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Characteristics and Seasonal Variations of Dissolved Oxygen

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ABSTRACT: Large amounts of degradable wastes including sewage water and agricultural waste or nutrients that stimulate growth of organic matter are discharged into the Caspian Sea. As a result, average dissolved oxygen concentration in deeper layers is decreasing. This paper presents distribution and seasonal variations of the concentration of dissolved oxygen over the southern shelf of the Caspian Sea adjacent to Iran. The dissolved oxygen data were collected down to 200 m depth in two areas in east (off Babolsar in Mazandaran) and west (off Kiyashahr in Gilan) of the southern coast of the Caspian Sea. Surface dissolved oxygen concentration varied between 7.1 and 10.9 mg/l. Distribution of dissolved oxygen across the depth was in accordance with the temperature structure. The presence of the seasonal thermocline during spring to mid winter significantly affected the concentration of dissolved oxygen across the depth. In autumn, in late October, the dissolved oxygen concentration ranged between 7.6 mg/l below thermocline at 40 m level to less than 5 mg/l at 160 m level and 4.2 mg/l at 200 m level. In winter in late February, in the upper 100 m mixed layer the dissolved oxygen concentration was more than 11 mg/l. The data indicates the possibility of significant decline in dissolved oxygen concentration and serious damage to marine life if algal bloom occurs during the strong seasonal thermocline. The results highlight the necessity of certain measures for an effective decrease in the inputs of degradable wastes and plant nutrients into the Caspian Sea.

Key words: Caspian Sea, Dissolved Oxygen, Seasonal Variations, Environment

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INTRODUCTION

The Caspian Sea, as the largest lake in the world with a unique marine environment has a great importance for the world and in particular for the lateral countries around it (Karpinsky *et al.*, 2005; Zonn, 2005b; Dumont, 1998). There are extensive oil fields within and close to the Caspian Sea. Oil industry is growing fast and becoming a major component of the economy of the littoral countries of the Caspian Sea. Fishing and caviar production is the second large industry in the Caspian Sea. The Caspian is the only water body in the world that has a large stock of sturgeon, yielding in recent years about 85% of the world's catch. These living fossils are of high biological, ecological, genetic and commercial importance (Zonn, 2005a; Karpinsky, *et al.*, 2005; Dumont, 1998).

The marine environment of the Caspian Sea, due to extensive human exploitation and discharge of large magnitudes of human waste, is under extensive pressure (Zonn, 2005a; Korshenko and Gul, 2005). Large amounts of degradable wastes including sewage water and agricultural waste or nutrients that stimulate growth of organic matter are discharged into the Caspian Sea (Korshenko and Gul, 2005). Intensification of the riverine water inflow (1980s to 1990s) and related enhancement in the nutrient supply together with the decrease in the severity of winter served as a strong factor in preventing the deeper layers of the Middle and South Caspian from ventilation (Tuzhilkin and Kosarev, 2005). As a result, a decrease in average dissolved oxygen concentration in deeper layers is changing into a major threat to the marine life and ecosystem of the Caspian Sea (Tuzhilkin, *et al*, 2005). Therefore, the understanding of distribution and concentration of dissolved oxygen is a very important requirement for the study of the quality and level of safety of marine environment in the Caspian Sea.

The study area in the west of the southern coast of the Caspian sea is located at approximately N37^o, 27' latitude and E49^o, 55' longitude, off Kiyashahr, Gilan Province in Iran (Fig. 1). The study area in the east of the southern Caspian coast is located at approximately N36^o, 41', 54" latitude and E52^o, 33', 23" longitude off Babolsar, Mazandaran province in Iran (Fig. 1). The Caspian shelves in the study areas in west and east have widths of about 9 and 10km respectively. The depth gradually increases to about 50m near the shelf break, after that the depth sharply increases to 500m about 18km from the coastline. In the east the Babolrood River and in the west the Sepidrood River discharges into the Caspian Sea in the study area.

The southern coast of the Caspian Sea has a subtropical climate characterized by warm humid summers and mild, wet winters (Kosarev, 2005; Kosarev and Yablonskaya, 1994). The air temperature is maximum in August and minimum in January. Winds with northerly and southeasterly directions are the most stable and dominate winds over the Caspian Sea during the major part of the year (Kosarev, 2005). In the South Caspian, strong winds are rarely observed and the recurrence rate of weak winds here reaches 90%. In the southern part of the sea, the number of days with storms (wind speed greater than 15 m/s) is not greater than 20-30 per year (Kosarev, 2005).

Owing to the isolation of the Caspian Sea from the world oceans, the formation of its thermohaline and circulation regime proceeds only under the action of atmospheric processes over the sea basin and its vast drainage area. Together with river runoff, the fluxes of heat and freshwater across the sea surface caused by this action control the large-scale features of the thermohaline structure and its temporal variability (Tuzhilkin and Kosarev, 2005).

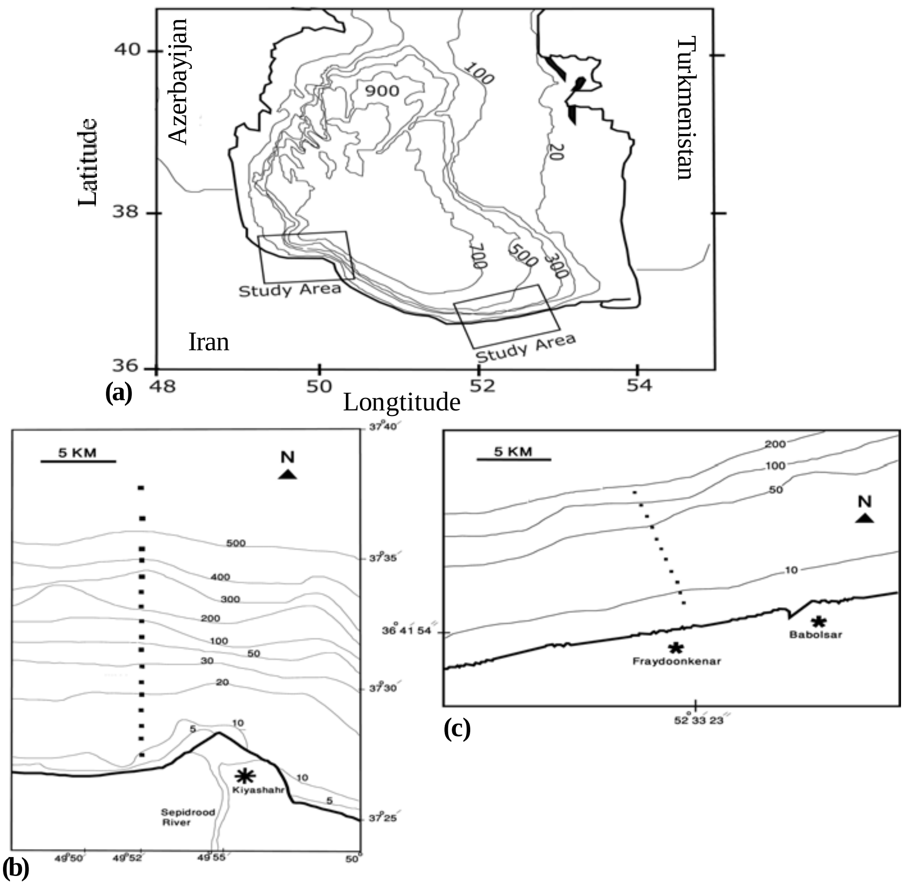

Fig. 1. a) Southern Caspian Sea Basin and position of the study areas in east and west of the Southern Caspian Coast. b) Topography and sampling stations in the west of the southern Caspian coast off Kiyashahr. c) Topography and sampling stations in the east of the southern Caspian coast, off Babolsar

MATERIALS AND METHODS

Dissolved oxygen data were measured using the oxygen sensor of Ocean Seven 316 CTD probe developed by Idronaut. The oxygen data had the accuracy of 0.1 mg/L and 1% saturation. Data were collected every 1 second with the profiler in a free fall mode falling at a rate of one meter per second. Dissolved oxygen profiles were measured in spring 2004 in the study area in the east of the south coast of the Caspian Sea and in autumn 2004 and winter and spring 2005 in the west of the south coast of the Caspian Sea. Data were measured along a transect perpendicular to the coast. In the east the data were collected at 11 stations with the distance of 1km. In the west the data were measured at 17 stations. The distance between the stations were 1km for the first 15 stations and increased to 2km for the last two stations.

RESULTS AND DISCUSSIONS

Vertical structure of dissolved oxygen in early spring (April 11, 2004) across a transect perpendicular to the coast in the east of the southern Caspian coast is presented in Fig. 2. On this time of the year the process of formation of the new seasonal thermocline was started and the temperature structure was characterized by a 10 m surface layer with a temperature of 14^{o}C. The temperature in the 10-30 m layer was 12^{o}C and gradually decreased to 8^{o}C at 90 m level (Zaker, *et al.*, 2007a). The salinity in the upper 30 m layer, under the effect of high local rivers inflow in spring, was below 12 and gradually increased to 12.3 at 40 m level (Zaker *et al.*, 2007a). The dissolved oxygen concentration outside of the shelf ranged between 8.3 and 9.2 mg/l (78-94% sat.) in the upper 40 m layer and then gradually reduced to 6.5 mg/L at 70 m level. Over the shelf the dissolved oxygen was mainly 8.6 mg/l (86-90% sat.) and horizontally varied towards the coast with a minimum of 7.1 mg/L (74% sat.) in a band of 3km width adjacent to the coast (Fig. 2).

Dissolve oxygen concentration in the study area in the west of the south coast of the Caspian in autumn on October 27, 2004 is presented in Fig. 3. The temperature structure at this time was characterized by a thin thermocline in the 30-40 m layer. The surface layer was deepening and the thermocline was under destructions. The temperature above the thermocline ranged between 19 and 21^{o}C and below the thermocline it varied between 11.5 and 6.5^{o}C in the 40-200 m layer (Zaker *et al.*, 2007b). Salinity outside the shelf was uniform and equal to 12.35 in the surface layer and mainly ranged between 12.3 and 12.4 across the depth. Salinity reduced over the shelf and reached a minimum of 11.65 adjacent the coastline (Zaker *et al.*, 2007b). The Dissolved oxygen outside of the shelf in the upper 30 m layer was mainly 7.6 mg/L (74-90% sat.). Below the 30 m level the dissolved oxygen gradually reduced to 6 mg/L (55%sat.) at 100 m level and 4.6 mg/L (42% sat.) at 200 m level. Over the shelf near the coastline, under the effect of Sepidrood River inflow, the dissolved oxygen reached a maximum of 8.8 mg/l (100% sat.) (Fig. 3).

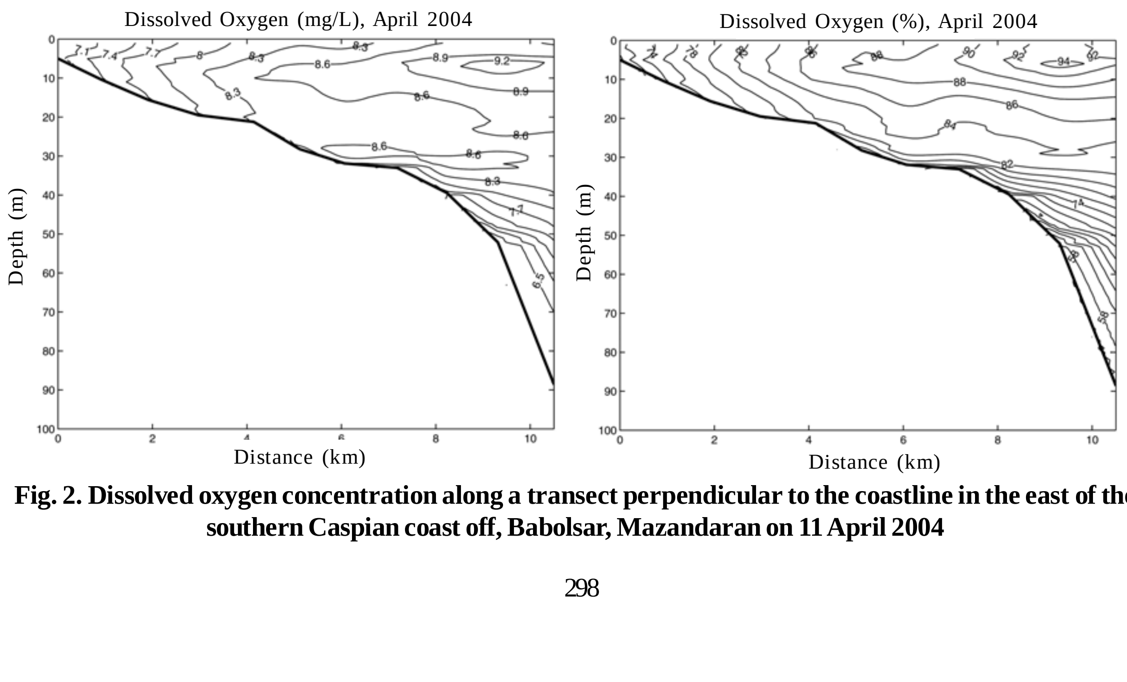

Fig. 2. Dissolved oxygen concentration along a transect perpendicular to the coastline in the east of the southern Caspian coast off, Babolsar, Mazandaran on 11 April 2004

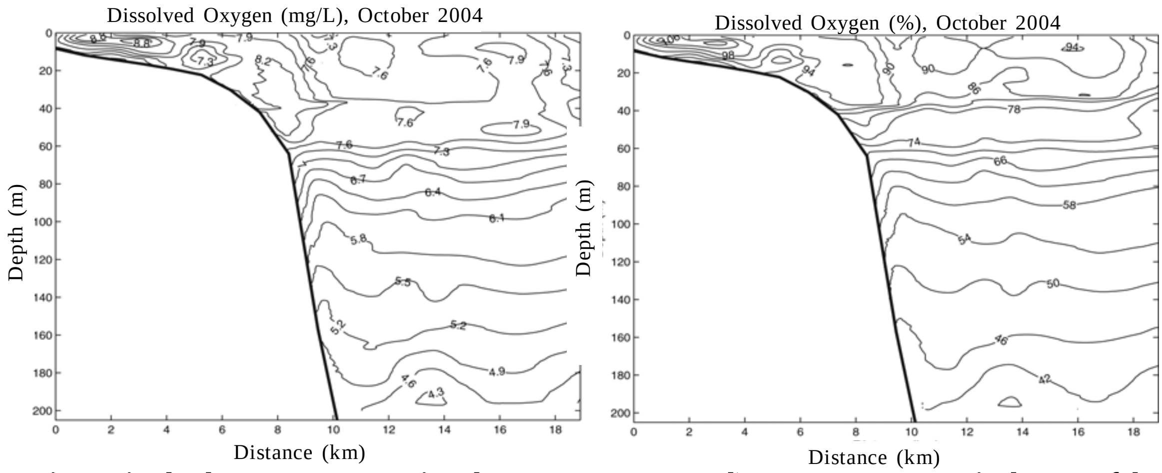

Fig. 3. Dissolved oxygen concentration along a transect perpendicular to the coastline in the west of the southern Caspian coast off, Kiyashar, Gilan on 27 October 2004

Dissolved oxygen concentration on 24 February in winter 2005 is presented in Fig. 4. At this time of the year the seasonal thermocline was disappeared and the temperature in the upper 100 m mixed layer mainly ranged between 9.5-10.5 ^{o}C. Below 100 m level, temperature gradually decreased to 7.2 ^{o}C at 200 m level (Zaker *et al.*, 2007b). Salinity in the upper 100-m mixed layer mainly ranged between 12.3-12.35 and below 100-m it was mainly 12.4 (Zaker *et al.*, 2007b). The dissolved oxygen in the upper 100 m mixed layer, due to high ventilation and low temperature, was high and mainly ranged between 10.9 (92%) to 11.2 (108%) mg/L. Below upper mixed layer, dissolved oxygen reduced sharply decreased to 7.9 (72%) at 180 m level (Fig. 4).

The dissolved oxygen concentration on May 7 in spring 2005 in the study area is presented in Fig. 5. In this time of the year the temperature structure was characterized by a newly formed thin thermocline in the 10-20 m layer (Zaker *et al.*, 2007b). The temperature above the thermocline was 17^{o}C and below thermocline it ranged between 11 and 6.8^{o}C at 200 m level. Salinity over the shelf, due to high inflow of Sepidrood in spring, was mainly less than 12 and was separated by a front from the adjacent waters outside the shelf with salinity of 12.3-12.4 (Zaker *et al.*, 2007b). Dissolved oxygen above the thermocline ranged between 8.1 mg/l (92% sat.) and 10.5 mg/l (96% sat.). Below thermocline in the 20-80 m layer, the dissolved oxygen distribution was patchy and ranged between 10.2 and 12 mg/l (100-120% sat.) and reduced to 8.4 mg/l (84% sat.) at 100 m level and 6 mg/l (52% sat.) at 200 m level (Fig. 5).

Higher values of dissolved oxygen were observed in winter in comparison to autumn and early spring (Figs. 2 to 5). The lack of seasonal thermocline as an obstacle for the ventilation of the lower layers, high turbulent kinetic energy and deepening of surface mixed layer to more than 100 m level together with lower temperatures increased the dissolved oxygen concentration in the upper 100 m layer in winter.

Dissolve oxygen concentration in early spring had significant decrease in lower layers in comparison with winter indicating the significant effect of seasonal thermocline on the vertical distribution of dissolve oxygen (Figs. 4 and 5). However, in comparison with autumn, the oxygen in the newly separated lower layers below thermocline was higher (Figs. 3 and 5).

Therefore, the lowest level of dissolved oxygen in the lower layers of water column is expected during the period of strong seasonal thermocline between late spring and early autumn. As shown by the data (Fig. 3) the oxygen content of the water column below 150 m level is unfavorable for the fish and biological activity and the situation rapidly deteriorate with increase in depth. This indicate that any occurrence of algal bloom event during the period with strong seasonal thermocline could result in very low levels of dissolve oxygen below thermocline and possible sever damage to the marine life in the region. Therefore, certain measures for reducing the input of degradable and plant nutrient wastes into the Caspian Sea are necessary and must be undertaken.

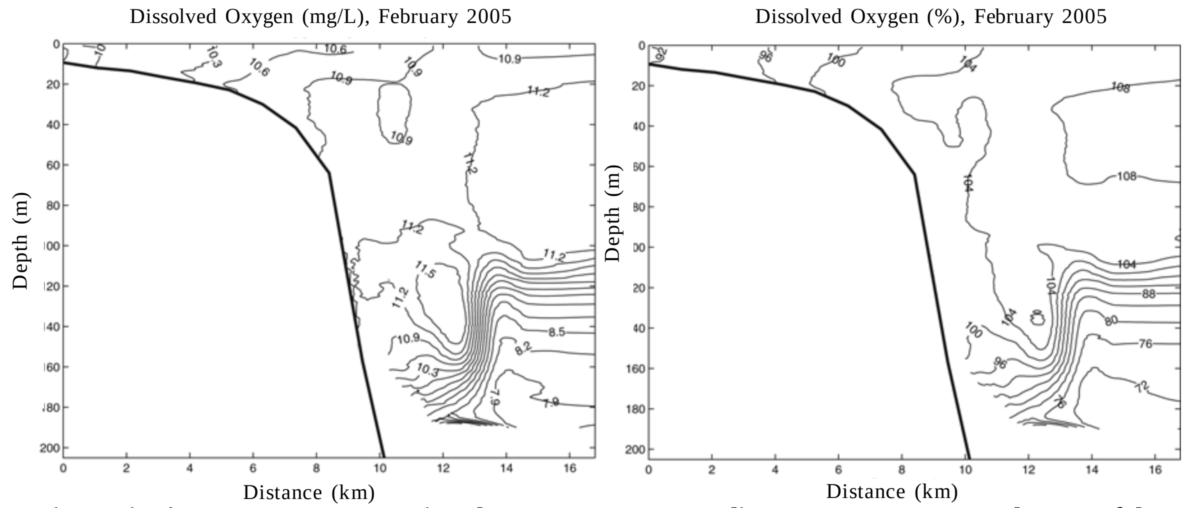

Fig. 4. Dissolved oxygen concentration along a transect perpendicular to the coastline in the west of the southern Caspian coast off, Kiyashahr, Gilan on 24 February 2005

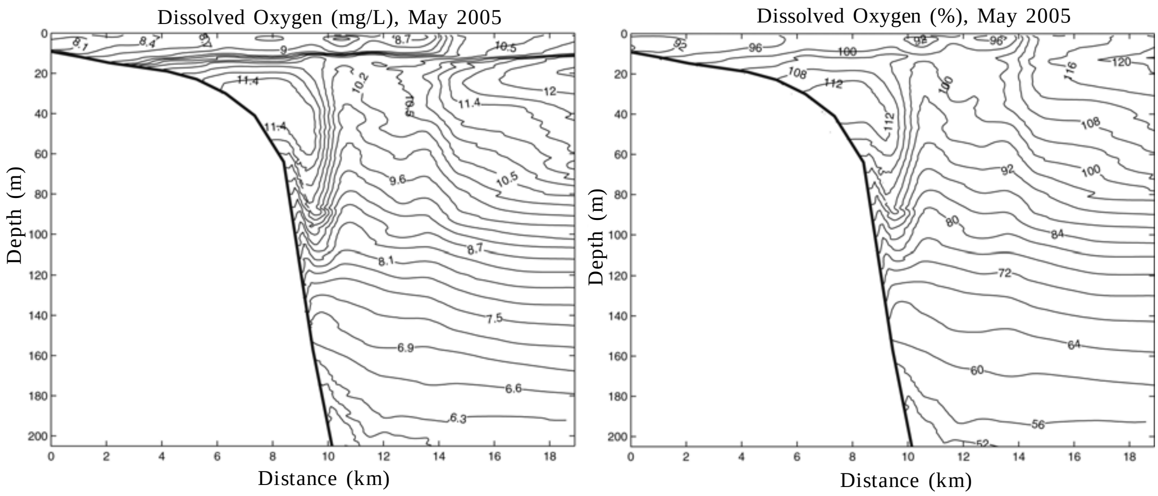

Fig.5. Dissolved oxygen concentration along a transect perpendicular to the coastline in the west of the southern Caspian coast off, Kiyashahr, Gilan on 7 May 2005

CONCLUSION

The dissolved oxygen concentration at water surface varied between 7.1-10.9 mg/L during the period of observation in Spring and Autumn 2004 and Winter and Spring 2005. The variations of dissolved oxygen concentration across the depth were correlated with the vertical temperature structure and the characteristics of seasonal thermocline. In autumn, the dissolved oxygen concentration below thermocline was 7.6 mg/L at 40 m level and gradually reduced to less than 5 mg/L at 160 m level. In winter the upper 100 m layer was almost mixed and a high dissolved oxygen concentration of 11.2 mg/L was observed in that layer. In early spring after formation of seasonal thermocline the dissolved oxygen concentration rapidly decreased with depth and reduced to 9.3 mg/L at 100 m and 6.3 mg/L at 200 m level. The results showed unfavorable condition for biological activity and fish below 150-200 m levels in terms of oxygen concentration. The results showed the possibility of dangerous low levels of oxygen concentrations in case of the occurrence of algal bloom in the presence of strong thermocline and imply the necessity of rapid measures to decrease the input of the oxygen demanding waste and plant nutrients into the Caspian Sea.

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REFERENCES

Dumont, H. J., (1998). The Caspian Lake: History, biota, structure, and function.Limnology and Oceanography, **43**(1), 44–52.

Ginzburg, A. I., Sheremet, N. A., and Kostianoy, A. G., (2005). Sea Surface Temperature Variability in the Caspian Sea. In: Kostianov, A.G. and Kosarev, A.N. (ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 59-81.

Kaplin, P., (1995). The Caspian: its past, present and future. In Mandych, A.F. (ed.), Enclosed Seas and Large Lakes of Eastern Europe and Middle Asia. SPB, The Hague, 71-117.

Karpinsky, M. G., Katunin, D. N., Goryunova, V. B., and Shiganova, T. A, (2005). Biological Features and Resources of the Caspian Sea. In: Kostianov, A.G. and Kosarev, A. N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 191-210

Korshenko, A. N. and Gul, A. G., (2005). Pollution of the Caspian Sea. In: Kostianov, A.G. and Kosarev, A.N. (ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 109-142.

Kosarev, A. N., (2005). Physico-Geographical Conditions of the Caspian Sea. In: Kostianov, A. G. and Kosarev, A. N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 5-31.

Kosarev, A. N. and Yablonskaya, E. A., (1994). The Caspian Sea. The Hague, SPB Academic Publishing, 274.

Tuzhilkin, V. S. and Kosarev, A. N., (2005). Thermohaline Structure and General Circulation of the Caspian Sea Waters. In: Kostianov, A. G. and Kosarev, A. N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 33-57

Tuzhilkin, V. S., Katunin, D. N. and Nalbandov, Y. R., (2005). Natural Chemistry of Caspian Sea Waters. In: Kostianov, A. G. and Kosarev, A. N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 33-57.

Zaker, N. H., Ghaffari, P., and Jamshidi, S., (2007 a). Dynamics of the Southern Continental Shelf of the Caspian Sea, off Babolsar, Mazandaran, Iran. Submitted to J.Coas. Res.

Zaker, N. H., Ghaffari, P., Jamshidi, S., and Nooranian, M., (2007 b). Dynamics of the Southern Shelf of the Caspian Sea, off Kiyashahr, Gilan. Submitted to Contin. Shelf Res.

Zonn, I. S., (2005a). Environmental Issues of the Caspian. In: Kostianov, A. G. and Kosarev, A. N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 223-242.

Zonn, I. S., (2005 b). Economic and International Legal Dimensions in the Caspian Sea. In: Kostianov, A.G. and Kosarev, A.N. (Ed.), The Caspian Sea Environment (Handbook of Environmental Chemistry). Springer, 243-256.