

# Chapter 6

## Water Quality Assessment of the Bourgas Port Waters

Zvezdimira Tsvetanova, Magdalena Korsachka and Jordan Marinski

**Abstract** The aim of environmental monitoring of the port of Bourgas is to deliver reliable data for pollution assessment of the port water body and to support the development of a program for environmental risk management. The present study attempts to assess the quality of the Bourgas port waters summarizing the water monitoring data and calculating the integrated trophic state index (TRIX).

### 6.1 Introduction

TEN ECOPORT and ECOPORT 8 projects involve Mediterranean and Black Sea ports in South East Europe and aim to improve the quality of ports management placing the prevention of pollution and preservation of natural resources in port areas and nearby coastal zones as pivotal to the maritime system. The port of Bourgas is a key-hub on Trans Border Corridor 8 and for that reason it was chosen as a pilot site for water monitoring in the ECOPORT 8 project. It covers the East Terminal, Bulk Cargoes Terminal, Terminal 2A, West Terminal, and the Oil Terminal. The estimation of ecological potential of port Bourgas waters is quite difficult because of the inland origin of Black Sea water contamination and the presence of the Oil Terminal belonging to “Lukoil” refinery. At the same time, anthropogenic eutrophication of the coastal Black Sea region has been identified as a key problem, and summer is pointed as a vulnerable season for its origination (Kolarov et al. 2010; Kolarova and Medinets 2012; Moncheva et al. 2002). In Bulgaria, sea water quality in port aquatories is not subject to any legislative regulation. Only the quality of coastal waters is governed by the Regulation No 8 (2001).

---

Z. Tsvetanova (✉)

The Stephan Angeloff Institute of Microbiology, Bulgarian Academy of Sciences, Acad.  
26 George Bonchev str., Sofia, Bulgaria  
e-mail: zvezdimira@yahoo.com

M. Korsachka · J. Marinski

National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences,  
66 Tsarigradsko shoes blv., Sofia, Bulgaria  
e-mail: marinski@bas.bg

© Springer International Publishing Switzerland 2015

C. Stylios et al. (eds.), *Sustainable Development of Sea-Corridors and Coastal Waters*,  
DOI 10.1007/978-3-319-11385-2\_6

Environmental monitoring of the port of Bourgas aims to deliver reliable data for characterization of the port water body, pollution risk assessment, and development of a program for environmental risk management. The main goals of the present study were to summarize the port water monitoring data and to assess the quality of the Bourgas port waters. The present study was an attempt to apply the integrated trophic state index (TRIX) for scaling the eutrophication of port waters and to select relevant indicators of ecological water quality.

## 6.2 Materials and Methods

The water quality data were collected using the automatic monitoring system built in the frame of the ECOPORT 8 project. The monitoring network includes three water monitoring stations located in the port area (Fig. 6.1).

Sampling station 1 was selected to cover the impact of loading–unloading activities at the old bulk cargo terminal, inflows of city storm water sewage, and untreated waste water from service port buildings. Station 3 monitored the impact originating from liquid cargos operations (mostly oil products) and a storm water inflow from bulk cargo Terminal 2A as well. Station 4 monitored the aquatory adjacent to the Container Terminal, the most actively operating port unit, and the impact of fish vil-lage and Vaja Lake inflow as well. The monitoring process started in March 2012.

EUREKA Manta 2 Multiprobe incorporating multiple sensors in one instrument was used for triple daily measurement of pH, water temperature, dissolved oxygen and oxygen saturation, turbidity, conductivity, and salt content. Chlorophyll a, blue-green algae cells, and crude oil were measured by fluorometric sensors (Turner designs). SYSTEAM Micromac C analyzer for measurement of ammonia, nitrites, nitrates, and phosphates was used. Specific servicing software for remote control of the equipment and real-time database transfer and accumulation was applied.

On the base of monitoring data, the TRIX, proposed by Vollenweider et al. (1998), was calculated for the classification of the eutrophication level of marine port waters. The index is given by the equation:

$$\text{TRIX} = (\text{LOG} [\text{Chl} * aD\%O * N * P] - [-1.5]) / 1.2,$$

where *Chl* is chlorophyll a in  $\mu\text{g/L}$ , *aD%O* is oxygen as an absolute deviation from saturation  $aD\%O = [\text{abs}|100 - \%O|]$  in %, *N* is dissolved inorganic nitrogen as  $\text{N} - (\text{NH}_4 + \text{NO}_3 + \text{NO}_2)$  in  $\mu\text{g/L}$ , and *P* is dissolved inorganic phosphorus as  $\text{P} - \text{PO}_4$  in  $\mu\text{g/L}$ .

Numerically TRIX is scaled from 0 to 10 defining four trophic categories: <4—low trophic level, 4–5—moderate level, 5–6—high level, and >6—very high eutrophication level (Caruso et al. 2010; Giovanardi and Vollenweider 2004; Vollenweider et al. 1998). The molar *N:P* ratio is calculated as well.



**Fig. 6.1** View of the port of Bourgas and location of the water monitoring stations: 1—in Terminal East (old harbour), 2—for air monitoring, 3—in port waters between Terminal 2A and new breakwater, 4—in port waters near the Container Terminal and private fish port, 5—a reference point

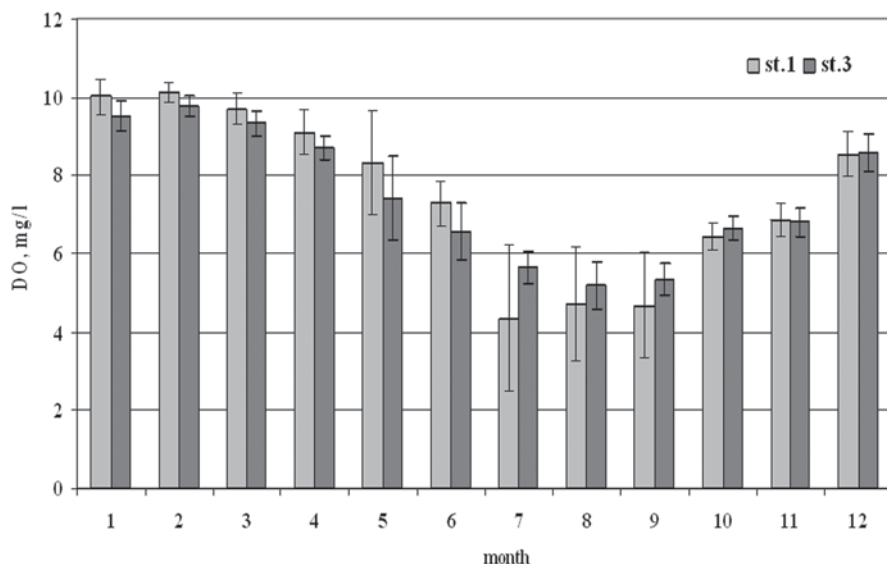


Fig. 6.2 Monthly average values of dissolved oxygen (DO), measured in stations 1 and 3

### 6.3 Discussion

The pollution and eutrophication of the Bourgas Bay were well documented, but a few data are available for the port water body (Kolarov et al. 2010). The port water was under human impact as a result of port activities, the close proximity of the town of Bourgas, and the industrial zone along the beach. Analyzing data, the impact of Vaja Lake and Mandra Lake water on the port basins' water in the corresponding monitoring points should also be taken into consideration because of the discharges of treated waste waters from the Bourgas city waste water treatment plant (WWTP) and untreated sewage waters of Aitos and Kameno towns into Vaja Lake.

Water monitoring performed in the main port basins demonstrated seasonal changes of water temperature and effect of lake water inflow as well. The pH values of port waters changed slightly. Turbidity (measured as nephelometric turbidity unit (NTU), equal to 1 mg/L dissolved Si) was influenced by port activities, season, and water mass exchange with open sea, having the highest values registered in summer. The salinity of sea water was low (17.3 ‰). From May to August, it was lower in station 3 (13.3 ‰) than station 1, due to the lake water impact, while in September it increased to 18.0 ‰ influenced by open sea currents.

Variation of dissolved oxygen (DO) content in the port waters correlated with water temperature and water pollution. The DO values were lowest during the summer, as a result of oxygen consumption and intensified mineralization of organic pollutants (Fig. 6.2).

The nutrients, measured as N-NO<sub>2</sub>, N-NO<sub>3</sub>, N-NH<sub>4</sub> and P-PO<sub>4</sub>, characterize biological processes. The nitrite nitrogen values were in the range from 0.005 to 1.41 µg/L. Nitrate nitrogen varied from 7.0 to 70.4 mg/L (with the highest monthly

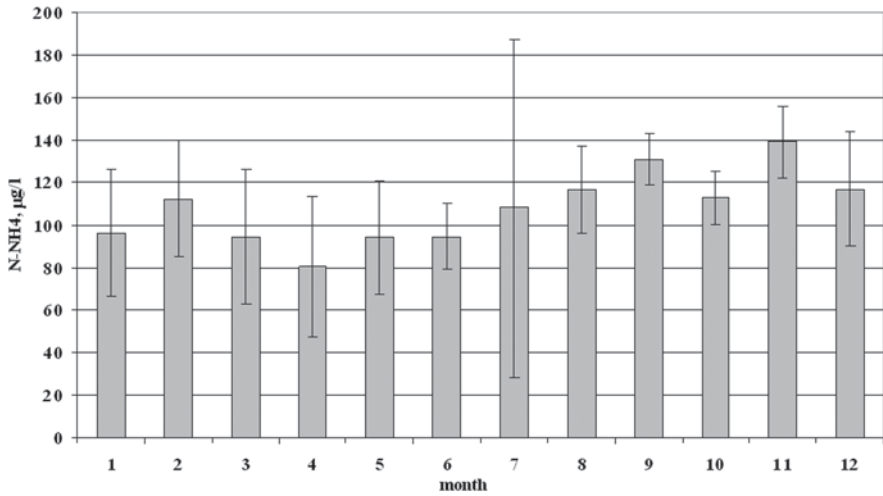


Fig. 6.3 Temporal distribution of ammonium nitrogen (N-NH<sub>4</sub>), measured in station 4

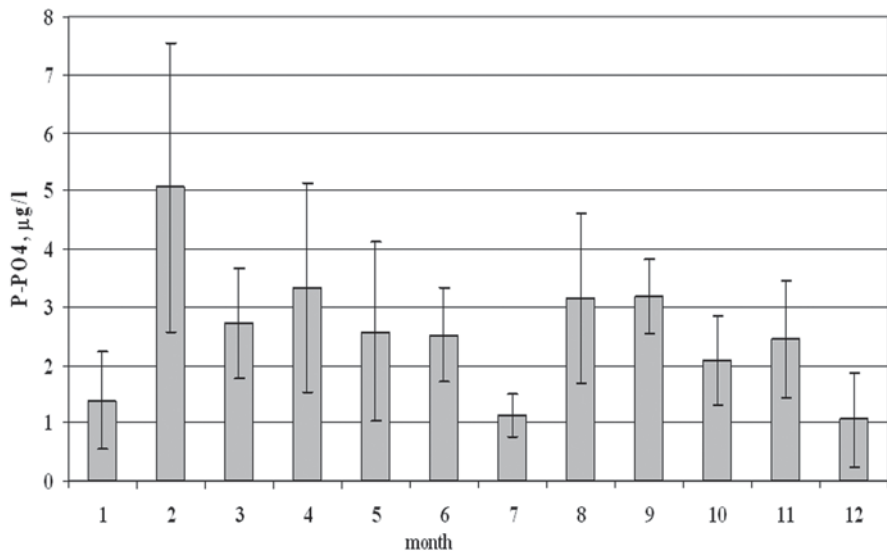


Fig. 6.4 Temporal distribution of phosphorus (P-PO<sub>4</sub>) in the port water, measured in station 4

average value in February and the lowest ones during the summer). Ammonium nitrogen (Fig. 6.3) showed seasonal distribution and the lowest monthly values were in spring (the minimum in April). The highest values were registered in August, September, and November. The monthly average N-NH<sub>4</sub> values did not agree with the limit of 0.1 mg/L according to the Regulation No 8 (2001), and most daily values exceed it. The deviations could be explained with the impact of the nutrient polluted waters from Mandra and Vaja lakes on the port aquatory. Phosphates content of the port waters (Fig. 6.4) was permanently low, varying from 1.1 to 5.1 µg P-PO<sub>4</sub>/L.

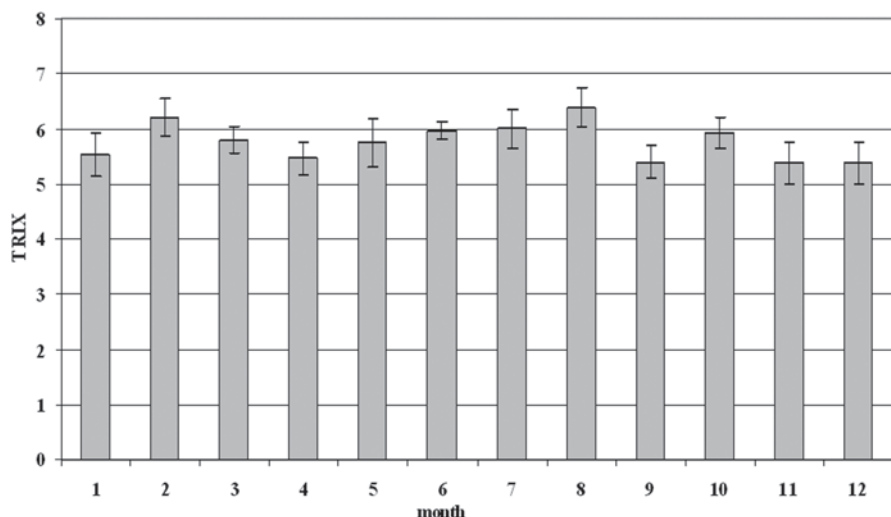
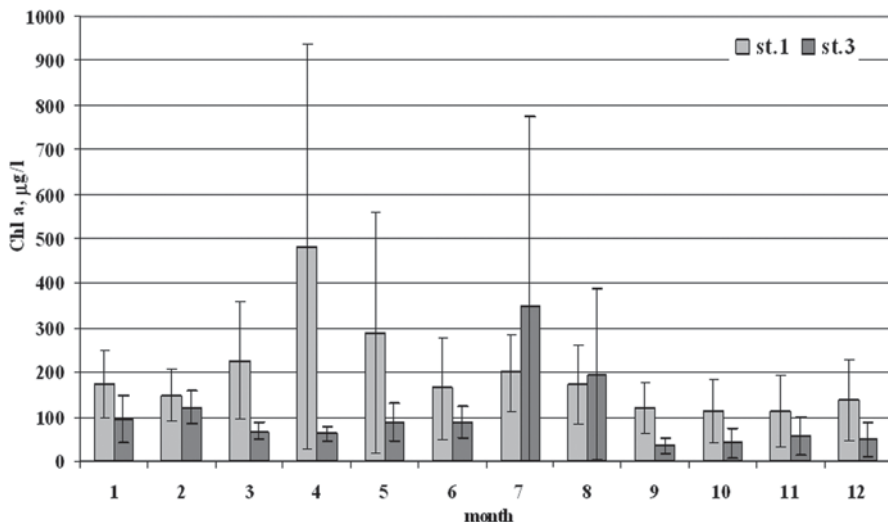


Fig. 6.5 Monthly average values of the trophic state index (TRIX) of the Bourgas port water

The multimetric TRIX can be a useful means in the classification of ecological status of port waters, especially when complemented with  $N:P$  ratio or other addition information. The values of the TRIX of the Bourgas port water (Fig. 6.5) were in the range from 5.4 to 6.4. The average annual value of  $5.8 \pm 0.3$  according to the classification of Vollenweider et al. (1998) corresponds to the category of high eutrophic water. Seasonal dynamics of the TRIX showed the lowest values of 5.4 or 5.5 found in April and from September to January. Nutrient pollution during active summer tourist season probably was a reason for increasing index, as the highest TRIX value of 6.4, characterizing very high eutrophication, was found in August. However, the opposite seasonal variations of the trophic index, characterizing with decreasing summer values, have been pointed out for the coastal waters of the northern Bulgarian coast (Moncheva et al. 2002). The obtained data for the port waters conform to the TRIX data for the western Black Sea coastal water, showing similar TRIX values (Kolarova and Medinets 2012).

The TRIX was in agreement with the information inherent to the individual nutrients. The obtained data for low dissolved oxygen content and daily  $N-NH_4$  values exceeding the threshold were indicative for the eutrophic potential of the port water. Values of water quality indicators that exceeded the thresholds were detected at places with discharges of treated waste water from urban treatment plant and from industrial facilities to the port area. This showed that port activities cannot be regarded as a major polluter of the port.

Phytoplankton growth is generally considered to be limited by one of the major nutrients and the ratio between dissolved inorganic nitrogen and phosphorus ( $N:P$ ) available for primary production is an indicative number of potential nutrient limitation. If the molar  $N:P$  ratio deviates from 16, primary production is limited either by nitrogen ( $N:P < 16$ ) or by phosphorus ( $N:P > 16$ ). Our results determined that



**Fig. 6.6** Temporal distribution of the chlorophyll a monthly average values, measured in the Bourgas port waters

the monthly values of  $N:P$  ratio were in the range from 61 to 137, and nitrogen-impacted port waters were moving towards phosphorous limitation. The highest  $N:P$  ratio was found in March, September, and October, while the lowest values in winter months.

Chlorophyll values of the port waters were low (Fig. 6.6). Usually, chlorophyll content measured in station 1 was higher than in station 3, related to the urban-treated wastewater discharges and higher plankton productivity. On the contrary, in July and August the chlorophyll values were higher in point 3, attributed mainly to Vaja Lake water, having significant phytoplankton growth.

From the ecological point of view, the petroleum hydrocarbons parameter is an important one, giving account to entirely anthropogenic influence. Petroleum hydrocarbons were the main pollutants of the port waters in both monitoring stations (Fig. 6.7), although they were below the normative value of 0.15 mg/L.

The oil product values measured in station 3 were higher than in station 1, that is, in relation to the liquid fuel uploading. The highest values were registered in February.

## 6.4 Conclusions

On the basis of the data from the automated water monitoring stations, the ecological condition of the seawaters at the separate aquatories of the port of Bourgas was assessed. The quality of port waters was influenced by the port activities and by other point and nonpoint pollution sources (lake water inflow, waste water discharges, etc.). In the aquatory of Terminal East (station 1), the deviations could be due to the

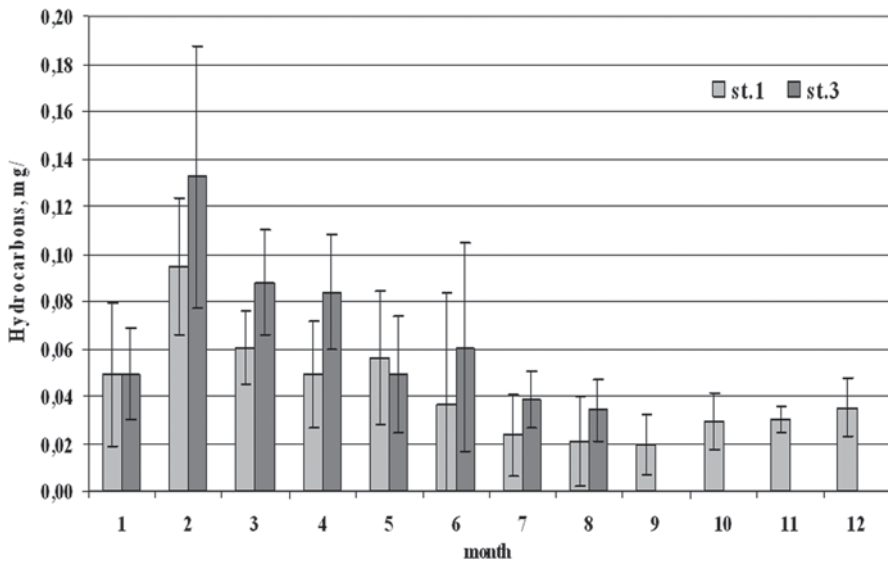


Fig. 6.7 Temporal distribution of the monthly average values of petroleum hydrocarbons, measured in the Bourgas port waters

untreated domestic waste waters. In the aquatory near the Container Terminal (station 4), water quality was strongly influenced by the Vaja Lake and the discharge of the urban treated waste waters, whose impacts were beyond the capabilities of the port management, while the increased content of oil products could be directly related to the port activity (liquid fuel uploading).

The automated water monitoring network could supply the information needed for a quality assessment of the port waters and for an identification of the main ecological problems. On the basis of these data, the port authorities could assess pollution sources leading to environment disturbance and undertake appropriate measures for their elimination.

**Acknowledgments** This paper was made possible thanks to a research grant provided by the South East Europe (SEE) Program within TEN ECOPORT with the code SEE/D/0189/2.2/X.

## References

- Caruso G, Leonardi M, Monticelli LS, Decembrini F, Azzaro F, Crisafi E, Zappalà G, Bergamasco A, Vizzini S (2010) Assessment of the ecological status of transitional waters in Sicily (Italy): first characterisation and classification according to a multiparametric approach. *Mar Pollut Bull* 60:1682–1690
- Giovanardi F, Vollenweider RA (2004) Trophic conditions of marine coastal waters: experience in applying the Trophic Index TRIX to two areas of the Adriatic and Tyrrhenian seas. *J Limnol* 63(2):199–218



- Kolarov P, Dimitrova I, Angelova E, Droumeva G, Marinski J (2010) Water quality of Bourgas port aquatorium. *Ecol Eng Environ Prot* 1:25–34
- Kolarova N, Medinets V (2012) Comprehensive assessment of long-term changes of the Black Sea surface waters quality in the Zmiinyi island area. *Turki J Fish Aquat Sci* 12:485–491
- Moncheva S, Dontcheva V, Shtereva G, Kamburska L, Malej A, Gorinstein S (2002) Application of eutrophication indices for assessment of the Bulgarian Black Sea coastal ecosystem ecological quality. *Water Sci Technol* 46(8):19–28
- Regulation No 8/25 (2001) Quality of Bulgarian coastal marine water. *State J* 10:2
- Vollenweider RA, Giovanardi F, Montanari G, Rinaldi A (1998) Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. *Environmetrics* 9:329–357