrophication; production; pollution; limiting nutrients; dissolved oxygen.

INTRODUCTION

Eutrophication of receiving waters resulting from elevated loadings and cycling of plant nutrients have been a major water quality problem which has received considerable attention over the last three

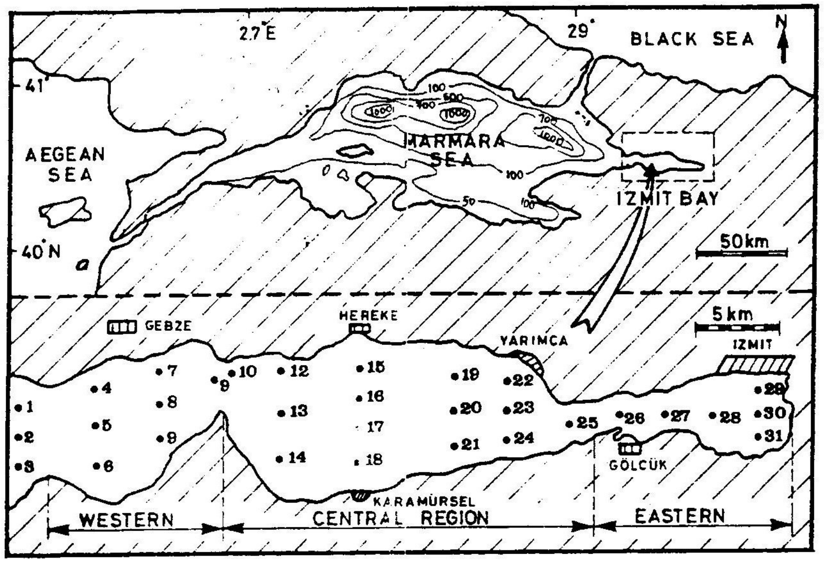

Fig. 1. Map of the Marmara Sea and sampling stations in the Izmit bay.

decades. The most conspicuous manifestation of this condition is the occurance of nuisance algal blooms (Devan, 1984; Bell, 1990). The effect of permanent stratification of the water column and reduction of horizontal advection are discussed extensively by Vukadin (1990); Sorokin, (1983); and Kullenberg (1983). Spatial and temporal variation of salinity is a general characteristics of estuaries and enclosed seas, e.g. Baltic Sea, Black Sea and Marmara Sea possesing permanent stratification (Sorokin 1983; Kullenberg 1983; Baştürk et al, 1990.).

Although several studies have discussed and treatment alternatives of waste effluents (Timur et al., 1982; Akkaya et al., 1983), very limited work has been performed on measuring general oceanographic characteristics of the Izmit bay systematically (Sweko, 1976; Damoc, 1971; Kor, 1974). In the bay, as a part of the Marmara Sea, the existence of a permanent, two-layer hydrographic feature appears to limit vertical mixing and exchanges between segments and the adjacent Marmara Sea, resulting in eutrophication in the bay due to large inputs of land based chemical pollutants (Akkaya, 1983). In this paper, long term data obtained between 1984 and 1988 have been examined to define the present physical and biochemical properties of the bay as well as potential limiting nutrient(s) for the bay ecosystem.

FIELD OF STUDY

The elongated bay of Izmit (Figure 1) is approximately 49 km in length, varying from 2 to 10 km in width. It may be divided into three subregions (western, central and eastern) connected to each other with narrow openings. The central bay comprises the largest and deepest site of the basin.

In the area surrounding the bay more than 250 large industrial plants have been built since 1965. Some of them discharge their solid and liquid wastes directly into the bay without any pretreatment. Uncontrolled population increase causes a similar rise in the quantities of untreated sewage discharge directly into the bay. Chemical load of unpurified waste waters of both domestic and industrial origin is now so great that the biological self-purification capacity of the bay is no longer sufficient to restore itself to its normal equilibrium state. In recent years, periodic red-tide events have been observed in Izmit bay. In addition to land-based pollution sources, special and hazardous wastes originating from shipping traffic have most probably contributed to damage the bay ecosystem.

MATERIALS AND METHODS

In order to understand spatial and temporal variations of the bay oceanography, the station network illustrated in Figure 1 was visited systematically by the R/V ARAR of Istanbul University and then by the R/V BILIM of Middle East Technical University. Water samples were collected from standard depths by Nansen bottles. A Sea-Bird or Inter-Ocean model CTD probes were used to measure temperature, salinity and dissolved oxygen.

The silicate samples were kept cool at 4°C, whereas the others were deep frozen. Nutrients were analyzed by using the Technicon Autoanalyzer II system and following the standard methods with some modifications (TIS, 1978; Standart Methods, 1985). The major nutrients analyzed were silicate, nitrate+nitrite, ortho-phosphate. The samples for bioassay studies of limiting nutrients were collected from two meter depth at Stations 2,8,10,17,22,23,27,30. The samples for phytoplankton production taken from the depths where surface irradiance was reduced to 75%, 25%, 10%, and 1% at the selected four stations were processed by following Gargas' (1975) procedure. Briefly subsamples prefitered through a 200 micron net were enriched with defined amounts of nutrients either single or in combinations. Then, they were incubated on a shaker at *in situ* temperature of the sample for 15 hours under continuous light. Later, ^{14}C spiked aliquots were incubated for 2 hours and filtered through 0.2 μm membrane filters. The growth of phytoplankton was determined by ^{14}C uptake rate using liquid scintillation counter.

RESULTS AND DISCUSSION

The Izmit bay oceanography is influenced to a large extend by the water exchanges taking place between the Black Sea and Aegean Sea. Therefore, its hydrographic properties follow the trend in the Sea of Marmara. Summer surface temperature range between 20 and 23°C with the maximum values in August and lower surface salinity increasing from 21 ppt to 24 ppt from June to September. October is a transitional period which corresponds to the beginning of decrease in temperature and increase in salinity at all stations. The decrease in surface salinities in the spring are related to the brackish water inflow from the Black Sea through the Bosphorus. The bottom waters flow through the bay without much change in their character and are identified by approximately 37.5-38.5 ppt salinity and 14.5-15°C temperature throughout the year.

Since the Sea of Marmara forms a transition between the Black and Aegean Seas, it can be deduced that the chemical and biological characteristics of the basin are significantly influenced by the biochemical properties of the two adjacent water masses. The permanent halocline which separates waters of Black Sea origin from that of the Mediterranean origin, plays an important role in the distribution of hydrochemical properties within the bay of Izmit. In the upper layer, concentrations of nutrients are relatively low and show seasonal fluctuations, depending on the rate of sinks and sources.

Concentration of phosphate in the surface water was in the range of 2.0-8.0 µg/l in the productive spring-autumn period. Winter mixing and accompanying low production resulted in considerable increases in the surface nutrient values; it was as high as 18 µg/l for nitrate, 2.9-5.6 µg/l for phosphate and 50 µg/l for silicate.

In deep waters of the bay, the dissolved N/P ratio in weight is always less than 5, (versus 7 in open seas) since, phosphate and nitrate+nitrite concentrations range between 25-35 µg/l and 90-150 µg/l in deep waters of the bay, respectively (Figure 2). The highest nutrient values in the bottom waters were observed in the summer months following the productive spring season. In winter months, their values show significant decrease due to the strong vertical mixing and low production in the surface waters. Nitrate concentration in the surface waters of the bay increased from western to eastern.

The silicate distributions in the bay are generally consistent with the nitrate and phosphate variations. Low silicate concentrations (<50 µg/l) in May-July period indicate that silicious diatoms dominate the primary production in the bay as also confirmed by recent observations in the Marmara Sea and Izmit bay. The concentration increased steadily in the deep waters and reaches values of 1000 µg/l from the spring to the autumn months due to the lower water exchange rate and high input of silicate material from the surface.

The spatial and temporal variation of chlorophyll-a demonsrate that plant biomass increases towards the eastern part of the bay. The highest chlorophyll-a concentration of 22 mg/m^3, was detected in March 1988 where as the lowest value was 0.1 mg/m^3 from February 1987. In January, however, chlorophyll-a values are occasionally encountered as high as in the productive month due to favorable environmental conditions persisting several days in the area. However, it was limited to the surface layer (0-5 m) due to insufficient light intensity in late summer and early autumn, photosynthetic production decreases significantly owing to insufficient nutrient supply to the euphotic zone.

Dissolved oxygen (DO) concentration shows variations both time and region. DO, being at near saturation levels in the surface waters, exhibits a sharp decrease in the halocline and reaches to minimum level (<0.5 mg/l) immediately below the halocline, especially during summer periods, due to the long residence time of the bottom waters and large amounts of biodegradable organic matters sinking from the surface layers. Consequently, the dissolved oxygen in the subhalocline waters of the inner bay decreases steadily from 2-2.5 mg/l in the spring to below 0.5 mg/l by October.

Changes in environmental and hydrographic conditions determine the intensity of plant production in the bay. Winter mixing results in and accumulation of nutrients in the surface waters and thus late winter-early spring bloom occurs both in the bay and Marmara Sea. During summer the phytoplankton production fluctuates more or less randomly depending on the predation pressure by the zooplankton and supply of nutrients from the lower layer and from existing sources on the coast.

Annual production estimated from ^{14}C-based measurement between 1987 and 1988 was about 365 g C/m^2 in the central bay which was about 2-4 times larger than the production in the outer bay (165 g C/m^2) and Marmara and Black Seas. On the seasonal basis, the largest production was recorded in March 1988, as 3327 mg C/m^2/day at station 17. The data from this location were always higher than

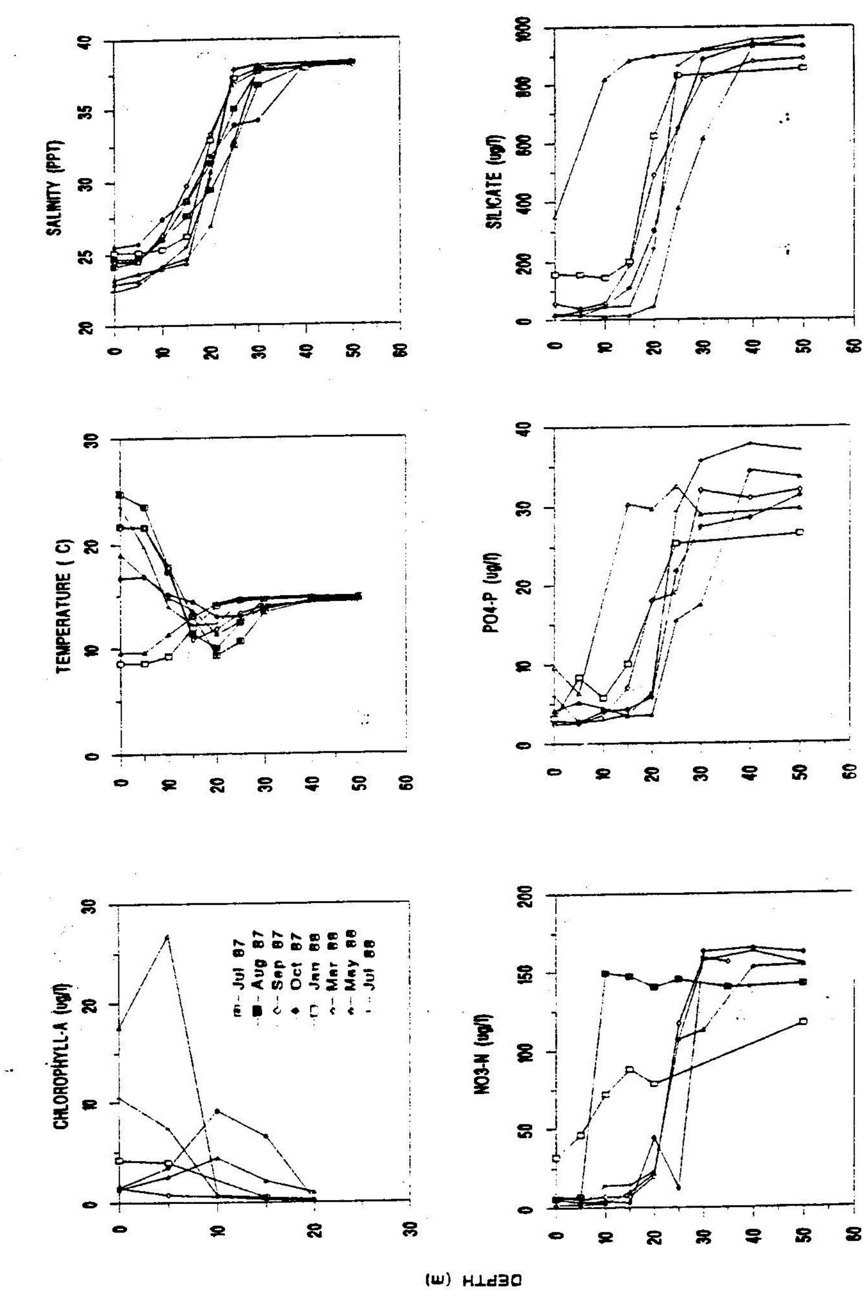

Fig. 2. Vertical variation of physical and chemical parameters at station 17.

at the more polluted location, station 23, due presumably to lower water transparency and in adequate physiological conditions for algal growth at locations where large quantities of toxic chemicals and suspended solids were discharged. Though the lowest production rate occured in the early autumn when the surface waters were impowerished in nutrients, production values as lower as 125 mg C/m^2/day were recorded in June 1987 at station 2.

Because of large particle discharges from land, the euphotic zone is limited to first 10-25 m, depending on location and season. However, the highest production rate were consistently observed in the water column extending from the surface to 10% light depth corresponding near to the Secchi disc depth which varied between 3-10 m in the bay with the lowest values in the eastern bay and larger ones from the western region in late summer-early autumn.

The relation between algal growth and nutrients has been investigated to define limiting nutrients. A positive response was measured in ^{14}C uptake of natural assemblage of phytoplankton when phosphate was added to bioassay samples collected in July, August and September. At station 2, the degree of limitation has a factor of 2.5 relative to unenriched sample recorded in July and it declined to 2 in August. The responses of 0.5 and 1.7 were observed in July at stations 8 and 10, respectively. The highest uptake rates of 1.8 and 6 were found at stations 27 and 30 in September, respectively. The nitrate spiked samples showed 2-fold increase in ^{14}C uptake rate relative to unenriched control sample only at the station 23. The enrichments with dissolved silicate demonstrated that it was the most important limiting nutrient for the growth. The response of ^{14}C uptake changed significantly from a factor of 1 to 30 with respect to the unenriched control. Larger responses to silicate enrichment appeared in samples from the polluted inner bay. For example, at station 23, in August, October 1987 and May 1988 the response of uptake increased 2, 2.6 and 4, respectively. The enrichment of natural phytoplankton with both nitrogen and phosphorus resulted in measurable increase in ^{14}C uptake rate with respect to the enrichment by single nutrient. This response is presumably due to the fact that when one nutrient is limiting and the other is close to be limiting, the enricment will terminate the actual limitation, but results in that the other nutrient becomes limiting.

In conclusion, the bay is occupied by two distinctly different water masses. Though the inner bay receives large quantities of wastewater discharges, no significant increases appeared in inorganic nutrients of the surface waters due to consumption by photosynthesis. Since the subhalocline water of the bay is drastically depleted in DO due to low content of the inflow from the Marmara basin, organic matter in wastewater to be discharged into the bay lower layer waters has to be removed by biological treatment on land. Excessive inorganic nitrogen and phosphorus in wastewater discharged to the bay surface have lead to appearance of silicate as a major limiting element for algal growth. Therefore, the removal of phosphorus in the biological treatment may contribute to restore the bay ecosystem on a long (annual) time scale in the future.

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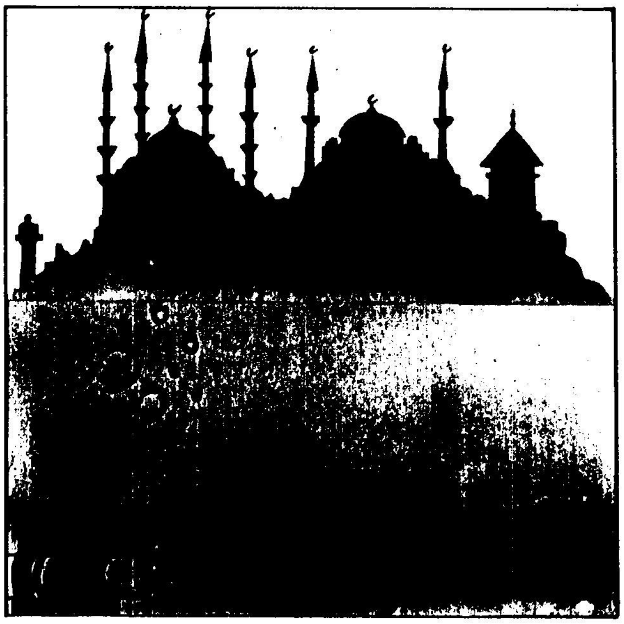

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