Marine Pollution Bulletin xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Note

Number of bacteria decomposing organic phosphorus compounds and phosphatase activity in the sand of two marine beaches differing in the level of anthropopressure

Z.J. Mudryk [a], P. Perliński [a,*], J. Antonowicz [b], D. Robak [a]

[a] Department of Experimental Biology, Pomeranian University in Słupsk, 76-200 Słupsk, Poland
[b] Department of Environmental Chemistry, Pomeranian University in Słupsk, 76-200 Słupsk, Poland

ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form 20 October 2015
Accepted 23 October 2015
Available online xxxx

Keywords:
Beach
Bacteria
Phosphorus
Decomposition

ABSTRACT

Number of heterotrophic bacteria ability to decompose organic phosphorus compounds and the level of phosphatase activity in the sand of two marine beaches (southern coast of the Baltic Sea) differing in the level of anthropopressure were studied. The study showed that the number of bacteria and level phosphatase activity were higher in the sand of the beach subjected to stronger anthropopressure. In both studied beaches bacteria hydrolysing DNA were the most numerous (92.7–302.8 CFU·g^{-1} d.w.). The least numerous were phytin (26.0 · 10^{3} CFU·g^{-1} d.w.) and phenolphthalein diphosphate (11.1·10^{3} CFU·g^{-1} d.w.) decomposing bacteria. Number of bacteria able to attack tested organic phosphorus compounds were the most numerous in dry zones (10.77–739.92 CFU·g^{-1} d.w.) then wet zones (3.34–218.15 CFU·g^{-1} d.w.). In both studied beaches bacteria hydrolysing organic phosphorus compounds and phosphatase activity generally were more numerous in surface sand layer. Seasonal variation in the occurrence of bacteria in both studied beaches was observed.

1. Introduction

Phosphorus (P) is undeniably an important element in the marine environment. Its role as a limiting macronutrient for primary and secondary productivity inextricably links it to the global carbon cycle and thus the climate system over geologic time scales (Paytan and McLaughlin, 2007; Sabarathnam et al., 2010). Consequently, the availability of phosphorus may ultimately control biomass and organic production in the World Ocean (Clark et al., 1999). However, P is also a major contributor of eutrophication of water ecosystems (Pant et al., 2002). Phosphorus is primarily delivered to the marine basins via continental weathering mainly via riverine influx. However, atmospheric deposition through aerosol, volcanic ash and mineral dust is also important (Paytan and McLaughlin, 2007). In aquatic environment the total phosphorus (TP) occurs in three forms: dissolved inorganic phosphorus (DIP), particulate phosphorus (PP) and dissolved organic phosphorus (DOP) (Sabarathnam et al., 2010). It is well known (Clark et al., 1999; Kolowith et al., 2001) that in aquatic ecosystems a considerable proportion of water phosphorus is DOP. The release of organic phosphorus into water and sediment is the combined result of exudation from healthy cells, losses from grazing activities, leaching from dead cells and/or cell lysis caused by viral infections (Björkman and Karl, 2003). DOP consists of compounds containing P–O–C bonds and includes monoesters, diesters, nucleotides, phosphonates, phosphoproteins, phosphoglycosides, phospholipids and organic condensed phosphates such as ATP or coenzyme A (Paytan and McLaughlin, 2007). Dissolved organic phosphorus pool likely plays a critical role in driving growth, metabolism and community composition of marine microorganisms mainly heterotrophic bacteria (White, 2009). It has long been known that populations of heterotrophic bacteria are commonly held responsible for mineralising DOP in processes of enzymatic dephosphorylation and conversion back to DIP (Krstulović, 1980; Mudryk, 2004; Sabarathnam et al., 2010). Bacterial communities are able to respond quickly to input of organic phosphorus compounds because of their rapid growth rates and high physiological diversity (Björkman and Karl, 2003). Cunha et al. (2003) showed that the extant microbial community could derive up to 50% of their P from ambient DOP pool.

Only low (<600 Da) molecular weight DOP compounds (i.e. glucose-6-P, glycerol-3-P, glycerophosphoric acid, AMP and c AMP) are carried whole across the membrane providing a source of P, C and potentially N to bacteria (Siuda and Chróst, 2001; White, 2009). Most of the DOP accumulated in marine ecosystems has polymeric structure (Dyhrman et al., 2007). Polymeric molecules (>1000 Da) are too large to be directly incorporated into bacterial cells (Hoppe, 2003). For mobilisation of P from DOP pool aquatic bacteria produce enzymes mainly phosphatases and nucleases that catalyse the hydrolytic cleavage of phosphate from organic phosphorus (Siuda and Chróst, 2001; Pant et al., 2002; Hoppe, 2003). These extracellular hydrolytic enzymes decompose large DOP molecules into simple compounds as monomers, dimers, oligomers and inorganic phosphate (Spivakov et al., 1999). Those simple organic phosphorus compounds can easily diffuse into the periplasmic space

* Corresponding author.
E-mail address: pperlinski@apsl.edu.pl (P. Perliński).

http://dx.doi.org/10.1016/j.marpolbul.2015.10.057
0025-326X/

and are used to meet bacteria energy requirements and to build up many cell membrane components such as phosphoproteins and phospholipids (Paytan and McLaughlin, 2007).

Bacterial participation in the circulation and transformation of phosphorus compounds in marine environments is very complex and still not fully understood. A considerable amount of work (Maeda and Taga, 1974; Krstulović, 1980; Mudryk et al., 1991; Mudryk, 1998) has been carried on decomposition of organic phosphorus compounds by bacteria in seawater. However, our knowledge of bacteria decomposing organic phosphorus compounds in sand of marine beaches is limited (Podgórska and Mudryk, 2007; Mudryk, 2004). Thus, the objectives of this study were to determine the occurrence and horizontal/vertical distribution of culturable heterotrophic bacteria capable of degrading organic phosphorus compounds as well as the level of phosphatase activity in the sand of two marine beaches (southern coast of the Baltic Sea) differing in the level of anthropopressure.

2. Material and methods

2.1. Study area and sampling

The study was carried out on two exposed sandy beaches (Ustka—54° 35′N, 16° 51′E, Czołpino—54°43′N, 17°14′E) on the southern coast of the Baltic Sea (Fig. 1). These beaches are influenced by the conditions in the open sea, and represent a dissipative beach type with longshore bars and troughs; their slope is 7° and the width of ca. 60–70 m. In general, fine and medium-grained sand predominates on the studied beaches. The sand grain-size is between 350 and 700 μm (Kramarska et al., 2003).

Both studied beaches differ in the level of anthropopressure. Ustka Beach with its surf zone is one of the most picturesque and very popular bathing-beach in Poland. Polish and foreign tourists, and local inhabitants intensively visit this beach and it is usually very crowded during the summer months. All horizontal beach profile is subjected to tourist pressure. Moreover, the mouth of the polluted Słupia River is in the eastern part of the beach. This river carries 15.5 $m^3 \cdot s^{-1}$ of water into the sea, as well as 200,000–300,000 $m^3 \cdot y^{-1}$ of natural and anthropogenic sediments (Zawadzka, 1996). Water outflow in the river Słupia is characterised by a vary along the seasons (Jarosiewicz and Obolewski, 2013).

Czołpino Beach is located in the Słowiński National Park—the World Biosphere Reserve. The sandbars and moving dunes–unique in Europe–are protected, characteristic features of the Park. Dunes move with speed of approx. 5–30 m per year are covered by "*sand-loving*" saltgrass species, such as: *Cakile maritima* ssp. *Baltica*, *Honckenya peploides*, *Ammophila arenaria*, *Calammophila baltica*, *Corynophorus canescens*, *Eleymus arenarius*, *Helichrysum arenariumand* and *Linaria odora*. As the beach near Czołpino is located in the National Park, people rarely visit this place and human pressure is relatively low there.

Sand samples were collected from the studied beaches every season starting from autumn 2008 till summer 2009. Four sampling sites were located along a transect perpendicular to the shoreline (Fig. 1). Site 1 was located approximately 1–1.5 m from the waterline at a depth of about 1 m; site 2 was situated at the waterline; site 3—halfway up the beach, at about 30 m from the shore, and site 4—in a sheltered place among the dunes, about 60–70 m away from the shore.

Sand core samples, five per site, were taken with a hand-operated sampler (length—30 cm, inner diameter—15 cm). Already in the field, the sampled sand cores, each 15 cm long, were divided into two sections: 0–5 cm and 10–15 cm and placed in sterile glass jars. Jars were put into containers with ice and transported to the laboratory. We did not sample the 5–10 cm sediment layer because the results of our previous studies (Mudryk and Podgórska, 2007) and Olańczuk-Neyman and Jankowska (1998) showed the highest difference in

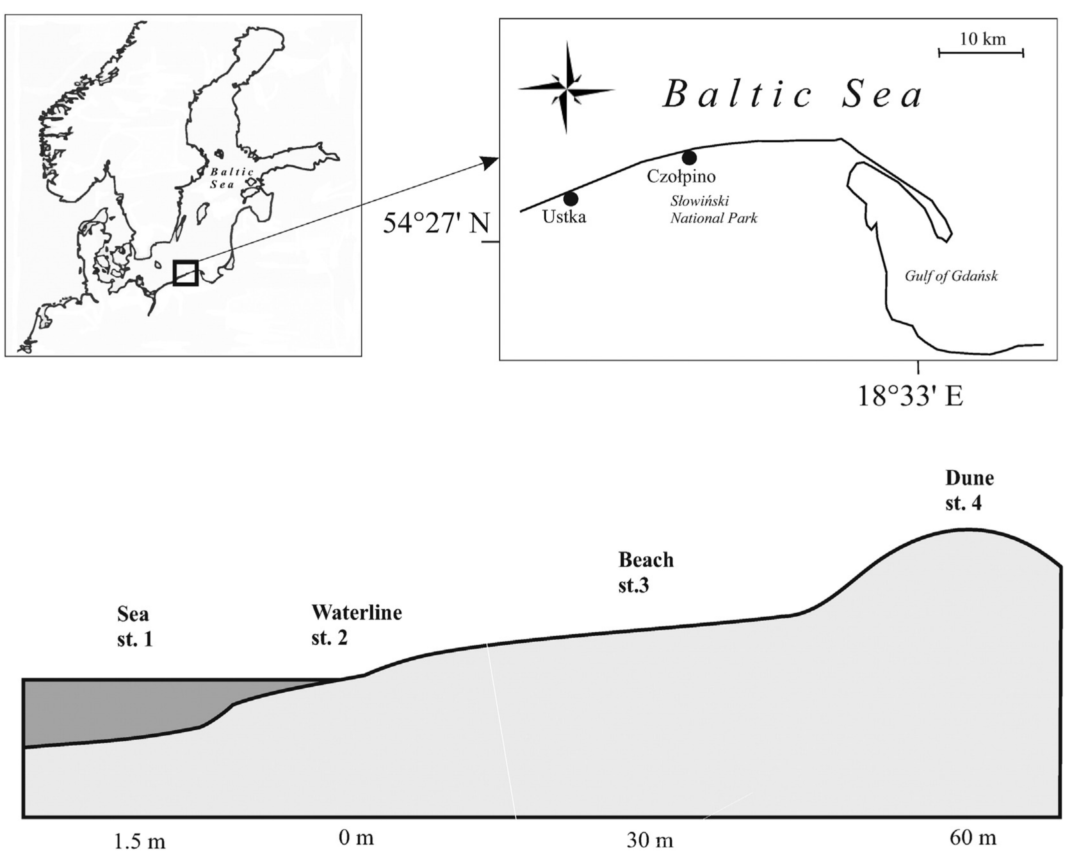

Fig. 1. Map of the study area: location of the sampling sites.