

# WATER POLLUTION MONITORING STUDY FOR THE PROTECTED AREAS IN EASTERN MEDITERRANEAN SEA, TURKEY

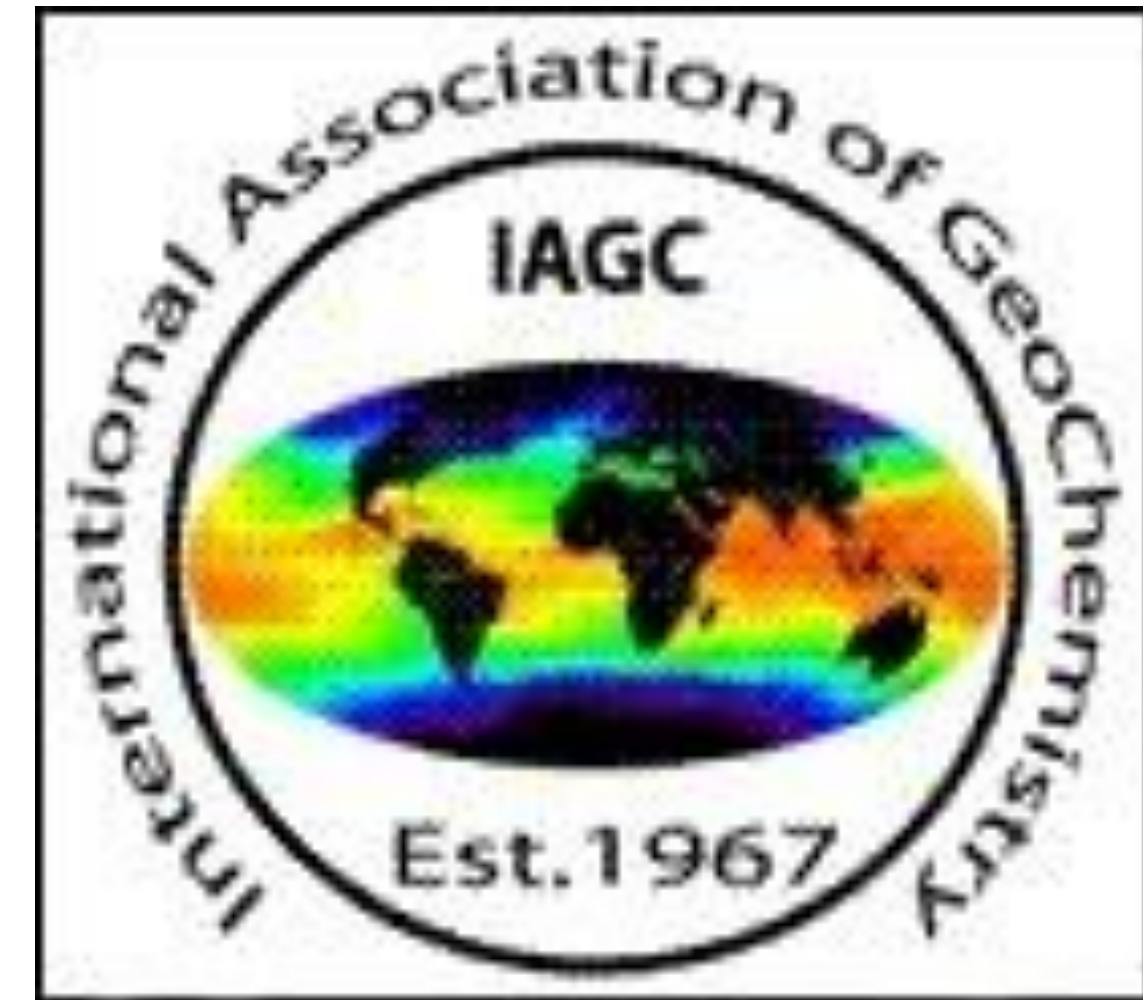
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## ABSTRACT

The aim of this research is to supply vital information for decision making on the use of natural resources and also to help to take compulsory and sufficient measures for protected areas of Belek, Patara and Kekova at the eastern Mediterranean Sea, Turkey. The study area is between Manavgat and Eşen Çay at the eastern Mediterranean Sea which is located in western and central part of the Taurides. It is necessary to get a sustainable amount of data by the measurements of physical, hydrogeochemical and microbiological parameters for 12 locations in these areas on surface and sea waters. Within the study, (i) in-situ measurements and sampling for hydrogeochemical and microbiological analyses in 12 locations of the area of surface and sea waters and (ii) hydrogeochemical and microbiological analyses were realized monthly. These measurements and analyses were evaluated and interpreted in comparison to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper

## 1. Introduction

The Authority for the Protection of Special Areas within the Ministry for Environment and Forestry of Turkish Republic desires to protect the natural resources and to prevent water pollution within the certain SEPRs (special environmental protection region). To help the various decisions about resource and to take sufficient protection measures, the ministry needs information and, for this purpose, a research contract signed by The authority for the protection of special areas within the Ministry for Environment and Forestry of Turkish Republic and Süleyman Demirel University, Isparta for the area of surface waters (Acısu, Sarısu, Köprüçay and Eşen Çay within Manavgat and Patara) and some marine sites (Çolaklı, Gündoğdu, Evrenseki, Gelemiş and Uçağiz) shown in Figure 1. In order to protect the pollution and disappear of natural resources in areas of surface and sea waters of Protection of Special Areas Belek, Patara and Kekova, it was aimed, (i) to take compulsory and sufficient measures and (ii) to develop various use decisions for these resources. Therefore, it was necessary to form a sustainable data bank by the measurements of physical, hydrogeochemical and microbiological parameters in areas of surface and sea waters.

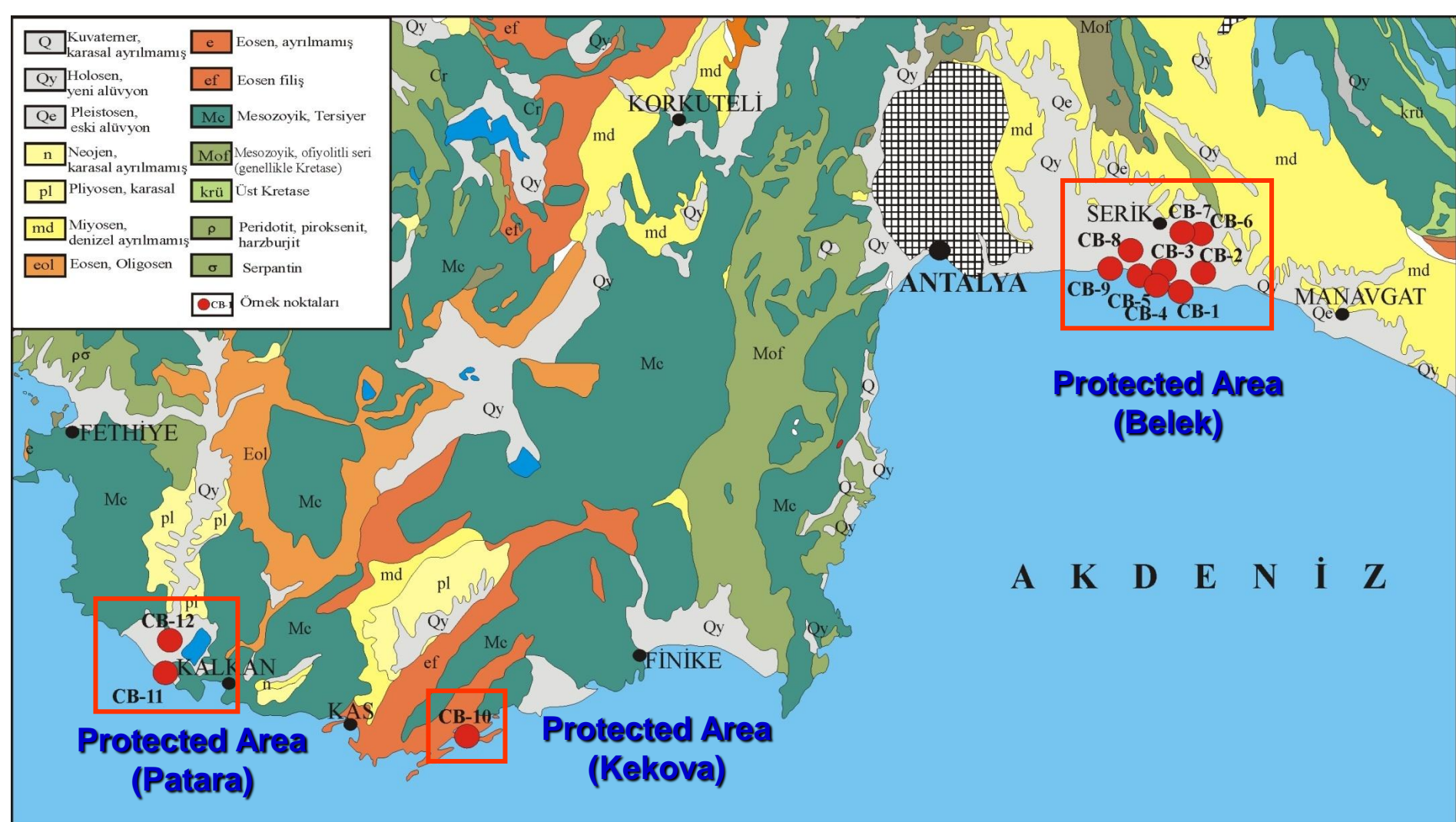


Fig. 1. Geological map of the protection of special areas and sampling locations in the area of surface and sea waters (compiled from Erentöz and Pamir, 1963 and Erentöz, 1964).

## 2. Sampling and Laboratory methods

For in-situ measurements, carried out at the field during May-December 2004, the following methods and instruments were used: (i) Testo 915-1 thermometer for temperature measurements, (ii) WTW pH 95 and pH 330i for pH and Eh measurements, (iii) WTW Oxi 320 ve 340 for measurements of dissolved oxygen and WTW LF 95, Cond 340i and Hach 44600 for measurements of electrical conductivity and total dissolved solids (TDS). Samples taken for hydrogeological analysis were carried into laboratory with polypropylene bottles of 250 and 100 ml. Samples for microbiological analysis were filled into sterilized glass bottles, protected against sun light and carried to the laboratory. The Merck Spectroquant Nova 60 was used for measurements of color, turbidity,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\Sigma\text{PO}_4$ , BOD and COD at the Research and Application Centre for Geothermal Energy, Groundwater and Mineral Resources. Thermoreactor – Merck Spectroquant TR 320 was used for COD analysis additionally. In addition, turbidity measurements were done by WTW Turb 550.  $\text{Ca}^{2+}$ ,  $\text{Na}^+$  and  $\text{K}^+$  analyses in samples of the areas surface and sea waters were realized by flame photometer (Jenway PFP 7). Merck Spectroquant Nova 60 was on duty for  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  and  $\text{NO}_3$  analyses. The values of  $\text{HCO}_3^-$  and  $\text{CO}_3^{2-}$  were calculated by Merck alkalinity and acidity tests.

## 3. Geology and Hydrogeology

The study area between Manavgat and Eşen Çay is located in the western and central parts of Taurides (Fig. 1; Özgür et al., 2004) and has, in general, undifferentiated rock series of Mesozoic to Tertiary and Upper Cretaceous of ophiolites. The locations of Çolaklı, Boğazkent and Gündoğdu which have been determined for periodical measurements in water samples are composed by alluvial (beach) sediments of Holocene whereas the area of Kekova and Uçağiz is overlain by Eocene flysch series. The area of the locations Acısu, Sarısu, Köprüçay and Eşen Çay are composed of Holocene alluviums. The rivers in the study area arise from the southern parts of the Taurides. These rivers make suitable drainage system in the area and flow into the Mediterranean Sea. The rivers and groundwaters pass through ophiolites, limestones, flysch series and conglomerates, carry the dissolved ions reasoned by rock-water interactions into the sea waters.

## 4. In-situ measurements and hydrogeochemical analyses

As mentioned in labor contract, in-situ measurements in formerly determined 12 locations (10+2) of areas of surface and sea waters have been completed within the field works from May to December 2004 monthly (Özgür et al., 2004). Besides the coordinates of the in advance determined locations, the parameters of surface and sea waters, i.e. temperature, pH, Eh, color, odor, taste, value of dissolved oxygen and total dissolved solids were measured in situ. In addition, the sampling of surface and sea waters for turbidity,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\Sigma\text{PO}_4$ , BOD ve COD and microbiological analyses (fecal and total coliform) were performed.

### 4.1 Area of surface waters

The waters in this area are surface waters with temperatures ranging from 11,5 to 29,5 °C during May to December 2004 (Fig. 2; Özgür et al., 2004). The low and high temperature values are related with seasonal effects emerged by summer and winter times. These measured temperature values are evaluated and interpreted according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper", and the measured waters can be classified as high quality waters less polluted waters. During May to December 2004, the pH values change from 7,17 to 8,42 (Fig. 3; Özgür et al., 2004) which correspond with standard values of pH ranging from 6,5 to 8,5 according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". In this manner, these waters can be considered as (1) first class waters (high quality waters), (2) second class waters (less polluted waters) and (3) third class waters (polluted waters). Color values in the area of surface waters range from <0,5 to 16,4 ( $\text{m}^{-1}$ ) during May to December 2004 (Fig. 3; Özgür et al., 2004) which can be interpreted as high values in comparison to sea waters. The turbidity in area of surface waters is distinguished by values ranging from <1 to 69 FAU during May to August 2004 and from 3,43 to 304,0 NTU during September to December 2004 (Fig. 3; Özgür et al., 2004). During May to December 2004, dissolved oxygen shows values from 1,66 to 10,04 (mg/l) (Fig. 3; Özgür et al., 2004) corresponding to 8 (mg/l) of the values of high quality waters and 6 (mg/l) of less polluted waters. In comparison, two locations (CB-2 and CB-3), which have been sampled and analyzed out of contract signed by both partners, show low dissolved oxygen values during July 2004 and lower values of same ions during August to October 2004 which can be led to increase of fecal coliform number. Ammonium nitrogen ( $\text{NH}_4\text{-N}$ ) values change from <0,03 to 21,50 (mg/l) during May to December 2004 (Fig. 3; Özgür et al., 2004). In locations of CB-2 and CB-3, which are out of contract,  $\text{NH}_4\text{-N}$  shows values 14,2-0,8 (mg/l) (May 2004), 7,72- 0,75 (mg/l) (June 2004), 7,75-6,75 (mg/l) (July 2004), 0,06-0,97 (mg/l) (August 2004), 6,60-0,13 (mg/l) (September 2004), 21,50- 0,29 (mg/l) (October 2004), 5,17- 0,15 (mg/l) (November 2004) and 0,82- 0,61 (mg/l) (December 2004). With exception of values of CB-2 and CB-3, the values are of 0,6-1,6 (mg/l) (May 2004), 0,08-0,70 (mg/l) (June 2004), 0,07-0,36 (mg/l) (July 2004), <0,03-0,46 (mg/l) (August 2004), 0,07-1,80 (mg/l) (September 2004), 0,05-2,40 (mg/l) (October 2004), 0,10-0,53 (mg/l) (November 2004) ve 0,12-0,86 (mg/l) (December 2004) which can be considered as high quality waters and less polluted waters according "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". In comparison, a less number of waters can be assigned to the less polluted waters (second quality waters) and polluted waters (third quality waters). The periodical measurements show that the waters in locations of CB-2 and CB-3 are polluted with  $\text{NH}_4\text{-N}$  in an advanced phase and can be considered high polluted waters (fourth class waters). The waters have  $\text{NO}_3\text{-N}$  values changing from <0,010 to 1,240 (mg/l) (Fig. 4; Özgür et al., 2004) during May to December 2004 and can be classified as high quality waters and high polluted waters according "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". During May to December 2004, the waters show  $\text{NO}_3\text{-N}$  values ranging from 0,28 to 6,30 (mg/l) (Fig. 4; Özgür et al., 2004) and belong to high quality waters and less polluted waters according "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". The waters are distinguished by total  $\text{PO}_4$  values ranging from <0,5 to 22,3 (mg/l) and can be considered as high quality waters and less polluted waters according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper" with exception of locations of CB-2 and CB-3. Total  $\text{PO}_4$  value of 22,3 mg/l at CB-2, measured on August 2004, seems to be associated with agricultural fertilizing and waste materials from the area of hotels.

During May to December 2004, the waters show total dissolved solids changing from 185,6 to 3745,0 mg/l (Fig. 5; Özgür et al., 2004) and can be attributed to high quality waters and less polluted waters according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". In the location, in which a high value of 3745 mg/l was measured, there is a sea water intrusion. BOD values in waters change from 0,1 to 40,9 mg/l during May to December 2004 (Fig. 5; Özgür et al., 2004). These waters can be considered as high quality waters and high polluted waters according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". A great number of these waters can be assigned to high quality waters and less polluted waters. The waters in the area show COD values between 7,6 and 132,0 mg/l (Fig. 5; Özgür et al., 2004) and are of high quality waters and high polluted waters according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". A great number of these waters can be assigned to high quality waters and less polluted waters.

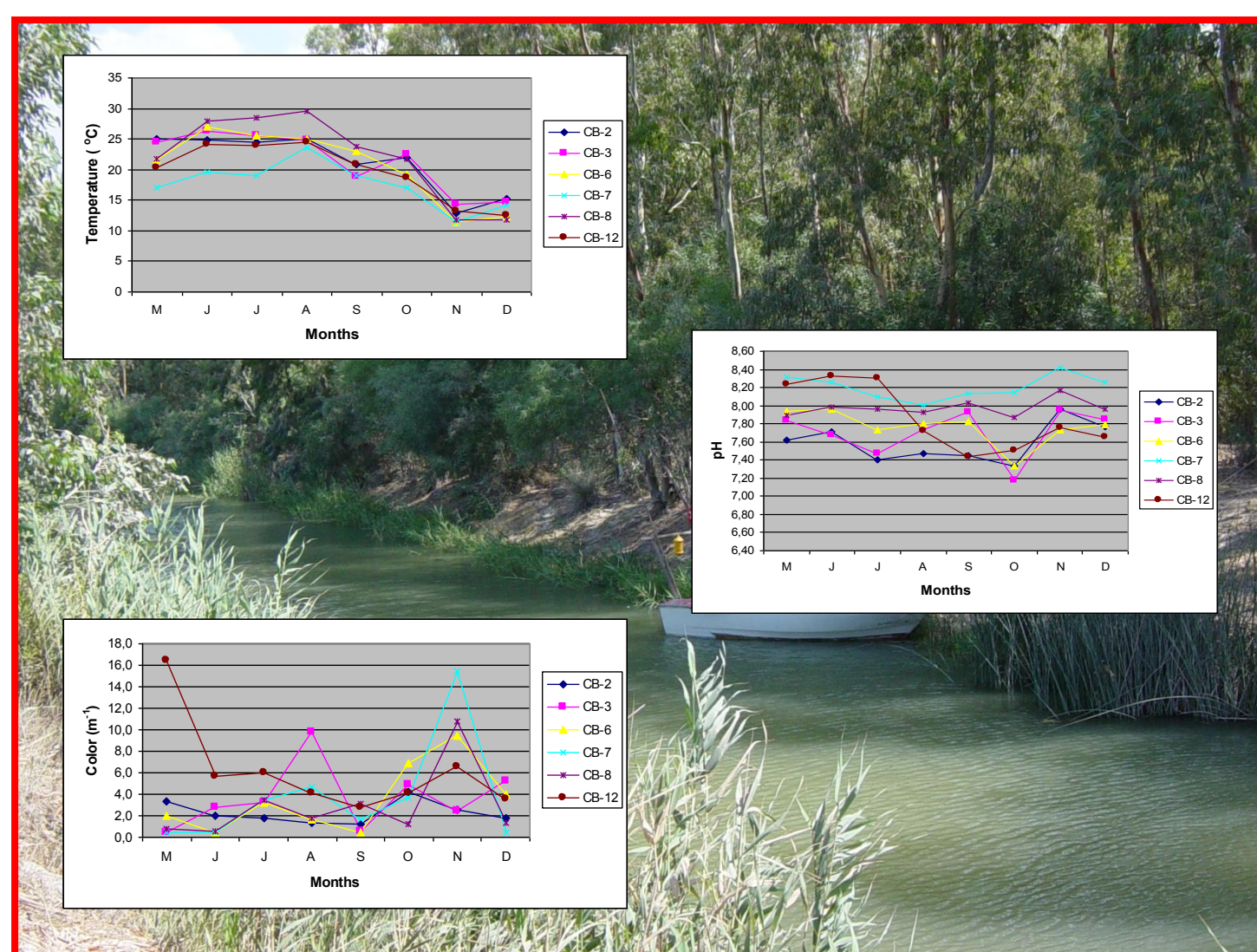


Fig. 2: Changing of temperature, pH and color of samples in area of surface waters from May to December 2004.

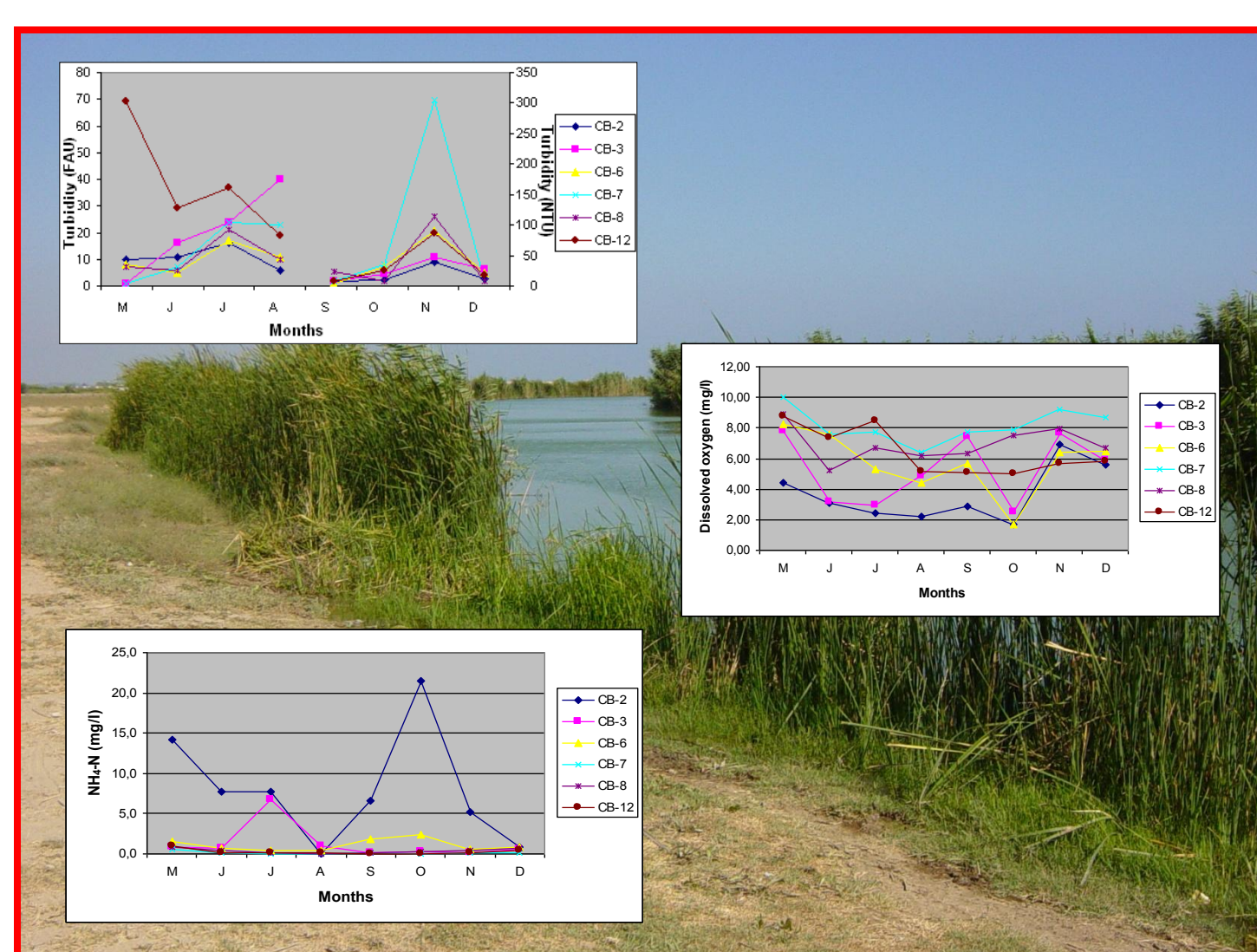


Fig. 3: Changing of turbidity, dissolved oxygen and ammonium-nitrogen of samples in area of surface waters from May to December 2004.

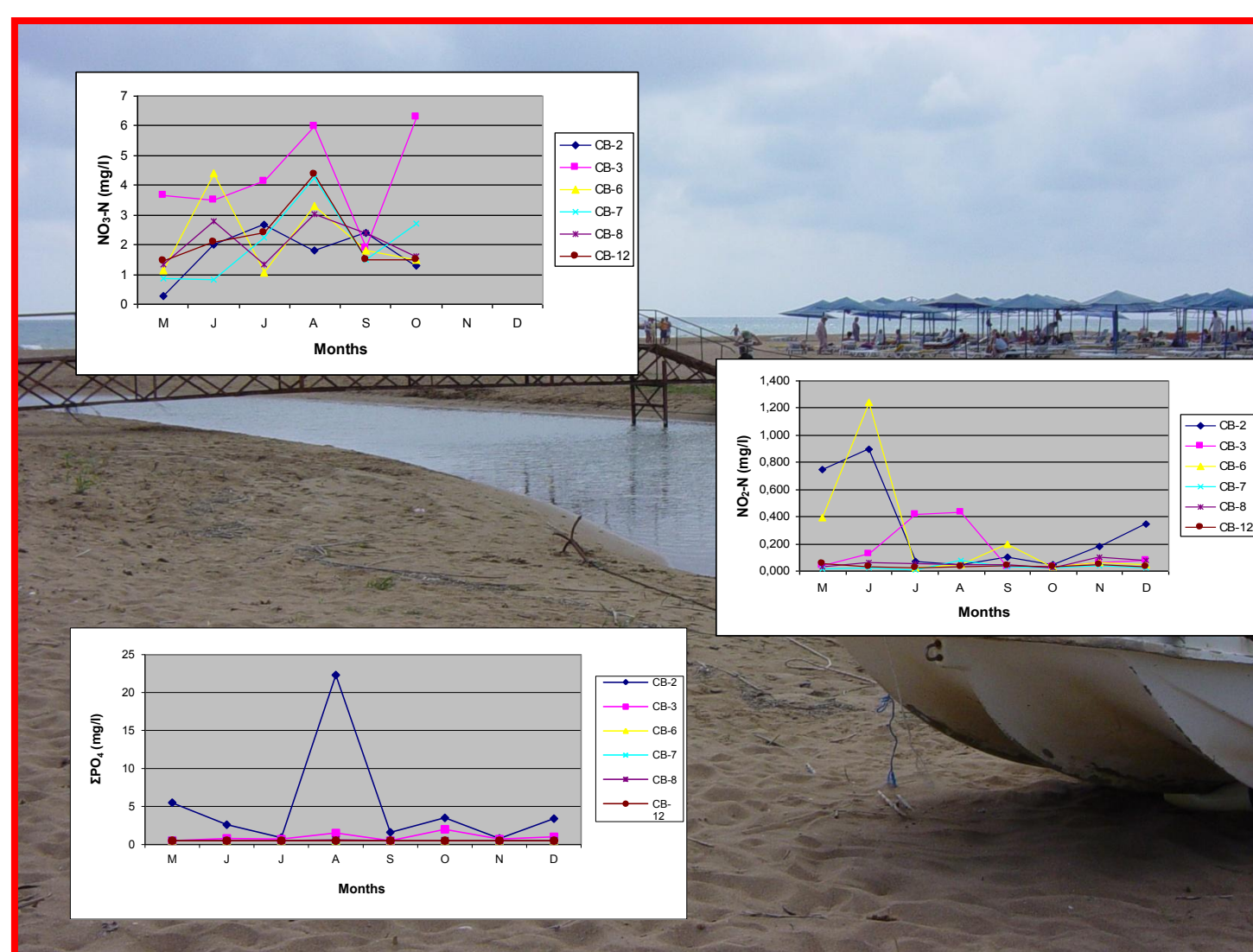


Fig. 4: Changing of  $\text{NO}_3\text{-N}$ ,  $\text{NO}_2\text{-N}$  and  $\Sigma\text{PO}_4$  of samples in area of surface waters from May to December 2004.

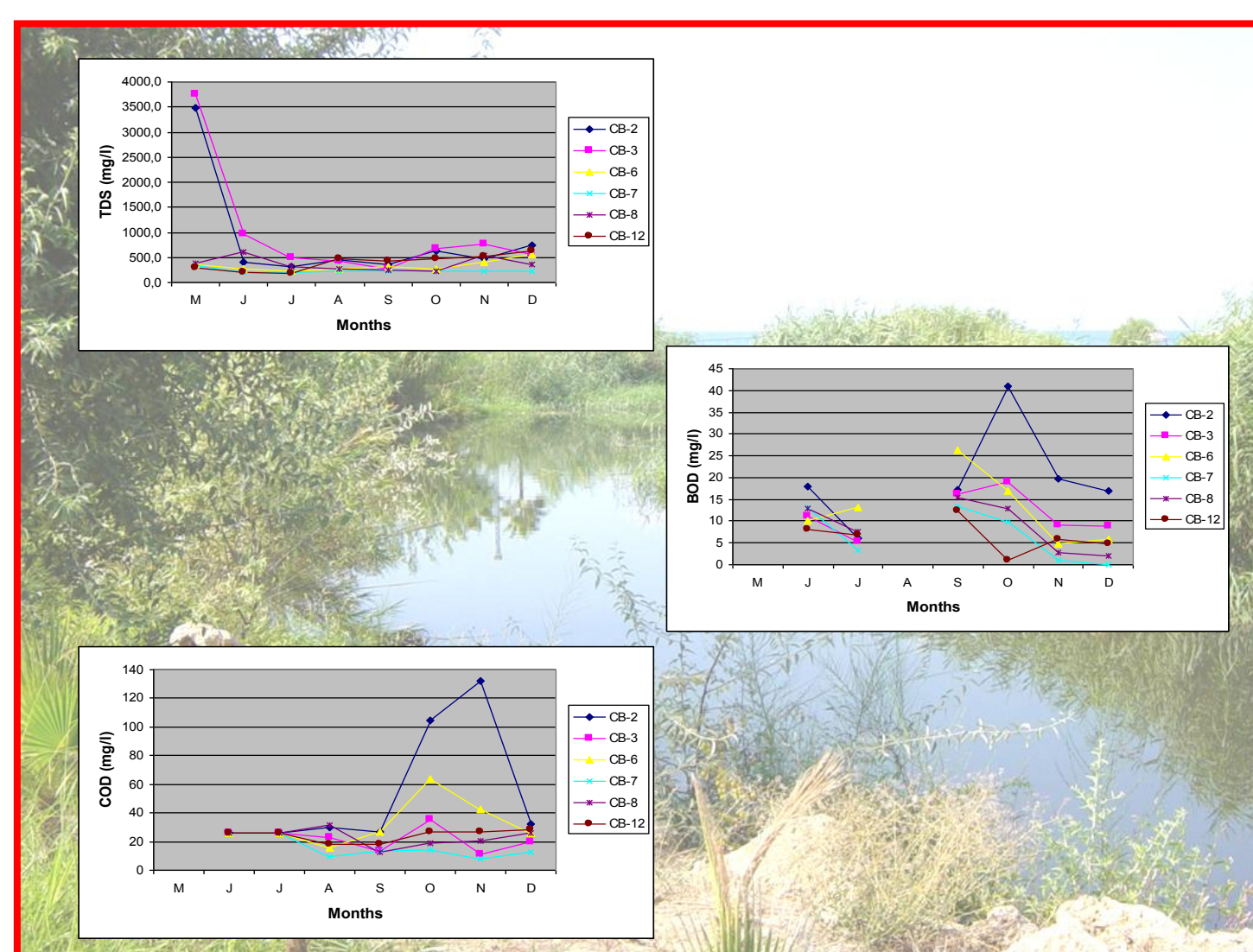


Fig. 5: Changing of TDS, BOD and COD of samples in area of surface waters from May to December 2004

### 4.2 Area of sea waters

The water temperatures in area of sea waters range from 14,8 to 30,3 °C (Fig. 6; Özgür et al., 2004) depending upon seasonal temperatures with increasing and decreasing values during May to December 2004. From May to December 2004, pH values change from 7,94 to 8,31 (Fig. 6; Özgür et al., 2004). These values correspond to the standards of sea waters using for recreation. During May to December 2004, color values between <0,5 and 26,5 ( $\text{m}^{-1}$ ) were measured (Fig. 6; Özgür et al., 2004) which can be considered as standard values. The value of 26,5  $\text{m}^{-1}$  at CB-11, measured on November 2004, is high depending upon extremely high waves of sea waters which can be confirmed by extremely high turbidity values. The sea waters area distinguished by turbidity values between <1 and 17 FAU during May to August 2004 and 1,05 and 429 NTU from September to December 2004 (Fig. 7; Özgür et al., 2004). These values can be considered as standard values. In consideration of standard values of sea waters using for recreation, the parameters of odor and taste in 12 locations can be considered as natural odor and taste from May to December 2004. Light permeability in the samples of sea waters ranges from % 4,06 to 99,54 during May to December 2004 (Fig. 7; Özgür et al., 2004). The low values in these waters are associated with turbidity of sea waters which can be confirmed by the measurements at CB-11 and CB-5 on November 2004. In comparison, a great number of measurements lie between % 80 and 99,5. Dissolved oxygen values in sea waters change from 5,50 to 9,22 mg/l (Fig. 7; Özgür et al., 2004) which show a mean value of 70-80 % oxygen and correspond to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper".

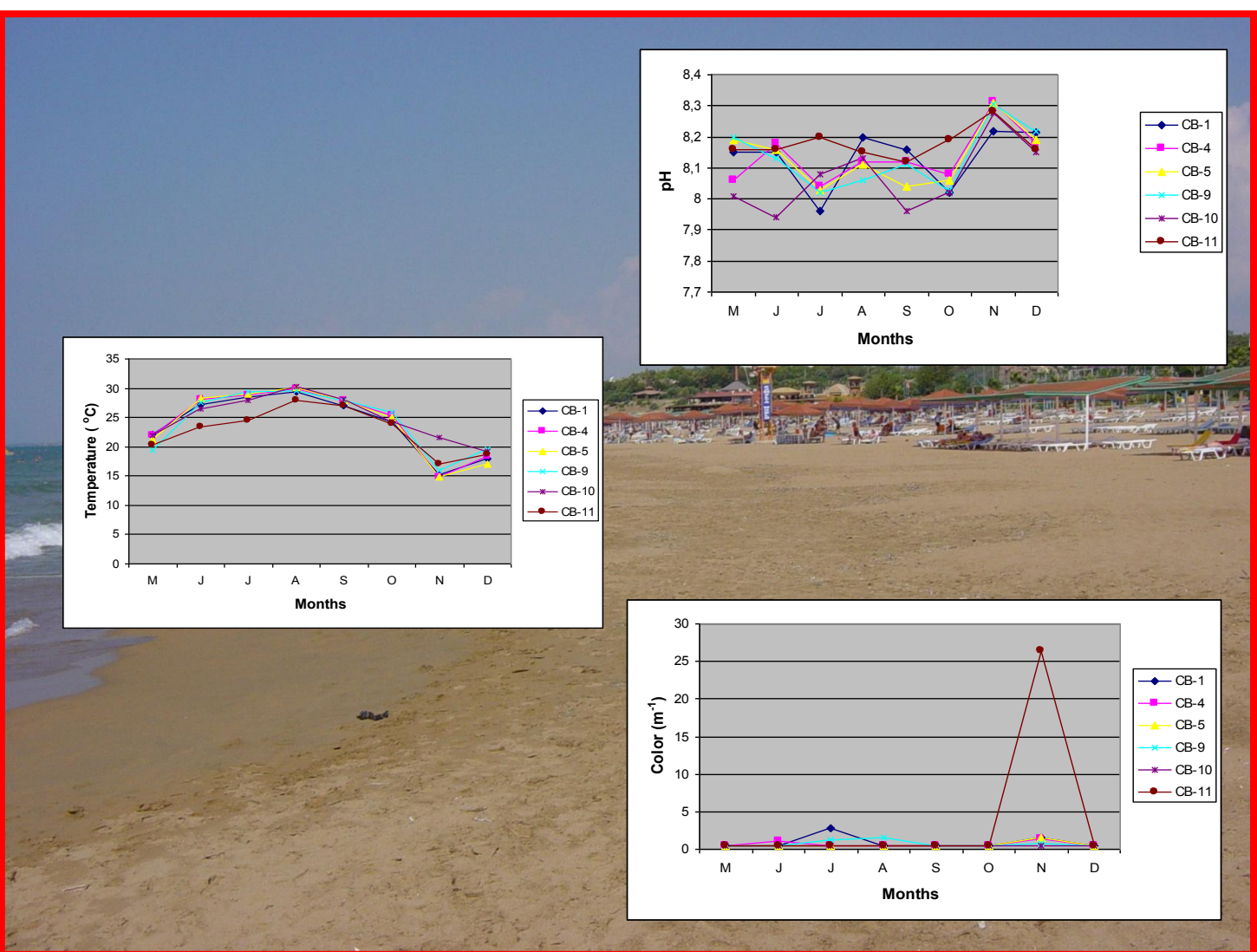


Fig. 6: Changing of temperature, pH and color of samples in area of sea waters from May to December 2004.

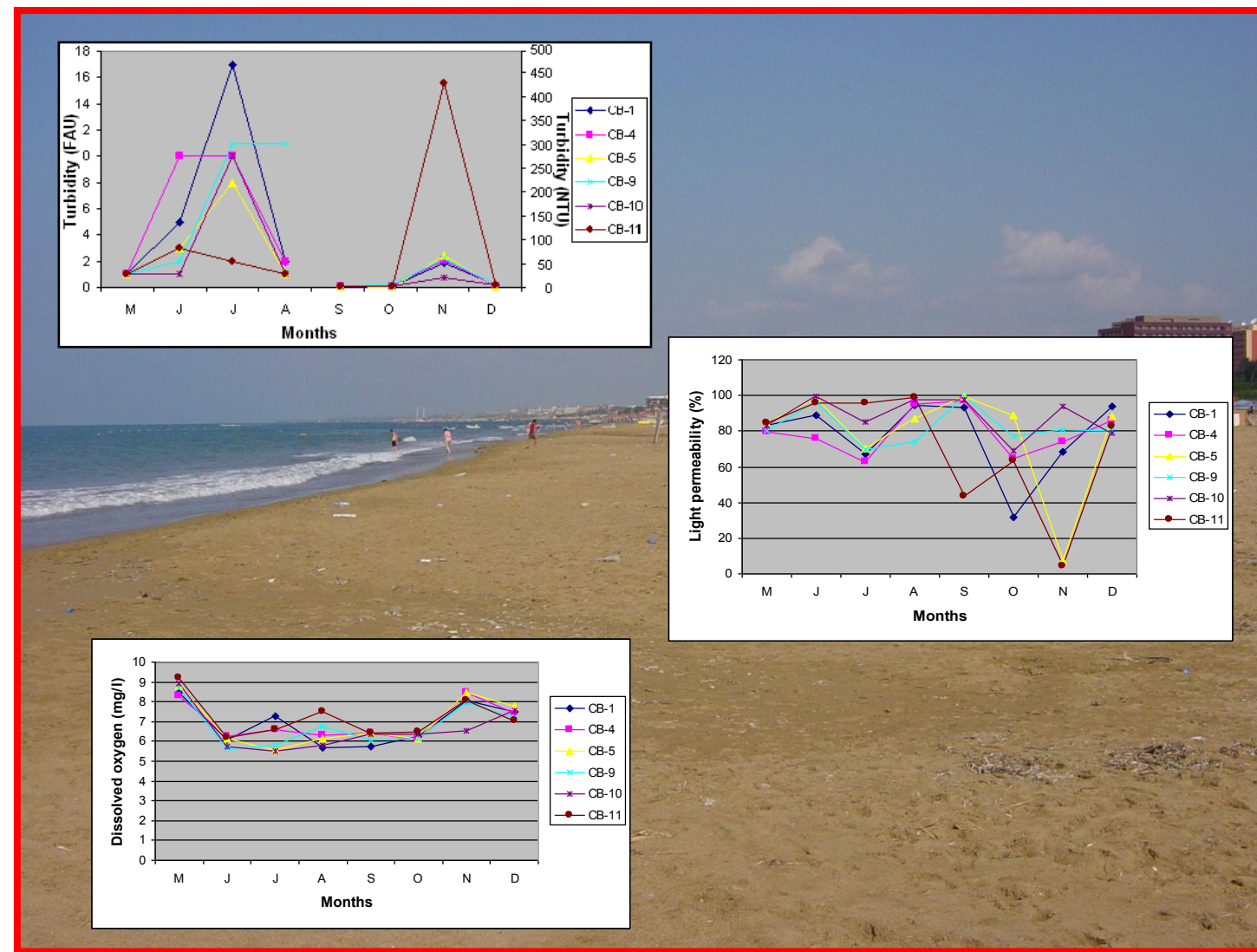


Fig. 7: Changing of turbidity, light permeability and dissolved oxygen of samples in area of surface waters from May to December 2004

## 5. Bacteriological analyses

Bacteriological fecal coliform and total coliform analyses were done during May to June 2004 by using Millipore method. In this method, fecal and total coliforms in water samples taken in aseptic conditions were determined, but it was not possible to count fecal and total coliforms. Therefore, the values of fecal and total coliforms were determined using by method "most probable number" (MPN) from July 2004 (Özgür et al., 2004). The number of fecal coliforms in area of surface waters are between 0 and 6 MPN/100 ml (July 2004), 0 and 33 MPN/100 (August 2004), 19 and 1350 MPN/100 (September 2004), 4 and 8500 MPN/100 ml (October 2004), 45 and 790 MPN/100 ml (November 2004) and 10 and 940 MPN/100 ml (December 2004) (Fig. 8). These coliforms in area of sea waters area of 0-2 MPN/100 ml (July 2004), 0-40 MPN/100 ml (August 2004), 0-22 MPN/100 ml (September 2004), 0-27 MPN/100 ml (October 2004), 2-130 MPN/100 ml (November 2004) and 0-140 MPN/100 ml (December 2004) (Fig. 9). Total coliforms in area of surface waters are of 120-5400 MPN/100 ml (July 2004), 700-17.000 MPN/100 ml (August 2004), 920-16.000 MPN/100 ml (September 2004), 1200-80.000 MPN/100 ml (October 2004), 1100-27.500 MPN/100 ml (November 2004) ve 225-92.000 MPN/100 ml (December 2004) (Fig. 9). Total coliform values in area of sea waters area distinguished by 0-130 MPN/100 ml (July 2004), 0-350 MPN/100 ml (August 2004), 0-350 MPN/100 ml (September 2004), 0-220 MPN/100 ml (October 2004), 49-1700 MPN/100 ml (November 2004) ve 0-5400 MPN/100 ml (December 2004) (Fig. 9). The values of total coliforms in area of sea waters are correspond with standards of sea waters using for recreation ("Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper"). The locations of CB-2, CB-3 and CB-6 in area of surface waters are distinguished by high values of fecal and total coliforms. As mentioned in interim reports, the values of the locations CB-2 and CB-3 are associated with civilization in the hotels. Therefore, the high values of total coliforms can be attributed to this civilization in the environment of hotels. Moreover, the high value at CB-6 can also be led to the civilization there. In the area of surface waters, there is a such contamination which can be continued in future. In the area of sea waters, the pollution could not be determined generally.

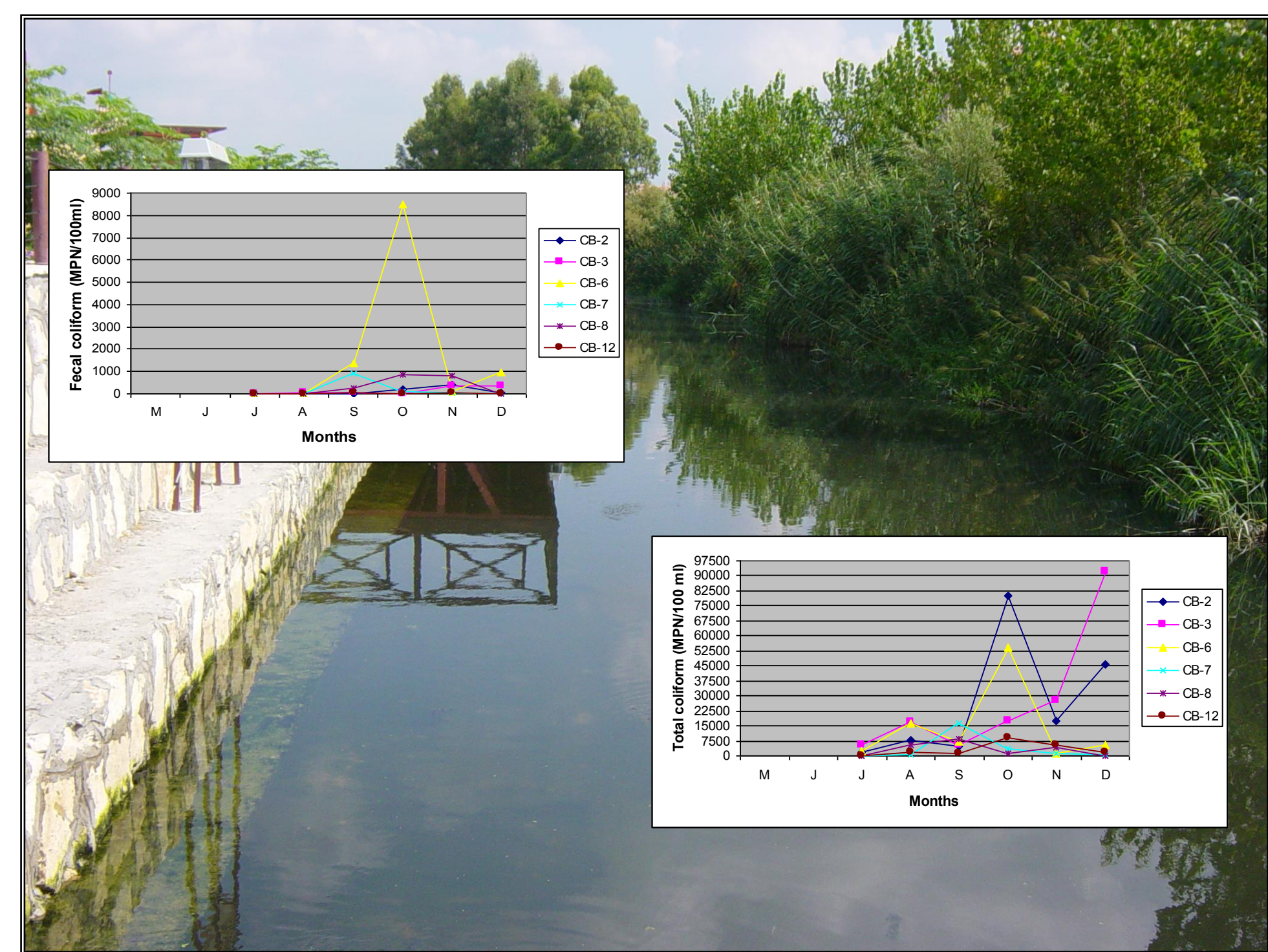


Fig. 8: Changing of fecal and total coliforms of samples in area of surface waters from May to December 2004.

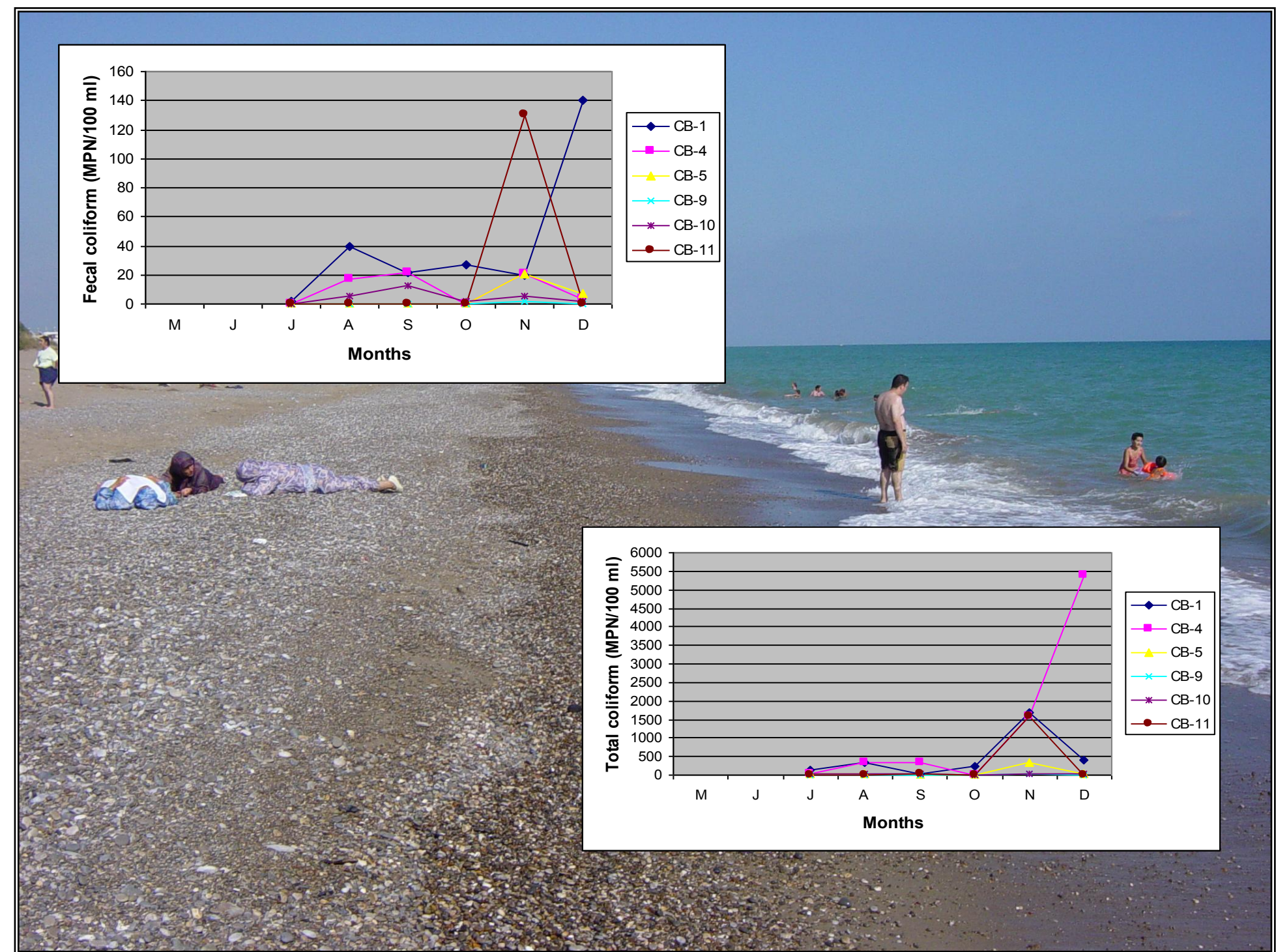


Fig. 9: Changing of fecal and total coliforms of samples in area of sea waters from May to December 2004.

## 6. Conclusions

In the study area, which is located between Manavgat in the east and Eşen Çay in the west and was declared to special environmental protection areas by the Authority for the Protection and Special Areas within the Ministry of Environment and Forestry of Turkish Republic, periodical in-situ measurements and sampling of surface and sea waters were done by the Research and Application Centre for Geothermal Energy, Groundwater and Mineral Resources monthly from May to December 2004. These waters samples were analyzed in the same institution hydrogeochemically and microbiologically. These measurements and analyses were evaluated and interpreted according to "Water Pollution Control Rules, dated 4 September 1998 and with number of 19919 in official Turkish Government newspaper". In consideration of temperature, pH, color, turbidity, dissolved oxygen,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\Sigma\text{PO}_4$ , TDS, BOD and COD in area of surface waters, the waters in this area belong to a range from high quality waters to high polluted waters depending upon seasonal effects. It is a general trend that the Agricultural and touristic activities in the area can increase the pollution in surface waters in future likely. Therefore, precautionary measures have to be taken against to this pollution as soon as quickly. The measured values of temperature, pH, color, turbidity, light permeability, odor, taste, dissolved oxygen and hydrogeochemical analyses (Tab. 3) correspond standards of sea waters closely. The locations of CB-2 and CB-3 are polluted hydrogeochemically and microbiologically which flow into the sea waters at the location of CB-1 and can pollute the sea waters in future. During October to December 2004, the values of fecal and total coliforms in the area of surface waters, especially at CB-2, CB-3 and CB-6, show increase in an extremely high size depending upon seasonal changes. This increase of both coliforms is associated with decrease of surface waters. Moreover, it depends upon the discharge of waste waters containing fecal and total coliforms, which flow into drainage system. On the other hand, the dilution of the fecal and total coliforms in waste waters can not be taken place completely due to low discharge of surface waters.

## Acknowledgements

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