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SUSPENDED MATTER MAPPING USING OPTICAL AND ELECTRONIC PROCESSING OF THE AERIAL PHOTOGRAPHS

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ABSTRACT:

Results of the investigations on the suspended matter horizontal distribution obtained from coastal zone aerial photographs are presented. Using densitometric and digital image processing, the suspended matter detailed distributions in several mixing zones have been obtained.

Photointerpretation of the aerial photographs is an important source of useful information, especially in the shallow nearshore zone studies. Wavefield characteristics, details of the shoreline configuration and of the bottom topography, extension and patterns of the transitory phenomena such as phytoplanktonic blooms, upwelling, internal waves, space distribution of the pollutants - all are clearly visible on the colour or black-and-white aerial photographs.If,furthermore,the sea radiation induced optical density variations are analysed, quantitative information about the process or phenomenon can be obtained.

In this field, the first conclusive results have been obtained in the turbidity pattern mapping using the strong reflexion and backscattering produced by the suspended mineral and organic particulate matter (1, 2).

The applied methodology requires,on one hand, gathering of the field data on the suspended particulates in several points covering a large turbidity range and, on the other hand, determination of the film density in the entire investigated area. Using densitometric data for the images of the measurement points and the corresponding suspended matter concentration values, the regression curves are then constructed for each analysed zone. They are used for suspended matter distribution mapping on an analog-digital-analog system consisting of a TV camera transforming the image into video signals,a processing unit(performing signal quantization, digital computation and digital-to-analog conversion) and a CRT display.

The image processing can be accomplished in two ways, both of them conducting finally to the maps of the suspended matter distributions. In the first way, using the transmittance values corresponding to selected turbidity classes, a bandpass filtering is repeatedly performed, the results being displayed on the CRT and sequentially photographed. Subsequently, succesive projection of the images, each of them containing a selected turbidity class, allows to obtain the map of the isoconcentration curves. In the second way, the colour-coding of the transmittance classes gives a fals colour image of the turbidity class distribution on the display; on the colour print of this image, the isoconcentration map can be drawn.

The procedures previously described allow not only to obtain the suspended matter distribution in the whole area covered by one aerophotograph, but also to extend the mapping on several partially overlapping frames thus increasing the investigated region beyond the limits of the area where sea-truth measurements have been made.It is also possible to perform"zoom-type enlargement" of a restricted area from a given image,so that more detailed information can be obtained.

The first described method for digital processing was used for the aerial photographs taken in 198o at Năvodari and Agigea. In the waste water mixing zone Năvodari, succesive displaying of the film density levels resulted in the map of the suspended matter (Fig.1).The intricate structure of the turbulent mixing zone, as well as the suspended matter "accumulation" along the current convergence line(due to the outfall position relative to the main current) are readily visible.

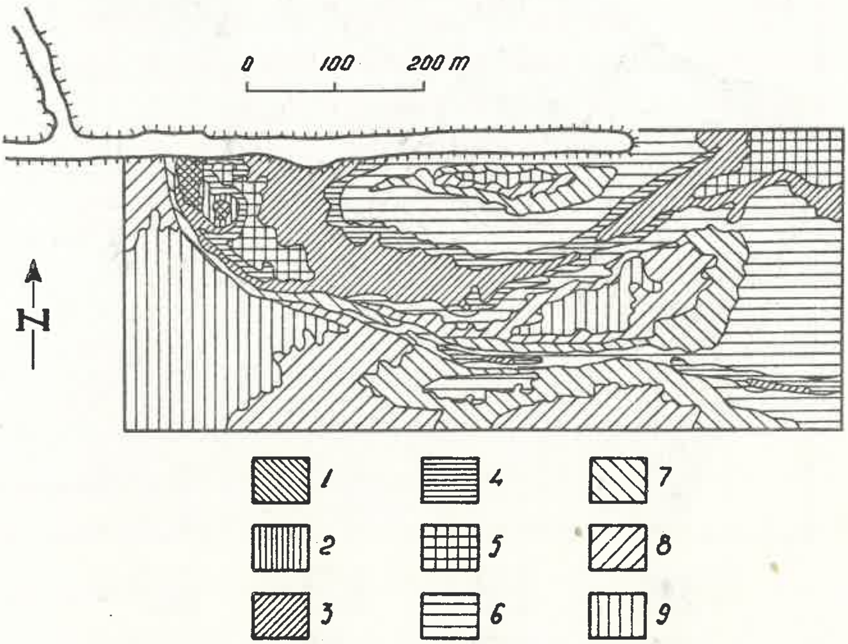

Fig.1 - Suspended matter distribution.
Năvodari - 18.06.1980

The mapping carried out in the area just south of the new harbour Constantza - Agigea (Fig.2) makes evidence of the diffusion of the waste water discharged at the south pier base,as well as of the dispersion of the suspended matter from a new jetty under construction.

For the aerial photographs taken in 1981, the second procedure was applied upon, using the colour coding of the film density (or, alternatively, of the positive print reflectivity), optical density S of the negative and its transmittance D (obtained by densitometric methods) being related by:

$$S = \mathrm{Log}\,(1/D)$$

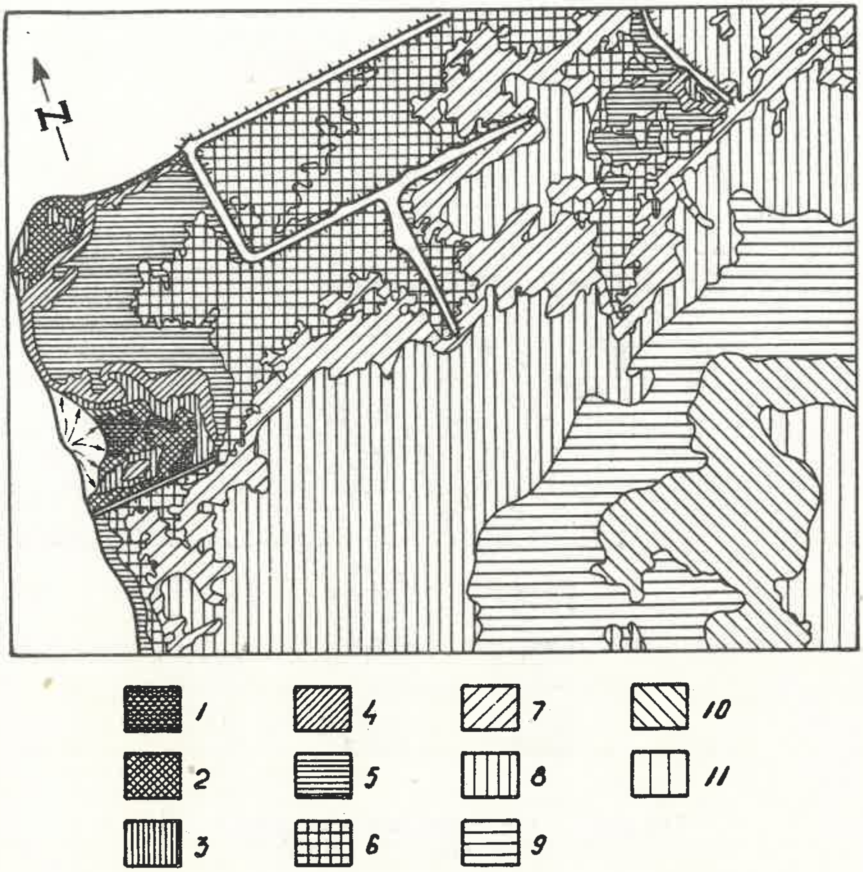

Fig.2 - Suspended matter distribution
Constantza (Agigea) - 18.o6.198o

For the Năvodari mixing zone, the correlation between transmittance values (measured in the image points corresponding to the measurement points) and the suspended matter contents (Fig.3) was used for constructing the map of the turbidity space distribution (Fig.4). For concentrations three times smaller than the previous ones (Fig.1), the method resolution has been improved and thus a very intricated pattern of the mixing zone was revealed.

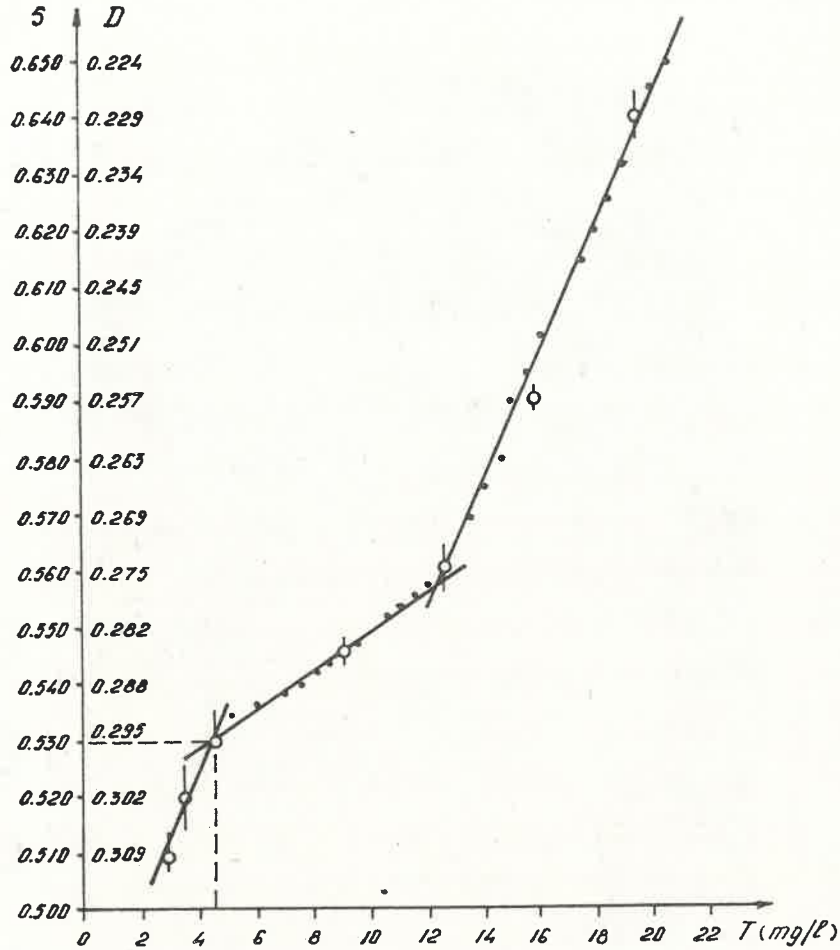

Fig.3 - Correlation between turbidity and film density.
Năvodari - 14.07.1981

Similar determinations made for the area near Periboina inlet allowed to establish the correlation between transmittance and turbidity (Fig.5) and, subsequently, to map the mixing zone at a scale two times larger than that of the photograph (Fig.6). The measurements have been repeated after three months in different hydrological conditions and a new high resolution image of the mixing zone was obtained (Fig.7).

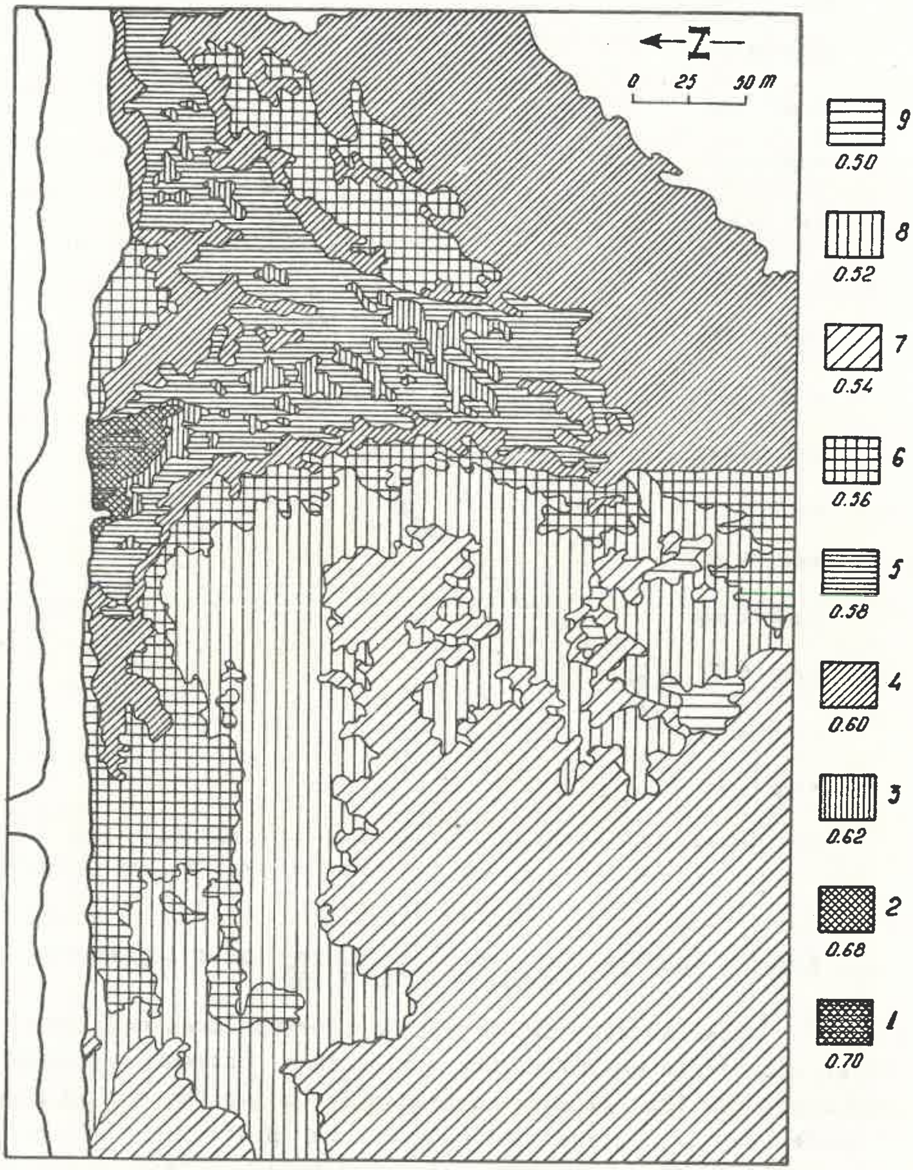

Fig.4 - Suspended matter distribution.
Năvodari - 14.o7.1981

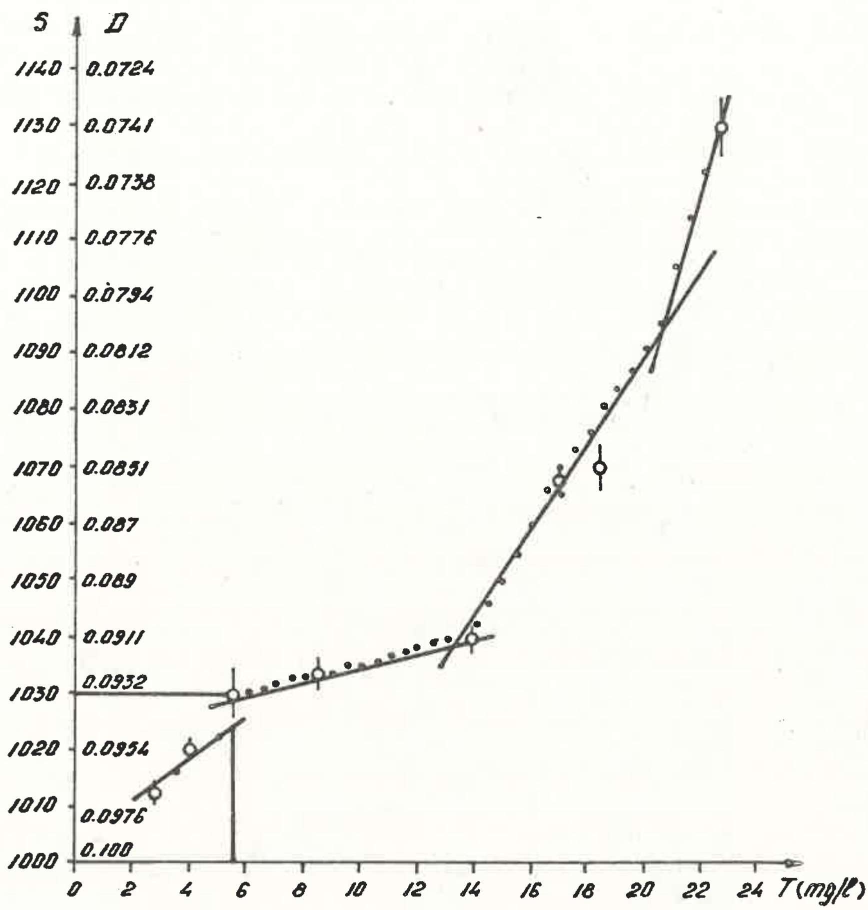

Fig.5 - Correlation between turbidity and film density.
Periboina - 10.06.1981

It should be noted that in this latter case, the "sea-truth" measurements were carried out only in the proximity of the inlet, covering a small turbidity range (only relatively high values) so that for the remaining mapping area, the concentration classes have been obtained by extrapolating the correlation with the density levels.

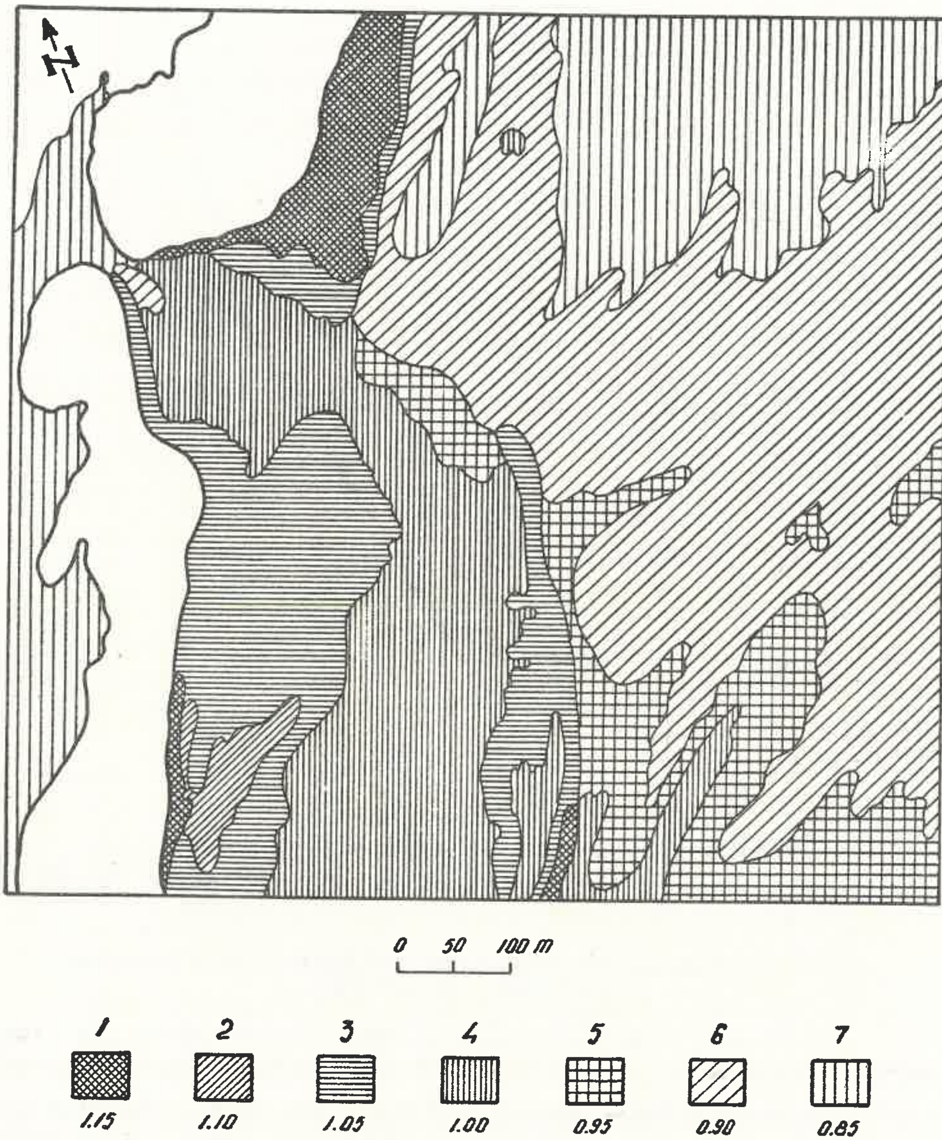

**Fig.6 - Suspended matter distribution
Periboina - 1o.o6.1981**

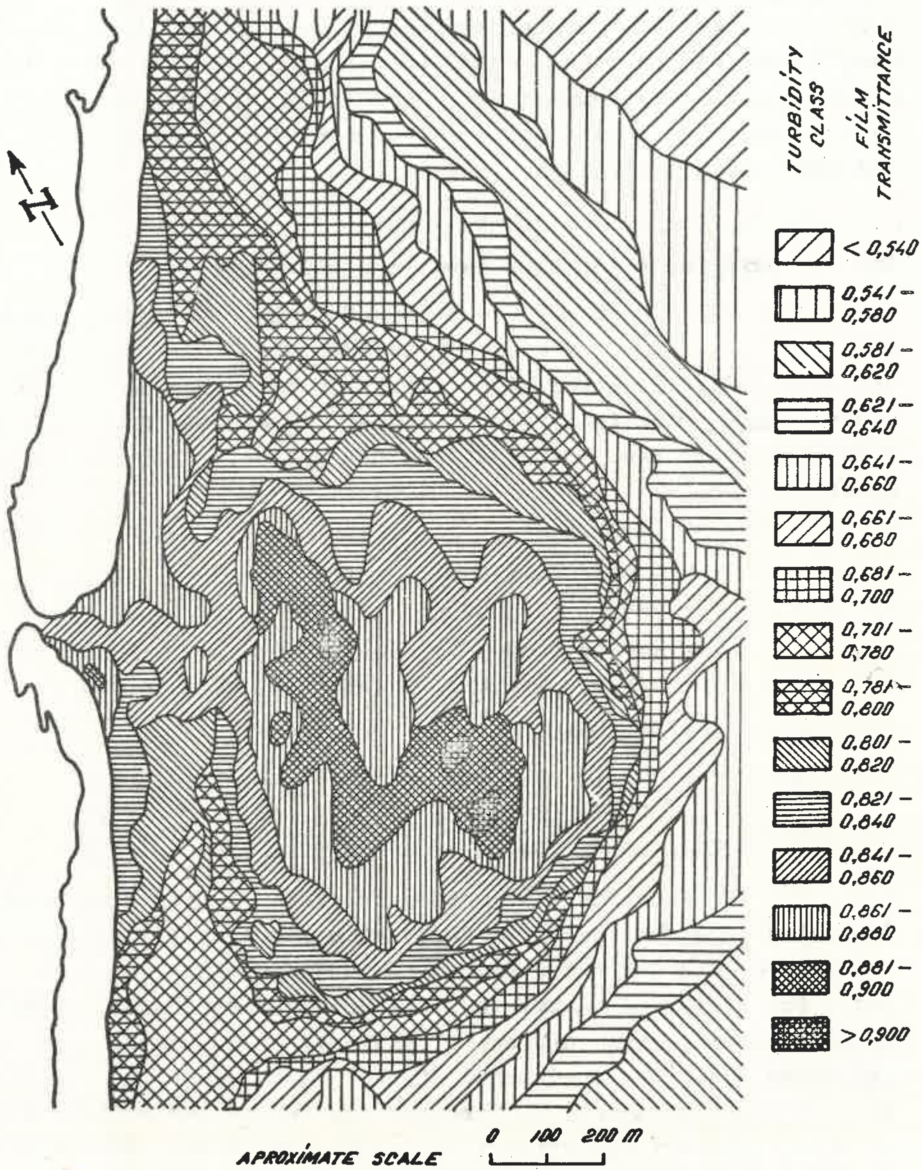

Fig.7 - Suspended matter distribution. Periboina - o2.o9.1981

The detailed analysis of the densitometric results reveals , on one hand, a clearcut difference between the transmittance values at Năvodari and Periboina (for the same turbidity range) and, on the other hand, the nonlinearity of the transmittance-turbidity dependence for both correlations (Fig.3 and Fig.5). Assuming a continuous dependence of the optical density S and the turbidity T of the form

$$T = a + b\ (S-C)^{n}$$

the following relationships have been obtained:

$$T = 5{,}5 + 83{,}85\ (S-1.029)^{0.612} \quad \text{for Periboina,}$$

and

$$T = 4{,}0 + 113{,}01(S-0{,}529)^{0.817} \quad \text{for Năvodari,}$$

but such a fitting curve gives considerable errors in several turbidity ranges. For this reason, linear regression for different sub-ranges have been computed, and the following relationships are obtained:

- for Periboina:

$$T = 266.46\ (S-1.003) \qquad 2.5 \leqslant T < 5.5$$
$$T = 785.65\ (S-1.022) \qquad 5.5 \leqslant T < 13.5$$
$$T = 118.52\ (S-0.925) \qquad 13.5 \leqslant T < 19.5$$
$$T = 85.29\ (S-0.851) \qquad 19.5 \leqslant T < 26.0$$

- for Năvodari:

$$T = 121.14\ (S-0.495) \qquad 1.5 \leqslant T < 4.5$$
$$T = 294.51\ (S-0.516) \qquad 4.5 \leqslant T < 12.5$$
$$T = 88.58\ (S-0.418) \qquad 12.5 \leqslant T < 20.5$$

A reason for this option is given by the fact that the T-S pairs were obtained from zones with sharp hydrological fronts (regions of discontinuous transition between different water masses). The suspended matter content of the water masses separated by a front may have different granulometric properties, which influence upon the dependence of the radiance on the concentration. The granulometric differences are due to the different time of sedimentation (settling) because the water masses either originate from several sources and the travel times to the investigated area are different (at Periboina) or they come from the same source but have different residence times (at Năvodari) due to frequent circulation changes.

The presented methodology can be applied for mapping any hydrological parameter affecting the natural sea water reflectance. It has the advantage of supplying complete quantitative information, for large areas based only on a few sea measurements.

The author wishes to notify that survey flights have been carried out by a special team from IGFCOT (Institute for Geodesy, Photogrammetry, Carthography and Land Organisation) and that the densitometric and digital processing of the aerial photographs has been carried out in cooperation with the specialised laboratory from IMH (Institute for Meteorology and Hydrology), using their equipment.

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2. OWEN R.W.Jr., 1973 - The Effect of Particles on Light Scattering in the Sea. Journal of the Oceanographical Society of Japan: 29, 5: 1 - 14.