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THE BIOCHEMICAL COMPOSITION OF SEDIMENTARY ORGANIC MATTER IN SANDY BEACHES OF VARIOUS ANTHROPOPRESSURE

Jan Trojanowski, Katarzyna Bigus

Department of Environmental Chemistry,
Institute of Biology and Environmental Protection,
Pomeranian University in Słupsk,
ul. Arciszewskiego 22, 76-200 Słupsk, Poland
e-mail: jan.trojanowski@apsl.edu.pl

Abstract

Beach sediments from two beaches at the Polish coast of the Baltic Sea were collected and analyzed. The sediments were collected in two seasons – winter and summer – at two stations, depending on the influence of the sea water on the examined sediments. At each station, surface sediments (0-5 cm) were collected as well as sediments at the depth of 10-15 cm. The results of the conducted tests reveal, that anthropopressure, the depth where the collected sediments were taken and the direct influence of the sea water on the sediments have impact on the chemical composition of beach sediments and their food quality for the inhabiting psammon. The conducted tests disclose that there is more organic matter and its labile forms in the sediments originating from Ustka. Strong anthropogenic pressure found at the beach in Ustka also contributes to higher concentration of uncharacterized fraction of organic carbon in the area. Analyzing alimentary usefulness of the organic matter there, it seems to be higher at the beach in Czołpino.

Key words: organic matter, beach sediments, anthropopressure

INTRODUCTION

Sea coasts are specific ecosystems constituting contact zones between the land and the sea or the ocean. They form an unusually dynamic ecosystem in which the processes taking place in atmosphere, hydrosphere and lithosphere cooperate (Defeo et al. 2009). Sandy beaches which constitute about 40% of the total length of the sea coasts are its characteristic elements. The beaches make up a specific ecosystem inhabited by microorganisms, which participate in transformation and mineralization of the organic matter (Koop and Griffiths 1982, Phillips et al. 2011). Sea beaches

constituting a contact zone between the waters of seas, oceans and the land play a very important role in cleaning of such ecosystems. The water washing the beach sediments is filtered by them. Consequently, beaches constitute specific cleaning filters capable of accumulation and neutralization of an enormous volume of pollutants which reach them (Nair and Bharathi 1980, Phillips et al. 2011). Sandy sea beaches are also extremely important elements for the contemporary man from the business and economic points of view. They are selected as leisure destinations by most people around the world. So, they should be characterized by clean coastal waters as well as beach sediments.

Pollutants can reach sea coast in two ways. They can originate from the sea, as an effect of the sea transport, and from the land, as municipal and industrial wastewater, agricultural downflow from fields, and an impact of the tourist activity (Gheskiere et al. 2005, Santhiya et al. 2011). At present, it is estimated that the pollutants originating from the land as a consequence of direct human activity constitute 90% of pollutants reaching this environment (Andrulewicz 1994).

Biogenic substances are especially dangerous for this ecosystem. Introduction of excessive volume of nitrogen and phosphorous compounds to the water ecosystem causes extensive euthropication of this ecosystem. Introduction of pollutants, such as petroleum compounds and polycyclic aromatic hydrocarbons and other hydrocarbons as well as heavy metals lead to negative transformation of these ecotones caused by intoxication of plant and animal habitats and replacement of inhabiting autochtonous organisms (Żmudziński 1990).

The Baltic Sea beaches are characterized by substantial porosity, so they cumulate a large quantity of pollutants. It is estimated that they can accumulate 1,100 mg C * m^{-1} (McLachlan and Brown 2006, Podgórska and Mudryk 2007). Covered beaches characterized by fine-grained sediments, have much higher capacity of accumulation of pollutants (McLachlan et al. 1996). However, exposed beaches characterized by fine-grained sediments, good oxygenation and high drainage, accumulate them in lower quantity. The organic matter accumulated in beach sediments is decomposed and mineralized by inhabiting microorganisms into simple inorganic compounds. In this way, it can be used again and included into further circulation by microorganisms. The remaining organic matter which was not mineralized as well as anthropomorphic pollutants are transported to the deeper layers of sediments. The transport of pollutants into the deep layers of sediments is caused by sea water washing the sediments or by precipitation in the places where the sediments are not directly affected by the activity of sea waves. However, sometimes the organic matter load is so big, that ecosystems cannot clean themselves. Utilization of the whole oxygen which is there for the purposes of mineralization of organic matter causes creation of anaerobic zones in the deeper layers of sediments along with creation of reduced forms of sulphur and nitrogen.

The aim of the presented work was:

- the qualification of the anthropopresure influence on the content of organic substances in two sediments of different beaches in relation to anthropogenical factors,
- obtainment of the information about labile quantity of organic compounds being the measure of the potential accessible food to be consumed by the benthos,

– estimation of alimentary quality of organic matter contained in studied sediments and their change in the year.

MATERIALS AND METHODS

Research area

Test samples were collected at two beaches of the Polish coast of the Baltic Sea (Fig. 1). The first examined beach is situated in Ustka and the sediments were collected at eastern side of the Słupia River. The other beach is situated in the vicinity of Czołpino within the limits of the Slovinski National Park. Both examined beaches have been classified as exposed ones. However, they differ from each other as to the level of their exploitation by tourists and the influence of anthropopressure. The beach in Ustka is a city beach situated in the vicinity of a sea port. Since Ustka has a status of a health resort, it is visited by many tourists and bathers throughout the year. Western winds blowing over this area make a large part of pollutants from the Słupia River reach the beach under consideration.
The samples of beach sediments were collected twice a year: in January and July in the period 2009-2010. A horizontal transept was established on the beach, where two stations were installed depending on a direct impact of the sea waves:

– Station 1 – situated in the sea about 3 meters from the shoreline,
– Station 2 – situated in the middle of the beach.

Specimens of sediments were collected using a Morduchaj-Bolkowski manual core scoop 30 cm long and 15 cm wide. The sediments were collected at two depth levels of 0-5 cm and 10-15 cm. The collected sand samples had been put in a special ther-

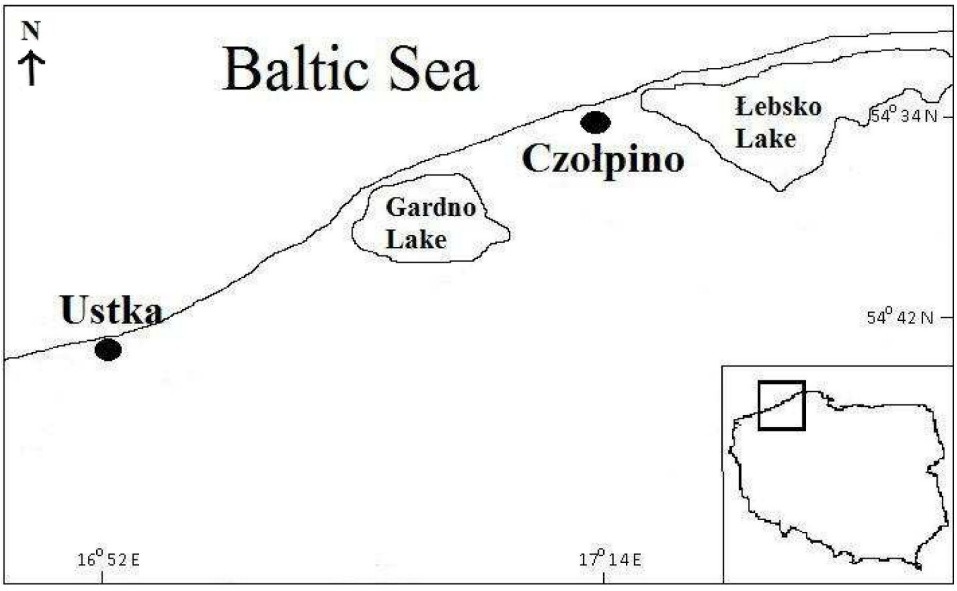

Fig. 1. Location of the study beaches (Ustka and Czołpino) on north Poland coast

mostat and were transported at the temperature of 5°C to the laboratory for chemical tests.
The organic matter content along with its components (protein, lipids and carbohydrates) was determined in the collected sediment samples along with the organic carbon content, and on their basis the biopolymeric carbon content (BPC), uncharacterized carbon fraction (COM) and food index (BPC:TOC) were specified.
Organic matter (OM) weight was determined as a loss on incineration by determination of a difference between a dry sample and a sample incinerated at the temperature of 450-500ºC in a muffle furnace to reach the solid mas. In order to eliminate carbonates before incineration, the sample was submerged in 10% hydrochloric acid.
The organic carbon (TOC) was determined by means of application of the Tiurin method (Myślińska 2001).
Protein (PRT) was determined by means of the method described by Markwell et al. (1978).
Lipides (LIP) were determined according to Zöllner and Kirsch (1962). This method comprises extraction of lipids by means of a mixture of chloroform and methanol.
Carbohydrates were tested by means of the method of Dubois et al. (1956).
In addition, equivalents of organic carbon included in protein, lipids and carbohydrates were determined. To do this, the content of particular individual compounds was multiplied by 0.49 for protein, 0.70 for lipids and 0.40 for carbohydrates respectively (according to Danovaro and Fabiano 1997). After summation of the organic carbon included in labile forms of the organic matter, biopolimeric carbon was obtained (BPC). Uncharacterized carbon fraction (COM) was determined as well, from the difference between the total organic carbon and the biopolimeric carbon (TOC-BPC). Food index expressed in percentage was obtained from the relation BPC:TOC (Cividanes et al. 2002), which is the measure of usefulness of organic matter for benthos inhabiting the sand.

RESULTS AND DISCUSSION

The organic matter reaching sandy ecosystems of beaches can be of two kinds. It can be a mixture of compounds included in living organisms as well as it can be constituted by components of disintegration of their remains or products made by the organisms inhabiting coastal beaches. It can also originate from the load of substances transported by the rivers or carried up from the bottom sediments. The first kind of matter is natural and constitutes labile forms of matter such as protein, carbohydrates and lipids. Such matter is easily mineralized by psammon organisms and constitutes effortless available source of food for the inhabiting benthos. The second type of matter is mostly anthropogenic and its presence in such ecosystems reflects negative impact of human activity (Gheskiere et al. 2005).
Chemical analysis of the collected beach sediments represents their real role in accumulation and mineralization of pollutants reaching seaside beaches. The percentage evaluation of its particular components constitutes an index of a real degradation of seaside beaches and makes it possible to establish the quality of the organic matter as a source of food for microorganisms inhabiting sediments (Cividanes et al. 2002).

Changes in quantity and quality of organic matter available in the seaside ecosystem influence metabolism and distribution of all bottom sea organisms, from bacteria to macrofauna (Buchanan and Longbottom 1970, Graf et al. 1983, Grant and Hargrave 1987, Duineveld et al. 1997, Fabiano et al. 2004, Defeo and McLachlan 2005). Measurement of the total volume of organic matter does not provide full information on its availability as food for consumers (Bianchi and Levinton 1984, Newell and Field 1983, Cividanes et al. 2002). Nor full information concerning food usefulness of organic matter for benthos is given by the measurement of the concentration of particular components of organic matter, such as carbohydrates, lipids and proteins. The diversity of climate and hydrographic conditions makes the psammon inhabiting there use various compounds as basic food sources. Different use of alimentary substances is connected not only with availability of a given component in the environment, but also with the capacity of microorganisms to its decomposition and assimilation. In recent years, such approach has been widely propagated and researchers trying to specify the usefulness of the organic matter as food specify not only its quantity but also its quality by determination of, so called, food index (Cividanes et al. 2002, Fabiano et al. 1995).

The organic matter content and its components are illustrated by Table 1. The results of the research show, that the organic matter content is more than two times higher in the beach sediments of Ustka than is the sediments of Czołpino, as it varies from 3.53 to 7.34 mg g^{-1}. However, concentration of the organic matter in the sediments originating in Czołpino varies at the lower level, between 1.31 and 3.68 mg g^{-1}. It seems, that the higher concentration of matter in the sediments from Ustka is caused by the economic and tourist recreational human activity. The location of a city agglomeration, a seaport, intensive tourist exploitation of the beach as well as the Słupia River estuary in the vicinity cause, that much more pollutants reach the beach sediments in Ustka than the beach sediments in Czołpino (Trojanowski et al. 2001).

Table 1

Average values of biochemical parameters in sandy beaches of Ustka and Czołpino (north Poland, OM – organic matter, TOC – total organic carbon, LIP – lipid, PRT – protein, CHO – carbohydrate, COM – uncharacterized carbon fraction, BPC:TOC – food index)

Parameters	Ustka			Czołpino		
	x*	x_{min}-x_{max}	SD	x*	x_{min}-x_{max}	SD
OM (mg/g)	4.49	3.53-7.34	0.37	2.19	1.31-3.68	0.23
TOC (mg/g)	2.583	0.753-4.218	0.221	1.258	0.780-2.891	0.104
LIP (μg/g)	307.1	59.1-730.2	19.4	193.8	59.4-470.1	12.7
PRT (μg/g)	180.6	72.6-356.6	15.3	133.0	58.7-212.6	12.3
CHO (μg/g)	578.9	157.6-1342.2	103.8	392.0	152.3-653.9	41.5
BPC (μg/g)	404.8	152.9-1196.2	84.5	387.3	149.1-687.5	30.8
COM (mg/g)	2.178	0.389-3.819	0.172	0.871	0.093-2.575	0.156
BPC:TOC (%)	20.84	7.31-61.80	2.11	30.79	5.80-88.14	2.04

Table 2

Changes in average content of biochemical parameters in sandy beaches of Ustka and Czołpino depending on season, stations and depth (OM – organic matter, TOC – total organic carbon, LIP – lipid, PRT – protein, CHO – carbohydrate, COM – uncharacterized carbon fraction, BPC:TOC – food index)

Parameters	Ustka						Czołpino					
	winter	summer	sea	beach	0-5 cm	10-15 cm	winter	summer	sea	beach	0-5 cm	10-15 cm
OM (mg/g)	3.60	5.37	4.92	4.05	4.06	4.91	1.57	2.81	2.87	1.52	2.15	2.24
TOC (mg/g)	2.073	3.092	2.834	2.330	2.330	2.822	0.911	1.622	1.653	0.872	1.241	1.258
LIP (μg/g)	194.5	419.8	88.9	511.7	310.5	290.1	92.8	294.9	82.2	304.2	192.9	193.5
PRT (μg/g)	97.3	264.0	183.8	177.5	194.2	167.1	115.8	150.2	115.1	151.0	174.8	116.2
CHO (μg/g)	244.5	913.3	355.6	802.3	606.1	551.8	190.2	593.7	315.0	468.8	399.0	384.8
BPC (μg/g)	272.0	537.6	294.5	769.8	561.1	499.5	235.9	538.8	253.6	521.2	405.3	369.5
COM (mg/g)	1.801	2.554	2.539	1.560	1.769	2.322	0.675	1.083	1.399	0.351	0.836	0.888
BPC:TOC (%)	13.12	17.40	10.39	33.04	24.08	17.70	25.89	33.22	15.34	59.77	32.66	29.37

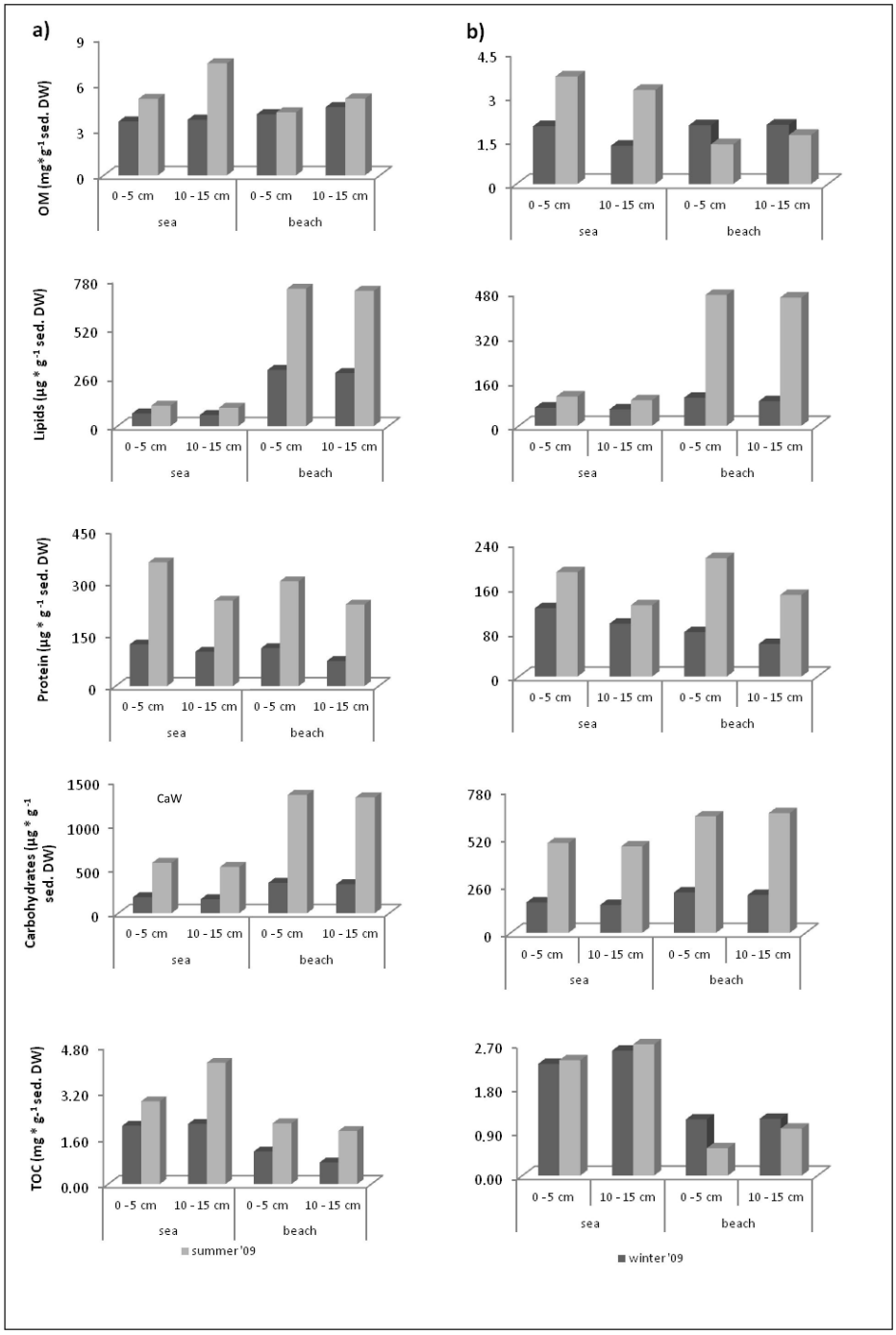

Fig. 2. The content of organic matter (OM), total organic carbon (TOC), lipid (LIP), protein (PRT) and carbohydrate (CHO) in sandy beaches of Ustka and Czołpino depending on season, stations and depth

Comparison with beaches of south Europe as organic matter concentrations in Ustka and Czołpino beaches were similar to reported in literature (Fichez 1991, Meziane et al. 1997, Incera et al. 2003, Fabiano et al. 2004).

Ecosystems of sandy beaches constitute an important and inseparable element of the human economic and life activity. Therefore, they are often examined by scientists all over the world (Gheskiere et al. 2005, Anschutz et al. 2009, Bergamino et al. 2011, Ariza et al. 2012). Among others, Trojanowski and collaborators (2007) dealt with analyses of influence of anthropopressure on ecosystems of Baltic sandy beaches. The results obtained by them show that the sediments originating from the beach in Sopot, which is a beach of high anthropopressure, are characterized by twice as much organic matter content than the sediments in Czołpino. This fact reflects a big impact of the human activity on natural ecosystem.

In Ustka, a higher organic matter content was observed in sediments collected at the depth level of 10-15 cm independently of the seasons of research (Table 2). It is especially true during the summer period at Station 1 (Fig. 2). Observed differences were statistically significant, with $p < 0.05$ (Table 3). At Station 2, the differences under consideration were much lower. At the beach in Czołpino, with statistically insignificant differences, the examined sediments at the depth level of 0-5 cm (Fig. 2) contained slightly more organic matter. The reason of higher concentration of the organic matter in the deeper layers of sediments may be connected with its infiltration along with the sea water at the first station and precipitation at the second. In case of a big quantity of organic matter, its substantial volume penetrates to the deeper layers where the speed of mineralization is much lower than in the surface layer due to a lower oxygen concentration. However, in Czołpino, probably with a lower quantity of the organic matter, its big portion undergoes decomposition and mineralization in the surface layer and its lower quantity penetrates the deeper layers, so the differences between the said layers are insignificant.

During the tests of the collected sediments, it was found that in winter, organic matter content in the examined sediments at both research stations was comparable within the areas of both beaches (Fig. 3). In summer, the effect is opposite. Then, the precipitation having direct contact with the sea water (St. 1) is characterized by a higher organic matter content than at Station 2. It could be an effect of more intensive vegetation in summer and additional supply of organic matter from coastal waters (Trojanowski et al. 2001). At both beaches, the organic matter content in summer was substantially higher than in winter (Table 3).

The content of labile forms of the organic matter such as lipids, protein and carbohydrates was higher than in the sediments originating in Ustka (Table 1, Fig. 2). Only in case of protein, the difference between the beaches under consideration was statistically insignificant (Table 3). The average lipids content in the sediments from Ustka is 307.1 $\mu g\ g^{-1}$ and 193.8 $\mu g\ g^{-1}$ in the ones originating from Czołpino (Table 1). The content of protein in the examined sediments originating from Ustka varied from 72.64 $\mu g\ g^{-1}$ to 356.6 $\mu g\ g^{-1}$and originating from Czołpino varied from 58.7 $\mu g\ g^{-1}$ to 212.6 $\mu g\ g^{-1}$. Carbohydrates have the highest share in the organic matter volume. Their average content in the sediments originating in Ustka was 578.9 $\mu g\ g^{-1}$ and was between 157.6 $\mu g\ g^{-1}$ and 1342.2 $\mu g\ g^{-1}$. The carbohydrates content in the Czołpino sediments was 392.0 $\mu g\ g^{-1}$ and was between 152.3 $\mu g\ g^{-1}$ and 653.9 $\mu g\ g^{-1}$.

Table 3

Summary U Mann – Whitney test of protein (PRT), carbohydrate (CHO), lipid (LIP), organic matter (OM), carbon of the biopolymeric fraction (BPC), total organic carbon (TOC), uncharacterised carbon fraction (COM), BPC:TOC ratio. Significance levels *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

		OM		TOC		LIP		PRT		CHO		BPC		COM		BPC:TOC	
		U	p	U	p	U	p	U	p	U	p	U	p	U	p	U	p
localisation		2	**	4	*	12	*	22	ns	6	**	20	ns	3	*	16	ns
season	Ust.	3	**	21	ns	10	**	0	**	0	***	5	*	32	ns	10	*
	Czoł.	5	*	25	ns	2	***	18	ns	2	**	6	**	24	ns	18	ns
station	Ust.	31	ns	16	ns	6	***	26	ns	6	***	12	**	16	ns	6	*
	Czoł.	9	*	2	*	10	**	28	ns	10	**	5	***	10	*	6	**
depth	Ust.	11	*	30	ns	24	ns	22	ns	28	ns	25	ns	29	ns	28	ns
	Czoł.	32	ns	28	ns	29	ns	16	ns	16	ns	25	ns	30	ns	22	ns

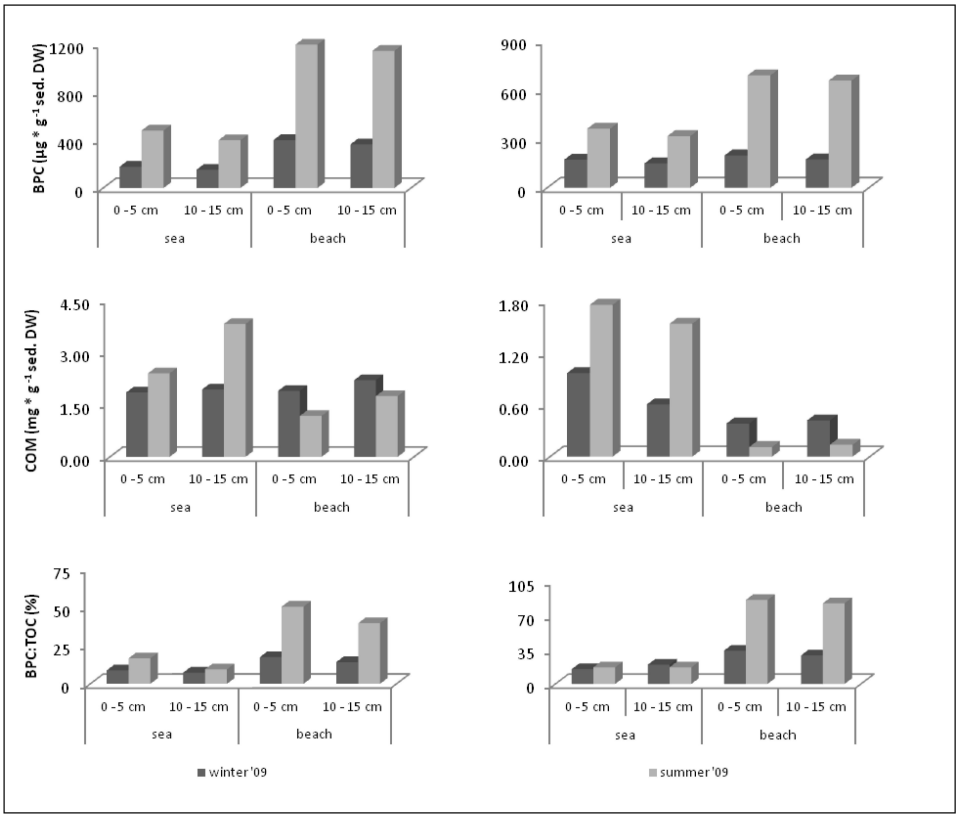

Fig. 3. The content of carbon of the biopolymeric fraction (BPC), uncharacterized carbon fraction (COM) and value of food index (BPC:TOC) in sandy beaches of Ustka and Czołpino depending on season, stations and depth

Examining the content of labile forms of organic matter, a vivid influence of a season on concentration of the parameters under consideration can be observed. The lowest condensation of protein, carbohydrates and lipids was found in winter (Table 2), the highest in summer which is obviously connected with the season of vegetation. Substantially larger concentration of lipids and carbohydrates was observed at the second station at both beaches, where the sediments have no contact with sea water. Such visible and valid difference, however, was found in case of protein (Table 3). Analyzing the depth of the collected sediments and their chemical composition, we found higher concentration of proteins, carbohydrates and lipids mostly in the surface level sediments of both beaches (Fig. 2). It is especially true in case of proteins in the summer season, while the differences in concentration of lipids between the compared layers were very insignificant. Generally, it was found that the differences in concentration of labile forms of organic matter between the examined layers under consideration were statistically insignificant.

The organic matter plays a significant role in the food chain of detritus. Its quantity and quality in the sediments, especially the surface ones, is considered to be a basic

nutritive source influencing development of bottom fauna and its metabolism. Percentage share of its particular components has influence on quality and availability of organic matter as food for benthos. In sediments, food quality plays an important role for bacteria (Deming and Yager 1992), meiofauna (Danovaro et al. 1995, Danovaro 1996) and macrofauna (Rosenberg 1995). During the tests of the collected sediments, carbohydrates were found to have the highest contribution to the quantity of the organic matter, independent of the station, depth and season (Table 2). However, the mutual proportion of lipids and proteins was changeable. At the first research station, both in the sediments originating in Czołpino and Ustka, a higher concentration of proteins in relation to lipids was observed. The situation changed at the second station where the concentration of lipids was higher than the concentration of proteins. Analysis of linear correlation shows that the concentration of protein and carbohydrates in the examined sediments of both beaches, substantially depends on the concentration of the organic matter while the concentration of lipids does not (Table 4). It suggests, that lipids originate from a different source than proteins or carbohydrates.

Comparing sediments of sandy beaches, originating from different regions, one can find differences both in case of organic matter as well as in the composition of its components. Carbohydrates have the highest participation in the sediments of the beaches of Polish sea coast. For example, the situation of sediments at Spanish beaches is totally different (Incera et al. 2003). Protein forming, most often, a fraction of organic matter in the sediments tested by us, constituted the highest percentage share. Such differences can result from climatic, hydrographic and anthropogenic differences between the examined beaches. Spanish and Polish beaches are inhabited by different species of microorganisms, respectively. Therefore, the differences in use of particular components of organic matter as food can be observed. The biochemical composition of sedimentary organic matter has been used to gather information on the origin, quality and food availability of organic matter (Fabiano et al. 1995, Danovaro 1996). In order to fully illustrate the usability of the organic matter as food, biopolimeric carbon (BPC), uncharacterised carbon fraction (COM) and the food index (BPC:TOC) were calculated. The values of those parameters are represented in Tables 1 and 2 as well as in Figure 3. Biopolimeric carbon is a sum of the carbon included in labile forms of the organic matter. Since higher concentration of proteins, carbohydrates and lipids can be found in the sediments originating in Ustka, BPC concentration is also higher in the sediments of that beach (404.8 $\mu g\ g^{-1}$, Table 1) than in Czołpino (387.3 $\mu g\ g^{-1}$). Incera and collaborators (2003) observed similar concentrations of the biopolymeric fraction of organic carbon in sandy sediments of Iberian Peninsula. In contrast, the lower of this fraction was observed in Legurian Sea beaches (Fabiano et al. 2004). Higher concentration of lipids and proteins in summer caused higher BPC values in summer than in winter (Fig. 3). For similar reasons, the sediments from Station 2 represented higher level than the sediments from Station 1. From analysis of the biochemical composition of organic matter, the carbon content of the biopolymeric fraction accounts forabout 15%, on average, of total organic carbon in Ustka and about 31% in Czołpino. The percentages reported here are higher than those reported by Fabiano and Danovaro (1994) from an estuarine and eutrophic environment (BPC = 3% of TOC) and similar those re-

ported for a highly oligotrophic system (BPC more than 20% of TOC; Fichez 1991). Although such differences may be due to large-scale geographical and geological differences or to different calculation methods, these results would suggest that moving from an eutrophic to an oligotrophic environment may cause an increase in the biopolymeric fraction and therefore enhance food quality (Fabiano et al. 1995).
The carbon from organic compounds other than labile forms of organic matter, e.g. hydrocarbons, constitutes the uncharacteristic fraction of organic carbon. This parameter to much extent specifies the level of pollution of coastal beaches. Its scale reflects how much pollution reaches the beaches and how much is accumulated in them. Beach sediments from Ustka are also characterized by higher content of uncharacteristic carbon fraction than the sediments from Czołpino (Table 1). Higher COM content in Ustka sediments reflects higher anthropressure of this area. There is an inversely proportional relationship between two forms of organic carbon (BPC and COM) characterized by negative correlation coefficients (Table 4). Since protein, carbohydrates and lipids constitute food for microorganisms, so the fraction of uncharacterized organic carbon is not used as easily absorbable food, and its mineralization and transformation by microorganisms is much more difficult. The ratio of BPC to TOC constitutes so called food index. It has been considered to be a possible indicator of the quality of organic matter as food potentially available to consumers (Danovaro and Fabiano 1997). Since the organic carbon content in the sediments of Czołpino is low, and at the same time its part constitutes carbon originating from labile forms of organic matter, the food index in Czołpino sediments is substantially higher than in the sediments from Ustka (Table 1). Therefore, correlation coefficient between the food index and the content of biopolimeric carbon is much higher for the beach in Czołpino than in Ustka (Table 4). A very high correlation coefficient between BPC:TOC and COM (-0.924, $p < 0.001$, Table 4) in Ustka is worth being considered. The higher concentration of uncharacterized organic carbon, the lower

Table 4

Sperman rang-order correlation analysis between environmental variables and biochemical compounds in Ustka: organic matter (OM), total organic carbon (TOC), protein (PRT), carbohydrate (CHO), lipid (LIP), carbon of the biopolymeric fraction (BPC), uncharacterized carbon fraction (COM), food index (BPC:TOC). Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$

	OM	**TOC**	**LIP**	**PRT**	**CHO**	**BPC**	**COM**	**BPC:TOC**
OM	1.000	**0.941****	**0.241**	**0.538***	**0.680****	**0.135**	**0.865*****	**-0.659****
TOC	0.912**	1.000	**0.241**	**0.562***	**0.185**	**0.157**	**0.812*****	**-0.714****
LIP	0.126	0.126	1.000	**0.682****	**0.897*****	**0.818*****	**-0.565***	**0.750*****
PRT	0.547*	0.566*	0.391	1.000	**0.559***	**0.297**	**-0.621***	**0.624****
CHO	0.553*	0.565*	0.797***	0.8***	1.000	**0.865*****	**-0.288**	**0.541***
BPC	0.391	0.391	0.891***	0.741**	0.956***	1.000	**-0.341**	**0.621***
COM	0.612*	0.642*	-0.609*	-0.053	-0.247	-0.397	1.000	**-0.924*****
BPC:TOC	0.006	0.006	0.959***	0.476*	0.785***	0.888***	-0.700**	1.000

food quality of organic matter. A similar relationship was discovered in the beach sediments in Czołpino, but they are not characterized by lower correlation index (-0.700, $p < 0.01$).
The linkage observed between the sea and land is the main factor controlling the origin and nature of sediment organic matter in these beaches as well as regulating bacterial community structure (Fabiano et al. 2004). The nearshore marine environment represents a key component that needs to be addressed by ecological studies for a assessment of the health and recovery of the Baltic beach ecosystems.

CONCLUSIONS

The sediments from the beach in Ustka which are under substantial influence of anthropogenic factors are characterized by much higher organic matter content and its components (lipids, protein, fats) than the analogical sediments from Czołpino, as well as by much higher content of uncharacterized fraction of carbon which can be the measure of pollution of the seaside beaches as well as biopolimeric coal.
The research done shows, that the organic matter content along with its components is closely dependent not only on anthropopressure, but also on the season, depth where the sediments were taken and direct influence of sea water on beach sediments. Their higher concentration was discovered in summer, which is directly connected with life activity of inhabiting microorganisms as well as with higher supply of anthropogenic matter in that period of time. The beach sediments which are under the direct influence of sea water, contained much more organic matter and uncharacterized fraction of organic carbon than the sediments at a farther distance. However, they were characterized by lower content of lipids, carbohydrates and biopolimeric organic carbon. The depth of the sediments did not show such substantial influence on the content of researched parameters as the season, anthropopressure or location within the beach area. Observed differences in the 0-15 cm layer were minor and did not reflect consistent regularities. Beach sediments from Czołpino contained the organic material characterized by much higher food quality than the sediments in Ustka.

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OCENA STOPNIA INFILTRACJI MATERII ORGANICZNEJ W OSADACH PLAŻ O RÓŻNEJ ANTROPOPRESJI

Streszczenie

Pobrano i zanalizowano osady plażowe pochodzące z dwóch plaż polskiego wybrzeża Morza Bałtyckiego. Osady pobierano w dwóch porach roku – zimą i latem – na dwóch sta-

nowiskach w zależności od wpływu wody morskiej na badane osady. Na każdym stanowisku pobierano osady powierzchniowe (0–5 cm) oraz osady z głębokości 10–15 cm. Z przeprowadzonych badań wynika, że skład chemiczny osadów plażowych, a także ich jakość jako pokarmu dla bytującego tam psammonu ma związek z antropopresją, głębokością, z jakiej pobierano osady oraz bezpośrednim wpływem wody morskiej na te osady. Wykonane analizy pokazują, że w osadach pochodzących z Ustki występuje znacznie więcej materii organicznej oraz jej labilnych form. Silna presja antropogeniczna występująca na plaży w Ustce jest również przyczyną znacznie większego stężenia niescharakteryzowanej frakcji węgla organicznego na tym terenie. Analizując przydatność pokarmową znajdującej się na obu plażach materii, można zauważyć, że jest ona znacznie większa w Czołpinie.