Particle size distributions in the Gulf of Gdansk

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Abstract

Suspended matter concentrations were measured in the Gulf of Gdansk in the years 1992-1993. Water samples were collected every month. The size and concentration of particles were analysed with Multisizer-II Coulter Counter. Against a background of corresponding hydrological conditions seasonal variability of suspended particles size distributions was studied.

The results show strong spatial and temporal variations of the particle size distributions. In space the horizontal variation of the PSDs appear to be stronger than the vertical. The Vistula River input seems to be reason of this variability. In time, particle size concentration distribution shows variations according to cycles of the biological activity and dynamical processes in the Gulf of Gdansk.

Introduction

The characteristics of suspended particulate material are related to basic biological, chemical and physical processes in the seas, for example scattering and absorption of light by sea water or transport of substances in the sea. As a consequence, knowledge about the properties and distribution of suspended particles can provide valuable information about the oceanographic processes affected by these particles.

The extent to which suspended particles influence these processes depends strongly on their size distribution, i.e. the number of particles in a volume of water as a function of their diameters. For quantitative characterisation of these influence and for purposes of the modelling of marine environment processes, it is important to find an approximation of particle size distribution by a simple arithmetic function with not too many parameters whose variability range needs to be evaluated.

In oceans, particle size distributions are predictable and described in detail (Carder *et al.*, 1971, Zalewski, 1977, Jonasz, 1983), but in coastal regions, like the Gdansk Bay, they vary due to large input of different materials from rivers or sewage, and require careful study (Jonasz, 1983).

The aim of this paper is to characterise the particle size distributions in the Gdansk Bay and to outline their spatial and temporal variability.

Materials and Methods

The data discussed here were collected during 1992 and 1993 at locations shown in Figure 1 and analysed with a Multisizer II Coulter Counter. If measurements couldn't be completed within a few hours after collection of the samples, they were frozen (volume ~100ml) onboard the ship and analysed later. A Coulter counter with a 200μm orifice and 2000μl sample volume was used to measure number of particles per unit volume for at least 50 size classes of equivalent spherical diameter in the range of 4 to 30μm. The equivalent spherical diameter is used to characterise the size of the irregularly shaped particles and means the diameter of a sphere having a volume equal to that of the particle. To limit errors resulting from inhomogenity of distribution of particles in water sample, average values of the particle concentration in every size class of at least 3 measurements were used to determine particle size distribution (PSD).

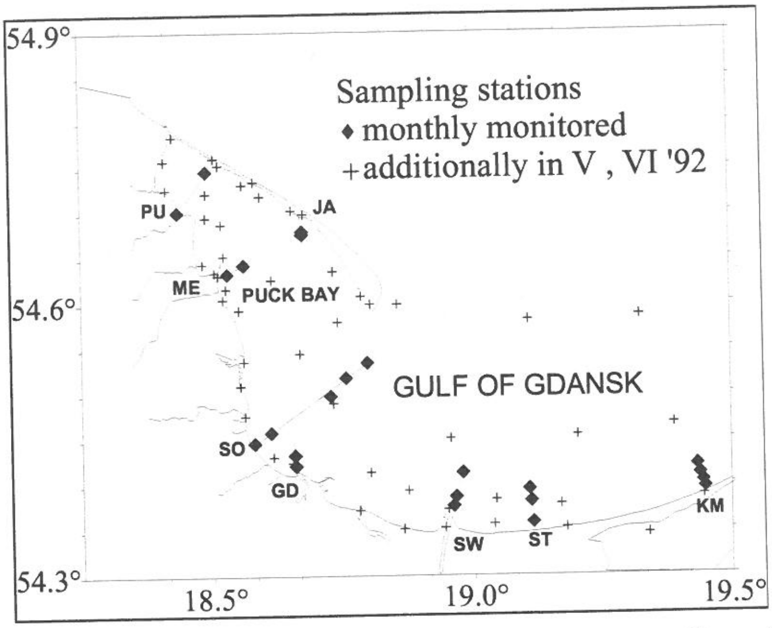

Figure 1 Location of sampling stations. Capital letters denote names of sampling profiles as follows: PU–Puck, ME–Mechelinki, JA–Jastarnia, SO–Sopot, GD–Gdansk, SW–Swibno, ST–Stegna, KM–Krynica Morska.

The particle size distribution function *FD(D)* is defined by the equation

$$dN = FD(D)dD$$

where *dN* is the number of particles per unit volume of sea water with diameters D in the range of *(D,D+dD)*.

The particle size distribution *FD(D)* was determined by differentiation of the cumulative distribution, *CD(D)*, of particle sizes, defined by the equation

$$CD(D) = \int_D^\infty FD(D')dD'$$

where *CD(D)* is simply the number of particles per unit volume having diameter greater than *D*. To evaluation, simplified procedure described by Jonasz (1983) was used. In this procedure, to convert $CD(D_i)$ into $FD(D_i)$ the least squares approximation to *CD(D)* by the function KD^{-m} was constructed at three points: D_{i-1}, D_i, D_{i+1} and its derivative at $D=D_i$ was evaluated. In the first and last step additionally its value at $D=D_1$ and D_n respectively was assigned to $FD(D_1)$ and $FD(D_n)$.

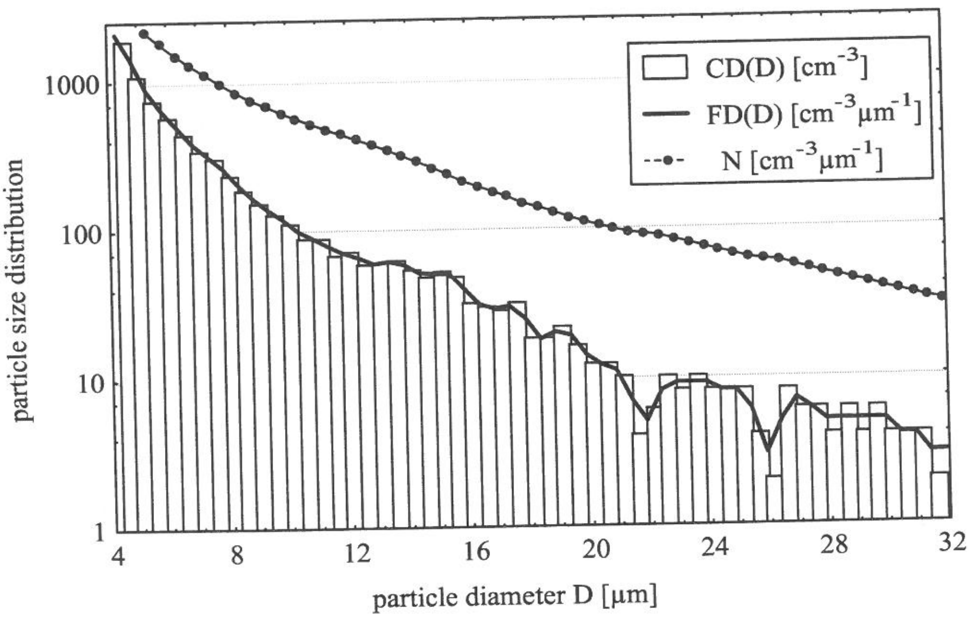

Figure 2 Particle size distribution characteristic for the Gulf of Gdansk presented in various manners.

$FD(D)$ computed in this procedure and the histogram $\Delta N(D,D+\Delta D)$ show a high goodness of fit (Figure 2). The relative error of $CD(D{=}4\mu m)$ in all computed PSDs was smaller then 5%.

Results and Discussion

Distribution of particle concentration

Results of measurements show differences between two main seasons, e.g. spring–summer and autumn–winter, characterised respectively by high ($1.7\times10^3 < CD(4\mu m) < 55\times10^3\,cm^{-3}$) and low ($0.6\times10^3 < CD(4\mu m) < 26\times10^3\,cm^{-3}$) concentration of particles suspended in water. This fact is thought to be a direct consequence of an autumn–winter minimum in biological activity and land runoff of suspended matter.

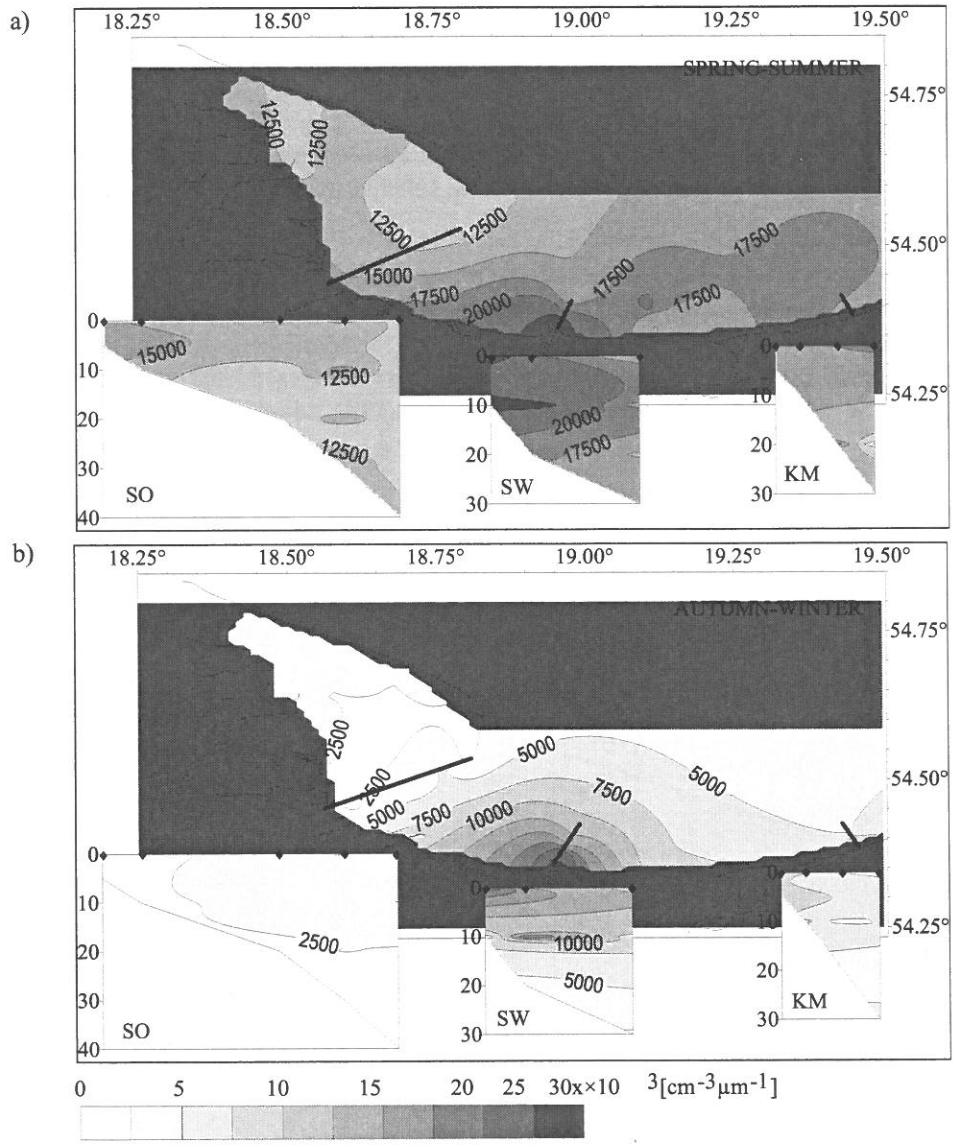

Figure 3 Surface distributions and vertical profiles of particle concentration ($CD(4\mu m)$) characteristic for the Gulf of Gdansk in a) spring and summer, b) autumn and winter months

Figure 3 shows representative surface distributions and vertical profiles of particle concentrations ($CD(4\mu m)$) found for spring–summer and for autumn–winter seasons. The most characteristic feature of these distributions are the division of the Gulf of Gdansk into two parts: eastern, that is strongly influenced by the Vistula river waters, rich in suspended matter, and western (called Puck Bay) with a relative lower concentration of particles.

The vertical distributions of suspended particle concentration differ in these regions and are time-dependent too, however, this variability is much smaller than the spatial variability. Puck Bay is characterised by rather uniform particle concentration, particularly in the autumn–winter season. In regions with higher amounts of particles the concentration was generally found to decrease with depth. An increase in particle concentration has been observed near the bottom due to resuspension of bottom sediments and in the layer just above the seasonal thermocline (in summer). The concentration of larger particles (D>20μm) was not found to vary as strongly as that of all particles (D>4μm). The concentration of larger particles appeared to stay approximately the same in the entire water column, except the thin surface layer when amounts of larger particles resulting from biological activity were found (Figure 4).

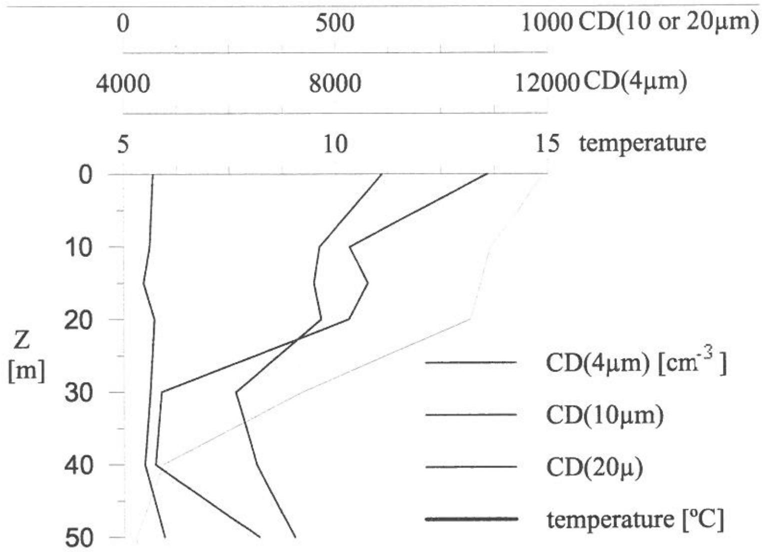

Figure 4 Vertical profiles of particles concentration for different size ranges, typical for deeper stations in summer, when seasonal thermocline occurs (June, 1992, 54°34'N 18°45'E)

Particle size distributions

Analysed particle size distributions from the Gulf of Gdansk show in most cases a regular shape with concentrations quickly decreasing with increasing particle diameter. The particle size distributions may be approximated using a hyperbolic function (Figure 5).

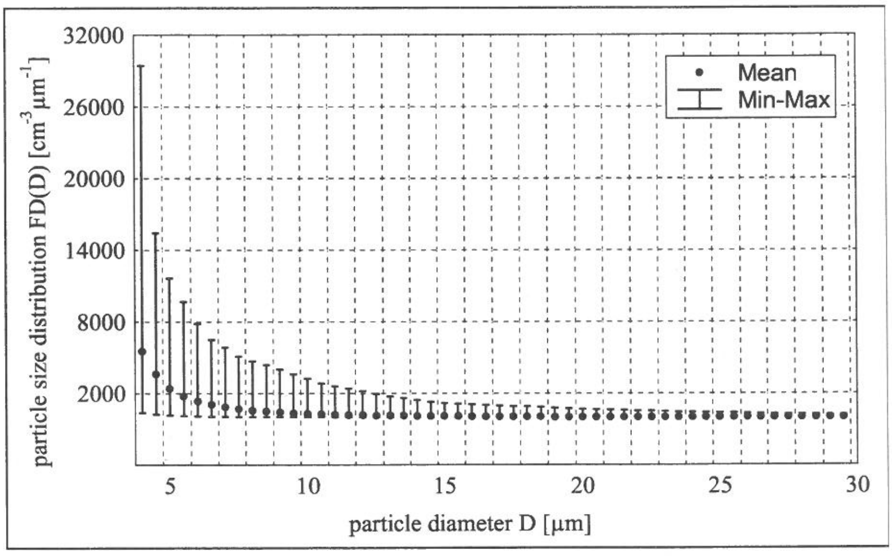

Figure 5 Mean particle size distribution function $\overline{FD}(D)$ in the Gulf of Gdansk. Vertical bars show the minimum and maximum values for diameter D.

For parametrisation of the PSD a hyperbolic function with two segments was used:

$$FD(D) = \begin{cases} k_1 D^{-m_1} (2\mu m \le D \le D_b) \\ k_2 D^{-m_2} (D_b < D \le 32\mu m) \end{cases}$$

In this equation k_1, m_1, m_2, D_b are parameters of the best fit and $k_2 = k_1 D_b^{-m_1+m_2}$ (Jonasz, 1983). Parameters m_1 and m_2 characterise slope of the particle size distribution in log-log scale. The relative square error of the approximation, ε, was less than 2% in about 80% of the measured PSDs. Only PSDs from water rich in suspended matter e.g. sampled during phytoplankton bloom or in regions closed to the land sources of particles, have shown deviations from that described by this function. They should be approximate rather by the sum of this function and a Gaussian function or by some statistical methods (Jonasz, 1983).

Parameter	min	max	mean	standard deviation	number of data
D_b	4.63	9.58	7.38	1.87	1276
m_1	0.20	9.19	3.64	0.78	864
m_2	1.35	5.37	3.47	0.57	864
k_1	3.7 E3	21.3 E6	26.8 E6	726 E6	864

Table 1 The values of parameters of the best fit found for Gdansk Bay particle size distributions

Since D_b has been found to be close to the lower limit of the analysed diameter range, only PSDs with at least 5 size classes of diameter in the range (4μm,D_b) were included for further consideration.

The slopes m_1 and m_2 differ negligibly, and m_1 varies in a wider range than m_2. A correlation between m_1 and m_2 was not found, but m_1 shows a slight relation (correlation coefficient r=–0.46) to the mass concentration of suspended matter in [mg×dm^{-3}] (Figure 6). It may suggest that the mass of suspended matter is determined mostly by the amount of particles with diameter D<10μm. The seasonal variations of m_1 and m_2 are shown in Figure 7. It is worthwhile noting that the relation between m_1 and m_2 is different for water with high and with low particle concentration. Generally m_1>m_2 when CD(4μm)<10^4cm^{-3}μm^{-1} and m_1<m_2 when CD(4μm)>10^4cm^{-3}mm^{-1}. The slopes m_1 and m_2 of the particle size distribution differ negligibly whereas k_1 is up to 10 times higher then k_2.

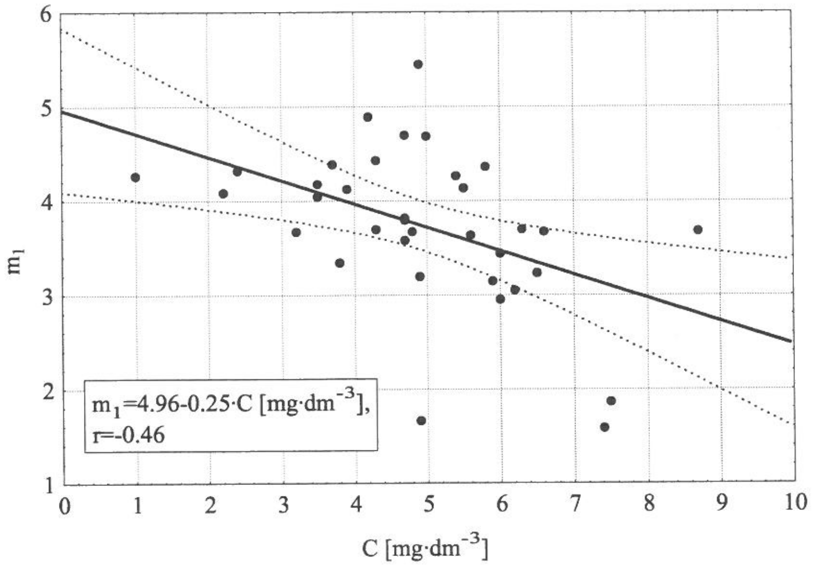

Figure 6 Relationship between the slope of the first segment of particle size distribution function m_1 and the dry mass concentration of suspended matter

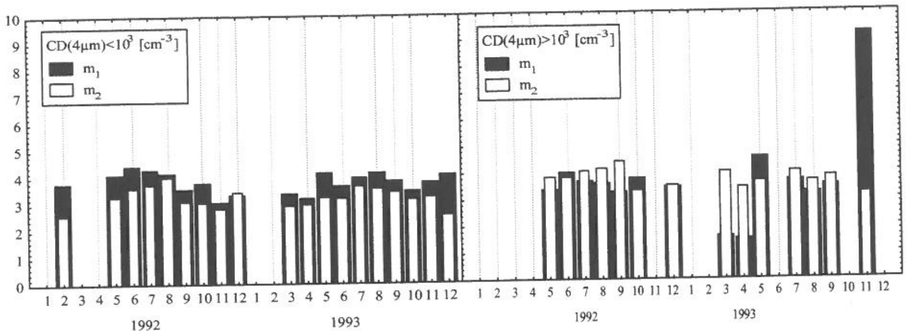

Figure 7 Temporal variations of parameters m_1 and m_2 during the analysed period for low (left) and high (right) amounts of particles in water volume

In space the vertical variation of the PSD appears to be weaker than the horizontal. The horizontal variability is wider for the first segment resulting from the variability of particle concentration connecting with land source activity. Figure 8 shows the evolution of the particle size distribution with depth in the spring–summer and in the winter–autumn seasons. The vertical variability occurs here rather than in the second segment and is evident only in the subsurface layer (deeper shape of PSD remains stable). This fact may suggest a biological reason for this variability.

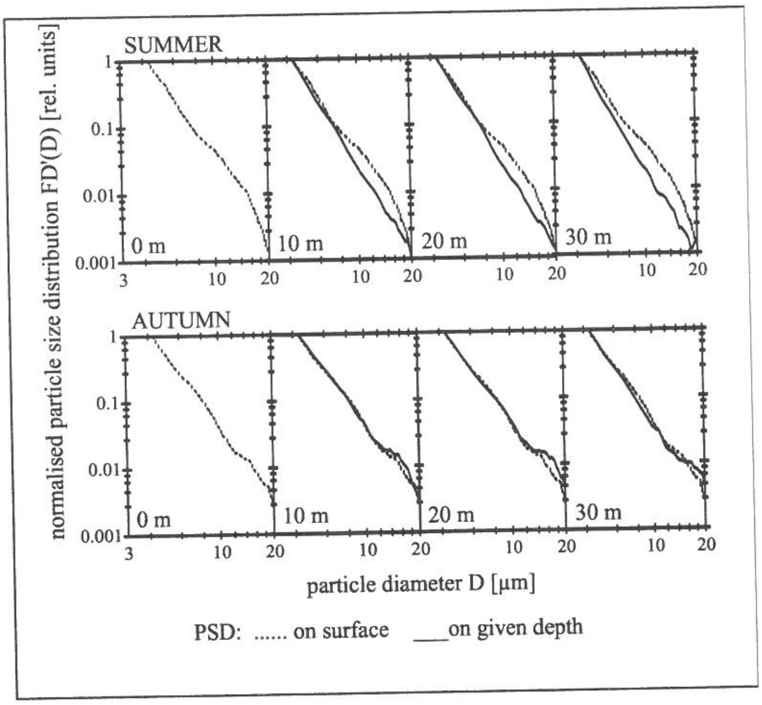

Figure 8 The evolution of the normalised particle size distribution with depth

Conclusions

Distributions of particle concentration in Gdansk Bay vary between the two main seasons: the spring–summer with higher and the autumn–winter with lower particle concentration, due to variation in biological activity and land runoff of suspended matter cycles.

The Vistula river waters, rich in suspended matter, influence the distribution of particle concentrations resulting in higher values in areas close to the river mouth during the whole year.

The vertical variability of the suspended particle concentration is much smaller than the spatial. The concentrations generally decrease with depth.

The particle size distributions measured in the Gulf of Gdansk can be described fairly well using hyperbolic functions with two segments. The parameters in the Gulf of Gdansk do not correlate between segments and the limiting diameter D_b is about 7μm.

Parameters of the particle size distribution best fit vary in time and space. The variability of the first segment of the particle size distribution can be attributed to variations in particle concentrations due to presence of the land sources of water rich in suspended matter while the second segment is due to the biological activity in surface layer. In the vertical the amount of particles relate to the density distributions and the concentrations of particles with $D>20\mu m$ vary only in the surface layer due to biological activity.

References

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