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Oceanographic Study in Coastal Waters of Babolsar

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ABSTRACT

Structures of seawater properties in the southern continental shelf of the Caspian Sea, off Babolsar were investigated. In November, water temperature was around 18°C at the sea surface and reached to about 9°C at 42 m depth. A seasonal thermocline observed below 30 m depth with more than 8°C temperature gradient across it. High concentrations of chlorophyll-a were observed in subsurface layer (at depth of 15 m) in the region. Vertical gradient of the sound speed across the thermocline was more than surface mixed layer. Variations of density and sound velocity in the coastal waters of the sea were in agreement with temperature changes.

Key words: Caspian sea, seawater properties, thermocline, continental shelf, babolrood river

INTRODUCTION

The Caspian Sea, the largest enclosed water body in the world is important for the country surrounded it (Dumont, 1998; Kosarev, 2005; Zonn, 2005a, b). Natural regime of seawater properties of the Caspian Sea is under effect of atmospheric factors and inflow of rivers (Kosarev and Kostianoy, 2005). The riverine network around the Caspian Sea in south and north parts is extremely difference. The parameters define the particular features of seawater properties structure is greater than the variations of the corresponding factors in open seas in the world (Kosarev and Kostianoy, 2005).

Regard to high human exploitation and discharge of urban, industrial and agricultural waste, the marine environment of the Caspian Sea is under extensive pressure (Zaker *et al*., 2007). Development of hydrocarbon exploration over the continental shelf and increase pollutant to the sea in last decades causes to make an increasingly studies of structure of seawater characteristics and comprehensive monitoring of the environmental conditions of the Caspian Sea (Kosarev and Kostianoy, 2005; Korshenko and Gul, 2005). The oceanographic studies are among the basic requirements for environmental and any other marine related studies and play an important role for designing the appropriate measures for reducing pollution and sustainable development of all water bodies including the Caspian Sea (Zaker *et al*., 2007).

Based on our previous studies in the Southern coastal waters of the Caspian Sea (Jamshidi *et al*., 2009; Jamshidi and Abu Bakar, 2009; Jamshidi and Abu Bakar, 2010a, b; Jamshidi *et al*., 2010a-c), the most variations of seawater characteristics over the continental shelf occurs thought upper layers (surface mixed layer and thermocline). Structure of water properties and marine environment at the mouth areas of the coastal waters is extremely under effect of outflow of the rivers.

The purpose of this study is to discussion on the seawater properties included of temperature, salinity, density, dissolved oxygen, chlorophyll-a and sound speed in the eastern part of southern continental shelf of the Caspian Sea, adjacent to Iranian coast.

THE COLLECTED DATA AND STUDY AREA

This analyze was made based on field data which was carried out in the Southern coastal water of the Caspian Sea at latitude about N36° 45' and longitude about E52° 38' in north of Iran (Fig. 1a, b). Babolrood River and Freidoonkenar port are located in the middle and western part of the study area, respectively. The southern coast of the Caspian Sea adjacent to Iran is rimmed by the Elburs mountain ridge (Kosarev, 2005). In this area, the air temperature is maximum in August and minimum in January (Kaplin, 1995; Kosarev and Yablonskaya, 1994). The Southern

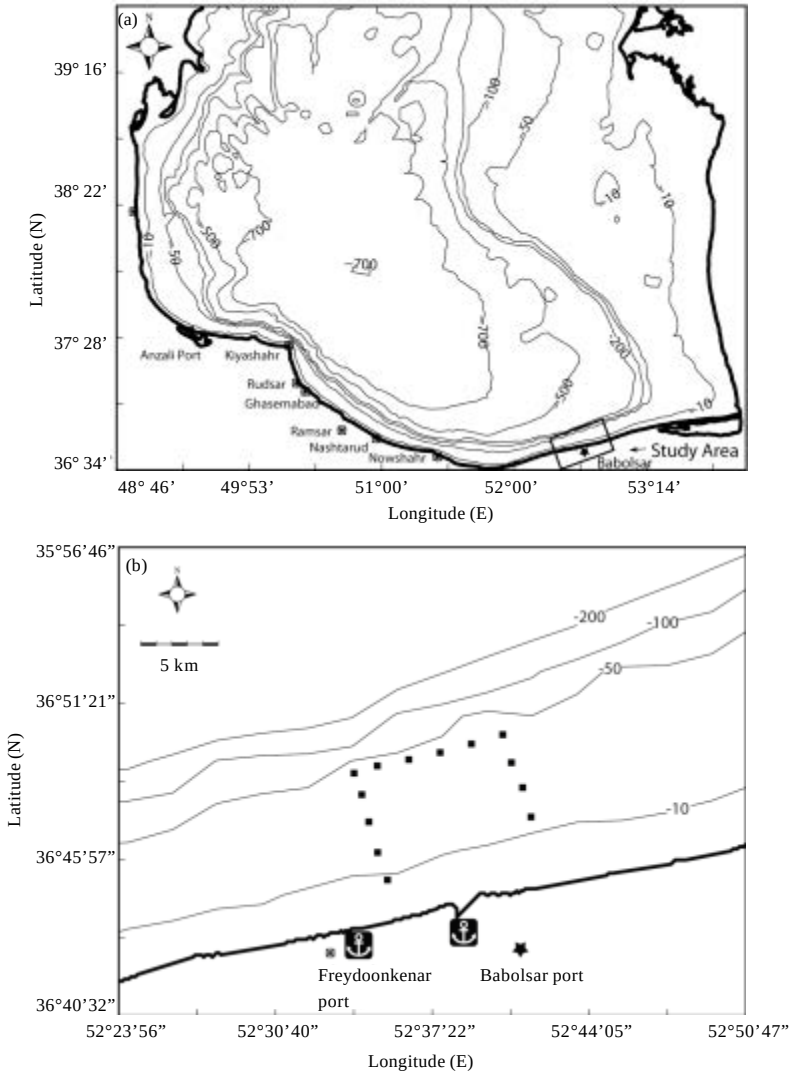

Fig. 1: (a) The Southern Caspian Sea and (b) sampling stations in the coastal waters of Babolsar. (a) The Southern Caspian sea and (b) CTD stations in the coastal waters of Babolsar port

coast of the Caspian Sea has a warm and subtropical climate (Kosarev, 2005). Data collection was done with a portable IDRONAUT CTD probe (Ocean Seven 316). The sets of data, which was used in the current research collected in 2008 over the southern continental shelf between the sea surface and the seabed at maximum depth of 42 m.

RESULTS AND DISCUSSION

Temperature, salinity and density: Variation of water temperature over the southern continental shelf mainly is under effect of atmospheric factors and river outflow. The surface temperature in the southern basin attains its annual minimum of about 7°C in February. In the deep water of the Caspian Sea, temperature are well below the annual mean temperature of the seasonal mixed layer and in the southern basin, they are even below the annual minimum of the monthly surface temperatures (Tuzhilkin and Kosarev, 2005). According to the data set was measured in November 2008, variation of temperature was between a maximum value about 18°C at sea surface and a minimum value of 9.2°C at depth of 42 m. in this time, thermal stratification in seawater column showed two layers over the continental shelf; surface mixed layer and thermocline. The temperature of the surface mixed layer ranged between around 18 to 17.6°C from the sea surface to above the thermocline (30 m depth). Towards the onshore stations, seawater was mixed with semi uniform temperature throughout the water column. Structure of temperature indicated a seasonal thermocline located below 30 m in autumn with more than 8°C gradient across it (Jamshidi and Abu Bakar, 2009). Zaker *et al*. (2007) reported existence of a strong thermocline at 20-50 m depths in summer with 15°C temperature gradient in the area in summer. Based on their measurements in autumn (October), the thickness of the thermocline reduced to 15 m between 30-45 m depths. The comparison between present study and the earlier surveys indicates that the thickness of the thermocline in November was approximately half of its thickness in the mid summer (August). In autumn with climate change and decrease of air temperature in the region, temperature of seawater decreases below 20°C. Therefore, deepening the surface mixed layer and destruction of the thermocline occurs in water column. Forming and destruction procedure of thermocline in the investigated area was seasonal and occurred between beginning of spring and end of autumn. Therefore, existence of a clear thermal stratification in the water column is not expected in winter.

The annual distribution of the evaporation intensity affects the seasonal features of the surface salinity field over the entire deepwater part of the Caspian Sea. The low value of the salinity in the Caspian Sea is due to freshwater input. The salinity in the southern basin of the Caspian Sea ranges between 12 and 13 (Kaplin, 1995; Kosarev and Yablonskaya, 1994). While climatic fields of the water salinity (PSU) in the surface layer of Southern basin of the Caspian Sea ranges between 12 and 13.5 PSU (Tuzhilkin and Kosarev, 2005). Some measurements in 2003 demonstrate existence of small variations of the salinity between 12.1 PSU and 12.35 PSU in the area (Zaker *et al*., 2007). In the time of observations in the current study, the salinity found to vary between 12.06 PSU and 12.67 PSU with an average value of 12.29 PSU in the study area. The salinity structure indicated a gradient of 0.6 PSU in seawater. The difference between maximum and minimum values of the salinity in the surface mixed layer was 0.24 PSU. There was a gentle increase of the salinity in the vertical structure with depth. The salinity grew across the thermocline, with variation from 12.3 PSU at 30 m depth to 12.67 PSU near bottom. Near the coastline in a band of 2 km width, the salinity reduces to 12.1-12.2 PSU due to the effect of local river discharges (Jamshidi and Abu Bakar, 2009). In general, it can be concluded that the salinity in the surface mixed layer was slightly less than salinity in the thermocline layer.

Density of seawater increased with depth and its vertical distribution from the sea surface to the bottom was between 1008.6 and 1010.4 kg m^{-3}. Across the surface mixed layer and thermocline, variations of density were found between 1008.8-1008.85 and 1008.9-1010.4 kg m^{-3}, respectively (Jamshidi and Abu Bakar, 2009). Due to the small salinity values of the Caspian Sea, the density changes correlated with water temperature variations. A seasonal pycnocline was formed at the position of the thermocline layer. This is reported by Zaker *et al.* (2007) in the coastal waters of the Babolsar port. Dispersion of temperature data was high below 30 m depth as well as for the density data. Salinity values were often concentrated around 12.3 PSU above 30 m depth. Due to Babolrood River discharge in the area, the salinity in the near shore stations (with less than 15 m depth) was less than offshore stations. There is a high correlation between temperature and density of seawater in the study area. There were two water masses identified in the area; the first is surface mixed layer, which consists of water influence by Babolrood River and the second is thermocline. The rivers in the southern coast of the Caspian Sea are sources for entrance of the human and industrial wastes and other pollutants to the coastal waters of the sea and change its physical and chemical properties.

Distributions of dissolved oxygen and chlorophyll-a: Investigation on the dissolved oxygen and chlorophyll-a concentrations is one of primary requirements in marine ecological, biological and environmental studies (Jamshidi *et al.*, 2009). The oxygen regime in the various parts of the Caspian Sea strongly is different. Variation of oxygen in the upper layers of the southern Caspian seawater is under effects of some factors. Seawater compositions and temperature, vertical stratification, development of phytoplankton and related photosynthetic activity are some of the important effective parameters in dissolved oxygen variations of the Caspian seawater (Tuzhilkin *et al.*, 2005). Based on previous studies in the Caspian Sea, in the upper layers of the southern basin, wintertime oxygen concentrations is mainly varied from 7 to 7.5 mg L^{-1}. In the spring with intensive photosynthesis proceeds in the upper 20 m layer, oxygen values incensement is about 0.2-0.3 mg L^{-1} related to the winter. In the summer, the greatest surface concentrations of dissolved oxygen are about 6.0-6.5 mg L^{-1}. In the fall, with destruction of the seasonal thermocline this value is reached to 6.5-7.5 mg L^{-1} (Tuzhilkin *et al.*, 2005). In addition, climatic fields of dissolved oxygen concentrations in the surface layer of the eastern part of southern coastal waters of the Caspian Sea (near the study area) were reported about 7.4 and 5.8 mg L^{-1} in winter and summer, respectively (Tuzhilkin *et al.*, 2005).

In November 2008, variations of the dissolved oxygen in the study area were considerable. In this time, the dissolved oxygen concentrations in the study area ranged between 8.4 and 11.2 mg L^{-1} over the continental shelf. There was a horizontal variation with lower dissolved oxygen concentrations in the Northern and Eastern sides of the area, which can be due to the effect of Babolrood River. The waters near the coastline were highly oxygenated close to the bottom. Existence of variability in the values of dissolved oxygen near the coastline can be due to the effect of Babolrood River inflow in the study area, stratification and coastal currents (Jamshidi *et al.*, 2009). Some observations of the dissolved oxygen concentrations in the study area in April 2004 indicated that values of the dissolved oxygen were mainly between 7.1 and 8.6 mg L^{-1} over the continental shelf (Zaker, 2007). Comparison between the presented data and Zaker *et al.* (2007) measurements showed that the concentrations of dissolved oxygen in the autumn are more than in spring. This variability may be under effects of climate change and distributions of water temperature. In the other words, owing to the decrease in seawater temperature in fall, deepening

the surface mixed layer and destruction of the seasonal thermocline in water column in the region, dissolved oxygen concentrations in the surface layers increase (Jamshidi and Abu Bakar, 2009).

On the large scale, the variations of chlorophyll in the Caspian Sea are under effect of North Atlantic Oscillation Index, Volga discharge, sea surface temperature and wind stress anomalies over different regions of the Caspian Sea (Karpinsky, 2005; Nezlin, 2005). Owing to the geographical conditions and bottom topography, the Caspian Sea can be subdivided into three parts: Northern, Middle and Southern Caspian. The deep parts of the Caspian (southern and middle) and shallow northern part are very different in hydrological ecological conditions (Nezlin, 2005). The deep southern and middle parts of the Caspian Sea are characterized with a clear vertical stratification and a sharp thermocline. In the time of measurements, the existed thermocline layer operates as a strong nutrient limitation of phytoplankton growth (Nezlin, 2005; Karpinsky, 2005). Here, the process of phytoplankton growth is regulated by vertical stratification of seawater column. The established summertime pycnocline works as a natural boundary separating deep layers (rich in nutrient) from upper mixed layer (well illuminated) where phytoplankton is concentrated (Nezlin, 2005). However, in the autumn wind stress and the cooling of the Caspian Sea surface erode the pycnocline, resulting in an increase of nutrient flux into the upper layer, which in turn stimulates phytoplankton growth (Nezlin, 2005). In the southern basin of the Caspian Sea, the seasonal pattern of chlorophyll-a shows maximum rate in chlorophyll-a concentrations in August that is together with maximum Sea Surface Temperature (SST) and wind stress. It should be noted that, with regard to analyzing the seasonal chlorophyll-a concentrations, the maximum concentration of chlorophyll-a recorded in summer 2001 which that was not related to SST and wind stress. Some researcher believe that this value was due to invasion of the carnivorous ctenophore *Mnemiopsis leidyi* to the middle and southern Caspian Sea (Nezlin, 2005; Kideys *et al*., 2008; Kideys and Moghim, 2003).

In November 2008, variations of chlorophyll-a were between 1.3-4.2 mg m^{-3} over the continental shelf in the area. Chlorophyll-a ranged between 2.5-2.9 mg m^{-3} at the sea surface and increased to 3.0-3.9 mg m^{-3} near depth of 5 m. Distribution of chlorophyll-a indicated a gently decreasing with depth in the study area. The most chlorophyll-a concentrations were found near the surface of the water (between 5 and 20 m depths). Horizontal gradient of chlorophyll-a concentrations in the area were considerable. Values of the chlorophyll-a concentrations in the eastern part of area is higher than its values in the west. In autumn with seasonal climate changes, mixed layer deepens down to 30 m depth. Therefore, destruction of seasonal thermocline and pycnocline starts and nutrients flux into the surface layers (Jamshidi *et al*., 2009).

High concentrations of dissolved oxygen and chlorophyll-a can be explained by influence of the Babolrood River to the area. Iranian lagoons and coastal regions have been steadily polluted with anthropogenic sources (fertilizer and pesticides used in agriculture and increased nutrient load of river flows due to deforestation of woodland) since the early 1980s. Thus, simultaneous rises in nutrient contributed to increases in chlorophyll-a values (Kideys *et al*., 2008; Kideys and Moghim, 2003; Kopelevich *et al*., 2008). It is assumed that, due to locating of the study area near the mouth of Babolrood River, the chlorophyll-a concentrations in the area was higher than other regions of the eastern parts of southern coastline. In the study area, chlorophyll-a concentrations changed with the factors that effect phytoplankton growth. Some of those factors were amount of sunlight, nutrient concentrations near coastline and amount of mixing (thermal stratification).

Variations of sound speed: Range of variations of sound speed was great due to high gradient in the temperature from surface to bottom. In November 2008, the sound speed varied between 1488-1460 m sec^{-1} between surface and depths of 42 m, respectively. At the surface mixed layer (0-30 m depth) range of the sound speed variations was not great (between 1487 and 1488 m sec^{-1}). Vertical difference of the sound speed below 30 m depth was more than upper layer (Jamshidi and Abu Bakar, 2010a). With increase the depth, amount of the sound speed in the deeper part of transect, was rapidly reduced. In the surface mixed layer, low changes of temperature were observed. Vertical variations of the sound velocity across the surface mixed layer were slight and less than thermocline layer. Affect of temperature changes on variations of the sound velocity were major. Due to existence of high agreement between changes of the temperature and sound speed and low range of temperature changes in mixed layer, vertical variations of the sound velocity were slight in this layer. At the time of measurements, most changes of sound velocity were across the thermocline layer. Based on the analysis of the collected data, there is a good agreement between variations of the sound speed in the study area with the temperature changes. Furthermore, the effect of the salinity on sound velocity changes was low. According to structure of temperature in various seasons in the southern coastal waters of the Caspian Sea, it is expected that, vertical gradients of the sound speed in warm months are more than its vertical gradient in cool months. The vertical gradients of sound velocity in winter and summer are minimal and maximal, respectively.

CONCLUSION

Analysis of collected data in the region showed a thermal stratification of seawater consist of surface mixed layer and thermocline from the sea surface to 42 m depth. The temperature structure was characterized by a thin seasonal thermocline below 30 m layer. In the near shore stations, the salinity was under effect of Babolrood River inflow. The temperature is an important and effective physical property of seawater over the southern continental shelf of the Caspian Sea. The sound speed variations follow the variations in temperature, indicating strong correlation between the two parameters in the study area. Maximum values of chlorophyll-a concentrations were in subsurface layer in the region. Dissolved oxygen concentrations ranged between 8.4 and 11.2 mg L^{-1} in the area. Discharge of rivers is represented main source of nutrients in the southern Caspian Sea. According to the discharge of local rivers in the coastal waters, seawater in the near mouth areas has different conditions from open areas by the enhanced values of dissolved oxygen content, nutrient and chlorophyll-a. Vertical structure of the sound speed indicated a sharply decreasing trend across the thermocline.

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