Analysis of the nitrate distribution in the Black Sea density field*

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Abstract — The paper discusses the results derived from the analysis of the vertical distribution of nitrates in the Black Sea density field during the winter of 1994. It has been shown that in the absence of winter-time convective mixing of waters, the vertical structure of nitrates is isopycnically defined. Maximum nitrates concentration persists throughout the warm period, normally changing from 5 to 9 μmol in the deep-water part of the area, and has not altered, in comparison with the 1980 data.

Investigation of the dynamics of inorganic nitrogen and phosphorus components in the Black Sea are of overriding importance, because the input of these elements into the photosynthesis zone and their availability in sufficient quantity to serve as food source for the phytoplankton, dictate the functioning of the basin's ecosystem. The Black Sea chemical regime depends upon the hydrological structure of the waters, which alongside the specific physical/chemical processes controls the occurrence of characteristic extreme values in the nitrates/phosphates vertical distribution [1,2]. It has been found out that, in the deep-water part of the Black Sea, during the stratification period, the maximum nitrates concentration took place within the layers, whose densities ranged from 14.2–14.4 to 16.0–16.2 conv.units [3–7]. The use of the conventional density scale allows us to exclude the effect of fluid dynamics, to assess realistic seasonal and multi-annual variations of the nitrates concentration, and to identify the mechanism for their influx to the photosynthesis zone. Today, seasonal and inter-annual dynamics of nitrates concentration in the layer where their content attains a maximum remains insufficiently studied. The purpose of this work is to analyse nitrates distribution in winter, as well as to compare recent data with the nitrate data compiled 15 years ago, in order to infer how anthropogenic forcing affects nitrates accumulation in the maximum nitrates concentration layer.

MATERIALS AND METHODS

The winter period has been studied, using the observations carried out during Cruise 32 of the R/V Professor Kolesnikov from 5 to 25 December 1994 (Fig. 1). Seawater was sampled from 10 to 18 depth levels, using a rosette of bathometers of the ISTOK-7 probe. The discreteness of sampling was largest within the isopycnic surfaces 14.2–14.4 and 16–16.2 conv.units, including depths where density was 15.4–15.6 conv.units. Nitrates concentration was determined by the standard method [8] by means of a KFK-3 photoelectric photometer.

To perform a comparative analysis, we have used the data collected during Cruise 9 of the R/V Professor Vodyanitsky in the summer of 1980. We have selected 12

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stations occupied in the western part of the abyssal Black Sea between 43° 00'-44° 30' N and 30° 00'-34° 00' E. Observations in that area were conducted from 3 to 10 September 1980. Seawater was sampled from the 0-100 m layer at 5-12 depth levels, using a 30-litre plastic bathometer. The acquired evidence frequently lacks data on nitrates concentration in the upper stratum of the layer of their maximum (14.2-14.4 conv.units) and at the maximum proper (15.4-15.6 conv.units). However, considering correlation between nitrates content and the density of the seawater during the warm period, it was possible to reconstruct their profile in the stratum bounded by the sea surface and the depth level where maximum nitrates concentrations occurred. It was assumed that to the 14.4 conv.units isopycn, beneath which lies the nitratocline, correspond nitrates concentrations in the overlying layers. This assumption was made, taking nitrates concentration to be uniformly distributed within the upper mixed layer down to the isopycn indicated above. An even distribution of nitrates in the upper part of the nitratocline has enabled us to determine their content in the maximum, applying the method of linear interpolation. The upper part of the nitratocline was restored from the 14.4 conv. unit isopycn (the beginning of the nitratocline) to the 15.6 conv.unit isopycn (nitrates maximum). The angle of the direct line inclination was determined graphically by the density values between the 14.4 and 15.6 conv.unit isopycns.

RESULTS

In December 1994, the hydrological structure of waters, as observed during the expedition, started modifying, with the winter-time properties being increasingly more pronounced. The test area included the jet of the Black Sea rim current travelling in zonal direction from east to west, as well as a number of cyclonically-vorticized areas situated to the left of the current. The topography of the 15.6 conv.units isopycnic surface, shown in Fig. 1a, depicts fluid dynamics in that area.

The vertical distribution of nitrates exhibited the traits characteristic of the Black Sea (Figs 2a and 2b). The depth of the upper nitrate-depleted layer in the western part of the area (31°15'-32°45' E), where nitrates concentration ranged from the analytical zero to 0.42 μmol, averaged 40 m. In the eastern section (33°15'-34°15' E), the layer's thickness was not determined because of the insufficient discreteness of sampling over depth. However, it has been noted that nitrates concentration in the eastern part of the test area was higher: nitrates content at the sea surface varied from 0.09 to 0.7-0.8 μmol. Nitrates concentration has been observed to increase when seawater density equalled 14.2-14.4 conv.units. The concentration reaches a maximum when the conventional density reaches 15.5-15.6 conv.units (Fig. 2b). Bearing this in mind, we can infer the distribution of the maximum nitrates concentration over the water column from the topography of the isopycnic surface 15.6 conv.units (Fig. 1a). The depth of the maximum nitrates concentration at issue changed from 71 to 163 m, being largest in the northern margins of the Black Sea rim current. In the areas where cyclonic vorticity took place, isopycns were observed to ascend; accordingly, maximum nitrates concentration occurred at a smaller depth. It was closest to the sea surface in the zone of cyclonic vorticity situated south-east of the test site (33°15'-34°15' E; 43°30'-44°00' N). In that area, sea surface temperature was particularly low (7-8°C), while salinity and density, conversely, were large: 14.2-14.4 conv.units isopycns were documented near the sea surface. Hence, the hydrological structure was on the verge of generating a new cold intermediate layer.