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Exchange of Suspended Matter and Organic Compounds at the Water Atmosphere Boundary in Indian and Atlantic Oceans

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Abbreviations: HCs: Hydrocarbons; SM: Suspended Matter; OCs: Organic Compounds

Introduction

Fronts and frontal zones belong to the most interesting phenomena in the ocean because of sharp increase of spatial gradients of the basic thermodynamic parameters compared to their background values Fedorov [1]. Until recent time, frontal zones were studied mainly by physical methods. Geochemical approach was seldom used. In addition, there is practically no data on the effect of frontal zones on the distribution of pollutants in the sea. In particular, it was found that accumulation of pollutants in the frontal oceanic zones occurs even in trace concentrations, as fluoro organic compounds Lohmann and Belkin [2]. These studies are also relevant for hydrocarbons (HCs), compounds of both natural and anthropogenic origin. Aeolian material in surface waters is mixed with aquatic suspended particulate matter and involved in sedimentary processes in ocean, i.e., in vertical and horizontal fluxes. Therefore, the atmosphere-water geochemical barrier zone is an important area of the oceanic sedimentation system Lisitzyn [3].

Studies of aerosols and surface waters wereperformed during cruise 47 of R/V "Akademik Ioffe" along the section across the Atlantic Ocean (Ushuaia-Gdańsk section; March 26-May 7, 2015) Nemirovskaya [4]. The long term work of the Institute of Oceanology of the Russian Academy of Sciences on the study of aerosols and surface waters along the vessel routewas continued in the expeditions of R/V "Akademik Nikolai Strakhov" (December 2015-January 2016) and "Akademik Boris Petrov" (January-April 2017). The route of R/V "Akademik Nikolai Strakhov" started in p. Colombo, R/V "Akademik Boris Petrov" got off the Singapore port. Studies covered the northern part of the Indian Ocean, the Red and Mediterranean seas, the eastern part of the Atlantic Ocean, the North and Baltic seas and ended in p. Kaliningrad (Figure 1). The aim of the research was to determine the influence of climatic features on the distribution of suspended matter (SM) and organic compounds (OCs) in its composition (natural and anthropogenic) in the near water layer of the atmosphere and in surface waters. The objectives of the research were to study: the variability of granulometric composition of the near water aerosol by means of aerosol particle counter; the distribution (2017) and composition of water SM in surface waters; production characteristics of the surface water layer (suspended organic carbon C_{org}, pigments); hydrocarbon pollution (2015, 2017). Ship routes covered tropical, subtropical and temperate zones in the humid and arid regions of the Indian and Atlantic oceans, as well as impact and background areas (Figure 1).

The study of the granulometric composition of the aerosol near water layer was carried out with the help of the 6 channel particle counter Aerotrak (USA) designed to determine the calculated concentrations of aerosol particles in the atmosphere. Samples of surface water were taken 3-4 times along the route during the daytime. The suspended matter was filtered onboard, and its analysis and OC analysis was carried out in the laboratory onshore. Details of the methodological procedures are described in Nemirovskaya [4].

The obtained data showed that the content of particles in the near water layer of the atmosphere varied in a large range, as the atmosphere is the most mobile and changeable of the Earth Geospheres, in which flows of substances change rapidly due to the movement of air masses Lisitzyn [3]. Particles with sizes of 0.3-0.5μm prevailed in all samples and amounted to 78-88% of the total (Figure 1). The small size of particles in the atmosphere is determined by the fact that they are formed by condensation of vapors or chemical reactions. For these particles, the mean concentrations depending on the area along the vessel route decreased in sequence (particles/l): Bab El Mandeb Strait (135190) > Gulf of Aden (102854)>Red Sea (91612)> North, Baltic Seas (76468) > Indian Ocean (64113)>Mediterranean Sea

(28397)>East Atlantic (14803) (Figures 1 & 2). The distribution of the near water aerosol in the ocean is mainly affected by the inflow of mineral particles of different composition, especially from the arid land regions Lisitzyn, [3], Nemirovskaya [4], Prakash et al. [5]. Therefore, their increased content is associated with the Bab El Mandeb Strait, the Gulf of Aden (where the maximum concentration is 379361 particles/l) and the Red Sea. In these areas, particles flow from the desert areas of the Arabian Peninsula with the North wind in case of the proximity of the shore Prakash et al. [5].

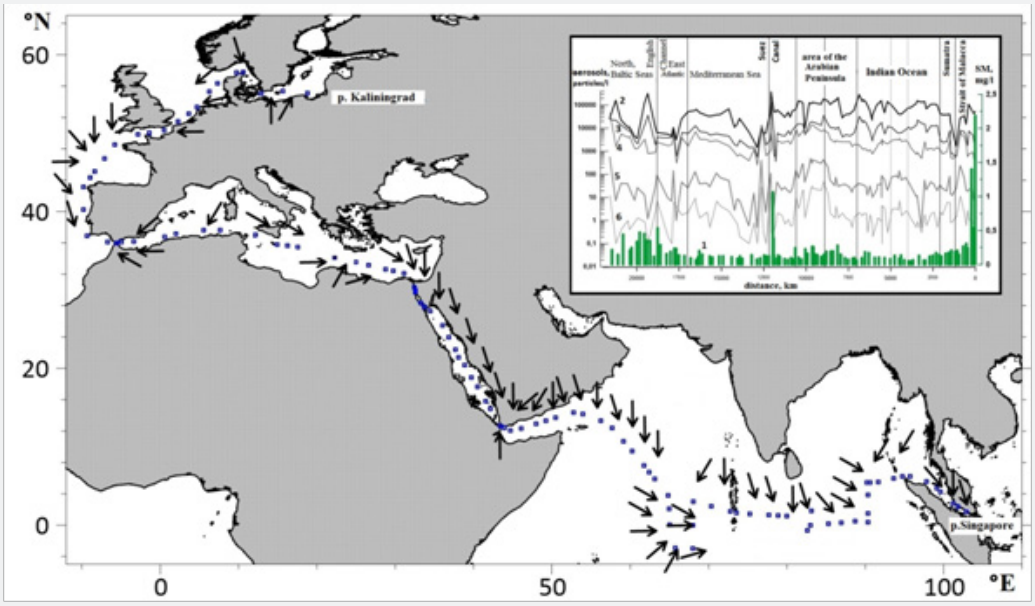

Figure 1: Sampling stations and the main wind direction along the route R/V "Academician Boris Petrov". The inset: 1 - the distribution of suspended matter (columns, mg/l) and the granulometric composition of the aerosols (μ) in the driving layer of the atmosphere: 2 - 0.3-0.5, 3 -0.5-1, 4 – 1-3, 5 – 3-5, 6> 5.

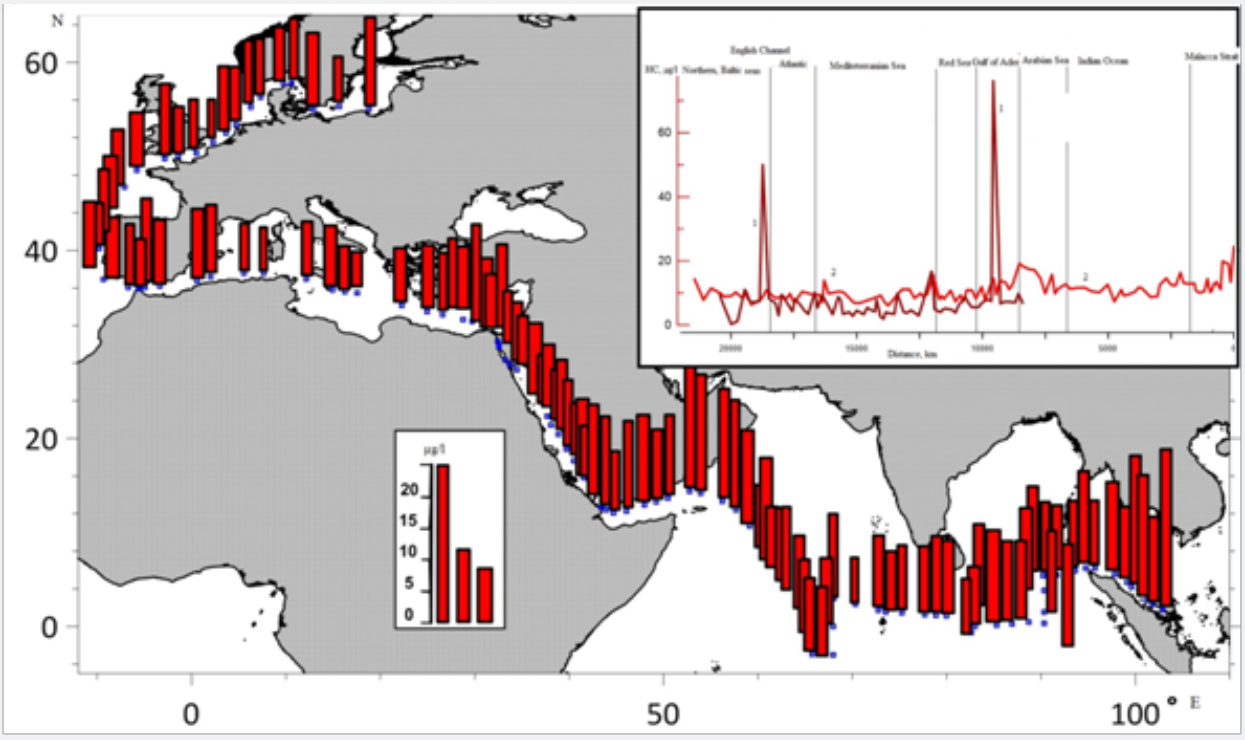

Figure 2: Distribution of hydrocarbons in surface waters in the cruise of R/V "Academician Boris Petrov" (columns). The inset: the distribution of hydrocarbons (μg/l) in surface waters in cruises 1 -R/V "Akademik Nikolai Strakhov", 2 - R/V "Akademik Boris Petrov".

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Dust storms in the southern part of the Arabian Peninsula are associated with summer time (from May to August), but in the Northern part of the Peninsula they occur mainly in the spring period. At the same time, the peak of dust activity is observed, as a rule, in the daytime, as intense solar heating of the earth creates turbulence and local pressure gradients. In the humid areas, aerosol fluxes decreased with a minimum in the Mediterranean Sea (1,441 particles/l) and increased again with anthropogenic inputs from industrial areas of Europe (English Channel). In surface waters the average SM concentrations in 2017 varied in the sequence (mg/l): Mediterranean Sea ≈ Indian Ocean (0.12)<East Atlantic (0.16)< area of the Arabian Peninsula (0.18)< the Red Sea (0.20)<the English Channel and the Baltic Sea (0.34). Its average content was more than 8 times lower compared to the data of 2016 Nemirovskaya and Titova [6] 0.21 and 1.746mg/l, respectively, due to different research seasons and different wind direction. In particular, at the end of winter 2017 the Northwest wind prevailed in the Red Sea, which led to a decrease in the concentrations of aerosols in the atmosphere near water layer and, in turn, mineral SM in surface waters.

Therefore, the content of SM in surface waters of the Red Sea was lower than in the Gulf of Aden (0.125 and 0.183mg/l, respectively) and significantly lower than in 2016, when its concentration reached 9.539 mg/l. The minimum concentrations of studied compounds were recorded in the Mediterranean Sea (0.080 and 0.190mg/l), and the maximum in the North Sea (0.760 and 15.92mg/l), respectively. The change of the phytoplankton community from winter to early spring was accompanied by a decrease in the concentrations of suspended matter and OCs in surface waters. According to the data from R/V "Akademik Boris Petrov" the content of chlorophyll "a" consistently increased from the open waters of the Indian Ocean (an average of 0.15μg/l) to 0.69μg/l in the English Channel. The highest concentrations were found in the North (up to 3.335μg/l) and Baltic (up to 3.675μg/l) Seas due to increased water productivity in coastal areas. Synchronous changes in the concentrations of SM and OCs occur only in open water areas of the Indian Ocean, with the similar sources of these compounds. Concentrations of hydrocarbons (HCs) in surface waters as well as SM content, was significantly lower than in 2016.

HC values in different regions varied from 6 to 20μg/l, and did not reach the maximum permissible concentrations for petroleum hydrocarbons (50μg/l). Even in the English Channel their concentration fluctuated in the range of 8 11 μg/l. Earlier the English Channel can be attributed to the field of small scale increase in HC concentrations due to oil pollution Nemirovskaya [7], the low content of hydrocarbons in 2017 in the Strait and the North and Baltic Seas could indicate the effectiveness of measures for the prevention of pollution. However, in relation to the SM, the HC content in the Red and Mediterranean Seas and even in the Indian Ocean exceeded 100 μg/mg of SM due to the low concentration of the suspension itself [8].

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