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Preliminary determination of concentration and distribution of suspension and roily oil emulsion in Kongsfiord, Spitsbergen

ABSTRACT: Concentration and dispersion distributions of mineral suspension and crude-oil particles in waters of the Kongsfiord (Spitsbergen) were examined in 1997. Most suspension occurs at glacier margins and decreases towards a fiord outlet.

Key words: Arctica, Spitsbergen, suspension, roily oil emulsion.

Introduction

Mineral and organic suspension in sea water is composed of particles bigger than 0.1 μm in diameter (Ivanoff 1978). Fines in glacial streams, icebergs and ice fields, wind-blown soil particles, industrial matter and others, transported during global circulation in the atmosphere, provide to mineral suspension in the Kongsfiord.

Chemical content, structure and dispersion of suspension depend on location of water sampling sites. Glacier-derived suspension is completely different than the one from a sea. Suspension in a surface layer is different than suspension in a deep sea (Horne 1972, Jerlov 1976, Ivanoff 1978). Physical parameters of suspension depend on dynamic phenomena *i.e.* melting of snow and ice, interaction between meteorological processes at the border of land (free of snow and ice) and glacier, and at the border of glacier and sea. Mineral suspension is often subjected to solution and biochemical processes, and therefore it influences physical properties of water (Gurgul 1993a, b; 1996).

Concentration of suspension in water is one of its most important parameters. In clean sea water there are about 10^9 particles diameters larger than 1 mm in sus-

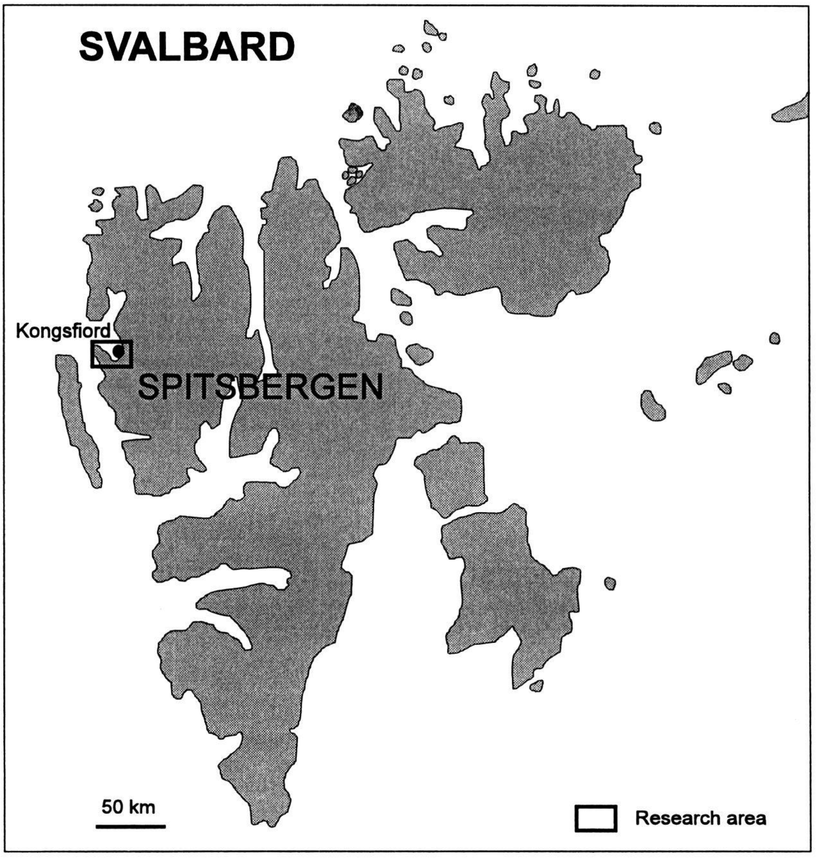

Fig. 1. Study area.

pension per a cubic metre. Concentration of suspension offshore increases and exceeds 10^{13} units/m^3 (Dera 1983). Number of particles in suspension per unit volume changes with latitude. For example in the section from the English Channel to the Straits of Drake, the largest amount of suspension appears in high latitudes and the smallest in the tropics (Gurgul *et al.* 1995). Large concentration, equal to 1.4×10^{12} units/m^3, was recorded on the King George Island in Antarctica during intensive glacier melting in March 1989.

Concentration of organic suspension depends on day/night changes, and on long-term changes of physical parameters of air and water. The largest concentration appears in a surface sea layer and within a thermocline. Below the euphotic layer, phytoplankton dies out. In the case of the Kongsfiord, changes in concentration of organic suspension are influenced by inflow of sun energy to a sea, exchange of waters between the Atlantic Ocean and the fiord, and water circulation.

The performed examination focused on measurements of concentration of mineral and organic suspension in waters of the Kongsfiord and determination of contamination with roily oil substances in surface waters.

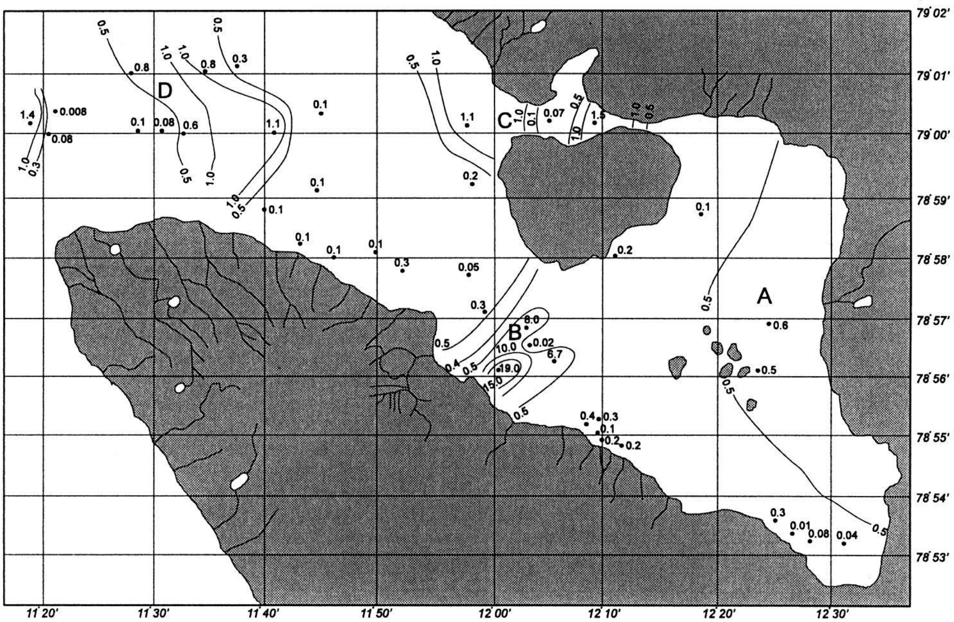

Fig. 2. Kongsfiord, bathymetry of a bottom in metres.

Location and methodology

Examinations in the Kongsfiord were carried out on July 10–17, 1996, during a cruise of the research ship *Oceania* of the Oceanology Institute of the Polish Academy of Sciences in Sopot (Fig. 1). The Kongsfiord is one of the most salient fiords in the northern part of western Spitsbergen. It spreads from 78^{0}52' to 79^{0}04'N, and from 11^{0}20' to 12^{0}35'E. The largest glaciers are close to the eastern and northern coast of the fiord, and the southern coast is ice-free.

Topography of a fiord bottom is complicated (Fig. 2). In the southwestern part of the fiord there is a ditch, a depth of which exceeds 400 m. There is a step in the centre, with depth generally less than 20 m and there are also many small rocky islands. In the eastern part of the fiord there are depressions to 50 m depth. Varying topography of a fiord bottom influences complex circulation of water and its exchange with the ocean, and therefore affects transport of suspension.

Water samples were collected from a surface layer to depth 0.5 m (Fig. 2) and subjected to microscopic analysis. Examinations were carried out with magnification 1000 times, using the Bürker's table. The counted particles were divided into classes, different one from another with 1 µm in diameter, determined by the Feret's method. The counted particles in different size classes formed a dispersion pattern of suspension distribution (Kopeć *et al.* 1990, Gurgul 1996).

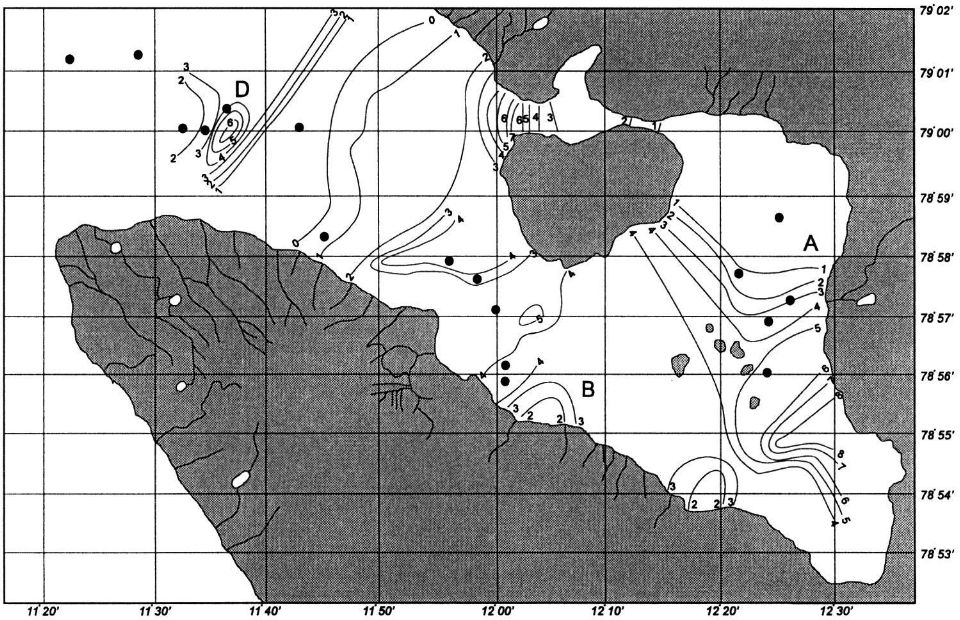

Fig. 3. Surface concentration of mineral suspension in 10^{11} per 1 m^3; water-sampling sites indicated with circles; A–D – regions corresponding to the largest concentration of mineral suspension.

Results and discussion

Suspension particles in sea water are different in size, forms and structures. They are permanent components of sea water and affect its physical and chemical properties. Suspension plays an important role as food for sea organisms and influences development of microbes (Horne 1972). Every suspension particle is characterised by its diameter, surface area and volume. Apart from this, concentration of suspension influences also physical phenomena in a sea.

Maximum concentration of mineral suspension in the Kongsfiord appeared close to the glaciers (Fig. 3). Glacial streams between the Fairingfielet and Ossian Sarsfiellet contribute most suspension to the fiord. Concentration of suspension at **A** was equal to 3.01×10^{13} units/m^3 and brown colour of water could be seen with naked eye. The stream of this water crossed the fiord and vanished near Clesund. Large concentration of mineral suspension appeared also at glaciers in the south--eastern and northern parts of the fiord, exceeding in many places 5×10^{12} units/m^3. Concentration of suspension decreased towards the exit of the fiord.

Concentration of organic suspension in the fiord indicates that the regions **A** and **C** are the very places where fresh cold water from glaciers is mixed with sea water (Fig. 4). In the region **B** sea water is mixed with desalted sea water. Presence of a hill affects mixing of waters in this region (Fig. 2). Intensive mixing occurs during a tide from the ocean side of a step and during the ebb tide from the opposite

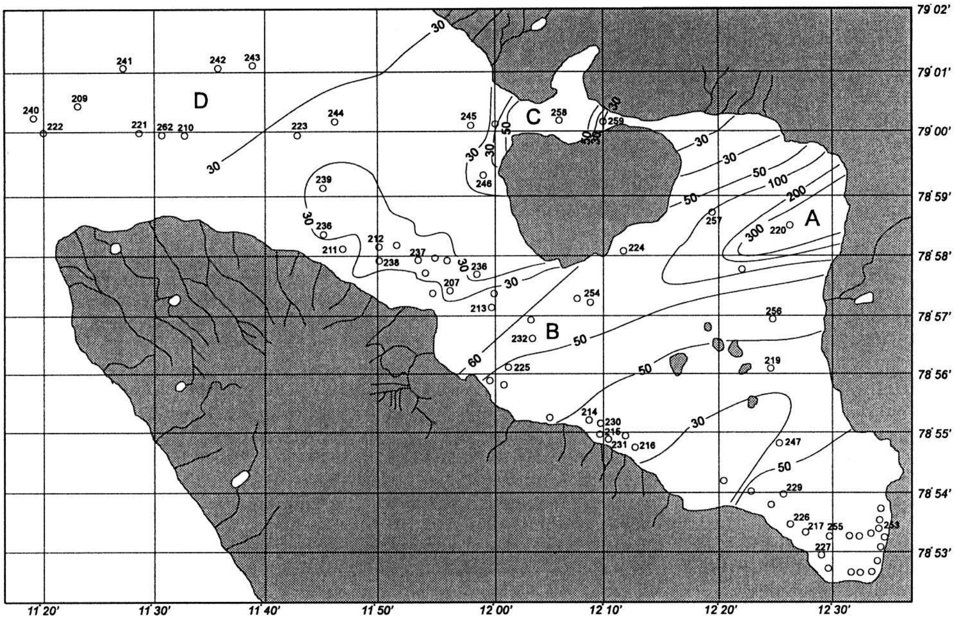

Fig. 4. Surface concentration of organic suspension in 10^{11} per 1 m^3; sites with roily oil substances indicated with black circles; A–D – regions corresponding to the largest concentration of organic suspension.

side. The largest concentration of organic suspension appeared in the eastern part of the fiord and was equal to 8×10^{11} units/m^3, and between the island Blomstrananalröer and the northern coast of the fiord, reaching 6–7×10^{11} units/m^3. Similar concentration was observed in the region **D** at the fiord outlet, where the ocean water is mixed with the fiord one.

Dispersion distribution of suspension is an important parameter. Gurgul and Kopeć (1985) presented its theoretical description. A mineral suspension can be applied from geometric distribution, according to the formula:

$$f(x)=\frac{1}{1-x}\sum_{n=0}^{\infty}x^{n};\quad p_{n}=(1-\lambda)\lambda^{n-1};\quad n=1,2,\ldots \tag{1}$$

where l – estimator obtained with the maximum likelihood method, and x – diameter of particles in suspension.

A modified geometric distribution can be also applied:

$$f(x)=(1+x)e^{x};\quad p_{n}=\frac{e^{-\lambda}}{1+\lambda}\lambda^{n-1}\frac{n}{(n-1)!};\quad n=1,2,\ldots \tag{2}$$

or the Poisson's distribution:

$$f(x)=\frac{e^{x}}{1-x};\quad p_{n}=(1-\lambda)\lambda^{n-1}e^{-\lambda}\sum_{\nu=0}^{n-1}\frac{1}{\nu!};\quad n=1,2,\ldots \tag{3}$$

in which the notation is the same as in the equation (1). On the map, close to the places where the water samples were collected, there are the numbers denoting a

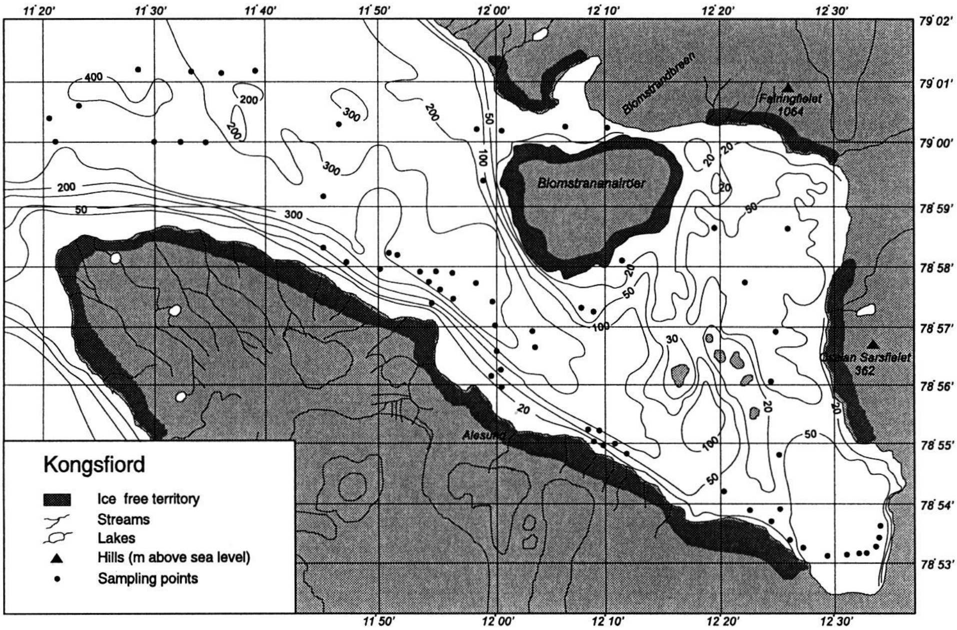

Fig. 5. Dispersion distribution of mineral suspension. 1 – geometric distribution; 2 – modified geometric distribution; d – diameter in mm; p – probability; n – number of suspension particles of a given diameter; N – total number of suspension particles in a given sample.

serial number of the samples subjected to preliminary analysis and for which a dispersion distribution was done. The performed examination indicates that the samples 210, 237, 246, 256, 259 and 261 present a modified geometric distribution. The Poisson's distribution was not discovered.

Dispersion distribution of mineral suspension is the probability one (Figs 5–6). It can be regarded as modified geometric distribution for the sample 246 and as geometric distribution for the sample 256 (Fig. 5). Apart from this classification, another one of distribution with respect to the range of changes of suspension particles diameters ("short" and "long") in a given sample is to be taken into account. Dispersion distribution of suspension in the sample 210 (Fig. 6) presents a "short" distribution. Water samples collected at the fiord outlet and at distant places (from glaciers and glacial streams) present similar dispersion distribution. The sample 224 represents a "long" distribution. A size range is wide, from 1 to 13 mm. Such distribution is typical for samples collected close to the glaciers.

Diameters or radii, cross-sections and volume are the next basic parameters of suspension. The largest mean radii appeared in samples collected close to the glaciers, in the main suspension stream, in the northern part of the fiord and at the fiord outlet. It corresponds to the places of water mixing (Fig. 3). Basing on calculations there are mean section areas for every measurement series and then, volumes of suspension in a series could be determined.

Table 1

Location of sampling points for roily oil contamination and its concentration.

Latitude	Longitude	Concentration [ppm]
79°00.0'	11°34.0'	0.300
78°58.3'	11°40.7'	0.070
78°56.6'	12°00.7'	0.030
78°55.5'	12°06.9'	0.004
78°56.6'	12°21.0'	0.150
78°58.5'	12°26.9'	0.170
79°00.6'	11°21.0'	0.440
78°56.0'	12°00.1'	0.410
78°54.2'	12°29.0'	0.160
78°27.5'	11°57.1'	0.120
79°00.7'	11°22.0'	0.020
79°01.0'	11°28.0'	0.320
78°59.9'	11°52.4'	0.010
78°57.6'	12°20.4'	0.020

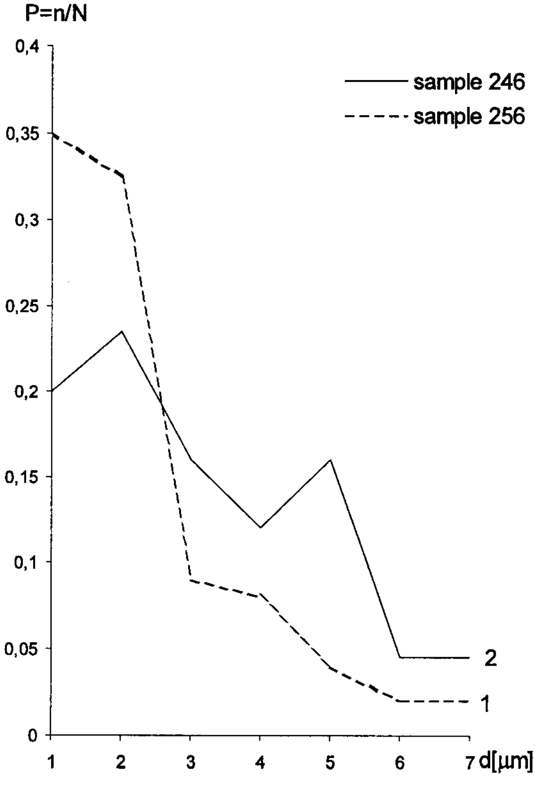

Fig. 6. Dispersion distribution of mineral suspension. 1 – "short" distribution; 2 – "long" distribution; for other explanations see Fig. 5.

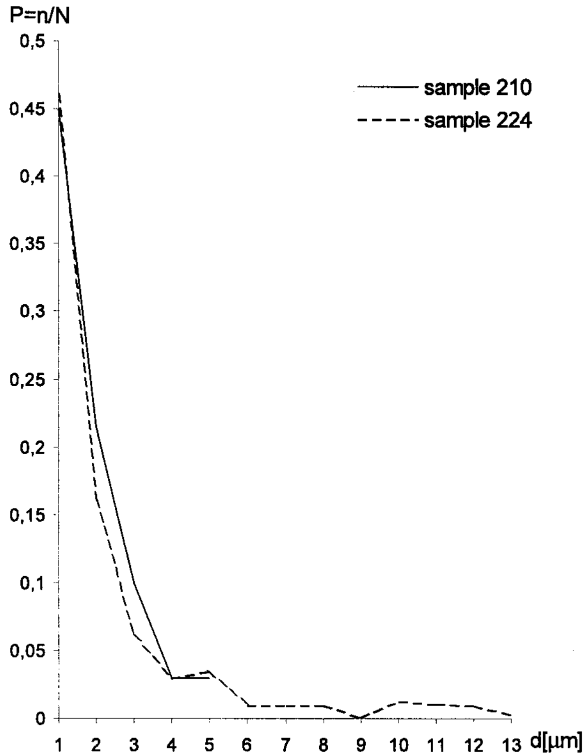

Fig. 7. Surface distribution of mean volume of suspension (in 1 m^3) in different measurement series.

Measurements and calculations indicate that there are also regions with the largest mean volume of a series. Mean volume of the series is equal to 0.5×10^{-18} m^3 in the region A, 19×10^{-18} m^3 in B, 1.6×10^{-18} m^3 in C and it exceeds 1.4×10^{-18} m^3 in the region D (Fig. 7).

Apart from mineral and organic suspension there are also particles of roily emulsion in the waters of the Kongsfiord (Fig. 4, Table 1). Their largest concentration varied from 0.004 to 0.44 ppm in the examined region. Contamination appeared in the south-western, central and eastern part of the fiord. It could come from ships entering the fiord or from leaking pipes that transport crude oil to Ny Olesund. Location of roily oil contamination in the fiord testifies to large influence of sea transport on the environment. Circulation of water in the fiord influences remarkably a contamination in the eastern part of the fiord.

Conclusions

The examinations were performed in a week during summer, at a beginning of intensive melting of glaciers and in consequence, rising concentration of suspension and its transportation. Such examination should be carried out, starting from a beginning of the arctic summer and lasting until the autumn. On the basis of such examination the analysis of concentration changes in suspension and dispersion distribution of suspension could be performed for a period of glacier melting. This enabled to determine transported suspension, and its influence on scattering, absorption and attenuation of light into a sea. After examination of such dynamic phenomena as sea tides, waving and water circulation, velocities and directions of propagation of suspension in the Kongsfiord could be studied.

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Streszczenie

Podczas rejsu r/v *Oceania* od 10 do 17 lipca 1997 roku po wodach Spitsbergenu, zbadano koncentrację i rozkłady dyspersyjne zawiesin i cząsteczek emulsji substancji ropopochodnych w wodach powierzchniowych Kongsfiordu (tab. 1). Stwierdzono, że zawiesiny występujące w tym fiordzie tworzą rozkłady dyspersyjne typu geometrycznego zmodyfikowanego. Największa koncentracja zawiesin wystąpiła przy czołach lodowców i malała w kierunku wyjścia z fiordu. W oparciu o wykonane pomiary sporządzono mapy izolinii koncentracji zawiesin występujących w tym akwenie (fig. 1–7).