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Focus

# Marine environment status assessment based on macrophytobenthic plants as bio-indicators of heavy metals pollution

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ABSTRACT

The main aim of study was to develop the environmental quality standards ($EQS_{MP}$) for selected heavy metals: Pb, Cd, Hg and Ni bioaccumulated in the tissues of marine macrophytobenthic plants: *Chara baltica*, *Cladophora spp.*, *Coccotylus truncatus*, *Furcellaria lumbricalis*, *Polysiphonia fucoides*, *Stuckenia pectinata* and *Zanichellia palustris*, collected in designated areas of the southern Baltic Sea in period 2008–2015. The calculated concentration ratios (CR), which attained very high values: $10^4$ L kg$^{-1}$ for lead, $10^3$ L kg$^{-1}$ for nickel and mercury and even $10^5$ L kg$^{-1}$ for cadmium formed the basis for the determination of $EQS_{MP}$ values. The $EQS_{MP}$ values were: 26 mg kg$^{-1}$ d.w. for Pb, 33 mg kg$^{-1}$ d.w. for Cd, 32 mg kg$^{-1}$ d.w. for Ni and 0.4 mg kg$^{-1}$ d.w. for Hg. The application of macrophytobenthic plants as bioindicators in marine environment status assessment of certain areas of the Baltic Sea is also described in the paper.



## 1. Introduction

Natural environment, including the marine environment, is exposed to continuous human activities related pressure. It is well known that to register any changes undergoing in the environment it is necessary to monitor specific elements corresponding to the anthropogenic pressure. Monitoring results, in turn, forms the basis for measures aiming to improve or maintain the good environmental status. Implementation of legal acts on the international scale is one of the main directions leading to the improvement of the environmental status. The activities of the Baltic Sea countries within the Convention on the Protection of the Marine Environment of the Baltic Sea Area, known as the Helsinki Convention are an outstanding example of such cooperation. In Europe, there are recent examples of even wider and more restrictive legal acts like: the Water Framework Directive (WFD) - a major directive in the field of water policy (Anon, 2000), and the Marine Strategy Framework Directive (MSFD) - establishing a framework for community action in the field of marine environmental policy (Anon, 2008). The transposition of those Directives to national jurisdiction of the Member States implies the obligation to monitor and assess the status of waters, including marine areas, and to establish adequate measures to maintain the good environmental status of waters or improve it.

Hazardous substances, presence of which in the natural environment is continually growing, in respect of both the number and the diversity, belong to the key points in marine environment pollution monitoring. The data on hazardous substances' concentration levels in the marine environment constituents provide information on actual pollution, however they do not allow for determining direct changes the ecosystem is undergoing. To assess the status of the marine environment certain threshold values – border concentrations, also called reference values or relative concentrations – have to be established which would delimit the good environmental status (reference status). Good environmental status is assumed if the concentrations of hazardous substances do not cause any disturbances in functioning of the ecosystem.

Specification of the threshold values is a demanding task (eg. SEPA, 2000, OSAPR, 2009). In the case of abiotic elements the most common approach is to apply the historic data mining, or to use the concentrations levels specific to undisturbed conditions and characteristics of the ecosystem (COAST, 2002, Babut et al., 2003, Maggi et al., 2008). In regards to marine organisms, in an ideal situation, the reference values could be determined by studying the correlation between the substance concentration and the effect it produced.

Macrophytobenthic plants, which are one of the key marine biotic elements, are commonly used as a bioindicator of environmental status (e.g. Bondareva et al., 2010, Burger et al., 2006, Chakraborty et al., 2014). The occurrence of certain species, specific to an area, as well as their biomass quantity, might be indicative of the good environmental status, relating to optimal habitat conditions. Besides the positive, desirable plant species, opportunistic plants appear in the marine environment, indicating a deterioration of environmental conditions, e.g. due to increased concentration of nutrients (Osowiecki et al., 2012). The plants can also serve as accumulation bioindicators owing to their outstanding accumulation properties, due to which macrophytobenthic plants deserve particular attention as nearly ideal bioindicators of the environmental status

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(e.g. Carlson & Erlandsson, 1991, Carlson & Holm, 1992, Rainbow, 1995, Leal et al., 1997, Ostapczuk et al., 1997, Kruk-Dowgiałło, 1998, Muse et al., 1999, Malea & Haritonidis, 2000, Sawidis et al., 2001, Topcuoğlu et al., 2003, Burger et al., 2006, 2007, Żbikowski et al., 2007, Zalewska & Saniewski, 2011, Zalewska, 2012a, 2012b, Zalewska & Suplińska, 2012, Chakraborty et al., 2014). Their response to environmental disturbance, including increase of pollutant concentrations in their direct environment, is very fast because they assimilate nutrients and other substances directly from seawater. This direct exchange of elements, without intermediate stages, is facilitating the interpretation of results (Szefer, 2002). Macrophytobenthic plants, as secured to the substratum, occur in defined areas, hence they are reflecting the status of the given area.

The application of macrophytobenthic plants for the environmental status assessment regarding pollution with hazardous substances, especially heavy metals, presents an alternative to the method based on analyses of their concentrations in water. Analytically, the direct measurements of trace concentrations of metals in seawater, is highly erratic, and above all it requires advanced analytical equipment guaranteeing the limits of quantification allowing for measuring trace concentrations with respectively low uncertainties.

Application of macrophytobenthic plants as bioindicators in environmental status classification requires setting up so-called target values, i.e. concentrations defining the border between good and inadequate environmental status. Target values form the Environmental Quality Standards (EQS) for the monitored substances content in plant tissues. It has to be borne in mind that setting a sharp threshold delimiting the good and inadequate status is an uncompromising method, which might pose certain risk of drawing incorrect conclusions due to simplified parameterization and incomplete picture of the ecosystem complexity and possible interactions between the polluting substances and living tissues.

In an ideal situation, the good environmental status with respect to heavy metals should represent environment where the respective concentrations of these substances do not cause any dysfunctions in biotic elements of the assessed ecosystem.

The heavy metals: Pb, Cd, Ni and Hg, concentrations of which are to be monitored by applying accumulation bioindicators, have been selected in consideration of the recommendations of the EU Directive 39/2013/UE from 13 August 2013, amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy (Anon, 2013). Additionally, Pb, Cd and Hg are formally accepted core indicators by the HELCOM CORESET Project (HELCOM, 2012).

The presented study was aimed at developing a set of environmental quality standards for metals Cd, Pb, Ni and Hg in certain macrophytobenthic plant species for their application in marine environment status assessment and classification.

## 2. Materials and methods

### 2.1. Sampling

Benthic plants were collected in the southern Baltic Sea, at four locations: Klif Orłowski, Jama Kuźnicka, Rowy and Słupsk Bank (Fig. 1).

Sampling was conducted by a scuba diver who collected the plants from the seafloor at different sampling depths, depending on location. In the Klif Orłowski area, the plants were collected at depths from 1 m to 8 m, in Jama Kuźnicka – 1 m to 4 m, in Rowy – 6 m and 7 m, and in the Słupsk Bank at 14 and 15 m depth. The sampling had been conducted twice a year, in June and in September or October to follow seasonal changes, from 2008 to 2015. The collected samples, secured in plastic bags, were transported to the laboratory for further processing.

### 2.2. Description of sampling areas

In the southern Baltic Sea, macrophytobenthic plants occur in areas with specific hydro-morphological properties. Macrophyte monitoring in the Polish sector of southern Baltic Sea has been conducted since 2000 (Krzymiński et al., 2001, Miętus et al., 2009, Jakusik et al., 2013). Macrophytes are collected at four locations representative of various water types (Fig. 2). Three of these sampling sites have been set up in transitional and coastal waters following the implementation of Water Framework Directive (WFD) (Krzymiński et al., 2004). The area of Jama Kuźnicka (JK) is representing a transitional water body – Puck Lagoon; Klif Orłowski (KO) also represents a transitional water body – outer Puck Bay, while the boulder area of Głazowisko Rowy (RO) is located in the costal water body (Krzymiński et al., 2004). Another macrophyte sampling site (ŁS) is located within the Słupsk Bank, a shoaled area in the off shore region; this area belongs to the Bornholm Basin – an assessment subbasin distinguished in the HELCOM Monitoring and Assessment Strategy – MAS (HELCOM, 2013) regarding the MSFD regional assessment scheme. According to the HELCOM MAS,

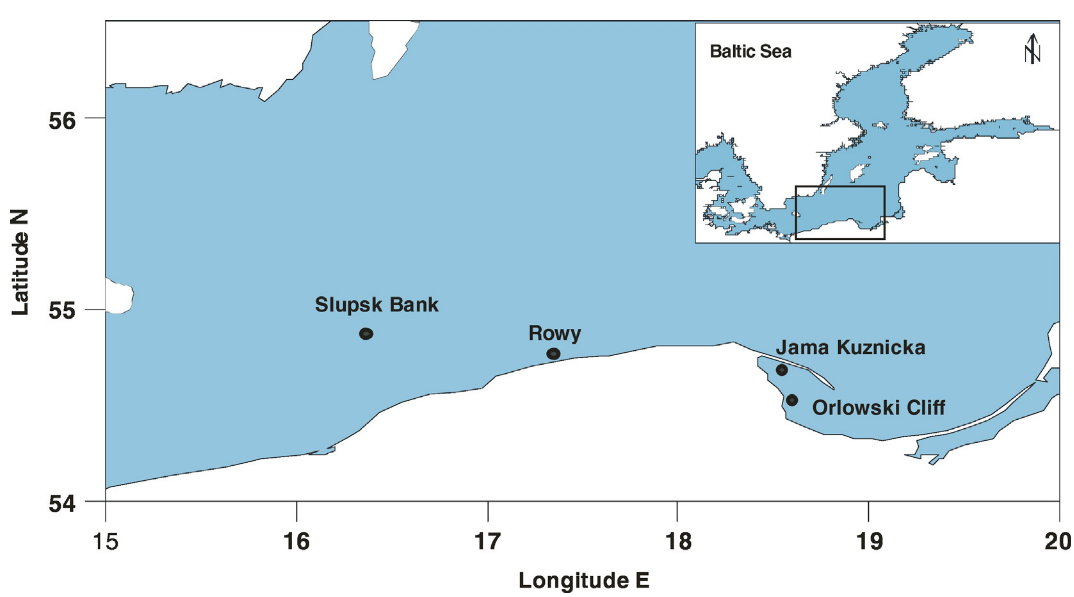


**Fig. 1.** Sampling locations of macrophytobenthic plants for heavy metal determination.

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