2. ABSTRACTS

2.1. ABSTRACT IN ENGLISH

2.1.1. Introduction

Suspended particulate matter (SPM), along with dissolved substances, is one of the most important groups of seawater constituents. In the sea, suspended matter is mainly formed by biological production, shore and bottom abrasion, as well as in precipitation processes from dissolved matter. Allochthonous SPM is mainly supplied by rivers, the atmosphere and groundwaters. The SPM concentration in waters is the subject to seasonal (related to both cyclic river runoff, plant dusting as well as seasonal fluctuations of phytoplankton) and regional variability.

As shown in the study by Pempkowiak et al. (2002), the concentration of SPM in open waters of the South Baltic varies from 0.27 to 1.78 mg dm^{-3}. The highest concentration of SPM is observed in the coastal zone, lagoons and estuaries, and especially in river estuaries from 0.36 to 35 mg dm^{-3} (Eisma et al., 1991; Krężel and Cyberski, 1993; Emelyanov, ed., 2002; Schiewer 2008). Suspended particles, among others, are responsible for transportation, accumulation and transformation of many chemical compounds (e.g., biogenic substances, carbon, metals and non-biodegradable organic pollutants entering the sea) (e.g., Szefer, 2002; Turner and Millward, 2002). Suspended matter also affects the optical properties of water, interacting with light in absorption and scattering processes to modify the color of water, which stands for a predominant source of information in satellite monitoring of water bodies.

Conducting the research of the waters of the Baltic for many years and direct participation in research cruises made me interested in the yellow suspension covering large areas of the sea in the spring time (Figure 1).

Figure 1. Pine pollen grains in waters of the Baltic Sea (view from the ship's deck). *Source: author's archive.*

Microscopic observations depicted it to be pine pollen floating on the water surface. Attempts to find closer information about this natural phenomenon have shown that there is very little knowledge on the study of this water component in the Baltic, as well as in the other seas. In the international literature, there was only a brief mention of the intention to study the pollen present in the Gulf of Maine in the USA (Keller and Matrai, 1998).

I realized that there is a large gap in the issues concerning the inflow of pollen from pine forests to the Baltic Sea, its influence on this sensitive ecosystem, as well as on the presence of pollen in the Baltic Sea, methods of measuring it in the aquatic environment and its optical properties. The results of this dissertation not only supply this knowledge in the mentioned area, but can also contribute to a significant improvement in the interpretation of satellite images. In the future, they can be used to improve satellite algorithms for remote measurements of water composition and its properties, including the measurement of a parameter considered a major indicator of water body productivity - chlorophyll *a* concentration. The results of this study should be included in the analyses of biogeochemical cycles in the Baltic Sea. Pine pollen in the spring time appears to be an important, and so far not considered, component which periodically contributes significant amounts of nutrients and carbon to the Baltic Sea, at the same time modifying the processes occurring in the sea. Investigating the presence and properties of pollen seems to be a good justification for the novel character of the doctoral dissertation.

The research conducted as the part of the dissertation covers the pine pollen season. The research carried out during the research cruises refers to the area of the Southern Baltic, while the satellite research covers the entire Baltic. The source of pollen delivered in very large quantities to the waters of the Baltic during the spring season is the pine forests overgrowing large areas of land surrounding this inland sea (Richardson and Rundel, 2000; EUFORGEN 2009; Nobisa et al., 2012; Houston Durrant et al., 2016). Transportation by air of pine pollen is the result of complex natural forces that include factors related to climate, biosphere and geomorphology. As numerous studies have shown through the air route, pine pollen can be carried on considerable distances from the source of their production (Hesselman 1919; Erdtman 1938; Dyakowska 1948, 1959; Środoń 1960; Harmata and Olech 1991; Benkman 1995; Proctor et al., 1996; Rousseau et al., 2008; Robledo-Arnuncio 2011; Sitters et al., 2015; Szczepanek et al., 2017). Transportation by air and initial floating facilitate pollen grains' peculiar structure embracing two air-sacs. Long-distance transportation and redeposition can also occur when pollen is carried by flowing waters (rivers flowing into the sea and ocean currents). This causes the presence of large

concentrations of pollen in the form of a yellow raid which is not unusual even in the central areas of the Baltic. Sometimes in the Baltic, pollen concentrations are so high that they form a distinct layer on the surface giving the water a distinct yellow color (Fig. 1). This greatly determines the optical properties of the water surface, among others, modifying the color of the sea (see Figure 1), and significantly changes the concentration and composition of suspended SPM. Many works indicate that pine pollen suspension is also an important source of macronutrients supplied to aquatic ecosystems (Richerson et al., 1970; Doskey and Ugoagwu, 1989; Cole et al., 1990; Graham et al., 2006; Rösel et al., 2012). This is why, it can be assumed that even small concentrations of pollen can be very important for ecosystem functioning.

The issues of pine pollen in the marine environment are very poorly cognised. Conducting measurements directly in seawater is a very complex issue. Measurements must be carried out within time limits limited by the pine pollen season and in the body of water where the pollen deposition occurred. In addition, the weather conditions at sea must be suitable so that the study can be carried out. Therefore, in this dissertation, research was conducted not only at sea, but also in the laboratory.

In carrying out the work, the following research hypotheses were formulated:

1. Pine pollen is a considerable aquatic component which has not been considered so far, and plays an important role in the Baltic ecosystem especially in the spring time.
2. One can elaborate methods enabling its concentration in the aquatic environment *in situ* and to determine the extent of pollen in Baltic waters with satellite techniques.
3. The presence of pollen is observed not only in the coastal zone, but also in the entire area of the Baltic Sea.

Effecting the research topic among others required defining a number of partial research goals from which the most important are:

1) Studying selected geometric, optical and chemical characteristics of pine pollen grains.
2) Developing and testing the method enabling measuring *in vitro* and *in situ* concentrations of pine pollen grains being present in the surface layer of the Baltic Sea.
3) Planning and conducting experimental studies at the sea and collecting an empirical data enabling the determination of pollen concentrations along with other biogeochemical parameters of seawater in the sea surface layer.

4) Determining the extent of spatial and temporal changes in the concentration of pine pollen grains in the surface waters of the Baltic Sea.

The aforementioned research goals have been described in four scientific articles of international scope, from the so-called Philadelphia list, which constitutes this dissertation. The first article describes the method of measuring this component of SPM and presents the results of *in situ* pollen concentration measurements in the coastal zone of the Baltic Sea near Ustka (Poland). Already first measurements of pollen carried out in seawater showed that it can locally even be the dominant component in the SPM suspension being present in the Baltic. The second paper showed in detail the results of validation and verification of the proposed pollen measurement method with the LISST-100X meter under laboratory conditions and a Coulter counter (Multisizer 4 Coulter Cell Analyzer - Beckman Coulter). The work depicts the high efficiency of the proposed method for measuring pollen in the marine environment. The third article presents laboratory measurements of remote pollen reflectance and a method for remote pollen detection in Baltic waters using satellite methods. The maps presented there confirm the presence of pine pollen over almost the entire Baltic Sea. The last paper presents the results of measurements of spatial variation of pollen concentration in the surface waters of the Southern Baltic. The absolute concentration of pollen and its contribution to the rest of the SPM was measured at individual measurement stations. In this work, the chemical composition of pine pollen was analyzed, indicating that the substances contained in it should have a significant impact on the functioning of the Baltic ecosystem.