

PAPER • OPEN ACCESS

The Suspension Characteristics Determining Method with the Help of Images Processing

To cite this article: D A Antonenkov 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **272** 022152

View the [article online](#) for updates and enhancements.

The Suspension Characteristics Determining Method with the Help of Images Processing

D A Antonenkov¹

¹Marine Hydrophysical Institute of RAS, Kapitanskaya St., 2, Sevastopol 299011, Russia

E-mail: dmitry_science@mail.ru

Abstract. The article presents the developed method for determining the parameters of the bottom sediments that allow obtaining the express data on the concentration and size composition of suspended particles in water. The method is based on the use of high-speed photography of the aquatic environment. A special feature of the method is its operability under considerable dynamic activity of water masses and high concentration of suspended matter of terrigenous origin in the coastal zone. A brief description of the developed technical means design intended for the method approbation is given. The designed software operation principle is described, that allows determining the particles length frequency on the images and calculating the suspension concentration for a given volume. The method approbation results in a laboratory environment are presented.

1. Introduction

Under the conditions of increasing anthropogenic impact on coastal areas, water suspensions parameters operational monitoring and the associated shoreline and bottom relief changes are necessary to carry out the works to strengthen and preserve coasts and beaches, ensure the navigation safety in shallow areas and control the dynamics of water pollution in coastal zones.

The most important parameters that determine to a large extent sediment flows are the suspended solids concentration and length frequency and their vertical distributions (profiles)[1]. Controlling of the instantaneous values of suspended sediments concentration and length frequency is one of the main tasks, without which it is impossible to obtain reliable estimates of bottom sediments mineral substances flows.

In the course of the work, the analysis of the main ongoing methods and instruments for sediments concentration and size composition measuring was made, namely: measuring the sediments concentration by the weight method [2,3], determining the particles size composition by the sieve method [4,5,6]; particles size measurement by the dynamic light scattering method [7, 8]; determining the suspensions concentration using "transmissometers", applying to measuring the attenuation of directional light [9, 10]; nephelometric method for determining the particles size composition [11, 12]; the mineral and organic suspensions characteristics determination with the help of cytometers [13, 14]; determination of the suspension concentration vertical profile based on sound backscatter [15, 16, 17]. It was found that the most of the above-mentioned methods do not allow making a research in a surf zone characterized by high hydrodynamic loads and a high concentration of the suspensions with an inhomogeneous size composition. Thus, the need of developing new technical and software tools that



would allow obtaining the vertical distribution of the suspension concentration and its size composition under such conditions determines the relevance of the studies.

The aim of this work is to show the features of the developed method of determining the parameters of the suspended matter in the bottom sediments, based on the obtaining and special processing of the aquatic photo images.

2. Hardware and software development

The core of the method is high-speed photo recording (the exposure time of the frame is about 4 microseconds) of a thin water layer with particles of suspended matter directly adjacent to the porthole (the "foreground") using the developed photo recorder. Further, by processing the images obtained, with the help of the created software, the concentration of suspended matter and the particles size composition in the test volume are determined.

To test the method, a special test bench was designed to create a field of suspended matter with a certain vertical distribution of its concentration. Figure 1 shows the design of the test bench.

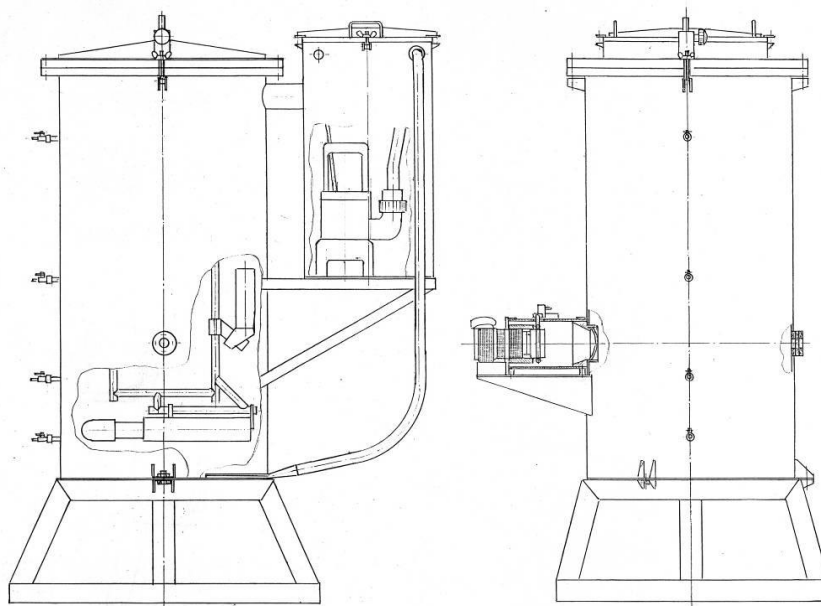


Figure 1. The test bench design.

The test bench operation concept is outlined as follows: the pump at constant speed supplies water to the bottom area of a completely filled tank with water. Horizontal jets, flowing at a high rate from a system of holes located on the bottom, excite turbulent flows, that weight the bottom material (sand) is placed there, and after a while create some vertical suspension concentration distribution in the tank corresponding to a given pump capacity and the parameters of the bottom material. The vertical movement of water in the tank at a low speed, created by the pump, only maintains the finest fractions of the bottom material in suspension.

The main advantage of the created test bench is the possibility of creating the conditions for carrying out the experiments close to reality, from the point of view of the dynamics of the bottom material weighing process, which was confirmed by the tests. For this purpose, ripple measurements of three velocity vector components were made with the help of a special device - IPSTT, created at the Marine Hydrophysical Institute [18].

To obtain photo images of the aquatic environment, a photographic recorder was used, that consists of a Canon camera, a lens with manual focusing and a created system of pulsed illumination. The design of the photo recorder is shown in Figure 2.

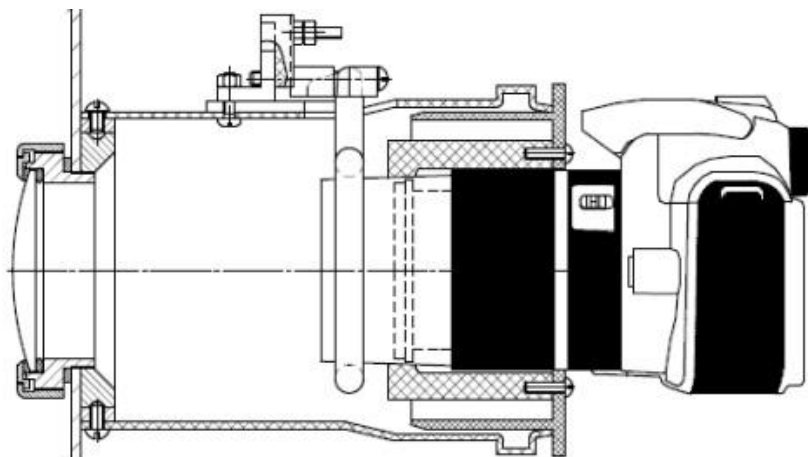


Figure 2. The photo recorder design.

The required time exposure in the photographic recorder is provided by a specially developed illumination system, the main element of which is the IFB 300 flash lamp. The use of this lamp, the radiating part of which is located around the lens, allows obtaining the main light flux directed parallel to its optical axis, thereby virtually eliminating the appearance of particles shadows on the image.

The use of a special scheme for forced lamp extinction makes it possible to obtain a short light pulse with a required length of about 4 μs .

Thus, in the course of the experiments, a series of images were obtained that meet the specified quality requirements. An example of the images obtained is shown in Figure 3.

To calculate the suspensions concentration and the particles size composition, the software was developed, consisting of a number of subprograms. So the preprocessing subprogram, whose algorithm is based on determining the limit values of background pixels and objects pixels brightness, and then performing the contrast transformation, makes it possible to obtain an image with leveled brightness and enhanced contrast. The image segmentation subprogram, based on the analysis of brightness differences between the background pixels and objects, makes it possible to clearly identify the particles in the foreground.

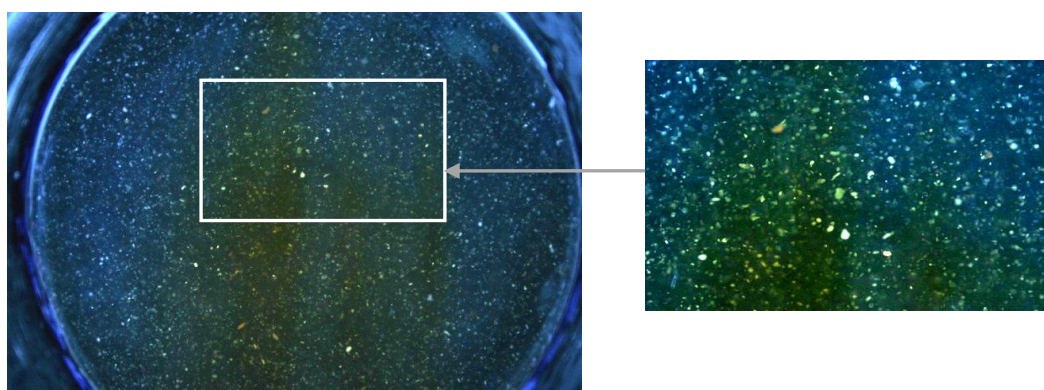


Figure 3. The image received by the camera and its enlarged fragment.

To filter the particles that are out of the range under study, a morphological cut-off filter is applied to the resulting image after segmentation. This filter is based on the erosion operation using a structuring full-circle element with a radius of 50 μm and subsequent dilatation [19,20]. The radius of the structure-forming element in pixels is defined according to the pixel size calculated separately.

The concentration and particle sizes determination on the image processed is carried out using the developed subprogram "Calculations" according to the following scheme:

1. The total number of elements is calculated and the number of pixels belonging to each of them is determined. As a result, we get the numerical particles concentration in the registered area and the area of each particle in pixels.
2. For each particle, the radius of the equivalent sphere is calculated, which is taken as a particle radius, taking into account the assumption that the particle is approximate in shape to the shape of a circle.
3. The volume and mass of each particle are calculated.
4. The mass concentration of particles is calculated.

As a result, the developed software allows obtaining, for the image analyzed, the following data: an array containing equivalent particle radii; an array containing particles masses; particles number; the particles mass concentration in the volume under study and the average concentration of suspended particles in water based on the results of series of images processing [21, 22].

3. Verification of the results

During the laboratory testing of the developed method, arrays of the aquatic environment images were obtained. As a result of the necessary calculations performed by the software, the data on the average suspension concentration were obtained. In addition, a quantitative and mass particles distribution for the fractions was obtained, including particle sizes from 100 μm to 800 μm in 100 μm increments. The results are shown in Figures 4 and 5.

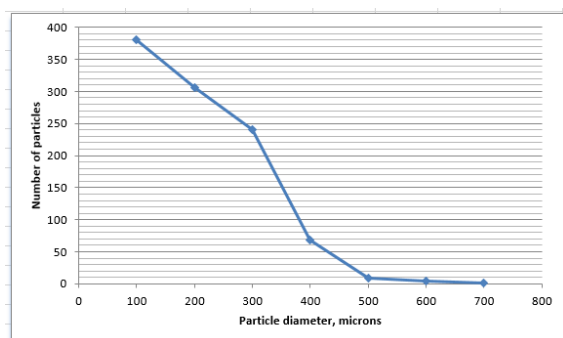


Figure 4. The particle size distribution diagram.

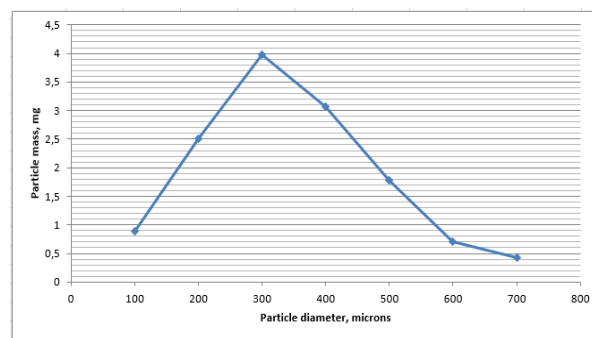


Figure 5. The diagram of the particles distribution by the fractions mass content.

To determine the method operability, the concentrations and the size composition of the suspensions have been determined using standard sieving and weighing methods. The analysis samples were taken with the help of the valves provided on the test bench. The sampling moment has been synchronized with the photo images registration moment.

The analysis of the results obtained showed that the discrepancies in the final average values of the concentration determined by the developed method and the standard method do not exceed 10%, which is a good result for the indirect method of determining the suspension parameters for their high temporal variability.

A comparison was also made of the data obtained as a result of the particle-size analysis of the selected samples by the sieve method with the data obtained after software image processing. Both methods showed that in the sand samples under study the majority of the particles are fractions from 100 to 500 μm . Thus, the sieve method showed that the largest proportion (70%) is occupied by particles ranging in size from 100 to 500 μm , and the developed method is that particles of this size make up 64% of the total mass. A slight difference in the fractional composition is due to the fact that in the developed method the fraction up to 200 μm is represented by a narrower particles range with a diameter of 160 to 200 μm . The total particles mass distributions by the size of both methods are

identical, from which it can be concluded that the results obtained with the developed method are reliable, and it can be used to determine the size composition of the suspensions.

4. Conclusions

Thus, the developed method allows obtaining data on the size composition of particles in a range of 50-1000 μm , and determining the suspensions concentration to a precision of $\sim 12\%$. This method can be technically implemented for the instruments intended for in situ measurements, using specialized technical means that allow obtaining short exposure intervals, for example using image-converter tube acting as an image intensifier and a high-speed electronic shutter. The main advantage of the method is its operability under the significant dynamic activity of water masses at high particle transfer rates and a high suspensions concentration.

5. References

- [1] Ivanov V et al 2006 *Modern methods and means of control of the marine environment* (Sevastopol: Marine Hydrophysical Institute) p 113
- [2] Yakovlev K I and Alekseeva G M 2005 *Gravimetric (weight) analysis: methodological guidelines for studying the course of quantitative chemical analysis* (St. Petersburg: Publishing House of the SPCFA) p 27
- [3] Shifrin K S 1983 *Introduction to the optics of the ocean* (L.: Gidrometeoizdat) p 280
- [4] Petelin V P 1967 *Granulometric analysis of marine bottom sediments* (M.: Nauka) p 128
- [5] DSTU ISO 11277: 2005 Soil quality Determination of the granulometric composition and mineral soil material Sieving and sedimentation method. (ISO 11277: 1998, IDT) (K.: Derzhospozhivstandart of Ukraine) p 29
- [6] GOST 12536-79 Soils Methods of laboratory determination of granulometric (grain) and microaggregate composition (M: Izd-vo standards) p 22
- [7] Pecora R 1985 *Dynamic light scattering – applications of photon correlation spectroscopy* (New York: Springer-Verlag) p 434
- [8] Brown W 1993 *Dynamic Light Scattering: the Method and Some Applications* (Oxford)
- [9] Mankovsky V I and Solov'ev M V 2003 Relationship between the attenuation of radiation and the concentration of suspended matter in the waters of the Black Sea *Marine Hydrophysical Journal* **2** 60
- [10] Dykman V Z et al 2008 Transparency for the determination of the parameters of a large suspended matter in the sea by measuring the fluctuations of the directional light attenuation index *Ecological safety of coastal and shelf zones and integrated use of shelf resources* **16** 236-242
- [11] Haltrin V I et al 1996 Polar nephelometer for sea truth measurements *Airborne remote sensing Conf. San Francisco* 444–450
- [12] Gilyazov S F 1987 *Methods for solving linear ill-posed problems* (Moscow: Izd-vo MGU) p. 120
- [13] Chernyshev A V et al 1995 Measurement of scattering properties of individual particles with a scanning flow cytometer *Applied Optics* **34** 6301– 6305.
- [14] Melamed M R et al 1990 *Flow cytometry and sorting* (New York: Wiley-Liss) p 1140.
- [15] Thorne P D et al 1993 Analysis of acoustic measurements of suspended sediments *Journal of Geophysical Research* **98** 899–910
- [16] The AQUAscatter 1000 Acoustic System. [Electronic resource]. http://www.fzk.uni-hannover.de/fileadmin/institut/Ausstattung/Messinstrumente/Suspensionsmessgeraete_-_ABS/AQUAscatter1000.pdf. Checked on 05/15/2018
- [17] Sukhinov A I and Cherchago A A 2009 Estimation of the concentration of suspended particles using acoustic backscattering of the ADCP probe *Izvestia of the Southern Federal University. Technical science* **8** 37-42
- [18] Dykman V Z et al 2001 Measuring complex for studying the processes of exchange in the near-

- bottom sea region *Environmental monitoring systems* 31-40
- [19] Gonzalez R et al 2006 *Digital image processing in the Matlab environment* (M.: Technosphere) p 616
- [20] Gonzalez R and Woods R 2005 *Digital image processing* (M.: Technosphere) p 1072
- [21] Antonenkov D V, Solovev D B 2017 Mathematic simulation of mining company's power demand forecast (by example of "Neryungri" coal strip mine) *IOP Conf. Series: Earth and Environmental Science* **87** [Online]. Available: <http://dx.doi.org/10.1088/1755-1315/87/3/032003>
- [22] Antonenkov D A 2016 Method of the aquatic environment image processing for determining the mineral suspension parameters *Marine hydrophysical journal* **5** 38–47

Acknowledgments

The work was carried out within the framework of the state task on the topic No. 0827-2018-0004 "Integrated interdisciplinary studies of oceanological processes determining the functioning and evolution of the ecosystems of coastal zones of the Black and Azov Seas".