HYDROOPTICAL STRUCTURE OF WATERS IN THE EASTERN PART OF WHITE SEA

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Light attenuation index of sea water was measured with a sounding transparency meter at the radiation wavelength of 530 nm. *The measurement results demonstrate that the spatial distribution of the index is connected with the hydrological structure of sea waters.*

White Sea is a traditional source of biological products, e.g., algae, fish, sea mammals etc. At present, it attracts much attention as promising object for prospecting and recovery of deposit diamonds and other minerals in the Gorlo region (i.e., the narrow entrance to the gulf). Gorlo is characterized by intensive tide streams mixing the waters from the surface to bottom.[1] So one can suppose that, in the region of diamond recovery from the sea bottom, the thickness of Gorlo waters can be turbid due to suspended particles of pelite-aleurite coarseness. The suspension plume can spread into the adjacent regions of the sea by streams.

It is well-known that phytoplankton photosynthesis is one of the main factors determining the quantity of primary biological produce in the sea. The photosynthesis, in its turn, depends not only on the biogenic elements dissolved in water and temperature but, to great extent, on the illumination conditions. Photosynthesis activity and the depth of its optimum are larger in transparent waters as compared to turbid waters, other conditions being equal.

Thus, industrial exploitation of diamond deposits at the bottom of Gorlo can effect natural formation of primary biological produce not only in this region but also in the Bassein (basin) and Voronka.

In this connection, it is necessary to obtain information about water transparency in the eastern part of White Sea prior to industrial exploitation of minerals. Variation of this parameter will make it possible to estimate the degree of technogenic effect upon the sea ecosystems.

DATA AND PROCESSING TECHNIQUES

This paper is based on the data characterizing water transparency in the eastern part of White Sea. The data were collected by authors during the mission organized by the Institute of Ecological Problems of the North, Ural Branch of the Russian Academy of Sciences, in August, 1995 at PTS–74. The observations were carried out at 66 suspended hydrooptical stations placed as sections (see Fig. 1). The coordinates of stations deployed at distances up to 25 miles were determined by a shipborne radar; the positions of stations beyond the radar operation range were determined by navigational reckoning.

As an objective indicator of hydrooptical water structure, we used the value of light attenuation by sea water (ε) at the wavelength 530 nm in the visible range in a narrow interval of the spectrum, 20 nm wide. The value ε was measured by a contact *in situ* method with a submergible device "KvantB[3] which enables one to measure ε with an error not more than 0.01 m^{-1} by continuous sounding of water thickness from the surface to the bottom.

Measurement results demonstrate that the optical structure of waters in the area under study is characterized by large spatial inhomogeneity and broad range of values of the light attenuation index: from 0.2 to 6.2 m^{-1} in Voronka; from 0.3 to 2.3 m^{-1} in Mezen' Bay; from 0.3 to 2.0 m^{-1} in Gorlo; from 0.5 to 2.8 m^{-1} in the eastern part of Bassein and Dvina Bay.

DISCUSSION OF THE RESULTS

There are two main types of hydrological regimes in White Sea. The homogeneous type is characteristic of shallow regions, i.e., Onega Bay, Gorlo, Mezen' Bay, and Voronka where waters are mixed from the surface to the bottom due to strong tide streams. The stratified regime is characteristic of a broad region of weakly moving waters in deep parts of Bassein, Kandalaksha and Dvina bays. In the regions of the stratified regime, one can isolate the depth and surface water masses. The former fills sea hollows down to about 100 m. The upper layer of the latter has a seasonal modification in summer. The modification is a quasihomogeneous layer of desalted and warmer waters mixed by wind seaway. The layer is clearly separated by pycno- and thermocline.[1,4]

In this connection, when discussing the information obtained, it is necessary to say about certain connections between the index ε and hydrological structure of waters.

The analysis of the data obtained on the spatial distribution of the light attenuation index clearly demonstrates the known scheme of quasiconstant

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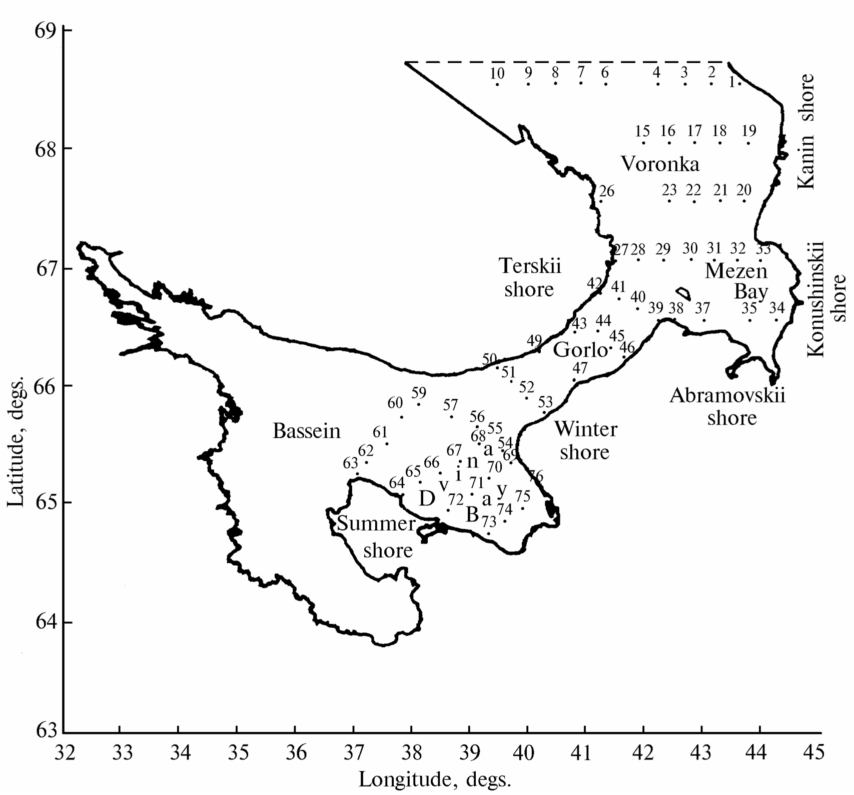

FIG. 1. Location of the hydrooptical stations installed in August, 1995.

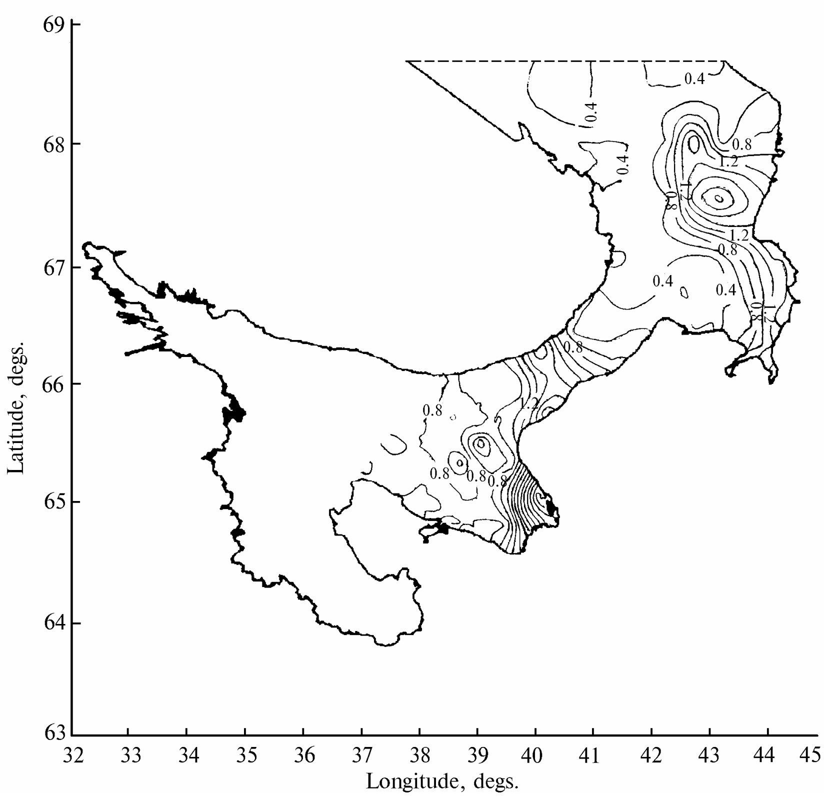

FIG. 2. Distribution of the light attenuation index $\varepsilon\,(\mathrm{m}^{-1})$ *at the depth level of* 10 m. *White Sea, August, 1995.*

surface streams in White Sea[5] by the degree of water transparency. For instance, in Dvina Bay, Onega stream carries relatively transparent waters with the index ε equal to 0.7–0.8 m^{-1} near the Summer shore; the flow of turbid waters of the Severnaya Dvina is carried by Dvina stream from the vertex of the bay along the Winter shore. Besides, at the boundary between Bassein and Dvina Bay, binary structure of dynamical vortices is clearly seen in the surface layer. The anticyclonic vortex is characterized by lift of depth waters (ε = 0.6 m^{-1}); the cyclonic vortex lowers the turbid surface (ε = 1.3 m^{-1}) waters.

At the boundary of Bassein and Gorlo, near the Winter shore, the Dvina stream divides into two flows. One of them is directed to Gorlo and then to the north to Terskii shore. The second one deviates to north-west along the zone of mixing of Bassein and Gorlo waters. A flow of relatively transparent water (ε = 0.4 m^{-1}) may be seen in Gorlo near the Terskii shore at the depth of 15–25 m. The flow passes to Bassein along the shore. In the northern part of the sea, the value ε makes it possible to separate out the Mezen' and Kanin streams, and the Barents Sea stream entering into Voronka near the Terskii shore. As an example, the distribution of the attenuation index ε at the 10 m depth is presented in Fig. 2.

At the conventional boundary between the White and Barents Sea, vertical separation into layers is observed. Intrusion of the most transparent (ε = 0.2 m^{-1}) Barents Sea waters was observed at St. 4 (Fig. 3) in the layer of 2–8 m. Flows of less transparent waters were seen at St. 3 and St. 10 where the values of ε are 0.4 and 0.5 m^{-1} in the layers of 10–20 and 0–20 m, respectively. In the rest of the northern part of the sea, i.e. in Voronka and Mezen' Bay, the values of ε are constant from the surface to the bottom (for instance, at St. 7). This points to the fact that the process of vertical turbulent mixing prevails over the buoyancy forces in this region.

The relatively deep western part of Voronka is filled with waters with ε equal to about 0.3 m^{-1}. The waters are spread to Mezen' Bay (St. 30, 31) and reach Gorlo near Winter and Terskii shores (St. 39, 42). In the central part of the Mezen' Bay, water transparency decreases to ε = 0.5 m^{-1} (St. 35); near Abramovskii and Konushinskii shores (St. 38, 34) to 1.2 and 1.4 m^{-1}, respectively.

In the shallow water of the eastern and southern parts of Voronka, a clearly observed nepheloid layer of thickness 1–3 m is observed in the near-bottom waters. The layer is formed due to washout and stream transfer of bottom deposits. The maximum value of the light attenuation index (ε = 6.2 m^{-1}) was recorded in shallow water near the Kanin shore at St. 20, in the zone of counterflows of Mezen' stream passing from the bay and the Kanin stream. Between the regions with clearly homogeneous vertical structure of waters and shallow water regions with a nepheloid near-bottom layer, an intermediate type of vertical distribution of ε is also observed. Here, water transparency varies more smoothly from the surface to the bottom, or a stratified water structure is seen (Sts. 17 and 22, respectively, Fig. 3*a*).

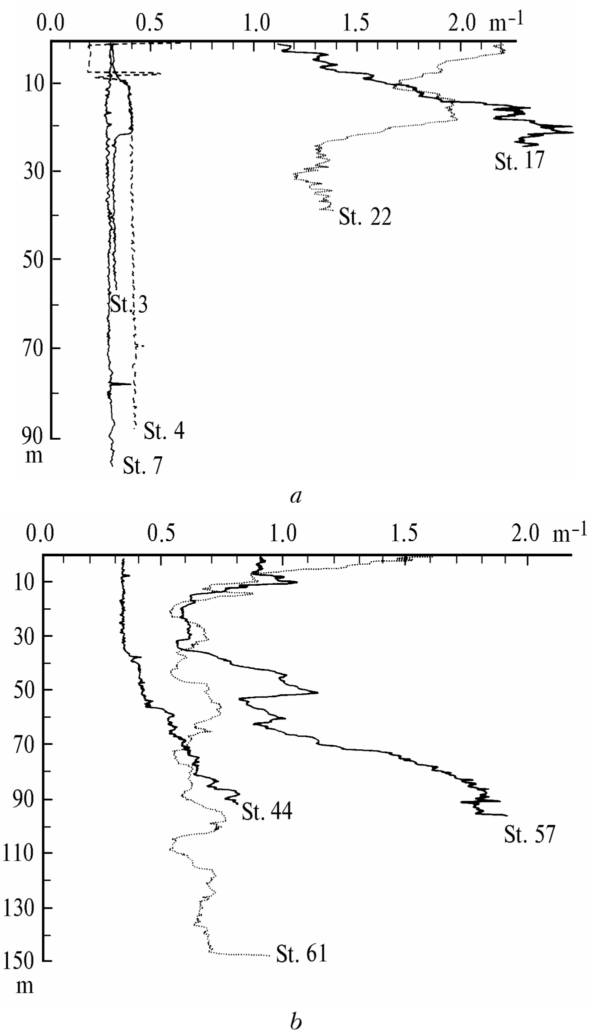

FIG. 3. The curves of the vertical distribution of the light attenuation index ε (m^{-1}) from the surface to the bottom. White Sea, August, 1995.

In Gorlo, mainly a homogeneous type of vertical distribution of ε is observed. The light attenuation index increases from 0.3–0.4 m^{-1} at the northern boundary of Gorlo to 0.6–0.9 m^{-1} at its southern boundary. However, in the deep channel that begins at the northern boundary of Gorlo and connects with Bassein, one can see three water layers with different vertical distributions of ε. In the surface layer, down to about 35 m, the index ε is about 0.35 m^{-1}; in the intermediate layer, from 35 to 55 m, ε equals about 0.45 m^{-1}; in the "deepB layer, from 55 m to the bottom, the values of ε gradually increase to 0.8 m^{-1} at the depth of 90 m (Fig. 3*b*, St. 44).

In the region of slowly moving waters of the deep part of Bassein and Dvina Bay, the vertical distribution of ε is stratified. The values of ε equal 0.7–1.5 m^{-1} in the upper quasihomogeneous layer

(0–10 m). Below the layer, one can also see the layers with the index ε equal to 0.50–0.55 m^{-1} at the depth of 15–20, 35–45, 65–80, and 100–110 m; and with the index ε equal to 0.65–0.70 m^{-1} at the depth 25–30, 50–60, and 85–95 m. The stratified structure of waters is most clearly observed at the boundary of Bassein and Gorlo. This seems to be connected with a powerful frontal stream directed from Winter shore to Terskii (Fig. 3*b*, Sts. 61 and 57).

Near the coast of the Dvina Bay the character of vertical distribution of ε considerably varies. Near the Summer shore, it is close to homogeneous with the index ε equal to 0.6–0.8 m^{-1} (St. 63); the stratified distribution is observed near Winter shore and at the vertex of the bay.

CONCLUSION

The measurements of the light attenuation index of sea water at the radiation wavelength 530 nm made it possible to reveal the background spatial distribution of this parameter in the eastern part of White Sea and to elucidate that hydrooptical structure of the White Sea waters is closely connected with its hydrological structure. This enables one to use optical parameters as an indicator of changes of water state and dispersal of turbid plumes occurring due to exploitation of mineral deposits at the bottom of the sea, and to estimate possible changes in the natural formation of primary produce in the sea.

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