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Nutrient and Chlorophyll a Trends after Wastewater Treatment Plant in Izmir Bay (Eastearn Aegean Sea)

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Abstract: The aim of the study is to determine effects of Izmir Big Channel Wastewater Treatment Plant on inorganic nutrients such as NO_3^--N, NO_2^--N, NH_4^+-N, PO_4^{-3}-P, Si and Chl-a levels in Izmir bay. Variations of inorganic nutrients and Chl-a were investigated weekly during 1 year period in 2003-2004 in Izmir bay. In addition, physico-chemical environmental parameters such as pH, Dissolved Oxygen (DO), water temperature and salinity were measured. The parameters mentioned above have been carried on in different depths of the 3 sampling stations which were located in middle and inner parts of Izmir bay. The concentration ranges of nutrients and chlorophyll-a were from BDL (Below Detection Limit) to 40.94 μM for NH_4^+-N, BDL to 21.35 μM for NO_3^--N, BDL to 28.99 μM for NO_2^--N, BDL to 31.43 μM for PO_4^{-3}-P, 0.16 to 54.12 μM for Si and BDL to 66.13 μg L^{-1} for Chlorophyll-a. When the results were compared with those obtained before Izmir waste water treatment plant had been operated, concentrations of Chl a and nitrogen forms declined while it was not the case for PO_4^{-3}-P.

Key words: Izmir bay, nutrient, Chl-a, physico-chemical parameters, forms, Turkey

INTRODUCTION

Coastal marine environments including bays, estuarines, wetlands, etc. are particulary sensitive to long and short term external factors. Coastal zones are especially exposed to diverse anthropogenic influences including industrial and domestic effluents, marine transportation, agricultural activities and alluvia carried by rivers and creeks. For all these reasons, water quality analyses of coastal ecosystems play a very important role in the environmental impact assesment of the marine environment. Water columns of coastal zones are major hosts for nutrient pollution and such as should be included in routine environmental monitoring programmes. It is vital to analyse, characterise and monitor the ecological status of coastal systems in terms of marine environmental health.

The bay of Izmir is located in the Western part of Turkey and surrounded by a dense human population community (Fig. 1). The bay of Izmir, the biggest natural harbour on the Aegean sea is of economic value for Izmir, the 3rd largest city in Turkey (Sunlu *et al*., 2009) . The bay is divided into an inner, middle and outer bays in terms of topographical and hydrographical characteristics. The inner bay is considerably small in area (57 km^2) 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. Therefore, Izmir municipality decided to construct the Izmir Big Channel Waste water Project in 1969.

Unfortunately, the construction of the plant failed to be completed until the end of 2002. In January 2000, the 1st section of the treatment plant was opened and 65% of the incoming daily sewage treated. Following the whole construction of the treatment in 2002, the pollutant levels of the inner bay water decreased gradually and the recovery period began.

There exist many a research made on physico-chemical environmental parameters and nutrient and Chl-a levels in Izmir bay (Sunlu *et al*., 2009; Kucuksezgin, 1996; Colak-Sabanci and Koray, 2001; Kucuksezgin *et al*., 2006; Kontas *et al*., 2004; Bizsel and Uslu, 2000; Bizel and Bizsel, 2001; Bizsel *et al*., 2001).

Moreover, effects of such parameters on composition of phytoplanktonic species are also discussed in the

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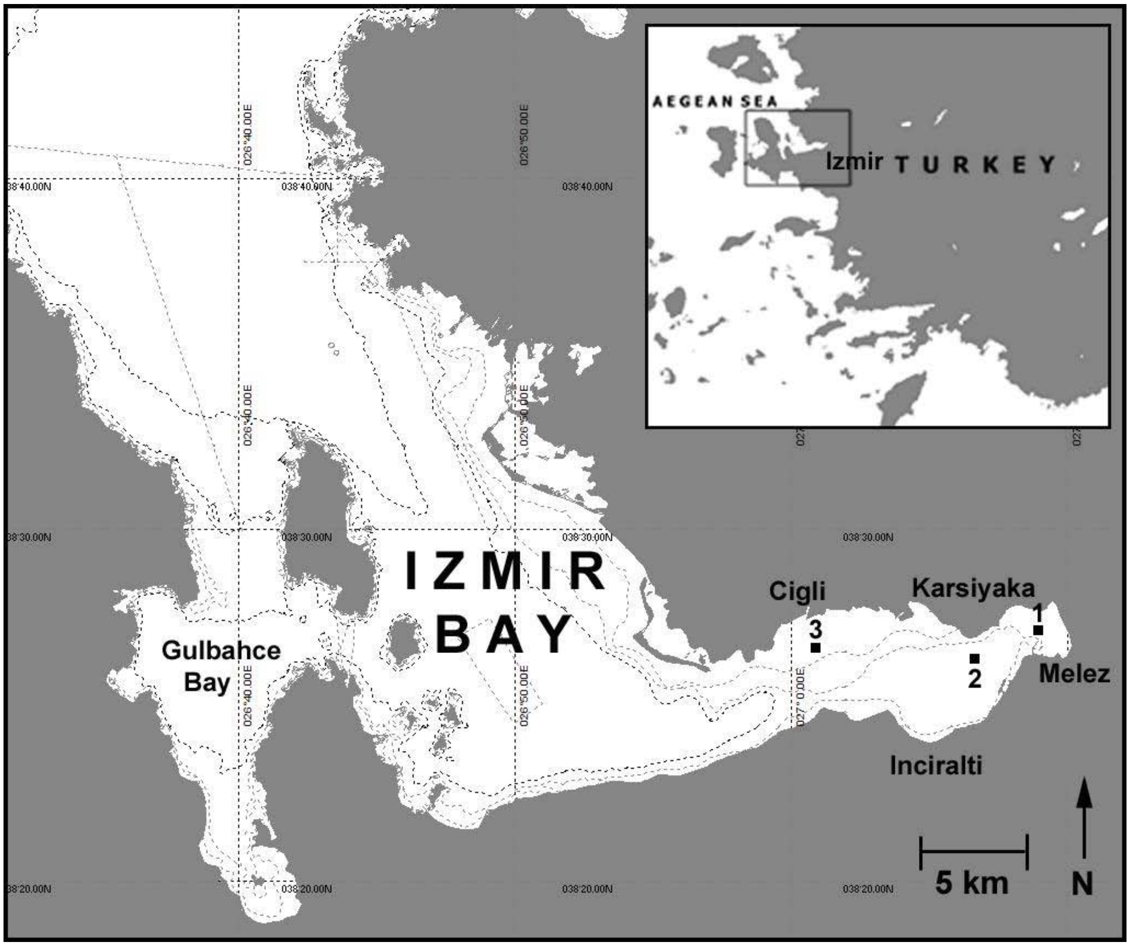

Fig. 1: Map of Izmir bay and the sampling stations

related literature (Koray, 1985, 1987, 1988; Buyukisik *et al*., 1994; Koray *et al*., 1999; Colak and Koray, 2005, 2007; Kukrer and Aydin, 2006).

On the other hand assesment of nutrients, physico-chemical parameters and nanoplanktonic organisms by artificial neural network and ecological modelling of Izmir bay were conducted by Sunlu *et al*. (2009) and Buyukisik *et al*. (1997), respectively.

In spite of these studies, there is only one research which was performed in the outer bay section with oligothrophic conditions and in which physico-chemical environmental parameters and nutrient and Chl-a levels were examined weekly.

The aim of the study is to determine the effects of Izmir Big Channel Wastewater Treatment Plant on the inorganic nutrients and Chl-a levels of Izmir bay. Variations of inorganic nutrients and Chl-a were investigated every week during 1 year period of 2003-2004 in Izmir bay.

MATERIALS AND METHODS

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 (Fig. 1).

Station 1 is near Izmir harbor (Inner bay) 38°27'17"N-27°09'37"E. Station 2 is off the Karsiyaka Yacht Club (Inner Bay) 38°26'86"N-27°06'56"E and station 3 is off the Wastewater Treatment Plant (Cigli, Middle bay) 38°25'47"N-27°00'05"E. The coordinates of the stations were read by ICON Marine plotter-sounder model FP561. The sampling points are shown in Fig. 1. The 1st 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 Izmir. The 2nd Station (St.) in Karsiyaka presents characteristics of mixture of St. 3 and 1 according to current system of the Izmir 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 which was particularly chosen to better understand effects of this plant on Izmir bay.

Physico-chemical environmental parameters, nutrients and some general biological parameters were measured weekly during the 1 year period. All these parameters were measured at different depths of the 3 selected sampling stations. For this study, water samples were collected using a peristaltic pump and screened through a 280 μ mesh to remove macrozooplankton. Polycarbonate bottles of 20 L were filled with sea water and moved to the laboratory.

***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).

Analytical measurements: 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 NO_3^--N, NO_2^--N, NH_4^+-N, SiO_4 and PO_4^{-3}-P using the methods by Strickland and Parsons (1972), Wood (1975) and Parsons *et al.* (1984).

For Chl-a, given amount of surface seawater was filtered through GF/C filter paper using the Milipore filtration system.

The analyses were carried using a UVD spectrophotometer (Bosch-Lomb Spectronic 21) according to the method by Strickland and Parsons (1972). The detection limits and precision of methods used were shown in Table 1.

Table 1: The detection limits and precision of methods used

Parameters	Precision	Detection limits
NO_3^--N	±0.2 μg at N L^{-1} (1 μg at N L^{-1} at 1.7 cm cell)	0.1-45 μg at L^{-1}
NO_2^--N	±0.2 μg at N L^{-1} (1 μg at N L^{-1} at 1.7 cm cell)	0.1-2.5 μg at L^{-1}
NH_4^+-N	±0.7 μg at N L (10 μg at N L^{-1} at 1.7 cm cell)	0.2-10 μg at L^{-1}
PO_4^{-3}-P	±0.03 μg at P L^{-1} (3 μg at N L^{-1} at 1.7 cm cell)	0.05-5 μg at L^{-1}
SiO_4	0.18 μg at L^{-1} (~4 μg at L^{-1}); ±9 (~150 μg at L^{-1})	0.26-400 μg at L^{-1}
Salinity	±0.05 psu	
Chl-a	±0.2 μg at N L^{-1}	0.2-50 μg Chl-a, b, c L^{-1}
Dissolved Oxygen (DO)	±0.3 mg L^{-1} (±0.2°C)	

RESULTS AND DISCUSSION

Physico-chemical parameters: In the study the minimum, maximum and average (±SE) values of the physico-chemical parameters related to the water samples from the Izmir bay are shown in Table 2.

Examination of salinity values showed that drops observed in the 1st quarter and 4th week of May were perhaps attributable to rainfall and/or river inflows. In addition, salinity increases in mid March and early May suggest that water discharge out of the treatment plant left the bay along the northern shores which is infact confirmed by the observation that of raphidophycean algae, *Olisthodiscus luteus* which grows in over saline water prevailed in and around the research area (TUBITAK, 2006).

Decreases found in salinity values in the 2nd week of July, the 1st forthnights of August and September and 1st and 3rd weeks of October are quite significant at St. 3 and may thus suggest a potential influence of fresh water from the treatment plant and/or rainfalls on the bay.

Table 2: The minimum, maximum and average values of the physico-chemical parameters related to the water samples from Izmir bay

	Station 1		Station 2		Station 3	
Parameters	Range	Mean±SE	Range	Mean±SE	Range	Mean±SE
Temperature	9.00-28.20	18.68±0.50	8.90-27.40	18.56±0.42	9.60-28.00	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	39.90±0.10
pH	7.400-8.60	8.03±0.01	7.50-8.70	8.08±0.01	7.50-8.600	8.09±0.01
DO	3.86-14.40	7.44±0.14	4.57-13.60	7.72±0.12	4.16-12.90	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	0.00-9.690	1.06±0.10
PO_4^{-3}-P	0.60-16.05	3.67±0.16	0.54-19.56	3.15±0.18	0.00-31.43	2.77±0.21
SiO_4	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
SiO_4/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

Temperature (°C), salinity (%), DO (mg L^{-1}), NH_4^+-N, NO_3^--N, NO_2^--N, PO_4^{-3}-P, SiO_4 (μM) and Chl-a (μg L^{-1})

However, increases observed in salinity in the 2nd week of August, the 1st week of October and November in 2003 and the 2nd week of January in 2004 were remarkable at St. 1, the reason for which is believed to be upwelling of bottom water up to surface. Such increases are occasionally seen at St. 2 as well.

Considerable increases in dissolved oxygen concentrations were observed in the 1st week of January, the 2nd of March, the 3rd of April, the 1st of May and the 3rd 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 2 were found to be below the oxygen saturation.

Increases seen in pH, one of physico-chemical environmental parameters between the 1 and 4th week of May were associated with those in Chl-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 3 and 4th weeks of August, 3rd week of September and last week of November, the general tendency to diminish in pH seems consistent with fall in dissolved oxygen saturation.

Minimum values of secchi disk values showed minimum levels down to 0.3 m measured in the 1st week of February and the 3rd week of June considering variations observed weekly.

The decrease in the 1st week of February was related to inorganic origin which is supposed to have emerged from inorganic particulate matter attributable to rainfalls. On the other hand, the decrease seen in June can be explained by phytoplanktonic biomass and POC increase in that period (TUBITAK, 2006).

The values of secchi disk measured from the 2nd half to November in particular remained quite stabilised with a drop at St. 1 following an increase and a rise at St. 3 and 2 and then a decrease by the end of the year.

Nutrients: One of parameter groups quite influencing lower trophic levels in aquatic ecosystems is nutrients. Accordingly, variable values of nitrogen forms, PO_4^{-3}-P and SiO_4 based on time and depth at the three stations in Izmir bay are discussed. Examination of the graphics goes to show that increases of NH_4^+-N and Si combination existed in surface waters off St. 1 in the 1st and last weeks of February, last week of April and 3rd week of June which might reflect influence of creeks in the area (Fig. 2). On the other hand, NH_4^+-N independently of Si, increased in surface waters around St. 3 in the 2nd week of January, the last of March the 1st 3 weeks of April and the 2nd week of June.

Increases of NH_4^+-N were related to waters around St. 1 and 2. Moreover, occasional minimal increases were significant at St. 3 as well in 2 and 3rd weeks of June the 1st week of September and 2nd week of November (Fig. 2-4).

However, examination of variations of NO_3^--N established related to time and depth at 3rd stations observed increases in the 1st week of January, 2nd of February, last of March, 1st and last of April and 1, 3 and 4th of June followed by small scale increases of NO_3-N in the 1st week of August, the 2nd of September and the 3rd of October by the end of the year which are all believed to have been caused by St. 1 and 2 (Fig. 2-4).

Melez stream-induced increases were generally observed in the 1st week of January, 2-3 of February, 3rd of March, 4th of April, May and 1-2 of June.

On the other hand, increases are caused by St. 1 and Karsiyaka except for observed decreases in the last 2 weeks of August, 1 and 3rd of September, the 1st 2 of October, 3rd of November and the last of December (Fig. 2).

Moreover, high values of NH_4^+-N, SiO_4, PO_4^{-3}-P, NO_3^--N from water off St. 1 in the 3rd week of June seem to be consistent with Chl-a increases (Fig. 2).

Increases in PO_4^{-3}-P in the 2-3 weeks of January, 1st and 3rd of March and the period between the last of May and last of June and those in 1st weeks of July and September and 3rd of October were observed in Karsiyaka (St. 2) and accounted for by surface water at St. 1 and 3 (Fig. 2-4).

Subsurface waters at St. 3 generally include lower PO_4^{-3}-P concentrations all the year round. It follows from all the graphics examined that phosphate shows quite different trends from NH_4^+-N and SiO_4 (Fig. 4).

Significant levels of SiO_4 were found during February, in the last week of April, the last 2 weeks of May and between the 1st and last of August. SiO_4 values measured at St. 3 were lower in general (Fig. 4). In addition to parallel increases observed in NH_4^+-N accompanied by SiO_4, two more increases emerged, representing deep water at St. 3 and 2.5 m in depth at St. 2 (Fig. 3) which suggests

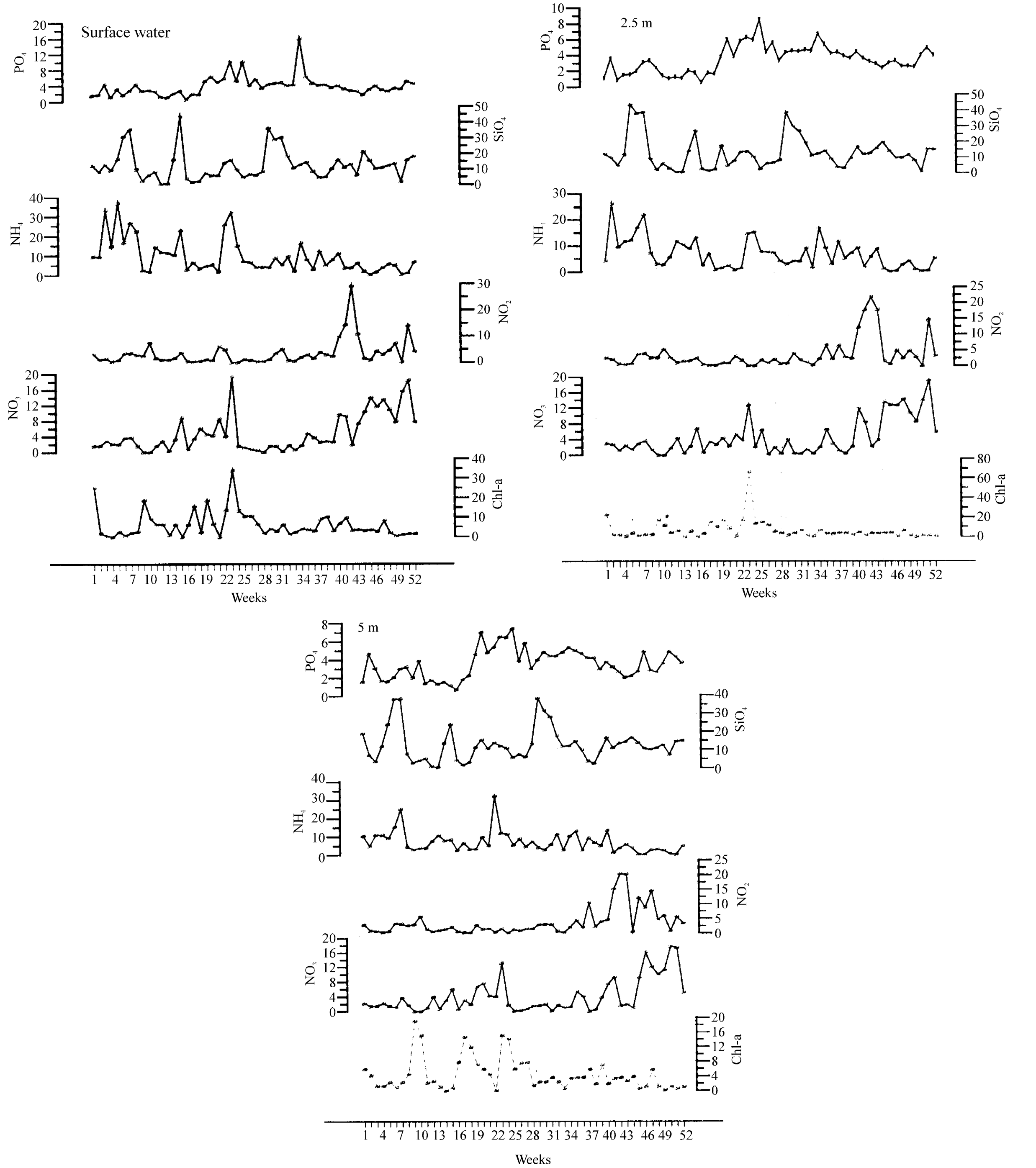

Fig. 2: Weekly variations of nutrients and Chl-a levels of St. 1 water column

presence of deep water as another source of SiO_4 (Fig. 4). Precipitation increased from 30.1-137 mm between the middle of January and 15th of February with SiO_4 concentration exceeding 40 μg at SiO_4 L^{-1} at St. 1. Level of Chl-a was significantly lower between the 2nd week of January and early March with absent diatom species (Parsons *et al*., 1984) which was also confirmed by the increase in SiO_4. Precipitation was <20 mm $week^{-1}$ until 3rd week of April, increasing up to >60 mm following the 4th of April. Despite SiO_4 concentrations being around 40 μg at SiO_4 L^{-1} again in this period, diatom population remained negligible (TUBITAK, 2006).

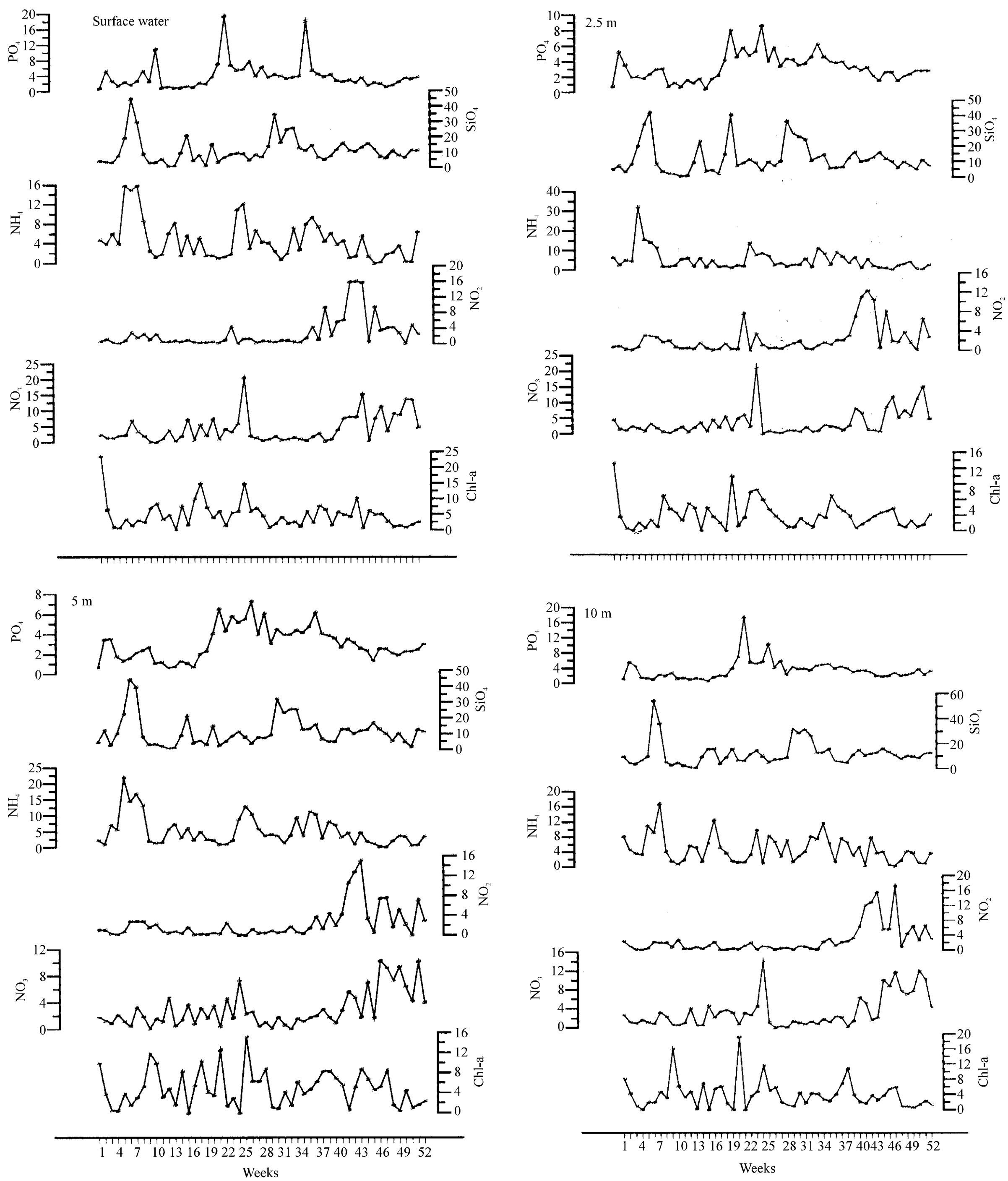

Fig. 3: Weekly variations of nutrients and Chl-a levels of St. 2 water column

Chlorophyll-a phaeopigment: Increases resulted from St. 1 and 2 in the 1st week of January, the 2nd of March and May and the 3rd of June and in the 5th of May, respectively (Fig. 2 and 3).

Considering the concentrations involved, the lowest and highest levels of Chl-a were observed at St. 3 (Fig. 4) and St. 1, respectively. In the weeks and areas phaeopigment concentrations increased (Fig. 2), Chl-a levels was low while chl a was high where phaeopigments decreased which indicates that microzooplankton grazing is of importance in spatio-temporal controlling of phytoplankton biomass. On the

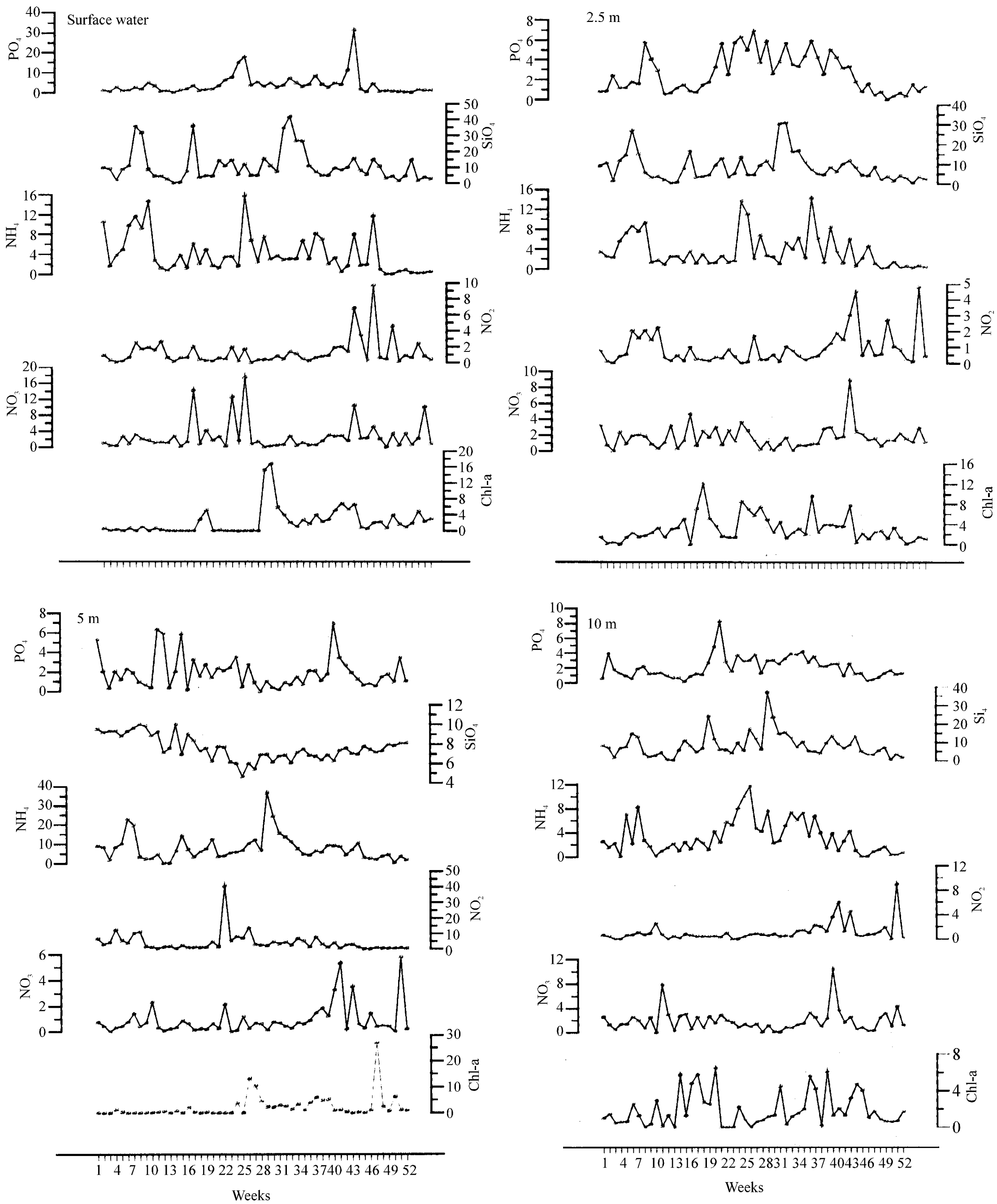

Fig. 4: Weekly variations of nutrients and Chl-a levels of St. 3 water column

other hand, values of chlorophyl a fluctuated <10 μg L^{-1} in the 2nd half of the year with in significant increases. Phaeopigmental variations observed at the 3rd stations all the year around showed significant fluctuations with the highest and lowest concentrations at St. 2 and 3, respectively.

Statistical evaluation: When the 3 stations were inspected regarding their phosphate and SiO_4 values, significant statistical differences were found between them (ANOVA, F-value: 22.08, 10.91 p-value: 0.000, $p<0.05$, respectively). Concerning the multiple range test results while St. 2 and 1 were similar, St. 3 indicated remarkable differences. NO_3^--N, NO_2^--N and NH_4^+-N values of the 3 stations also showed significant differences (ANOVA, F-value : 17.99, 38.29, 29.57 p-value: 0.000, $p<0.05$, respectively). The multiple range test results found that all the 3 stations differed from each other.

Comparison of 3 stations in terms of silicate values indicated that there were statistical differences between them (ANOVA, F-value: 10.91, p-value: 0.000, $p<0.05$). Consequences of multiple range test showed similar properties in St. 1 and 2 while those of St. 3 were different from them.

The Chl-a values also show differences between the stations (ANOVA, F-value : 18.63, p-value: 0.000, $p<0.05$). As for the multiple range test results, St. 2 and 1 are close however, St. 3 statistically varies from the both.

A strong relationship between PO_4^{-3}-P and NH_4^+-N values were found in St. 3 ($r = +0.4878$, $n = 208$ $p<0.05$). At the same station a relationship between the Si and NH_4^+-N concentrations was found ($r = +0.4201$, $n = 208$, $p<0.05$). At St. 3, Si and PO_4^{-3}-P values are also partially associated with each other ($r = +0.3964$, $n = 208$, $p<0.05$). St. 2 shows a strong relationship between NO_2^--N and NO_3^--N ($r = +0.4172$, $n = 208$, $p<0.05$).

As a result with the introduction of the waste water treatment plant, a decrease in the nitrogen and Chlorophyll-a levels was found. However, there is no such evidence regarding the phosphate levels.

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. About 18.4% of them is to a great extent governed by DO, Chl a, salinity and nitrit. About 12.6% is mostly controlled by SiO_4 and NH_4^+-N whereas 11.3% generally by NO_3^--N (Fig. 5).

All variables of PCA made for St. 2 were defined as four major components at St. 1 which explained for 62% of total variance. About 21% of it often depends on temperature, phosphate and DO whereas its 17.4% is mostly controlled by NO_2^--N, NO_3^--N, pH. About 14% of variance is found to be accounted for by NH_4^+-N and Si while its 9.6% is to a great degree under the control of phaeopigment, salinity and Chl-a (Fig. 6).

All variables were described as four major components at St. 3 which explained for 61.2% of total variance. About 25.2% of total variance is generally explained by temperature, phosphate, oxygen and phaeopigment NO_3^--N is seen to be responsible for 14.9% of it whereas its 11.8% is basically governed by salinity, Chl-a and NO_2^--N. On the other hand 9.3% of total variation is mostly controlled by Si and NH_4^+-N (Fig. 7).

Inorganic nutrients, especially PO_4^{-3}-P, NO_3^--N and SiO_4 have a major influence on phytoplankton community structure and biomass in aquatic environments (Heip *et al*., 1995; Hessen, 1999; Underwood and Kromkamp, 1999).

The fact that the processes affecting PO_4^{-3}-P and TIN occur at different times indicates significant changes 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 processes have been gathered as follows: Inflow from the creeks is especially evident during rainfall and there is a big

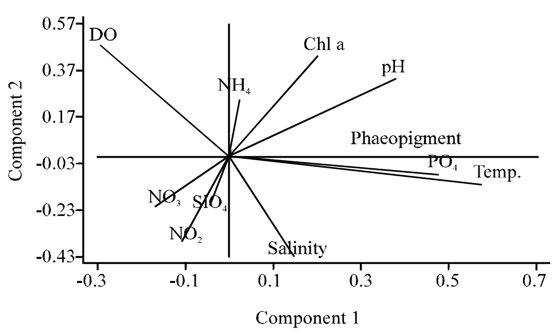

Fig. 5: PCA graphic of St. 1

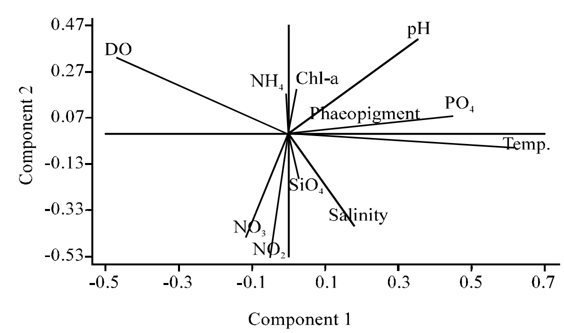

Fig. 6: PCA graphic of St. 2

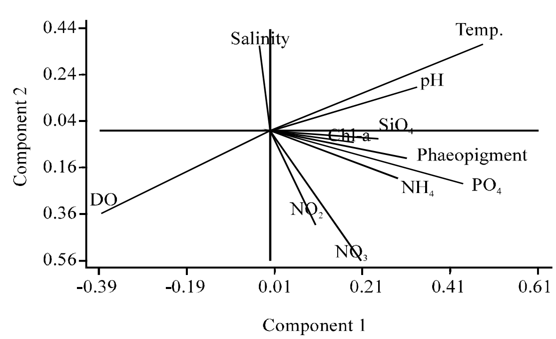

Fig. 7: PCA graphic of St. 3

Table 3: Minimum and maximum concentrations of nutrient and Chlorophyll-a in Izmir bay and Aegean sea from different studies

Locations	Period	NO_3^- (μM)	NO_2^- (μM)	NH_4^+ (μM)	SiO_4 (μM)	RP (μM)	Chl-a (μg L^{-1})	References
Inner part of Izmir bay	1993-1994	BDL-3.04*	BDL-4.65*	0,12-468*	-	0.36-49	BDL-189	Kontas *et al*. (2004)
Middle part of Izmir bay	1993-1994	BDL-3.49	BDL-3.57	BDL-44	-	0.06-3.79	0.5-62	Kontas *et al*. (2004)
Outer part of Izmir bay	1993-1994	BDL-4.91	BDL-0.16	BDL-1111	-	BDL-6.42	BDL-2.95	Kontas *et al* (2004)
Inner part of Izmir bay	1993-1994	BDL-3.11	BDL-4.65	BDL-468	-	0.18-49	BDL-189***	Bizsel and Uslu (2000)
Candarli 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	Aksu *et al*. (2010)
Middle-inner part of Izmir bay	1996-1998	0.13-27	0.01-18	0.10-21	0.50-39.00	0.01-10	0.10-26	Kucuksezgin *et al*. (2006)
Middle-inner part of Izmir bay	2000	0.15-18	0.02-12	0.13-34	0.43-20.00	0.13-3.8	0.46-18	Kucuksezgin *et al*. (2006)
Middle-inner part of Izmir bay	2001	0.29-16	0.02-4.3	0.11-50	1.2-18.000	0.14-2.9	0.38-7.8	Kucuksezgin *et al*. (2006)
Middle-inner part of Izmir bay	2002	0.26-6.7	0.01-6.1	0.10-6.7	1.0-26.000	0.14-4.4	0.13-3.7	Colak-Sabanci and Koray (2001)
Gerence bay (Aegean sea)	2002	0.04-2.19	BDL-2.51	BDL-3.53	-	BDL-2.82	BDL-0.320	Gencay and Buyukisik (2006)
Middle-inner part of Izmir bay	2003	0.12-8.6	0,01-1,0	0.12-2.4	2.60-32.00	0.32-4.5	0.24-2.6	Colak-Sabanci and Koray (2001)
This study	2003	BDL-21.35	BDL-28.99	BDL-40.94	0.16-54.12	BDL-31.43	BDL-66.13	This study

*Min-Max; **Average value; ***Data from Metin; BDL: Below Detection Limits

increase in SiO_4 and N forms which tends to restrict SiO_4 and N inflows into environment where fresh water inflows caused by precipitation have decreased due to global warming. Treated water from the treatment plant is another source of nutrient loss with N/P ratios being around <=2. PO_4^{-3}-P induced by treated water is apt to contribute to PO_4^{-3}-P reserves in Inner bay.

The winds although, increasing fresh water inflow and water column, frequently carry the deep water to the surface which shows that the inner bay is often exposed to a deep water-based nutrient enrichment.

Because water in the inner bay of Izmir takes 10 days to flow around the whole bay back into outer bay due to the present current system in the inner bay, nutrient load induced by various sources is the major reason for plankton bloom observed therein.

SiO_4 is essential for the diatoms to effectively compete with dynophylagellates and plays an important role in increase of the species in the bay. Thus the nutrient caused by rainfalls ashore in non-point and point sources (i.e., creeks and rivers) is of great importance for the inner bay.

Eutrophication is caused by farming processes in and around water sheds of rivers and high levels of nutrients from stock breeding nurseries to rivers due to precipitation.

With the treatment plant being introduced, previous reseach, ecological model studies and scenario estimations have found that light transperancy in water column has significantly increased. However, considerable decreases in light transperancy during given periods of the year such as Summer months have been observed to appear due to exceptional bloom of opportunistic phytoplanktonic species.

Because much of phytoplanktonic species is more difficult to be grazed by zooplanktonic organisms, they tend to increase in number in water column during both Summer and Winter months and therefore, their rapid sedimentation on the sediment makes the processes in it important and enables manure necessary to be formed for their next bloom with much of the nutrients flown into the Inner bay remaining there (TUBITAK, 2006). The researchers believe that unless nutrient levels are reduced in rivers the bay could maintain its present undesirable position for long periods of time. Although, a decrease has been observed in the nitrogen nutrients after the introduction of the waste water treatment plant, former studies have shown that the phosphate concentrations have not changed and that the plant has been ineffective on the matter (Kucuksezgin *et al*., 2006; Kontas *et al*., 2004; Kukrer and Aydin, 2006). In addition the treatment process would be a good precaution against new strategies which phytoplanktonic organisms might develop thus enabling a second nutrient (PO_4^{-3}-P) to be efficiently treated and dumped away in the process.

N/P relations show that almost all the year round the relation is <16 and that nitrogen is the limiting nutrient. In addition, Buyukisik and Erbil reported that nitrogen compounds become much more limiting based on their loss in Izmir inner bay to atmosphere and rapid regeneration of phosphate which we suppose could maintain the present process for a long time unless nutrient levels are not reduced. Moreover, efficient treatment of another nutrient (PO_4^{-3}-P) would be a good precaution against new strategies which phytoplankton could develop despite decreased TIN.

The phytoplankton blooms caused by the inflow of nutrients to the inner bay in turn result in the intake of nutrients by the phytoplankton (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.

Table 3 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. Construction of the waste water Treatment Plant 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 after waste water activated sludge technology plant except sudden and uncontrollable discharge while PO_4^{-3}-P concentrations were increased in the bay. In the middle and inner parts of the bay, Chl-a concentration has been gradually reduced after treatment.

CONCLUSION

In this study, researchers 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.

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