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Biogeochemistry of Northern Dvina mouth during flood

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Introduction

Study of biogeochemical processes in estuaries and deltas is of particular significance in understanding their role in global cycles of carbon and many other chemical elements. Most of the suspended matter is trapped in the estuaries where freshwater and salt water are mixed (salinity of about 2–15 psu), and rapid accumulation (precipitation) of fine-grained suspension occurs due to coagulation processes. According to A.P. Lisitsyn (1995), more than 90% of the suspended matter (including particulate organic carbon) and about 30% of the dissolved matter probably accumulate within this so-called “marginal filter”.

The Northern Dvina River is the main source of water and riverine suspended matter supply of the White Sea (Gordeev et al., 1996). The most part of suspended particulate matter (SPM), particulate organic carbon (POC), particulate inorganic carbon (PIC) are delivered to the White Sea during floods, but the particulate matter and nutrients in estuaries and deltas of rivers, flowing into the White Sea, practically is not studied (Artemyev and Romankevich, 1988; Lisitzin et al., 2003). The aim of the expedition to the Northern Dvina mouth in May 2004 was to study biogeochemical processes controlling the distribution of SPM, POC, PIC, nutrients during floods.

Materials and methods

The distribution of SPM, POC, PIC and hydrological characteristics of Northern Dvina River and its tributaries and branches were studied during the flood period from 13 till 30 May, 2004 (Shevchenko et al., 2004a). The studies were carried out onboard the RV “Iceberg-2”. Water samples were obtained from the water column by Niskin bottles and from the surface by plastic bucket. The filtration of water samples was carried out through pre-weighted Nuclepore filters 47 mm in diameter (pore size 0.45 μm) and Whatman GF/F filters 47 mm in diameter. After filtration filters were washed with distilled water and dried at 50–55°C. After that Nuclepore filters have been packed in plastic Petry dishes and then sealed in plastic envelopes and GF/F filters have been sealed in aluminium foil for later analyses in the land laboratory. In more detail working procedures are described elsewhere (Lisitzin et al., 2003; Shevchenko et al., 2004b). 141 samples of SPM and 119 samples of POC–PIC have been collected. At each station temperature, salinity, turbidity and chlorophyll “a” concentration were measured by CTD90 and 3”Micro CTD probes. POC and PIC have been measured by express-analyzer of carbon AN-7560 by means of dry burning of particulate matter in oxygen flow. Nutrients (dissolved silica, phosphorus, nitrites) concentrations were determined in 132 samples by standard hydrochemical methods (Maksimova, 2003). Grain size analyses of SPM were done by laser analyzer MALVERN 3600 Sizer in 25 water samples.

Results and discussion

Continuous measurements of water level and discharge at the Ust’-Pinega cross-section by specialists of gauging station of SEVHYDROMET show that in March and the first week of April both water level and discharge were very low (about 210 cm above the sea level and 880 cub.m/s, correspondingly). They sharply increase in the period from April 20 to May 19 (up to 750 cm and 16400 cub.m/s, correspondingly). Our field studies were carried out during the peak of flood. Both water level and discharge sharply decreased from June 2 to June 17.

Concentration of SPM at the Ust’-Pinega cross-section varied from 4 to 14.7 mg/l (8.9 mg/l on average, n = 16 samples). Near the same values were registered upstream this cross-section in the Pinega River (6.7–11.3 mg/l) and in Northern Dvina 10–50 km upstream the Ust’Pinega (7.3 mg/l). In the Maimaksa Branch from the Solombala Island to Lapominka concentration of SPM in the surface layer varied from 5.8 to 13.9 mg/l (10.2 mg/l on average, n = 11). It is at the same level as it was previously reported (Shevchenko et al., 2004b) for this branch for the end of flood at 11.06.2003 (13.2 mg/l); at middle of April 2003 it was 2.48 mg/l and 20.08.2003 – 6.14 mg/l. All these values were much lower than concentrations in marginal filters of the large Siberian rivers (Gordeev et al., 1996; Lisitzin et al., 2003).

In the mixing zone the concentrations of SPM sharply decrease with the increase of salinity. Near the Mud'yug Island they were 1.9 mg/l. In the marginal filter of Northern Dvina the same as in Siberia (Lisitsyn, 1995; Lisitzin et al., 2003), the following processes sequentially change each other at the way from the river to the sea: gravitational sedimentation, physico-chemical processes in colloid system (coagulation and flocculation, formation of sorbents), and, finally, biological processes (growth of phytoplankton with conversion of dissolved elements to biogenic suspended matter and the process of biofiltration).

Even in the outer part of the delta riverine water dominated. The distribution of temperature, salinity and turbidity (SPM) were influenced by tidal movements. In the mouth of Murmansky Branch near Kumbysh Island the concentrations of SPM at the Station 36 were 3.4–4.6 mg/l during the tide and 13–14 mg/l during the ebb. During the maximal tide the depth increased to 11 m and termo- and haloclynes were pronounced. Turbidity decreased under the picnoclyne. During the ebb all water column (water depth was 10 m) was gomogeneously mixed, values of temperature, salinity and turbidity were constant with the increasing the depth.

The contents and distributions of POC and PIC reflect the biotic production–destruction processes, geochemical and biogeochemical fluxes (precipitation, turbidization, burial, bioturbation, and others), optical properties of seawater. In the investigated region POC concentration ranged from 0.1 to 2.1 mg/l and comprised 1.0 mg/l on the average. These data coincide mainly with data early obtained in spring period in the mouth of Northern Dvina (Artemyev and Romankevich, 1988). PIC concentration ranged from 0.02 to 0.6 mg/l and comprised 0.2 mg/l on the average. POC and PIC comprised 2.6–48.4% of SPM (in average 14%) and 0.2–15.5% (in average 8%), correspondingly. The absence of noticeable water stratification in flood caused rather variegated both POC and PIC distribution in water column 0–8 m (with depth less 11 m at most stations).

Near the southern part of the Mud'ug Island at the Station 89 during the maximal tide the saline wedge was registered in 3-m layer over the bottom. Turbidity in this layer decreased. During the ebb at this station salinity was constant and very low (0.05 psu), temperature slowly decreased with the increase of depth, turbidity and SPM concentration increased in this direction.

SPM granulometric spectrum in the Northern Dvina mouth during flood was sufficiently similar. The peak of volume concentration was in the range from 20 to 60 um (aleuritic particles in general). Tide phases had an influence on SPM granulometric spectra. For an example, in the marine part of river mouth adjacent Mud'ug Island during ebb riverine SPM had good sorting and content of particles with diameter about 60 um until 50% during mean water. But during tide SPM spectrum was smoothed and the mode was shifted to the finer particles – about 30 um.

Concentrations of nutrients (dissolved silica, mineral phosphorus, nitrites) were higher than in summer time due to delivery from melting snow in catchment area. Generally, they decreased seawards.

Conclusions

During the flood period the concentration of suspended particulate matter (SPM), particulate organic and inorganic carbon (POC, PIC) in the lower stream and delta of the Northern Dvina were comparatively low.

Near the mouths of Northern Dvina the distribution of SPM concentrations, temperature and salinity are influenced by tides.

At the outer part of the delta the SPM, POC concentration is decreased with increasing of salinity; percentage of POC in suspended matter increased seawards.

In Northern Dvina mouth the same character of biogeochemical processes as in the large Arctic estuaries was revealed, but the scale of these processes is different.

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