Turkish J.Mar.Sci. 1.(2/3) : 81-94(1995)

CHEMICAL PROPERTIES OF THE TWO-LAYER FLOW REGIMES IN THE TURKISH STRAITS

TÜRK BOĞAZLARINDAKİ İKİ TABAKALI AKI REJİMİNİN KİMYASAL ÖZELLİKLERİ

SÜLEYMAN TUĞRUL, ÇOLPAN POLAT, ÖZDEN BAŞTÜRK, EMİN HATİPOĞLU, AYŞEN YILMAZ, SEMAL YEMENİCİOĞLU, CEMAL SAYDAM AND İLKAY SALİHOĞLU

Middle East Technical University, Institute of Marine Sciences,
P.K. 28, Erdemli 33731, Içel, Turkey

Key Words : Bosphorus, Dardanelles, phosphorus compounds, nitrogen compounds

Abstract

Systematic data obtained at the exits of the Bosphorus and Dardanelles straits between 1986 and 1994 permit us to understand the seasonal variations in the nutrient properties of the counter flows in the Turkish Straits. The brackish outflow from the Black Sea enters the Marmara Sea with low levels of inorganic nutrients (PO_4-P <0.1 μM; NO_3+NO_2-N <0.1-0.2 μM) from spring to autumn but possesses unexpectedly high concentrations (PO_4-P=0.3-0.4 μM; NO_3+NO_2-N=5-7 μM) in early winter. The calculated annual average concentrations of PO_4 and NO_3+NO_2 are about 0.11 and 1.3 μM, respectively. However, the nutrient properties of the brackish waters of Black Sea origin are modified noticeably as they flow through the Marmara basin and the Dardanelles, both by biomediated chemical processes and by the export of biogenic organic particles to the lower layer. The salty Mediterranean inflow to the Marmara deep basin via the Dardanelles Strait contains low nutrient concentrations (NO_3+NO_2-N=1.0 μM; PO_4-P=0.05 μM, on average). However, the salty water, before reaching the Black Sea via the Bosphorus, is much enriched with inorganic nutrients in the Marmara basin by the input from the surface flow; the average concentrations being as high as 9.6 μM for NO_3+NO_2-N and 1.0 μM for PO_4. In other words, the initially nutrient-poor Mediterranean water spreads into the Black Sea with its nitrate+nitrite and phosphate concentrations enriched at least 10-20 fold, which are larger than the biologically labile nutrient content of the Black Sea outflow.

Introduction

The Black Sea, an inland sea principally fed by fresh, riverine waters, is connected to the Mediterranean through the so-called Turkish Straits System (TSS) comprising the Sea of Marmara, the Dardanelles and the Bosphorus Straits (Figure 1). Accordingly, the counter flows in the TSS permit the water exchanges between the Mediterranean and the Black Sea throughout the year (Gunnerson and Özturgut, 1974; Sorokin, 1983; Beşiktepe *et al.*, 1993; Oğuz and Rozman, 1991), resulting in the formation of distinctly different two-layer ecosystems in both the Marmara and Black Seas (Sorokin, 1983; Baştürk *et al.*, 1990; Tuğrul, 1993; Polat and Tuğrul, 1995; Polat 1995).

During recent decades the chemical properties of the exchange flows in the TSS have been modified by large discharges of land-based chemicals to the adjacent seas (Mee, 1992; Orhon *et al.*, 1994; Tuğrul and Polat, in press). In particular, heavily polluted riverine discharges to the western Black Sea have dramatically modified the biochemical properties of the northwestern shelf waters (Bologa 1985; Mee, 1992) flowing toward the Bosphorus region through alongshore currents (Sur *et al.*, 1994). The Black Sea outflow is further contaminated by the waste discharged from the city of Istanbul into the Bosphorus surface current toward the Marmara Sea and by the natural input of vertical mixing from the Marmara lower layer (Orhon *et al.*, 1994; Baştürk *et al.*, 1990; Polat and Tuğrul, 1995). In the Marmara basin, the biogeochemical properties of the Black Sea outflow are modified by biomediated chemical processes, before reaching as far as the Aegean Sea (Baştürk *et al.*, 1990; Polat, 1995).

On the other hand, the salty, oxygen saturated waters of the Aegean Sea are well known to contain low concentrations of inorganic nutrients (Baştürk *et al.*, 1990). In the Marmara basin, the salty Mediterranean water becomes markedly enriched with inorganic nutrients due to biogenic particle snow from the surface to the Marmara lower layer (Baştürk *et al.*, 1990).

Systematic nutrient data from the Turkish Straits are of critical importance for establishing chemical balances both in the Sea of Marmara and in the Aegean Sea, though the Bosphorus fluxes are expected to make an insignificant contribution to the whole Black Sea ecosystem (Fonselius, 1974). These data are also essential for ecosystem and water quality models, as well as for the improved understanding of the long-term changes in the chemical oceanography of the TSS. With these goals, a national oceanographic monitoring and research programme has been conducted since 1986 throughout the TSS by the Institute of Marine Sciences of the Middle East Technical University (IMS-METU).

In the present paper, recent systematic data are discussed so as to characterize the hydrochemical properties of the Aegean and the Black Sea waters exchanging via the TSS.

Materials And Methods

Water samples were collected during the 1986-1994 cruises of R/V Bilim either with conventional Nansen bottles or a 12-bottle Rozette attached to a Sea-Bird Model CTD probe system. Phosphate and nitrate samples were kept frozen until processed by a twochannel Technicon Model AII auto-analyzer. The conventional colorimetric methods followed were very similar to those given in Strickland and Parsons (1972).

Results and Discussion

Vertical Profiles: The typical salinity and nutrient profiles displayed in Figures 2 and 3 enable one to deduce the boundaries of the surface and counter flows at both exits of the Bosphorus and Dardanelles. As shown in Figure 2a, at the northern entrance of the Bosphorus Strait, the brackish, 17-18 ppt salinity, waters of the Black Sea occupy the upper layer down to 45-50 m throughout the year, below which a counterflow introduces diluted Mediterranean waters from the Marmara basin to the Black Sea. The Bosphorus surface flow becomes as thin as 10-15 m at the southern exit but more saline by at least 2-3 ppt before spreading into the Marmara basin. The Black Sea outflow via the Bosphorus increases during spring and early summer and decreases during autumn and winter (Ünlüata *et al.*, 1990; Latif *et al.*, 1991; Oğuz and Sur, 1989; Latif *et al.*, 1992; Özsoy *et al.*, 1992; Beşiktepe *et al.*, 1994; Özsoy *et al.*, 1994).

The typical chemical profiles in Figure 2a demonstrate that the Black Sea waters enter the Bosphorus Strait with vertically uniform but seasonally varying concentrations of inorganic nutrients, namely reactive phosphate (PO_4-P) and nitrate (in fact nitrate+nitrite). At the northern exit of the strait the nutrient concentrations of the diluted Mediterranean waters increase with depth due to their mixing with the Black Sea waters having low nutrient for most of the year; however, in winter when the Black Sea outflow becomes enriched with nutrients by the land-based input and the decreasing assimilation by photosynthesis (Polat and Tuğrul, 1995), nutrient profiles may become vertically uniform in the entire water column, as is clearly seen in Figure 2a.

The salty waters of the Marmara Sea at the southern entrance of the strait also possess vertically homogeneous distributions of nutrients (Figure 2b). Moreover, the salty water is always enriched in phosphate and nitrate relative to the concentrations in the Bosphorus surface flow. Since the Black Sea outflow generally contains low concentrations of nutrients, a steep nutricline is formed within the interface whose slope changes significantly both with season and location in the strait.

The Marmara surface outflow at the northern entrance of the Dardanelles Strait has a vertically uniform salinity (isohaline feature) down to 20 m in summer (Figure 3); in winter it becomes thicker and at least 2-4 ppt more saline due to intense mixing in the Marmara basin (Oğuz and Sur, 1989). The counterflows in the strait are separated by a sharp interface as in the Bosphorus Strait. The surface mixed layer becomes thinner and more saline in the soutwestern entrance of the strait where, down to the lower halocline, the surface waters flow toward the Aegean Sea (Polat, 1995). The Aegean outflow (S=39.0 ppt) is diluted insignificantly by vertical mixing in the Dardanelles when the Marmara basin is reached (Figure 3).

As can be realized from the typical profiles in Figure 3, the salty Mediterranean water enters the Dardanelles Strait with only trace levels of both phosphate and nitrate concentrations; however, the vertically uniform concentrations of nitrate and phosphate have been observed to increase in winter (see Figure 3a) due to vertical mixing in the open sea. Similarly, the Dardanelles surface inflow to the Aegean Sea posesses low concentrations of inorganic nutrients in April-September, displaying a homogeneous distribution with depth. During the same period, the entire water column from the surface to the bottom has vertically uniform chemical profiles due to the similarities between the nutrient concentrations of the upper and lower layer waters at the strait exit. The winter nitrate increases in the salty Aegean outflow result in the formation of a seasonal nitracline coinciding with the permanent halocline (interface) at the exit (Figure 3a).

Sub-surface nitrate and phosphate maxima are generally formed in the the water column of the northeastern exit (Figure 3b) for most of the year. Such distinguished features with seasonally varying peak values are the result of intrusion of the nutrient-poor, denser Mediterranean waters below the nutrient-enriched, older Mediterranean water existing in the lower layer of the Marmara-Dardanelles Junction (MDJ). However, when the salty inflow from the Aegean Sea is strong enough to occupy the entire lower layer of the strait, the subhalocline waters in the DMJ region possess vertically uniform nutrient profiles as do the salty waters of the southern exit.

Seasonal Variations: The well-defined boundaries of the exchange flows in the strait entrances (Polat and Tugrul, 1995; Polat, 1995) permit us to determine the layer-averaged nutrient concentrations for the exchanging waters of the adjacent seas through the Turkish Straits. Figure 4a demonstrates the seasonal variation of inorganic nutrients in the Black Sea outflow via the Bosphorus. The concentrations have been observed to increase markedly from summer to winter; for instance, the nitrate values are always in the range of <0.1-0.2 μM in summer, reaching peak values of 4.5-7.5 μM in winter months. The winter increases appear consistently in late November-December when the assimilation of nutrients by photosynthesis tends to decrease to a minimum in the western Black Sea surface layer. Similar winter increases have also been reported for the northwestern coastal margin of the Black Sea (Bologa *et al.*, 1981), indicating that in winter, a significant fraction of land-based nutrients introduced to the northwestern Black Sea may have reached as far as the Bosphorus by alongshore currents. Phosphate concentrations of the outflowdisplay a similar seasonality; the summer values are always less than 0.1 μM whereas the winter concentrations may range between 0.3 and 0.4 μM (Figure 4a). In the late winter, whereas nitrate concentrations remain at peak levels, phosphate concentrations may tend to decrease due either to luxury consumption by photosynthesis or to sedimentation by adsorption onto particles in the coastal margins before reaching the Bosphorus. During the early spring bloom, the brackish water enters the Bosphorus with low inorganic nutrient concentrations but with large concentrations of particulate organic nutrients (Polat and Tuğrul, 1995; Polat, 1995).

The seasonality in the nutrient content of the Marmara surface outflow via the Dardanelles (Figure 5a) is much less pronounced than those in the Black Sea water entering the Marmara Sea via the Bosphorus (Figure 4a). The Marmara surface outflow is impoverished in nitrate and phosphate after the spring bloom, yielding typical summer values of <0.05-0.1 μM for nitrate and <0.1 μM for phosphate. The winter concentrations for the Marmara surface outflow, as high as 1.0-1.3 μM for nitrate and 0.2-0.3 μM for phosphate (Figure 5a), are therefore consistently less than the peak values recorded in the

Black Sea outflow (see Figure 4a). These winter maxima are the result of entrainment of the inorganic nutrient-enriched salty waters from the lower layer to the surface layer by intense vertical mixing because large winter input by the Bosphorus surface inflow is consumed by biomediated chemical processes in the eastern Marmara and the majority of the nutrient-associated organic particles sink out of the surface layer before Dardanelles is reached (Baştürk *et al.*, 1990; Polat, 1995).

Comparison of the nutrient contents of the Mediterranean waters flowing in the Dardanelles and the Bosphorus entrances (Figures 4b and 5b) indicates important spatial and temporal changes in the chemical properties of the salty outflow from the Aegean Sea. The Mediterranean water in the Dardanelles-Aegean Junction (DAJ) contains very low inorganic nutrient concentrations relative to its chemical properties in the Bosphorus region. Moreover, the concentrations in the DAJ vary markedly with season, increasing consistently from summer to winter (see Figure 5b). However, the seasonality is much more pronounced in the nitrate concentrations, varying from <0.1 μM in summer to 2.0-2.4 μM in winter, whereas the phosphate concentration ranges seasonally between <0.02 (detection limit of the method) and 0.06-0.08 μM. The consistent winter increases in the nutrient content of the salty water in the DAJ is principally the result of the input from the deep layers by convective winter mixing in the open Aegean Sea (Küçüksezgin *et al.*, in press), rather than the input from land-based sources. Particulate nutrient data obtained in the strait between 1991-1994, Polat (1995), are comparable with the inorganic nutrient concentrations of the Mediterranean water. The PON ranged seasonally between 0.04 and 0.70 μM, reaching peak values during the spring bloom though these are less than the winter nitrate concentrations. The particulate phosphorus (PP) concentrations were in the range of 0.01-0.35 μM; the PP maxima much exceed the phosphate maxima observed in winter (Polat, 1995).

The salty Mediterranean waters, poor in nutrients before they enter the Marmara Sea, become enriched at leat 10 fold with inorganic nutrients during their 6-7 years in the Marmara basin (Ünlüata *et al.*, 1990; Baştürk *et al.*, 1990; Polat, 1995). Accordingly, the Mediterranean water leaves the Marmara lower layer with seasonally varying concentrations of 0.7-1.3 μM for phosphate and 7-12 μM for nitrate as is clearly shown in Figure 4b. Since algal production in the Marmara Sea is limited to the upper layer, the inorganic nutrient content of the salty Marmara outflow via the Bosphorus is much larger than the concentrations of particulate nutrients which are of the order of 0.2-1.0 μM for PON and 0.03-0.07 μM for PP as discussed extensively by Polat (1995) and by Polat and Tuğrul (1995).

Annual Means of the Nutrient Concentrations: The annual means of the inorganic and particulate nutrients in the exchange flows of the Turkish Straits have been estimated from the long-term data evaluated above as well as those given in Polat (1995) and Polat and Tuğrul (1995). Though data is very scarce, the annual mean of ammonia (NH_4^+) is less than the nitrate contents of the exchange flows; it is of the order of 0.05-0.1 μM for the salty Mediteranean waters both in the Dardanelles and in the Bosphorus region, whereas the Black Sea inflow probably contains 0.5 μM of NH_4^+ (Polat and Tuğrul, 1995) dropping to a level of 0.1-0.2 μM when the surface flow reaches as far as the Dardanelles. The brackish outflow from the Black Sea possesses comparable annual concentrations of inorganic and particulate nutrients even though the concentrations reach peak values in different seasons; the estimated annual mean concentrations of nitrate and PON are 1.3 and 1.96 μM , respectively. The annual mean concentration of nitrate in the Marmara surface outflow via the Dardanelles drops to 0.33 μM whereas its PON concentration remains almost constant (1.94 μM) from the Bosphorus to the Dardanelles exit.

The salty Mediterranean water enters the Marmara basin with low annual inorganic and particulate nutrient concentrations; 0.05 μM for phosphate, <0.05 μM for PP whereas the annual nitrate and PON concentrations are 1.0 and 0.3 μM, respectively. The salty water reaches the Bosphorus region with relatively high annual concentrations of nitrate (9.6 μM) and phosphate (1.0 μM), which are much larger than their particulate components; 0.4 μM for PON and 0.05 μM for PP, on an annual basis.

In the surface outflows both from the Black and Marmara seas, labile (inorganic and particulate) nutrients have been observed to vary significantly with season; however, the combined concentrations of inorganic+particulate organic nutrients change only by some 10% on a yearly time scale because seasonal decrease in the inorganic nutrient content of the surface waters is partly compensated by an increase in the particulate organic nutrients of biogenic origin, as also emphasized by (Polat, 1995).

Comparison of the annual mean concentrations of chemicals occurring in the exchange flows in the Turkish Straits reveals that the labile nutrient concentrations of the salty waters flowing into the Black Sea are 2-3 times larger than those of the Black Sea inflow to the Marmara surface layer. However, an opposite trend appears in the ratios of the chemical contents of the counterflows in the Dardanelles Strait. As a concluding remark, when the annual volume fluxes in the straits are taken into account, biologically labile nutrients exported from the Black Sea are compensated by the importation from the Marmara lower layer, whereas the chemical export from the Mediterranean is less than the annual load of nutrients inflowing from the Sea of Marmara via the Dardanelles.

Figure 1 The location of Turkish Straits; Dardanelles and Bosphorus, between the Mediterranean and the Black Sea

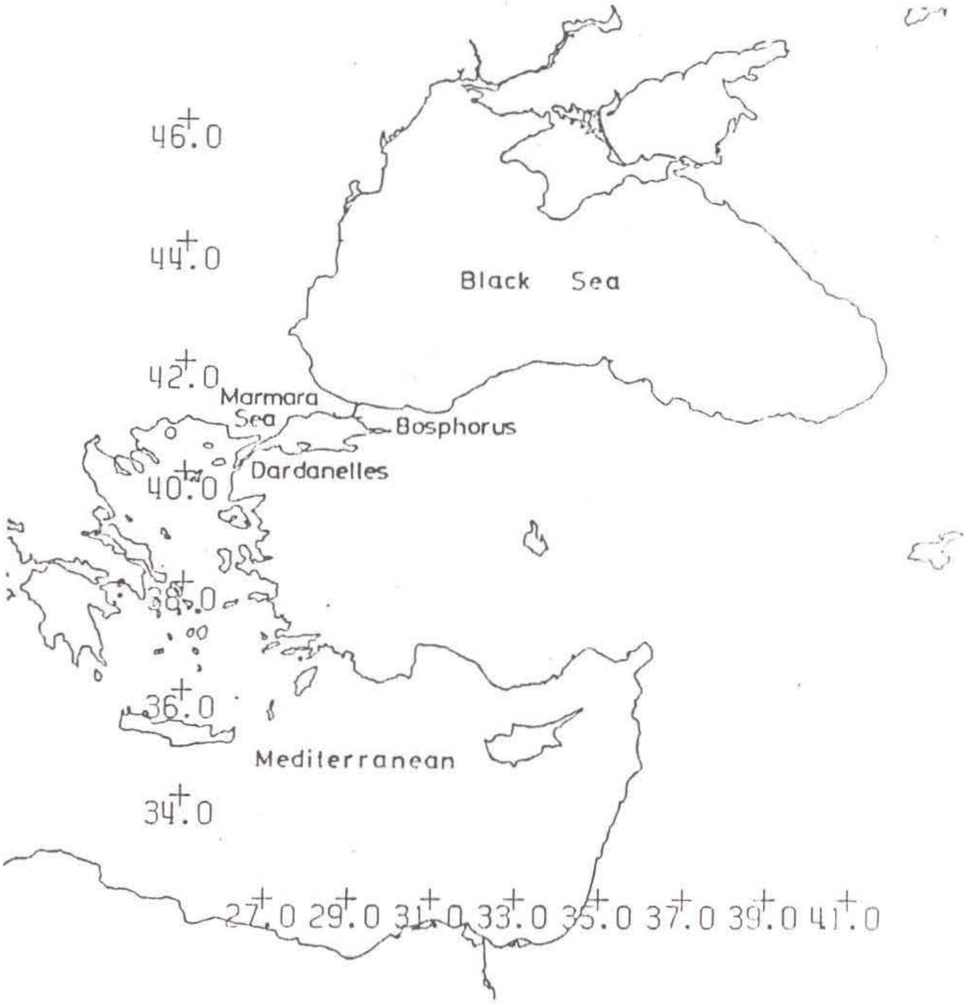


Figure 2 The typical hydrochemical profiles at the (a) northern and (b) southern exits of the Bosphorus Strait

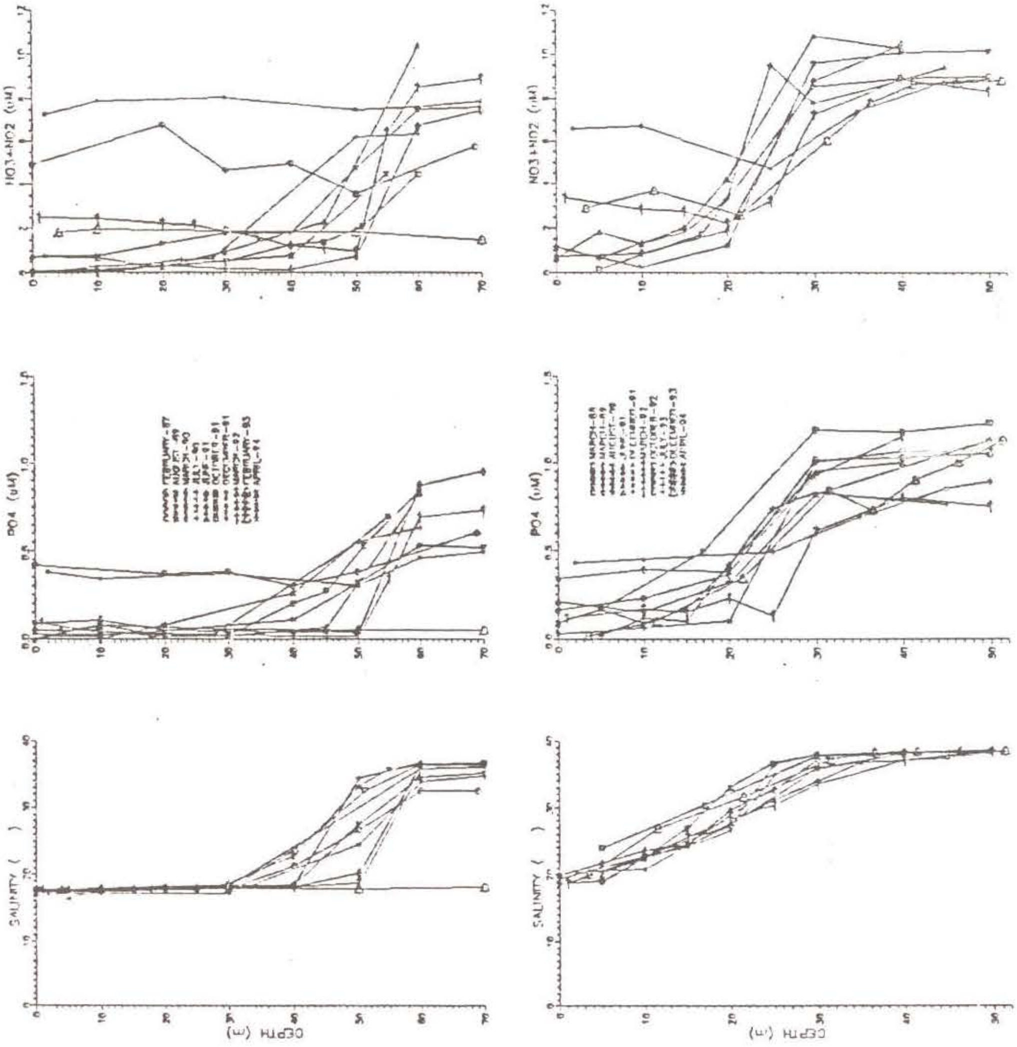


Figure 3 The typical hydrochemical profiles at the (a) southern and (b) northern exits of the Dardanelles Strait

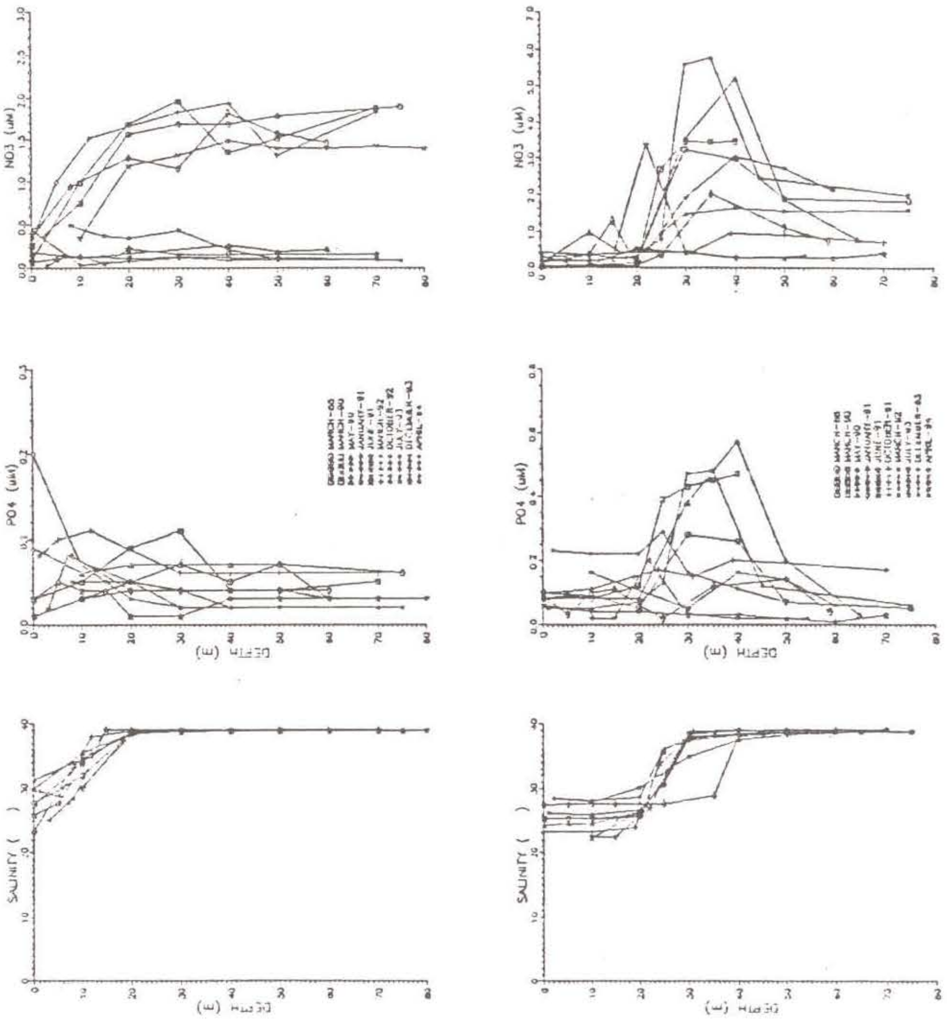
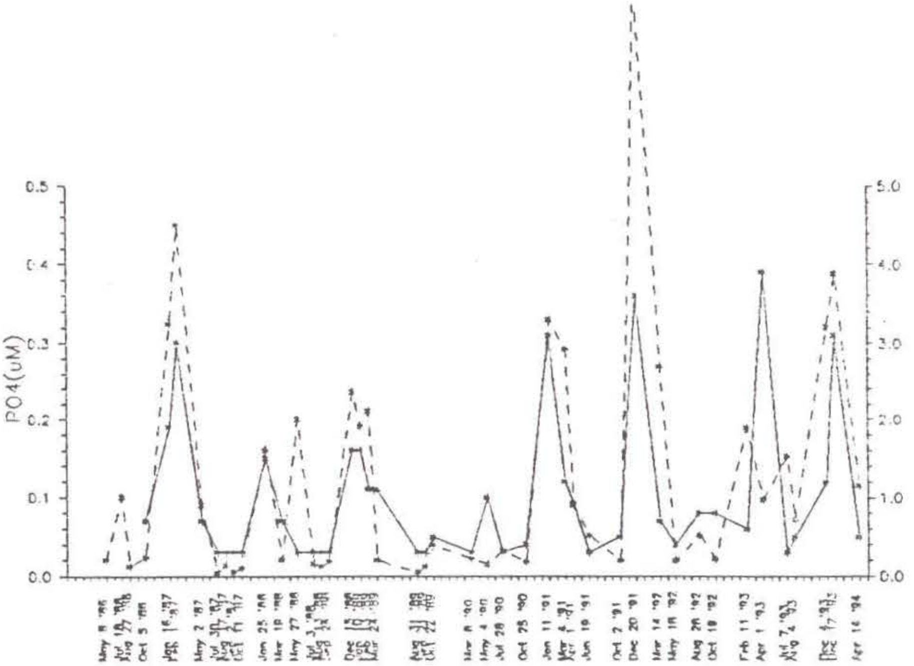


Figure 4 Temporal variations of PO_4-P and NO_3+NO_2-N for the (a) upper layer at the northern exit and (b) lower layer at the southern exit of the Bosphorus Strait



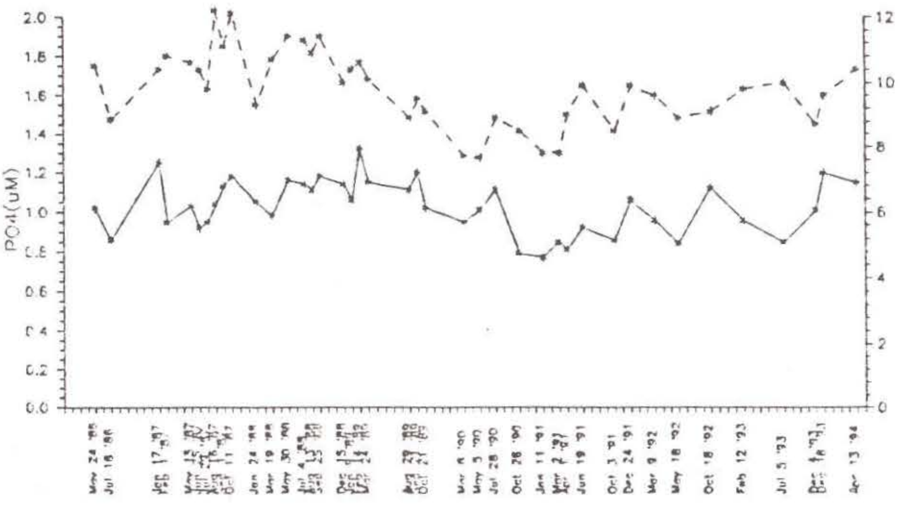
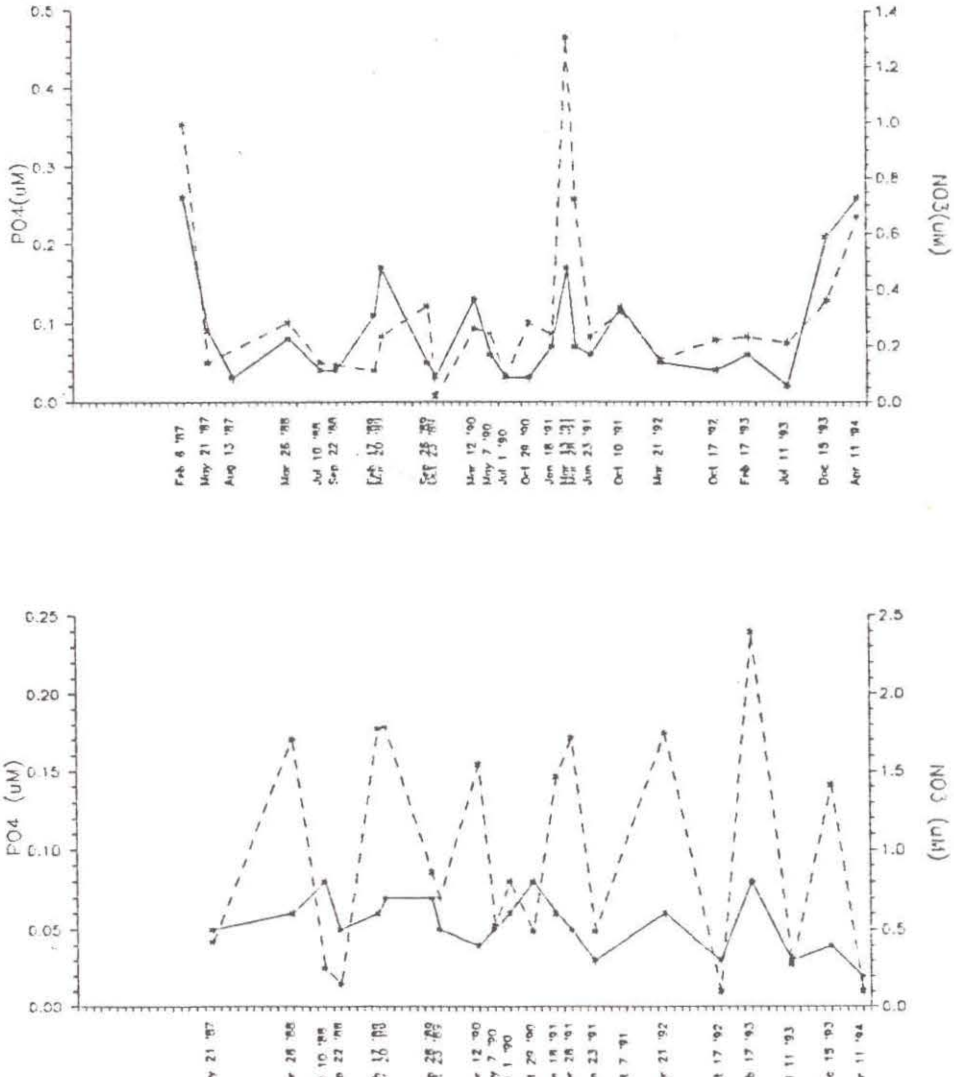


Figure 5 Temporal variations of PO_4-P and NO_3+NO_2-N for the (a) upper layer at the northern exit and (b) lower layer at the southern exit of the Dardanelles Strait



Özet

İstanbul ve Çanakkale Boğazlarında 1986 ve 1994 yılları arasında sistematik olarak toplanan veriler, iki tabakalı akıntıların besin tuzu özelliklerini ve bunların mevsimsel değişimlerini anlamamıza olanak tanır. Karadeniz suyu, ilkbahar-sonbahar döneminde Marmara Denizi'ne anorganik besin elementlerini düşük seviyelerde taşırken (PO_4-P <0.1 μM; NO_3+NO_2-N <0.1-0.2 μM) erken-kış dönemlerinde zaman zaman yüksek derişimlere (PO_4-P=0.3-0.4 μM; NO_3+NO_2-N=5-7 μM) rastlanır. Bu suda hesaplanan yıllık ortalama değerler PO_4 ve NO_3+NO_2 için sırasıyla 0.11 ve 1.3 μM'dir. Karadeniz suyu Marmara Denizi boyunca uğradığı biyokimyasal prosesler ve biyolojik kökenli partiküllerin alt sulara çökmesi sonucunda özellikleri yeniden şekillenmiş olarak Çanakkale Boğazına ulaşır. Tuzlu Akdeniz girdisi, Çanakkale Boğazı kanalı ile Marmara derin basenine düşük seviyelerde besin tuzu taşır (ortalama NO_3+NO_2-N=1.0 μM; PO_4-P=0.05 μM). Ancak, Akdeniz kökenli bu su İstanbul Boğazı kanalı ile Karadeniz'e ulaşmadan, Marmara Denizi'nde üst suyun etkisiyle anorganik besin elementlerince zenginleşir ve ortalama derişimler NO_3+NO_2-N için 9.6 μM, PO_4-P içinse 1.0 μM seviyelerine yükselir. Diğer bir değişle, başlangıçta besin elementlerince fakir olan Akdeniz suyu 10-20 kez zenginleşmiş olarak Karadeniz'e yayılır ki bu değerler Karadeniz üst su giridisindeki değerlerden de yüksektir.

Acknowledgements

We gratefully thank the scientists of IMS-METU and the captain and the crews of R/V Bilim for their contributions to this study which has been throughly supported by the Turkish Scientific and Technical Research Council (TUBITAK) and the NATO Scientific Affairs Division within the framework of the Science for Stability Programme.

References

Baştürk, Ö., Tuğrul S., Yılmaz, A., Saydam, C. (1990) Health of the Turkish Straits: Chemical and environmental aspects of the Sea of Marmara. METU-Institute of Marine Sciences, *Tech. Rep.*, 90(4), Erdemli-İçel, Turkey, pp.69

Beşiktepe, Ş.T., Özsoy, E. and Ünlüata, Ü. (1993) Filling of the Marmara Sea by the Dardanelles lower layer inflow, *Deep Sea Research* 40(9): 1815-1838.

Beşiktepe, Ş.T., Sur, H.I., Özsoy, E., Latif, M.A., Oğuz, T. and Ünlüata Ü. (1994) The circulation and the hydrography of the Marmara Sea. *Progress in Oceanography*, 34:285-334.

Bologa, A.S., Usurelu, M. and Frangopol, P.T. (1981) Planktonic primary productivity of the Romanian surface coastal waters (Black Sea) in 1979. *Oceanologia Acta*, 4(3):343-349.

Bologa, A.S. (1985) Planktonic primary productivity of the Black Sea: a review. *Thallassia Jugoslavica*, 21/22:1-22.

Fonselius, S.H. (1974) Phosphorus in the Black Sea. In: The Black Sea- Geology, *Chemistry and Biology*, Memoire No.20, pp.144-150, The American Assoc. Petroleum Geologists.

Gunnerson, C.G and Özturgut, E. (1974) The Bosphorus. In: The Black Sea Geology, *Chemistry and Biology*, Memoire No.20, pp.99-113, The American Assoc. Petroluem Geologists.

Küçüksezgin, F., Balcı, A., Kontaş, A. and Altay, O. Distribution of nutrients and chlorophyll-a in the Aegean Sea. *Oceanologica Acta* (in press).

Latif, M.A., Özsoy, E., Oğuz, T. and Ünlüata, Ü. (1991) Observation of Mediterranean inflow into the Black Sea, *Deep-Sea Research*, 38(2):711-725.

Latif, M.L., Özsoy, E., Salihoğlu, İ., Gaines, A.F., Baştürk, Ö., Yılmaz, A. and Tuğrul, S. (1992) Monitoring via direct measurements of the modes of mixing and transport of wastewater discharges into the Bosphorus underflow. METU-Institute of Marine Sciences, Tech.Rep. pp.92-2, 98.

Mee, L.D. (1992) The Black Sea in crisis: The need for concerted international action *Ambio* 21(4): 278-286.

Oğuz, T. and Sur, H.I. (1989) A two-layer model of water exchange through the Dardanelles Strait *Oceanologica Acta*, 12:23-31.

Oğuz, T. and Rozman, L. (1991) Characteristics of the Mediterranean underflow in the southwestern Black Sea continental shelf/slope region *Oceanologica Acta*, 14: 433-445.

Orhon, D., Uslu, O., Meriç, S., Salihoğlu İ. and Filibeli, A. (1994) Wastewater management for Istanbul: Basis for treatment and disposal *Environmental Pollution*, 84:167-178.

Özsoy, E., Latif, M.A., Beşiktepe, S., Oğuz, T., Salihoğlu, İ., Gaines, A.F., Tuğrul, S., Baştürk, Ö. and Saydam, C. (1992) Monitoring via direct measurements of the modes of mixing and transport of wastewater discharges into the Bosphorus underflow. Second Progress Report. Institute of Marine Sciences, Middle East Technical University, pp.310.

Özsoy, E., Gaines, A.F., Latif, M.A., Tuğrul S. and others, 1994. Monitoring via direct measurements of the modes of mixing and transport of wastewater discharges into the Bosphorus underflow. Final Report, Vol.1-2, Institute of Marine Sciences, Middle East Technical University.

Polat, S.Ç. and Tuğrul, S. (1995) Nutrient and organic carbon exchanges between the Black and Marmara seas through the Bosphorus Strait *Continental Shelf Research*, 15(9): 1115-1132.

Polat, S.Ç. (1995) Nutrient and organic carbon budgets of the Sea of Marmara: A progressive effort on the biogeochemical cycles of carbon, nitrogen and phosphorus. Ph.D. Thesis, Institute of Marine Sciences, Middle East Technical University: pp.215

Sorokin, Yu. I. (1983) The Black Sea. In: Ketchum, B.H. (Ed.), Estuaries and Enclosed Seas *Ecosystem of the World*, 253-291, Elsevier-Amsterdam.

Strickland, J.D.H. and Parsons, T.R. (1972) A practical handbook of seawater analysis, 2nd ed., Ottowa, Fisheries Research Board.

Sur, H.İ., Özsoy, E. and Ünlüata, Ü. (1994) Boundary current instabilities, upwelling, shelf mixing and eutrophication processes in the Black Sea *Progress in Oceanography*, 33:227-264.

Tuğrul, S. (1993) Comparison of TOC concentrations by persulphate-UV and HTCO techniques in the Marmara and Black Seas, *Marine Chemistry*, 41: 265-270.

Tuğrul, S. and Polat, S.Ç. Quantitative comparison of the influxes of nutrients and organic carbon into the Sea of Marmara both from anthropogenic inputs and from the Black Sea *Water Science and Technology* (in press).

Ünlüata, Ü., T. Oğuz, M.A. Latif, E. Özsoy, 1990: On the physical oceanography of the Turkish Straits, In: Pratt, J. (Ed.) The Physical Oceanography of the Straits, 25-60 NATO/ASI Series, Portrecht, Kluwer Academic Publishers.

Received 24.11.1995