12

Effects of Wastewater Treatment Plant on Water Column and Sediment Quality in Izmir Bay (Eastearn Aegean Sea)

F. Sanem Sunlu, Ugur Sunlu, Baha Buyukisik, Serkan Kukrer and Mehmet Aksu
Ege University, Faculty of Fisheries, Dept. of Hydrobiology
Turkey

1. Introduction

Economic and social consequences of damage to the marine environment are becoming increasingly evident. Unless seas and oceans are carefully protected, their economic potential can not be sustainable. The marine environment is one of humanity's most precious assets. Oceans and seas cover 71% of the earth's surface and are the greatest sources of biodiversity, containing 90% of the biosphere. Marine ecosystems play a key role in climate and weather patterns. They also contribute to economic prosperity, social well-being and quality of life and are literally a source of survival for coastal communities. However, this environment is under intense pressure. The pace of degradation of biodiversity and habitats; the level of contamination by dangerous substances and the emerging consequences of climate change are some of the most visible warning signals (Environment for Europeans 2005). Only recently marine eutrophication is being regarded as pollution, particularly in near shore environments where more often low water transparency, oxygen depletion and algal blooms occur. Nutrient concentrations in sea water and sediment increase remarkably going from offshore to inshore, due to the proximity of terrestrial and domestic inputs and to the increase of biotic and abiotic processes strictly related to the progressive decrease of water depth.

The Bay of Izmir is in a state of pollution centre in Turkish Aegean coast region in respect of aesthetic and welfare where pollution increased in the course of time from what it used to be in 1960s. The most important factors of this current status are; domestic wastes of more than 3 million people; industrial wastes from 1,500 factories; wastewater discharge during maritime transportation and shipyard services filling materials arisen from the recreation of seaside alluvions carried with rivers and valleys. Izmir Bay is surrounded by major agricultural plateau. Menemen plateau in the North–North West of Izmir is one of the most important production fields where agricultural irrigation is utilized. The Bay is also influenced by the pollution caused by the agricultural activities in the Gediz River water shed and erosion of a large area by Gediz River.

The bay of Izmir, which is the biggest harbour on the Aegean Sea, is of economical importance for Izmir, the third largest city in Turkey. The Bay is divided into inner, middle and outer bays in terms of topographical and hydrographical characteristics. The inner bay is considerably small in area (57 km²) and shallow in depth (max. 15 m). It had received the majority of domestic and industrial wastewaters before the construction of wastewater treatment plants. This section of the bay still receives some inflow of fresh water from several creeks which are mostly polluted by industrial wastewaters.

Because of limited water exchange with the Outer Bay and Aegean Sea, pollution of the Inner Bay had reached unacceptable levels. Eutrophication of the Inner and the Middle Bay had started and spread progressively to the outer part of the Bay. Red-tide occurrence was reported to have increase in frequency in last decade (Sunlu et al. 2007). For this reason Izmir Municipality decided to construct Izmir Big Channel WasteWater Project in 1969. However, wastewater treatment plant construction completed in 2002. At the end of the plant construction, the pollutant levels of the Inner Bay water decreased slowly and recovery period has begun (Kaymakci et al. 2000). This is why, the pollutant levels of the Inner Bay water decreased slowly.

The aim of this research is to determine the effects of "Izmir Big Channel Wastewater Treatment Project" to the sediment quality and water column of Izmir Bay. For this purpose, seawater samples and sediment samples were collected from three stations which are located in the middle and inner parts of the Izmir Bay. The water samples were collected as a weekly and sediment samples as monthly intervals during 2003.

2. Materials and methods

2.1 Location and sampling

In this study, three stations were chosen for sampling, two in the inner and one in the middle part of the Izmir Bay (Figure 1). Station 1 is near Izmir Harbor (Inner Bay) 38°27′17′′N-27°09′ 37′′E. Station 2 is offshore of the Karsiyaka Yacht Club (Inner Bay) 38°26′86′′N-27°06′56′′E and Station 3 is offshore of the Wastewater Treatment Plant (Cigli, Middle Bay) 38°25′47′′N-27°00′05′′E.

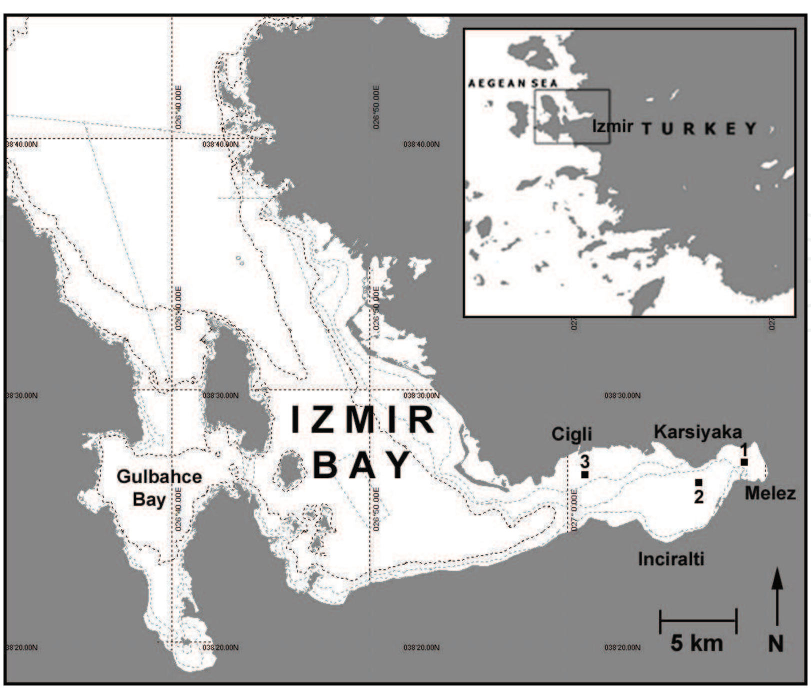


Fig. 1. Map of Izmir Bay and the sampling stations

The sampling points are shown in Fig. 1. The first sampling station is located in the area of the outflows of the Melez stream and consequently receives agricultural, domestic and industrial discharges carried on by it. This station is also influenced by the harbour activities of İzmir. The second station in Karşıyaka, shows characteristics of mixture of ST 3 and ST 1 according to current system of the İzmir Bay. The last station in Cigli where the physical and biological waste water treatment plant exists is affected by the current system of the bay. It was particularly chosen to better understand effects of this plant on İzmir Bay.

Physico-chemical environmental parameters, nutrients and some general biological parameters, were measured weekly during one year period. All these parameters were measured at different depths of the three selected sampling stations.

For this study water samples were collected using a peristaltic pump and screened 280 µ mesh to remove macrozooplankton. Polycarbonate bottles of 20 L capacity were filled with sea water and moved to the laboratory.

2.2 In situ measurements

Seawater temperature was recorded by an electronic thermometer with a sensitivity of ±0.1 °C. The pH of the samples were also measured on-site using a pH-meter (Hanna Ins.). Likewise, the dissolved oxygen concentration (DO) was measured with a portable dissolved oxygen-meter (YSI, Model 55).

2.3 Analytical measurements

The salinity of the seawater was determined by the Harvey method. The samples collected from the three different stations and different water depths were kept in 1 L polyethylene bottles and analyzed for nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), silicate and Reactive Phosphate (RP) using the methods by Strickland and Parsons 1972; Wood 1975; Parsons et al. 1984.

For chlorophyll a and phaeopigments, given amount of surface seawater was filtered through GF/C filterpaper using the Milipore Filtration system. The analyses were carried using a UVD spektrophotometer (Bosch-Lomb Spectronic 21) according to the method by Strickland and Parsons (1972). Particulate organic carbon (POC) analyses were carried out using wet oxidation method and spectrophotometry (Strickland and Parsons 1972; Parsons et al. 1984).

The detection limits and precision of methods used were given in Table 1.

PARAMETER	PRECISION	DETECTION LIMITS
NO_3^-	± 0.2 µg atN/L (1 µg atN/L at 1.7 cm. cell)	0.1-45 µg at/L
NO_2^-	± 0.2 µg atN/L (1 µg atN/L at 1.7 cm. cell)	0.1-2.5 µg at/L
NH_4^+	± 0.7 µg atN/L (10 µg atN/L at 1.7 cm. cell)	0.2-10 µg at/L
Reactive Phosphate (RP)	± 0.03 µg atP/L (3 µg atN/L at 1.7 cm. cell)	0.05-5 µg at/L
Si	0,18 µg at/L (~4 µg at/L); ± 9 (~150 µg at/L)	0,26-400 µg at/L
Salinity	± 0.05 psu	
Chl a	± 0.2 µg atN/L	0.2-50 µg Chl a,b,c /L
Dissolved Oxygen (DO)	± 0.3 mg/l (± 0.2 °C)	

Table 1. The detection limits and precision of methods used.

Sediment samples were collected from these three stations on a monthly basis between January and 2003 December 2003. Sediment samples were collected using Van-Veen Grap. Chlorophyll Degradation Products (CDP) were analyzed through acetone extraction and spectrophotometry (Lorenzen 1971). Organic carbon values were determined according to Modified Wakley-Black Titration Method (Gaudette et al. 1974).

3. Results

3.1 Water column

In this study, some environmentally important parameters and nutrients were measured weekly during one year period at different depths of 3 selected sampling stations in Izmir Bay.

Table 2 gives the minimum, maximum and average (± standart errors) values of the physico-chemical parameters related to the water samples from the Izmir Bay.

	Station 1		Station 2		Station 3	
	Range	Mean±SE	Range	Mean±SE	Range	Mean±SE
Temperature	9.0-28.2	18.68±0.5	8.9-27.4	18.56±0.42	9.6-28.0	18.90±0.37
Salinity	31.93-43.85	39.84±0.13	33.97-43.85	39.98±0.11	33.97-44.85	39.9±0.1
pH	7.4-8.6	8.03±0.01	7.5-8.7	8.08±0.01	7.5-8.6	8.09±0.01
DO	3.86-14.40	7.44±0.14	4.57-13.60	7.72±0.12	4.16-12.9	7.72±0.09
NH_4-N	0.21-36.97	7.83±0.56	0.00-32.19	4.89±0.30	0.09-40.94	3.84±0.29
NO_3-N	0.00-19.31	4.55±0.38	0.00-21.35	3.50±0.26	0.00-17.63	2.10±0.16
NO_2-N	0.00-28.99	3.54±0.38	0.00-16.99	2.54±0.24	0.00-9.69	1.06±0.10
PO_4-P	0.60-16.05	3.67±0.16	0.54-19.56	3.51±0.18	0.00-31.43	2.77±0.21
Si	0.31-43.89	12.62±0.77	0.47-54.12	11.47±0.64	0.16-41.80	8.81±0.54
N/P	0.57-15.69	5.43±0.29	0.23-20.52	4.46±0.26	0.00-53.65	4.36±0.40
Si/P	0.22-28.03	4.31±0.35	0.27-56.38	4.56±0.40	0.00-83.38	5.60±0.61
Chl a	0.00-66.13	5.72±0.59	0.00-23.55	4.65±0.28	0.00-12.82	2.78±0.17

Table 2. The minimum, maximum, average and standart errors of the physico-chemical parameters related to the water samples from the Izmir Bay. Temperature (^oC), salinity (%o), DO (mg/l), NH_4^+-N NO_3^- -N, NO_2^--N, PO_4^{-3}-P, Si (μM), Chl a(μg/l).

3.1.1 Physico-chemical parameters

Rainfall, evoporation, streams and wastewater discharge effect variations of salinity in the bay of İzmir. As a result of rain in winter salinity has decreased. In addition salinity began to increase in during spring months suggest that water discharge out of the treatment plant left the bay along the northern shores.

Considerable increases in dissolved oxygen concentrations were observed in the first week of january, the second of march, the third of april, the first of may and the third of june. Although fluctuations were found between january and july, there was a general decrease in the values concerned, which seems consistent with the general increase found in water temperature, suggesting that dissolution of gases in water diminishes based on temperatural increase. A very slow increase was observed in dissolved oxygene concentrations from early july to the end of the year. Dissolved oxygen concentrations at ST 1 and ST 2 were found to be below the oxygen saturation.

Increases seen in pH, one of physico-chemical environmental parameters between the first week and 4th week of May were associated with those in chlorophyll a values, suggesting a decrease in inorganic carbon induced by photosynthesis, which is believed to have been caused by any indirect biological or chemical phenomenon. While significant decreases in pH appeared in mid of august, end of september and november, the general tendency to diminish in pH seems consistent with drop of dissolved oxygen saturation.

3.1.2 Nutrients

One of parameter groups quite influencing lower trophic levels in aquatic ecosystems is nutrients. Accordingly, variable values of nitrogen forms, orthophosphate and silicate based on time and depth at the three stations chosen in Izmir bay are as follows.

When nutrients and chlorophyll-a concentrations were compared to the studies carried out before the construction of Wastewater Treatment Plant (WWTP), significant decreases were observed for the nutrients (Table 6), but chlorophyll-a concentrations were higher than the values determined after WWTP by Kukrer and Aydin (2006). This situation points out the role of primary production on reduction of nutrient concentration; and thus, it is thought that this reduction transformed into the phytoplankton biomass (Kukrer, 2009).

A similarity in the spatio-temporal distributions of NH_4–N and NO_2 –N were observed at all stations. Bizsel and Uslu (2000) explain this similarity with nitrification process: NH_4–N rapidly transforms into NO_2 –N but transformation of NO_2 –N to NO_3–N is a slower process (Ozkan *et al.,* 2008). Hence, NH_4–N and NO_2 –N had similar trend in this study. NO_2 –N values were lower than NO_3–N over the sampling period. Morris (1980) was reported that this situation was normal and NO_2 –N accumulates distinguishable under low DO condition (Kukrer, 2009).

Koray *et al*. (1992) emphasized that a big part of total nitrogen in the polluted Izmir Bay was the ammonium from industrial and domestic wastes. Contrary, in this study nitrate have the biggest share in total nitrogen concentration due to the wastewater treatment plant which reduces ammonium inputs. Additionally, ammonium concentration is kept under control by phytoplankton over a year. In spite of this progress, the ammonium enrichment continues owing to the creeks and sediment which have high ammonium concentration (Ozkan *et al*., 2008).

During the phytoplankton bloom period (January-August), NH_4–N, [$Si(OH)_4$-Si] and o.PO_4-P concentrations were lower than the values in Autumn. While inverse trend between NH_4–N and chlorophyll-*a* shows consumption of ammonium by phytoplankton, a similar relationship could not be observed between NO_3–N and chlorophyll-*a* (Kukrer, 2009).

The opposite trend between NH_4–N and chlorophyll-*a* showed the consumption of ammonium by phytoplankton, but an expected negative correlation between NO_3–N and chlorophyll-*a* could not be found. It can be explained that NH_4–N could block the uptake of NO_3–N and/or NH_4–N might be preferred by phytoplankton (Morris, 1980).

The study in which data was processed into Principal Component Analysis (PCA) aimed at determining contributions of the measured variables to total variance with different analysis for each station. All variables were defined as four major components at ST 1, explaining for 64.5% of total variance. Thus, temperature, phosphate, pH and phaeopigment account for 22.1 % of the variations involved. 18.4 % of them is to a great extent governed by DO, chl a, salinity and nitrite. 12.6 % is mostly controlled by silicate and ammonium whereas 11.3 % generally by nitrate (Table 3).

ST 1	*Component*	*Component*	*Component*	*Component*
	1	2	3	4
Phaopigment	**0,332992**	0,00587052	0,0782505	-0,345222
Temperature	0,148211	**-0,422099**	-0,15314	-0,234076
Salinity	**0,574924**	-0,113647	-0,0567523	-0,00371232
pH	**0,381094**	0,334592	-0,0951191	0,0634268
PO_4	**0,472503**	-0,0803457	0,0848547	0,368648
NO_3	-0,166612	-0,214467	-0,196831	**0,691634**
NO_2	-0,106301	**-0,364725**	-0,157476	0,155942
NH_4	0,0223274	0,240198	**0,656172**	0,133631
SiO_4	-0,0478669	-0,198481	**0,617408**	0,186501
DO	-0,292287	**0,478749**	-0,134424	-0,066133
Chl -*a*	0,20209	**0,430308**	-0,239983	0,355532

Table 3. Component Weights of ST 1

All variables of PCA made for ST2 were defined as four major components at ST 1 which explained for 62% of total variance. 21% of it often depends on temperature, phosphate and DO whereas its 17.4 % is mostly controlled by nitrite, nitrate, pH. 14% of variance is found to be accounted for by ammonium and silicate while its 9.6% is to a great measure under the control of phaeopigment, salinity and chl a (Table 4).

ST 2	*Component*	*Component*	*Component*	*Component*
	1	2	3	4
Phaopigment	0,190085	0,033317	-0,337102	**0,416977**
Temperature	**0,612123**	-0,0620875	0,00251255	0,050634
Salinity	0,175982	-0,389765	-0,0522611	**0,45086**
pH	0,350358	**0,409077**	-0,0404681	-0,241227
PO_4	**0,443203**	0,0770914	-0,0509096	-0,124404
NO_3	-0,120681	**-0,436475**	-0,160533	-0,282205
NO_2	-0,0501546	**-0,528066**	-0,152599	0,0743837
NH_4	-0,0090085	0,17262	**0,513087**	0,382987
SiO_4	0,0249009	-0,156039	**0,622841**	0,218553
DO	**-0,469988**	0,328992	-0,165754	0,194231
Chl -*a*	0,0188411	0,195156	-0,389454	**0,478833**

Table 4. Component Weights of ST 2

All variables were described as four major components at ST 3 which explained for 61.2% of total variance. 25.2 % of total variance is generally explained by temperature, phosphate, oxygen and phaeopigment Nitrate is seen to be responsible for 14.9 % of it whereas its 11.8% is basically governed by salinity, chlorophyll a and nitrite. On the other hand 9.3 % of total variation is mostly controlled by silicate and ammonium (Table 5).

ST 3	*Component* 1	*Component* 2	*Component* 3	*Component* 4
Phaopigment	**0,309441**	-0,115255	-0,118439	0,00891844
Temperature	**0,478778**	0,368824	-0,00879898	0,140916
Salinity	-0,024596	0,365174	**-0,519479**	0,253368
pH	**0,33159**	0,186109	0,321044	-0,0842017
PO_4	**0,437231**	-0,22811	0,0675536	0,134745
NO_3	0,200952	**-0,554785**	-0,129602	0,162289
NO_2	0,0991039	-0,401237	**-0,46215**	0,29997
NH_4	0,285814	-0,197389	0,0871168	**-0,468515**
SiO_4	0,244234	-0,0379852	-0,22798	**-0,566497**
DO	**-0,383154**	-0,345061	0,258506	-0,0662661
Chl -*a*	0,186924	-0,0491215	**0,501633**	0,479047

Table 5. Component Weights of ST 3

Table 6 shows minimum and maximum values of nutrients and *Chl a* in some previous studies which were carried out in the different parts of the Izmir bay. Izmir Wastewater Treatment Plant Construction was completed in the 2002. It works on the principle of nitrogen and phosphorus treatment technology with activated sludge. Previous studies indicated that the concentration of TNO_x-N has been reduced during after wastewater activated sludge technology plant except sudden discharge, while reactive phosphate concentrations were increased in the Bay. In the Middle and Inner Parts of the Bay Chlorophyll *a* concentration has been gradually reduced after treatment.

In conclusion, we are of the opinion that it would be of great use to develop and plan further similar studies periodically and for the long run considering that they could shed light on precautions to be taken in terms of both environmental and public health.

The changes in the state variables of ecological model for İzmir Bay before and after the sewage treatment has been given by Büyükışık et al., 1997 (Fig.2 and 3). They reported that average light intensities in water column would be recovered in a year if the treatment plant begins to work. Indeed, after one year from starting of sewage treatment (2003), the observation in recovery of the average light intensities in water column consistent with the model outputs in case of treatment.

But some changes in temporal variations of phytoplankton biomass has been observed (Fig.4). Some exceptional blooms has taken place in mid-winter, early summer and autumn. Model does not includes the kinetic parameters of *Ditylum brightwellii* (in winter) and *Rhizosolenia setigera* (in summer).

These two species are relatively large sized phytoplankton and they contributed greatly to the total phytoplankton carbon and POC values.

Specially some members of genus Rhizosolenia can change their cellular density, sink deeper, uptake and storage the nutrients and go on their growth.

Locations	Period	NO_3(μM)	NO_2(μM)	NH_4(μM)	Si(μM)	RP(μM)	Chl a(μg l^{-1})
Inner part of Izmir Bay	1993-1994	BDL-3,04*	BDL-4,65*	0,12-468*	-	0,36-49	BDL-189
Middle part of Izmir Bay	1993-1994	BDL-3,49	BDL-3,57	BDL-44	-	0,06-3,79	0,5-62
Outer part of Izmir Bay	1993-1994	BDL-4,91	BDL-0,16	BDL-11,11	-	BDL-6,42	BDL-2,95
Inner part of Izmir Bay	1993-1994	BDL -3,11	BDL -4,65	BDL -468	-	0,18-49	BDL -189***
Candarlş Bay (Aegean Sea)	1994-1995	0,001-0,31	BDL-0,1	0,42-2,38	27,74-63,19	BDL-0,48	BDL-1,13
Middle-Inner part of Izmir Bay	1996-1998	0,13-27	0,01-18	0,10-21	0,50-39	0,01-10	0,10-26
Middle-Inner part of Izmir Bay	2000	0,15-18	0,02-12	0,13-34	0,43-20	0,13-3,8	0,46-18
Middle-Inner part of Izmir Bay	2001	0,29-16	0,02-4,3	0,11-50	1,2-18	0,14-2,9	0,38-7,8
Middle-Inner part of Izmir Bay	2002	0,26-6,7	0,01-6,1	0,10-6,7	1,0-26	0,14-4,4	0,13-3,7
Gerence Bay (Aegean Sea)	2002	0,04-2,19	BDL-2,51	BDL-3,53	-	BDL-2,82	BDL-0,320
Middle-Inner part of Izmir Bay	2003	0,12-8,6	0,01-1,0	0,12-2,4	2,6-32	0,32-4,5	0,24-2,6
Inner part of Izmir Bay	2007-2008	1,54-11,77	0,00-3,51	0,23-22,28	1,99-41,94	0,00-5,96	5,03-30,26
This Study	2003	BDL-21,35	BDL-28,99	BDL-40,94	0,16-54,12	BDL-31,43	BDL-66,13

* Min-Max;
** Average value;
*** Data from (32);
BDL: Below Detection Limits

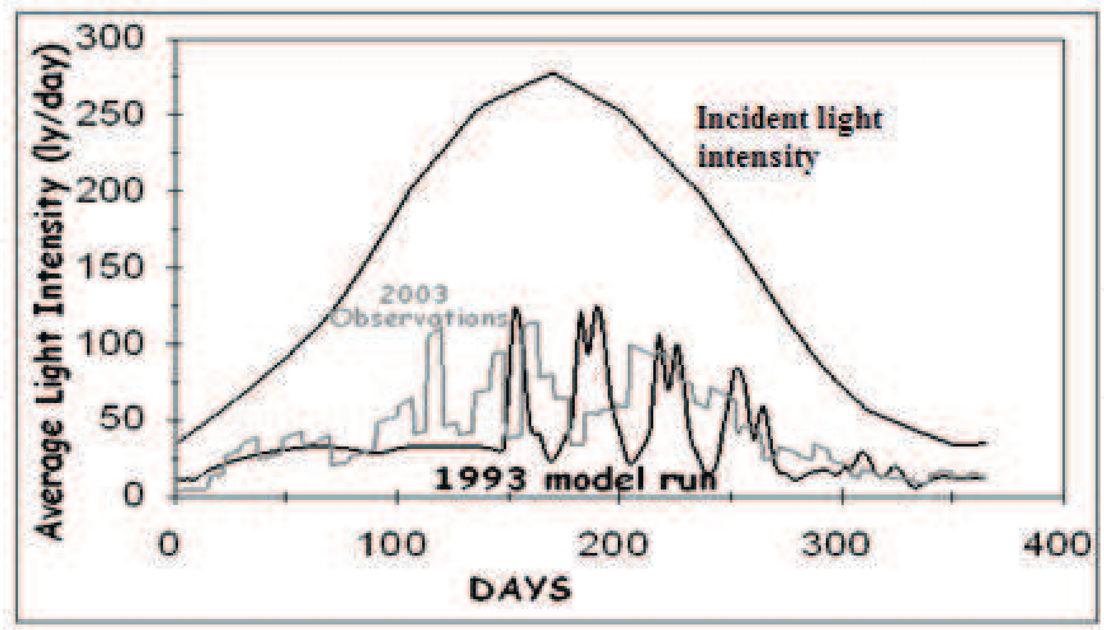


Fig. 2. Temporal changes of the average water column light intensities obtained from model in 1993 (Black curve, Büyükışık et al 1997) and from chl-*a* values in 2003 (gray lines, Sunlu et.al, 2007). The black curve at top represents the temporal changes in incoming sub-surface light intensities (Büyükışık et al 1997).

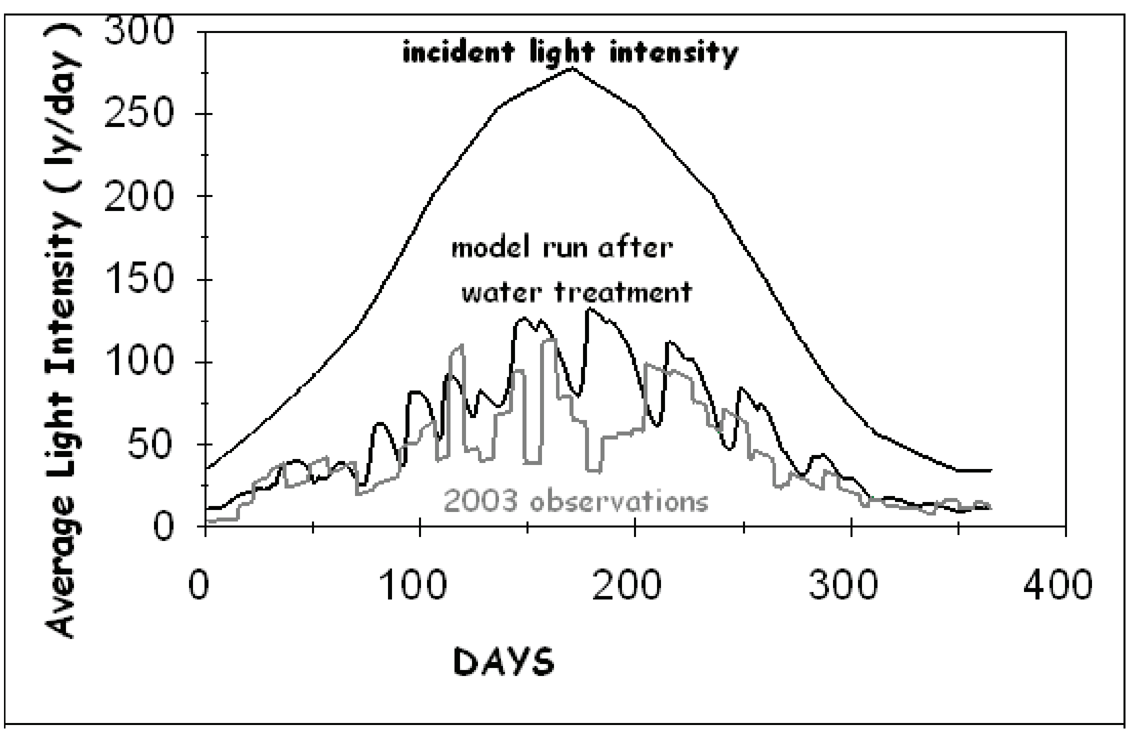


Fig. 3. Temporal changes of the average light intensities obtained from model in case of 90% nutrient treatment (black curve, Büyükışık et al 1997) and from chl-*a* values in 2003(gray lines, Sunlu et al, 2007). The black curve at top represents the temporal changes in incoming sub-surface light intensities (Büyükışık et al 1997).

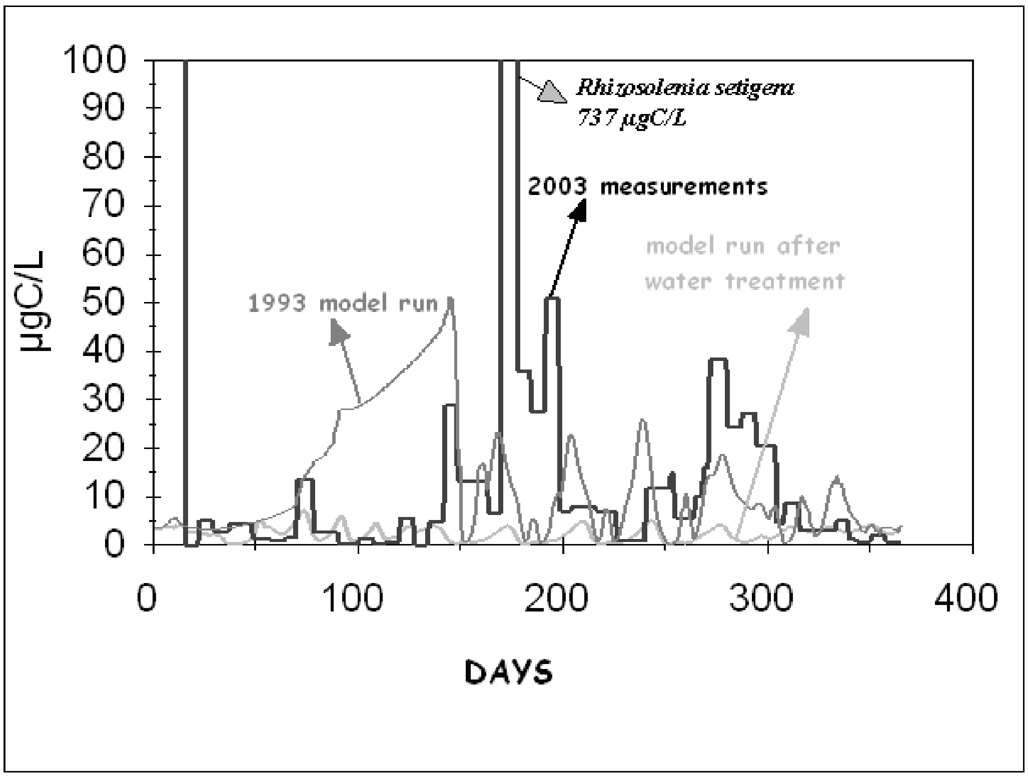


Fig. 4. Temporal changes of the phytoplankton biomass obtained from model in case of 90% efficiently treatment (light gray curve, Büyükışık et al 1997). The dark gray curve represents the model run outs in 1993 (moving average, Büyükışık et al 1997). Black column in graph represents the measurements in 2003 from biomass calculates two microscopic examinations (Sunlu et al, 2007).

3.2 Sediment

Values measured at stations ranged between; 0.09–9.32 µg/L for phaeopigment, 0.05–1.91 mg/L for particulate organic carbon in sea waters, 11.88–100.29 µg/g for chlorophyll degradation products and 1.12–5.39% for organic carbon in sediment samples. In conclusion, it was found that grazing activity explained carbon variations in sediment at station 2, but at station 1 and station 3 carbon variations in sediment were not related to autochthonous biological processes.

3.2.1 Organic carbon in sediment

Organic carbon values at station 1 ranged from 2.63 to 3.39%. Average concentration was 3.03%. Minimum, maximum and average organic carbon values at station 2 were 1.73, 5.39 and 4.33% respectively. Organic carbon values at station 3 ranged from 1.12 to 2.41%. Average concentration was 1.58% (Fig. 5). Previous carbon contents in the sediment samples from the different regions of Aegean Sea were given in Table 7.

3.2.2 Chlorophyll degradation products in sediment (CDP)

Chlorophyll degradation products in sediment at station 1 ranged from 50.79 to 90.66 µg/g and average value was found 62.62 µg/g. At station 2 average CDP value was 81.39 µg/g. Minimum and maximum values were measured as 41.58–100.29 µg/g respectively. CDP

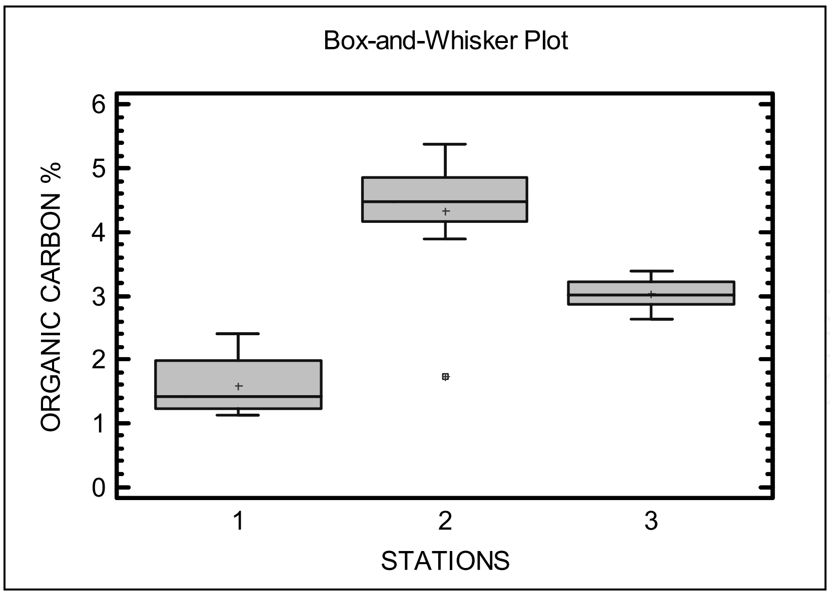


Fig. 5. Box and whisker plot of Organic carbon (%) values at all sampling stations.

concentrations at station 3 ranged from 11.88 to 52.12 µg/g. Annual mean was 34.44 µg/g(Fig. 6). When each three region was discussed separately, at the Station 2, algal sedimentation and/or mesozooplankton grazing explain variations of carbon in the the sediment samples ($r=0.7879$ $p=0.0023$). According to statictical analyses of C sed/CDP for each region, variations of CDP in sediment seems independent from carbon in sediment variations for station 1 and station 3 in sequence ($r=0.339$, $r=0.206$). Melez, Manda and Arap Rivers discharge their waters rich in organic mater around station 1 (Turkman 1981). At station 3, during the year CDP concentrations were at the lowest value and it can be explained by background carbon levels that mask carbon variations which is caused by algae (< %2). Besides, the output of the wastewater treatment plant is close to the station 3 and it constitutes crucial silicate source. Diatoms consist of skeleton with silica are known as having five times lower carbon content than Dinoflagellates (Hitchcock 1982 in Smayda 1997). That situation can explain that during the year phytoplankton community has lower carbon content. Even if export production to sediment increases relatively low productivity and low carbon content in water column can cause a similar situation in diatom dominated marine environments. By using overall data in Inner and Middle Izmir Bay, chlorophyll degradation products in sediment versus carbon values were plotted. A good linear relationship between CDP and carbon was obtained ($r2=0.771$, $p=0.000$):

$$[\text{Carbon}]_{sed}=0.2077+0.0466*[\text{CDP}]_{sed}$$

A general equation was found for predicting the Izmir Inner Bay's CDP and organic carbon values in sediment. It was found that there are no significant differences in sediment carbon values depending on time but spatial variations related to sampling stations are more evident. When spatial scale is widened, CDP variations explained 77% of carbon variations in the sediment for overall data. Approximately 23% of these variations were originated from allocthonous sources.

At station 3, it is possible that grazing on diatoms and/or mixotrophy in dinoflagellates are dominant on certain onths of the year. Consequently, it is not possible to explain variations of the carbon in sediment with the pigment contents of sediment. Station 2 has highest carbon and CDP values and also has a relationship between CDP and organic carbon content. This situation can be explained by the fact that station 2 is relatively away from external sources and has high biological activity (Sunlu et al. 2007). At station 1, however, relation is weak despite higher carbon and CDP values than at station 3. Contribution of external carbon sources as rivers may play important role on this weak correlation.

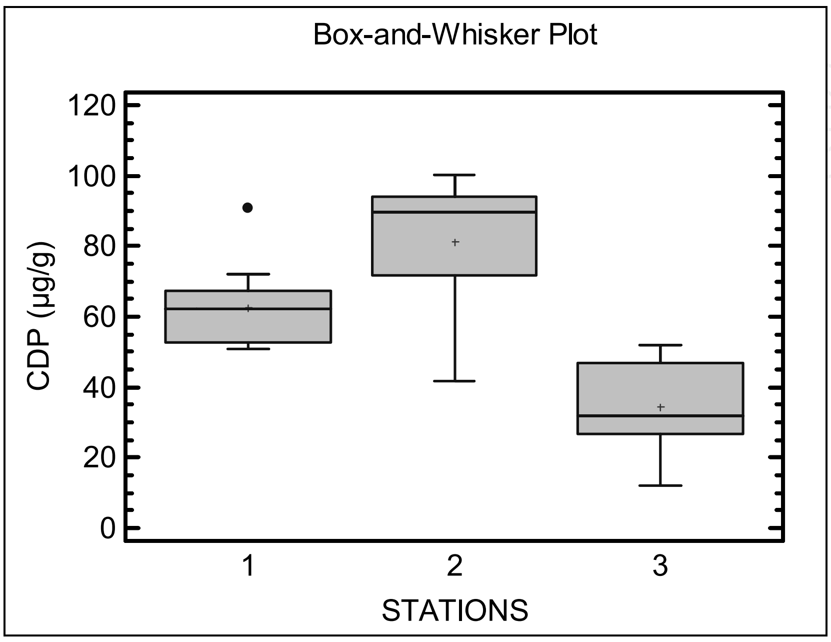


Fig. 6. Box and whisker plot of CDP (µg/g dry sediment) values at all sampling stations.

Locations	Carbon in Sediment (%)	Reference
Middle part of Izmir Bay	0.87-1.60	Yaramaz et. al. 1992
Inner part of Izmir Bay	0.57-3.42	Yaramaz et. al. 1991
Izmir Bay	11.4	Anonymous, 1992
Izmir Bay	2.0-7.0	Anonymous, 1997
Gulluk Bay (Southern Aegean Sea)	0.1-4.5	Egemen et. al. 1999
Gulluk Bay (Southern Aegean Sea)	1.07-2.13	Atılgan, 1997
Urla (Middle part of Izmir Bay)	1.25-2.1	Sunlu et. al. 1999
Pariakos Bay (Greece)	0.15-11.01	Varnavas and Ferentionos, 1982
Evoikos Bay (Greece)	1.2	Scoullos and Dassennakis, 1982
Evoikos Bay (Greece)	0.66-2.4	Angelidis et. al. 1980
Southern Turkish Aegean Sea	1.3-13.1	Aydın and Sunlu, 2005
Northern Turkish Aegean Sea	0.35-15.63	Sunlu et. al. 2005
Middle part of Izmir Bay	1.12-5.39	This Study

Table 7. Previous carbon contents in the sediment samples from the different regions of Aegean Sea.

4. Conclusion

When our mean results were compared with those obtained before Izmir wastewater treatment plant was operating, concentrations of chlorophyll a and nitrogen forms declined while it was not the case for orthophosphate.

The fact that the processes affecting Reactive Phosphate (RP) and TIN occur at different times indicates important differentiations in the temporal variations of these two nutrients in the Inner Bay. From the distribution of the nutrients and their percentages, important evidence regarding the process have been gathered. These processes:

- Inflow with the creeks is especially evident during rainfall and there is a big increase in Si and Nitrogen forms.
- Rapid decreases of freshwater inflows from rainfall based on current global warming tend to restrict Si and N inflows. Water outflow treated from treatment plant is another source of nutrient with N/P ratios being about <=2. RP induced by water from treatment plant thus contributes to RP reserves in Inner Bay.
- The winds, although increasing fresh water inflow and water column, frequently carry the deep water to the surface. This shows that the Inner Bay is often subject to a deep-water-based nutrient enrichment.

The phytoplankton blooms caused by the inflow of nutrients to the Inner Bay in turn result in the intake of nutrients by the phytoplanktons (especially diatoms) which are then exported to the deep waters and constitute the fuel for future phytoplankton blooms. Thus, the horizontal exportation of the nutrients out of the Inner Bay remains limited. It is only due to the winds that the wastewaters flow outwards from time to time.

Because total renewal of Inner Bay water by the current system takes about ten days, nutrient load provided by various sources in the area is most important reason for overgrowth of phytoplanktons observed in the Izmir Bay.

Silicate is essential for the diatoms to compete effectively with dynophylagellates and plays an important role in the increase in species in the bay and this nutrient, coming with the rainfall from the shore in non-point sources and point sources (i.e. creek, river), is of great importance for the Inner Bay.

We believe that unless the nutrient levels in the rivers are decreased, the Bay will continue its current state for a long time. Although a decrease has been observed in the nitrogen nutrients after the start of the wastewater treatment plant, former studies have shown that the phosphate concentrations have not changed and that the plant has been ineffective regarding this subject. The effective treatment of phosphate will be an important precaution against the new strategy that the phytoplankton might take up against the decreasing TIN.

The reason for this was that 2– 10 years elapsed between the two studies and the treatment facility begun to work in full capacity in 2002. On the other hand; carbon contents in the sediment samples of our study are considerably lower compared with the values obtained in a large scale previous research carried out by different regions around Aegean Sea.

General sediment texture of Izmir Bay was studied by Duman et al. (2004). Average sediment particle size was reported to be 4–8 ɸ and sediment texture to be sandy-silt. In Izmir Bay sorting coefficient indicates very poorly sorted deposits (SD=2–3). Prevailing wind direction in inner part of Izmir Bay was noted as Western and it has been reported that deep flow was toward to East and surface flow toward to West. Most of organic material remains in the silt near the pollution source and the correlation between grain size fractions and organic carbon was found to be highest in silt (Duman et al. 2004). One sediment component, vermiculite was found in the inner part of Izmir Bay at a rate of 3–11% and its

main source was from Melez River (near station 1). Caolinit was found at a rate of 8–12% with neogen sediments coming from the rocks around the Bay (Aksu et al. 1998). Percentage of organic carbon was reported to be between 0.40 and 5.39 by Duman et al., from Izmir Bay (Duman et al. 2004). Range for these values was found to be between 1.12 and 5.39% in our study. These values were higher than previous report (Duman et al. 2004). The reason for this was that 2– 10 years elapsed between the two studies and the treatment facility begun to work in full capacity in 2002. On the other hand; carbon contents in the sediment samples of our study are considerably lower compared with the values obtained in a large scale previous research carried out by different regions around Aegean Sea (Table 7). It can be said that high carbon levels observed in inner part of Izmir Bay were from raw sewage and industrial outfalls carried by Melez River at station 1. But at station 2 and 3 high carbon levels were due to organic material formed by secondary pollution. The biggest contribution to the sediment is provided byexport production which was especially effective at station 2. A general equation was found for predicting the Izmir Inner Bay's CDP and organic carbon values in sediment. There are no significant differences in sediment carbon values depending on time but spatial variations (related to sampling stations) are more evident . In conclusion, it was found that carbon variations in sediment at station 2 (Karşıyaka, Offshore of the Yatch Club) can be explained by grazing activity, but at station 1 (Melez, Izmir Harbour) and station 3 (Cigli, Offshore of the Wastewater Treatment Plant) carbon variations in sediment could be related not only with autochthonous biological processes but also with physical processes (e.g. sweeping out of plant material by advection from the Bay). Especially wastewater treatment improves the water quality, but sediment does not respond to this treatment as fast as water column. Improvement in the quality of bottom water and sediment is the evidence of the recovery of the whole ecosystem of the Izmir Bay.
In conclusion, it was found that carbon variations in sediment at station 2 (Karşıyaka, Offshore of the Yatch Club) can be explained by grazing activity, but at station 1 (Melez, Izmir Harbour) and station 3 (Cigli, Offshore of the Wastewater Treatment Plant) carbon variations in sediment could be related not only with autochthonous biological processes but also with physical processes (e.g. sweeping out of plant material by advection from the Bay).
Especially wastewater treatment improves the water quality, but sediment does not respond to this treatment as fast as water column. Improvement in the quality of bottom water and sediment is the evidence of the recovery of the whole ecosystem of the Izmir Bay.

5. Acknowledgments

The authors would like to thank TUBITAK (Turkish Scientific and Technical Research Council) Project no: 102Y116, Izmir Municipality Gulf Control Staff and Science and Technology Research Centre of Ege University (EBILTEM) for their efforts to join of this project and their scientific and financial supports.

6. References

Aksu, A. E., Yatar, D., & Uslu, O. (1998). Assessment of marine pollution in Izmir Bay; heavy metal and organic compound concentrations in surficial sediments. Turkish Journal of Engineering and Environmental Science, 22, 387–415.

Aksu, M., Kaymakçı Basaran, A. & Egemen,Ö. (2010). Long-term monitoring of the impact of a capture-based bluefin tuna aquaculture on water column nutreint levels in the

Eastern Aegean Sea, *Environ Monit Assess*, 171: 681-688, DOI 10.1007/s10661-010-1313-y.

Angeldis, M., Grimanis, A. D., Zafiropoulos, D., & Vassilaki- Grimani, M. (1980). Trace elements in sediments of Evoikos Gulf, Greece. *Ves Journe'es Etud. Poll.Cagliari, CIESM,* 413–418.

Anon (1992). *Environmental impact report of alternative dumping areas of Izmir Harbour and approaching channeldredged material, (in Turkish),* Dokuz Eylul Universitesi Deniz Bilimleri Enst. s, 14–15. Anon (1997). Izmir Bay Marine Research 1994–1998 (1997 Report), (in Turkish), D. E. U. Den. Bil.Tek.Enst.Proje No:DBTE-098.

Anon (1997). Izmir Bay Marine Research 1994–1998 (1997 Report), (in Turkish), D. E. U. Den.Bil.Tek.Enst.Proje No:DBTE-098.

Atılgan, İ. (1997). *Comparative investigations of carbon, organic matter (loss on ignition) and some heavy metal (Cu, Zn) levels of sediments of Gulluk and Homa Lagoon, (in Turkish)* (Yüksek Lisans Tezi, M.Sc.) E. U. Fen Bilimleri Enst. Su Urunleri Anabilim Dalı, pp. 1–15.

Aydın, A. & Sunlu, U. (2005). Investigation of carbon and organic matter (loss on ignition) concentrations in the sediments of South Aegean Sea, (in Turkish), *E.U. Journal of Fisheries and Aquatic Sciences volume*; 21, issue;3–4 pp. 229–234.

Bizsel, N. & Uslu, O., 2000, Phosphate, Nitrogen and Iron Enrichment in The Polluted Izmir Bay, Agean Sea *Mar Environ Res 49 (4): 397-397,*

Büyükışık, B., Ş. Gökpınar & H. Parlak. (1997). Ecological modelling of İzmir Bay. *Journal of Fisheries and Aquatic Sciences, 14(1-2):71-91.*

Colak-Sabancı, F. & T. Koray, 2001, The effect of pollution on the vertical and horizontal distribution of microplankton of the bay of Izmir (Aegean Sea). (in Turkish). *Journal of Fisheries and Aquatic Sciences,* 18(1-2) :187-202.)

Duman, M., Avci, M., Duman, S., Demirkurt, E., & Duzbastilar, M. K. (2004). Surficial sediment distribution and net sediment transport pattern in Izmir Bay, Western Turkey. *Continental Shelf Research*, 24, 965–981.

Egemen, O., Gokpinar, S., Onen, M., Buyukisik, B., Hossucu, B., Sunlu, U., et al. (1999). Gulluk Lagoon ecosystem (Aegean Sea/Turkiye), (in Turkish). *Turkish Journal of Agriculture and Forestry suplement issue*, 3, 927–947.

Environment for Europeans (2005). Keeping our seas alive. *Magazine of the Directorate-General for the environment.* No;21, pp.3–4. Brussels.

Gaudette, H. E., Flight, W. R., Toner, L., & Folger, W. (1974). An inexpensive titration method for the determination of organic carbon in recent sediments. *Journal of Sedimentory Petrology*, 44, 249–253.

Hilal Aydın Gençay & Baha Büyükışık, 2006, The studies on phytoplankton population Dynamics at DEM Harbour (Çandarlı Bay, Aegean Sea), *E.U. Journal of Fisheries & Aquatic Sciences, Volume 23, Issue (1-2): 43–53*

Hitchcock, G. L. (1982). A comparative study of the sizedependent organic composition of marine diatoms and dinoflagellates. *Journal of plankton research*, 4, 363–377

Kaymakci, A., Sunlu, U., & Egemen, O. (2000). Assessment of nutrient pollution caused by land- based activities in Izmir Bay, Turkiye. *Meeting on Interdependency between Agriculture, Urbanization: Conflicts on Sustainable Use of Soil, Water,* Tunisia: pp. 41–49.

Kontas, A., Kucuksezgin, F., Altay, O., & Uluturhan, E., 2004, Monitoring of eutrophication and nutrient limitation in the Izmir Bay (Turkey) before and after Wastewater Treatment Plant. *Environment International, 29*(8), 1057–1062.

Koray, T., Buyukisik, B., Parlak, H. & Gokpınar, Ş.,1992, Unicellular organisms effecting sea water quality in the bay of Izmir: red tides and other blooming, *Doğa Tr. J. of Biology* 16, 135-157 p.

Kucuksezgin, F.; Kontas, A.; Altay, O.; Uluturhan, E. & Darılmaz, E., 2006, Assessment of marine pollution in Izmir Bay: Nütrient, heavy metal and total hydrocarbon concentrations. *Environment International, 32(1), 41-51.*

Kukrer, S., (2009*). Investigating the effects of creeks to eutrophication in İzmir Bay on cleaning process*. Ege University,PhD thesis, 162 p.

Kükrer, S. & Aydın, H. 2006.Investigation of temporal changes of phytoplankton in Karşıyaka Yacht Port (İzmir iner bay). *E.U. Journal of Fisheries & Aquatic Sciences 2006 Volume 23, Issue (1-2): 139–144.* (in Turkish).

Lorenzen, C. J. (1971). Chlorophyll-degradation products in sediments of Black Sea. *WoodsHole Oceanographic Institution Contribution* No; 2828, pp. 426–428.

Morris, I., 1980, *The Physiological Ecology Of Phytoplankton.*(Studies İn Ecology; Vol 7) University of California Press. P. 621

Özkan, E.Y., Kocataş, A. & Büyükışık, B., 2008, Nutrient dynamics between sediment and overlying water in the iner part of Izmir Bay, Eastern Aegean, *Environmental Monitoring* Assess 143, 313-325 p.

Parsons, T. R., Matia, Y., & Lalli, C. M. (1984). *A manual of chemical and biological methods for seawater analysis* p. 173. New York: Pergamon Press.

Scoullos, M., & Dassenakis, M. (1982). Trace metal levels in sea water and sediments of Evoikos Gulf. Greece. *Ives Journe'es Etud. Poll. Cannes, CIESM*, pp. 425–429.

Smayda, T. J. (1997). Harmful algal blooms: Their ecophysiology and general relevance to phytoplankton blooms in the sea. *Limnology and oceanography*, 42(5, part 2), 1137–1153.

Strickland, J. D. H., & Parsons, T. R. (1972). *A practical handbook of seawater analysis*. Fisheries Research Board of Canada. Bull. 167. Ottowa, 310 p.

Sunlu, U., Aydın, A., & Egrihanci (Ozcetin) N. E. (2005). Investigation of carbon and organic matter (%) concentrations in the sediments of North Aegean Sea, (in Turkish), *E.U. Journal of Fisheries & Aquatic Sciences* 22,(3–4), 263–268.

Sunlu, U., Buyukisik, H. B., Koray, T., Brockel, K., Sunlu, F. S. & Sever, T. M. et al. (2007). The effects of Izmir Big Channel waste water treatment project to the lower trophic level of Izmir Bay (Aegean Sea, Turkey). The Scientific and Technical Research Council of Turkey (TUBITAK-CAYDAG) Project No;102Y116 Final Report. 253p. (in Turkish).

Sunlu, U., Egemen, O., Kaymakci, A., & Tüzen (1999). Investigation of impact of fish rearing at net cages on sediment in Urla Pier, (in Turkish), X. National Fisheries Symposium., 22–24 september l999. Adana.

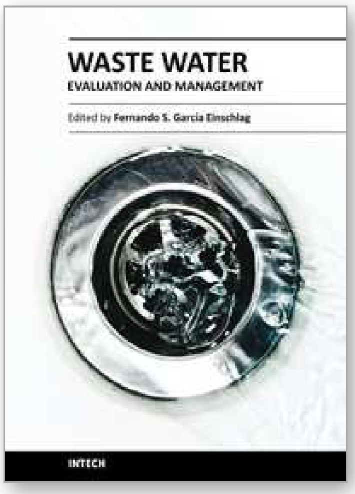
Turkman, A. (1981). Evaluation of results of the analyses of the secondary rivers discharging to Izmir Bay, (in Turkish), Devolopment of Soil And Water Resources Conference, 2, 723–750.

Varnavas, S. P., & Ferentionos, G. (1982). Heavy Metal distribution in the surface sediments of Pataraikos Bay, Greece, *Vies Journes'es Etud. Poll.Cannes, CIESM.*, pp. 405–409.

Wood, R., (1975). *Hydrobotanical Methods*, Univ.Park Press, *London:173.*

Yaramaz, O., Modogan, H., Onen, M., Sunlu, U., & Alpbaz, A. (1991). Investigation of some heavy metals (Fe,Mn, Ni) and organic matter (%C) concentrations in the sediments of the Izmir Bay, (in Turkish), X. National Fisheries Symposium.12–14 Kasim 1991, Izmir, s: 406–413.

Yaramaz, Ö., Önen, M., Sunlu, U., & Alpbaz., A. (1992). Comparative investigations of some heavy metal (Pb,Cd, Zn,Cu) levels in the sediments of Izmir Bay, (in Turkish), First International environmental protection symposium proceding, vol 2. In Zafer AYVAZ (ed.), s.15–19, Ege University Izmir-TURKIYE.



Waste Water - Evaluation and Management
Edited by Prof. Fernando SebastiÃ¡n GarcÃa Einschlag

ISBN 978-953-307-233-3
Hard cover, 470 pages
Publisher InTech
Published online 01, April, 2011
Published in print edition April, 2011

Fresh water resources are under serious stress throughout the globe. Water supply and water quality degradation are global concerns. Many natural water bodies receive a varied range of waste water from point and/or non point sources. Hence, there is an increasing need for better tools to asses the effects of pollution sources and prevent the contamination of aquatic ecosystems. The book covers a wide spectrum of issues related to waste water monitoring, the evaluation of waste water effect on different natural environments and the management of water resources.