Bottom Layer Oxygen Depletion - An Increasing Problem in the Adriatic Sea ?

Alenka MALEJ

Marine Biological Station Piran, Institute of Biology, University of Ljubljana, Slovenija (Yugoslavia)

Low dissolved oxygen (DO) or hypoxia (levels below 3 ppm) and anoxia resulting in mass mortalities of benthic organisms is a problem that appears to be in rise in many coastal areas (*Officer et al., 1984; Westernhagen et al., 1986*). The magnitute of hypoxia/anoxia problem is spreading also in some Mediterranean coastal water bodies (*Friligos, 1982*), among others also the Northern Adriatic Sea. Severly hypoxic and even anoxic conditions have been documented in this area several times during last three decades and most recently in November 1989 (*Smodlaka, pers. comm.*).

Although the general processes which govern the bottom water DO levels have been identified and extensively studied there are still uncertainties about the relative importance of individual processes leading to oxygen depletion as well as the role of anthropogenic influences. The most important events in the development of the seasonal anoxia are considered to be the "bottom-sealed-by-pycnocline" phenomenon (*Tolmazin, 1985*), incresed organic loading either from *in situ* production or from allochtonous sources, reduced vertical mixing and lateral exchange. Increased eutrophication, which is blamed for more frequent and more intensive phytoplankton blooms, has also been related to hypoxia/anoxia problem.

The debate on oxygen defficiency and other eutrophication problems intensified during the last decade also in the countries around the Adriatic Sea, where environmental problems have substantial economic significance.

The Gulf of Trieste, the northernmost and the shallowest part of the Adriatic Sea, shows varying degrees of seasonal (late summer-autumn) oxygen depletion in its deeper waters (> 20 m). The annual cycle shows that DO in bottom waters normally declines during mentioned period to a minimum concentration in late August-September. Critically low DO levels and anoxic bottom waters leading to localized benthic mortalities have been observed in 1974, 1980, 1983 and 1987, the areal extent being the largest in September 1983 when about 1/6 of the Gulf's bottom waters were infected. In order to determine the causes and effects of oxygen depletion, a massive sampling programme has been carried out during 1986-89. We studied physical processes affecting bottom DO levels, especially seasonal development of water column stratification, oxygen sources and sinks in the bottom layer as well as sediment biogeochemical processes.

Our estimates indicate (*Malej et al., submitted*) that even during summers not characterized by critically low oxygen levels (like 1986 and 1988), the oxygen demands of the water column above the bottom and sediments in the Gulf of Trieste were large enough to exceed the supply available from *in situ* pelagic (the below pycnocline water column) and bottom (benthic micro algae) photosynthesis, therefore physical mechanisms affecting oxygen resupply must have contributed to slower deep water oxygen depletion.

According to our measurements done during 1986-89 severe hypoxic patches can be expected almost any summer-autumn with unfavourable meteorological conditions in the Gulf of Trieste. The general pattern of observations suggest the central part of the Gulf of Trieste to be most vulnerable and the spreading of hypoxic waters towards the coasts. However, *Faganeli et al. (in press)* who studied paleoenvironmental conditions from a deep 40-m core could not confirm an accelerated rate of organic matter deposition recently. They concluded that past biogeochemical processes in the Gulf of Trieste were not markedly different from those of the present day. Therefore, it seems that anoxic events in the Gulf of Trieste are not of recent origin.

While human activities may still be very important sources of oxygen-demanding loadings to the Gulf, the quantities of some natural sources have not yet been estimated, especially the role of lateral advection, plankton dynamics during the stratified conditions and sediment regeneration. Therefore it would be advisable to:

- monitor DO levels and rates of decline in bottom waters as well as relevant physical properties especially the degree of stratification
- assess quantitatively the man-made and natural oxygen-demanding loadings
- develop a predictive model and long-term trends using available data
- improve our understanding of the dynamic processes in the coastal waters and in meantime
- try to diminish oxygen-demanding loadings which will reduce the likehood of severe hypoxia and anoxia events.

REFERENCES

FAGANELI, J., PEZDIČ, J., OGORELEC, B., HERDNL, G. J., DOLENEC, T. The role of sedimentary biogeochemistry in the formation of hypoxia in shallow coastal waters (Gulf of Trieste, Northern Adriatic). Modern and Ancient Continental Shelf Anoxia, London, 17 - 19 May, 1989, (in press).

FRILIGOS, N. 1982. Some Consequences of the Decomposition of Organic Matter in the Elefsis Bay, an Anoxic Basin. Mar. Pollut. Bull.. 3: 103-106.

MALEJ, A., MALAČIČ, V., TUŠNIK, P. Factors affecting oxygen depletion in the Gulf of Trieste (Northern Adriatic). Chemistry and Ecology (submitted).

TOLMAZIN, D. 1985. Changing coastal oceanography of the Black Sea. Progress in Oceanography 15: 217-276.

WESTERNHAGEN, H.v., HICKEL, W., BAUERFEIND, E., NIERMANN, U., KRÖNCKE, I. 1986. Sources and effects of oxygen defficiencies in the South-Eastern North Sea. Ophelia 26: 457-473.

An Observation on the Occurence of Near-Anoxia Conditions in the Sea of Marmara

O. BASTURK, A. YILMAZ, S. TUGRUL and C. SAYDAM

Middle East Technical University, Institute of Marine Sciences, P.K. 28, Erdemli-Icel (Turkey)

The Sea of Marmara is a relatively small, inter-continental basin with a surface area of 11,500 km² and a volume of 3378 km³ (Özsoy, *et al.*, 1986). It shows a transitory character between two semi-enclosed basins, the Black Sea and the Aegean Sea (Figure 1). The existence of less saline (22-24 ppt) Black Sea origin waters over the more saline (38.5 ppt) Mediterranean origin waters forms a strong salinity stratification at about 30m. Subhalocline waters of the Sea of Marmara recieve particulate organic matter, not only trough its own primary production, but also particulate organic matter originated from Black Sea and waste discharges around the İstanbul Metropolitan Area.

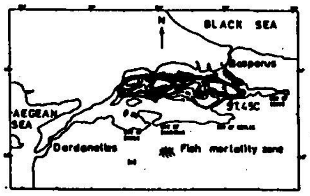

Figure 1. The Bathmetry of the Sea of Marmara (depths in meters) and location of Sta.45C

The stability of the halocline is further increased by thermal stratification developed during summer. The existence of a strong pycnocline prevents aeration of sub-halocline layer. The only possible route for the reaeration of subhalocline layer of the Sea of Marmara is the influx of oxygen rich waters through the Dardanelles lower layer flow. However, oxygen influx by this route is not sufficient to compensate the utilizations by sinking particulate organic matter from euphotic zone, thus the deep basins of the Sea of Marmara contain water with highly depleted oxygen content (1.0-1.5 mg O_2/l). Partial reaeration of the subhalocline waters by wind-induced vertical mixing was observed during late winter of

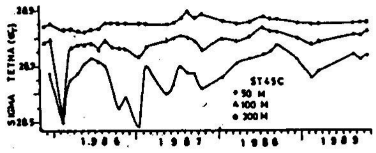

Figure 2. Time-variation of σ_T at Sta.45C for Nov.,1985-Oct., 1989 period

1986 and early spring of 1987 (Figure 2). However, a similar mixing was not seen during 1988-1989, probably due to a milder winter. Increased influx of relatively dense waters of Mediterranean origin (Fig.2) into deep basin of the Marmara during the summer of 1987 increased the stability. This, in turn, increased the AOU (Appearant Oxygen Utilization) levels of sub-halocline waters from about 5.0-5.5 mg O_2/l in 1986 to 6.0-6.5 mg O_2/l in mid-summer of 1987; the AOU, thereafter, increased gradually up to 7.0 mg

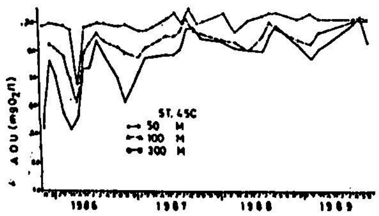

Figure 3. Time-variation of AOU at Sta.45C for Nov.,1985-Oct., 1989 period

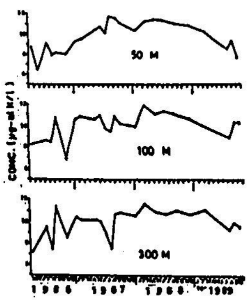

Figure 4. Time-variation of TO_xN at Sta.45C for April,1986-Oct., 1989 period

O_2/l in 1989 (Figure 3). A parallel increase was observed in the level of total oxidized nitrogen ($TO_xN=NO_3+NO_2$) which increased gradually to 11 µM through mid 1988 (Figure 4) and then indicated a decrease towards the end of the year, during which the AOU levels continued to increase. Increased oxygen depletion within the sub-halocline waters and episodic strong northeasterly winds in August, 1989 moved the interface upwards. The oxygen below the halocline was 0.3 mg/l. Mass mortalities of benthic and demersal fish in the region adjacent to the Anatolian coast of the BMJ region (Fig.1) were recorded following the observation.

REFERENCES

Özsoy, E., T.Oğuz, M.A.Latif and Ü.Ünlüata, 1986: Oceanography of the Turkish Straits, V.I: Phyiscal Oceanography of the Turkish Straits, First Annual Report, pp:133, METU-Institute of Marine Sciences, Erdemli, İçel