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Evaluation of pollution of Arenosols on the city beach in Gdańsk, north Poland

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Abstract

The purpose of the study was to assess the contamination of Arenosols on the beach, for this purpose the soil reaction and the content of heavy metals (Cd, Cu, Zn, Pb) were examined. To carry out the study, a municipal beach in Gdansk, Jantarowa Street, N Poland, which is heavily visited by tourists throughout the year, was selected. Twenty samples of sandy soil were taken from the beach, 18 samples from the designated bathing area and 2 control samples 500 meters away. They were taken every 10 meters from the surface layers of sandy soil (0–25 cm) using an Egner's stick. The surveys were performed in the spring of 2022. The construction of the beach was looked at and the possibilities of its economic use were analyzed. It focused on the problem of pollution of beaches around the world and pointed out the small amount of research on the subject, which may be related to the non-use of the beach area for activities other than tourism. Potential sources of pollution were analyzed and the most harmful ones were identified with an indication of the connection to the presence of large industrial plants in the vicinity. It was determined whether the permissible standards for heavy metals and soil pH are exceeded based on the Regulation of the Minister of the Environment of September 1, 2016 on how to conduct an assessment of pollution of the earth's surface and the guidelines of the Institute of Fertilization and Soil Science in Puławy. No risk was found on the basis of trace metal limits, and therefore the sandy soil was considered uncontaminated with natural trace metal contents. The average cadmium content in the area is 0.073 $mg \cdot kg^{-1}$, zinc is 9.34 $mg \cdot kg^{-1}$, copper is 4.06 $mg \cdot kg^{-1}$, lead is 4.54 $mg \cdot kg^{-1}$.

1. Introduction

One of the basic elements of the spatial structure of coastal municipalities is the shoreline and the accompanying beach. The beach is defined as the zone between the water line and the belt of dunes. In Poland, they are covered with loose material, usually sand, but also gravel with a smaller or larger grain diameter. Next to Arenosols, beaches are also built of mud, shells, and stones. The Baltic Sea and the accumulation material forming Polish beaches developed as a result of glacial retreat from the Scandinavian Peninsula 12 thousand years ago. The sandy shore has irregular shape primarily due to wind, waves, and sea level fluctuations. No two beaches are the same because of variable atmospheric conditions. Sandy beaches account for only 30% of all shores globally (Lindner, 1992). The beach does not only occur at seas and oceans. It is usually also encountered at water bodies with a smaller range, such as lakes, ponds, or even rivers. The area is only used for recreational purposes worldwide. It is caused by its infertility, ground instability, and possibility of periodic flooding during storms. Agricultural or industrial activity on a Arenosols is impossible.

The sandy seashore is inhabited by many birds and mammals. Its vicinity is rich in food sources for them, and provides attractive environmental conditions. Birds inhabiting coastal areas are relatively diverse. They include seagulls, terns, sandpipers, cormorants, or ospreys. All these birds are commonly known to feature various adaptations to life and requirements. Breeding of some of the birds overlaps with the holiday season during which beaches are frequented by vast amounts of tourists as well as the local communities. A considerable amount of additional infrastructure attractive for visitors appears. It can be problematic for the animals (Herbich, 2004).

Characteristics of the heavy metals studied

Cadmium is an element occurring in soils in small amounts. Its content depends on the type of bedrock, pH, and soil type. Factors such as cadmium emissions to the atmosphere from the vicinity, fertilisation, hydration, and development of various industries in the area are of great importance. Cadmium is highly soluble in soil in the acidic environment. Its mobility increases in light soils, making it easily available to organisms inhabiting the area (Chrzan, 2013).

Copper occurs in the soil in the form of largely immobile bonds. Its presence in the soil is related to the soil's grain size composition and reaction. A decrease in soil reaction results in an increase in the availability of the metal.

Lead is a metal relatively easily accumulating in the soil. The metal mainly originates from exhaust fumes, waste incineration, and different industries. Lead is highly immobile, but in acidic and sandy conditions it is much more available for plants. It can pose a serious threat for living organisms through its migration to the food chain.

Zinc is a metal commonly occurring in nature. It develops durable compounds with organic substance in the soil (Mantetti, 2020). It accumulates in the humic layer. Compounds of this heavy metal are relatively soluble. An increase in soil acidity and content of organic substance facilitates uptake of zinc from the soil. Zinc is supplied to the soil primarily as a result of industrial activity, fertilisation, use of wastewater, and transport (Jeong et al., 2020).

The study objective was the assessment of the pollution Arenosols in the city beach in Gdańsk at the Jantarowa Street. It involves the analysis of the content of heavy metals and soil reaction. Prior to the study, it was assumed that the beach was not contaminated with heavy metals that could negatively affect the environment.

2. Materials and methods

2.1. Characteristics of samples

The research was conducted on a frequented beach in Gdańsk. A total of 20 sandy soil formations samples were collected for analysis by wide swings along the surface of the beach in Gdańsk in the Jantarowa Street. 18 samples were collected in the guarded bathing area. The samples were taken every 10 metres. 2 control samples were collected 500 metres from the bathing area. The distribution of Arenosols sites is presented in Fig. 1. Sandy soil was collected from the surface soil layers (0–25 cm) by means of an Egner's cane. The sampled soil was air dried, sieved through a sieve with 2 mm mesh, and subject to analysis.

2.2. Methods

The potentiometric method was applied for the measurement of sandy soil pH in two ways, in a suspension with distilled water, and in KCl solution with a concentration of 1 mol·dm^{-3}. The determination of approximate to total quantity of trace elements involved water mineralisation with aqua regia (a mixture of concentrated hydrochloric acid and nitric acid in a volumetric ratio of 3:1). Available forms of heavy metals were also determined in the sandy soil from the beach, by means of a method involving extraction of metals from the soil with HCl solution with a concentration of 1 mol·dm^{-3}. After obtaining the extract, metals were determined by means of atomic absorption spectrophotometry (AAS). The content of heavy metals was determined, namely cadmium, zinc, lead, and copper. The results were given a statistical analysis.

3. Results

3.1. Content of heavy metals in the soil

The content of heavy metals Arenosols determined after extraction with 1 M HCl was varied depending on the place of sample collection and particular element (Table 1 and Fig. 2.).

In 16 out of 18 samples sandy soil formations, cadmium content was at the threshold of detectability. Mean content of cadmium in the area was 0.003 mg·kg^{-1}. In one sample – located close to the vegetation, the cadmium content reached 0.055 mg-kg^{-1}, before dropping to 0 mg-kg^{-1} in samples located along one line. In control samples taken outside the bathing area, cadmium

Fig. 1. Distribution of the collected sites on the beach in Gdańsk. Location of the intake point on the map

Table 1
Heavy metal content in soil after extraction with 1 M HCl

	HCl			
Nr	**Cd**	**Cu**	**Pb**	**Zn**
1	0.000	1.798	0.000	7.330
2	0.000	1.410	0.000	3.540
3	0.000	0.690	0.000	0.000
4	0.000	0.650	0.000	0.000
5	0.000	0.760	0.000	0.000
6	0.000	4.450	0.000	0.000
7	0.000	2.840	0.000	0.000
8	0.000	2.980	0.000	0.000
9	0.000	2.000	5.800	0.000
10	0.000	2.140	4.500	0.000
11	0.014	3.430	2.780	2.120
12	0.000	3.600	1.800	5.250
13	0.000	3.320	2.390	5.740
14	0.000	3.090	0.531	0.570
15	0.055	3.200	1.601	5.610
16	0.000	3.040	0.761	4.840
17	0.000	3.240	0.901	4.710
18	0.000	3.050	1.081	2.950
19	0.000	1.790	1.231	2.520
20	0.000	1.840	0.441	1.080
Mean	**0.003**	**2.466**	**1.191**	**2.313**
SD	**0.012**	**1.065**	**1.611**	**2.490**
Median	**0.000**	**2.840**	**0.761**	**2.120**

content was at the limit of quantification. The natural cadmium content in unpolluted soils (according to the guidelines of IUNG in Puławy) varies from 0.3 mg·kg^{-1} for light soils to 1.0 mg·kg^{-1} for heavy soils.

Copper content in the study area was highly variable, in a range of 0.65–4.45 mg·kg^{-1}. No trend was observed regarding copper content in the Arenosols. Mean content of copper in the area was 2.46 mg·kg^{-1}. In control samples collected outside the bathing area, content of copper was 1.8 mg·kg^{-1}. The natural content of copper in unpolluted soils (according to the guidelines of IUNG in Puławy) varies from 10 mg·kg^{-1} for light soils to 25 mg·kg^{-1} for heavy soils.

The content of lead in the Arenosols collected from the beach was variable. No trend related to its content was observed, however. In 8 out of 18 samples collected sandy soil formations from the beach, lead content was at the threshold of detectability. Mean lead content in the area was 1.19 mg·kg^{-1}. In one sample collected near the beach, lead content reached 5.8 mg·kg^{-1}. In control samples taken outside of the bathing area, the content was 0.835 mg·kg^{-1}. The natural content of lead in unpolluted soils (according to the guidelines of IUNG in Puławy) varies from 20 mg·kg^{-1} for light soils to 60 mg·kg^{-1} for heavy soils.

Zinc content in the study area was highly variable, in a range of 0.00–7.3 mg·kg^{-1}. No trend regarding zinc content in the sandy soil was observed. Mean zinc content in the area was 2.3 mg·kg^{-1}. In control samples Arenosols collected outside the bathing area, zinc content was 1.8 mg·kg^{-1}. The natural content of zinc in unpolluted soils (according to the guidelines of IUNG in Puławy) varies from 50 mg·kg^{-1} for light soils to 100 mg·kg^{-1} for heavy soils.

Based on the threshold values of the content of trace elements in the surface soil layer specified by the Institute of Soil Science and Plant Cultivation in Puławy, due to the % share of the clay fraction and reaction, the studied sandy soil was includ-

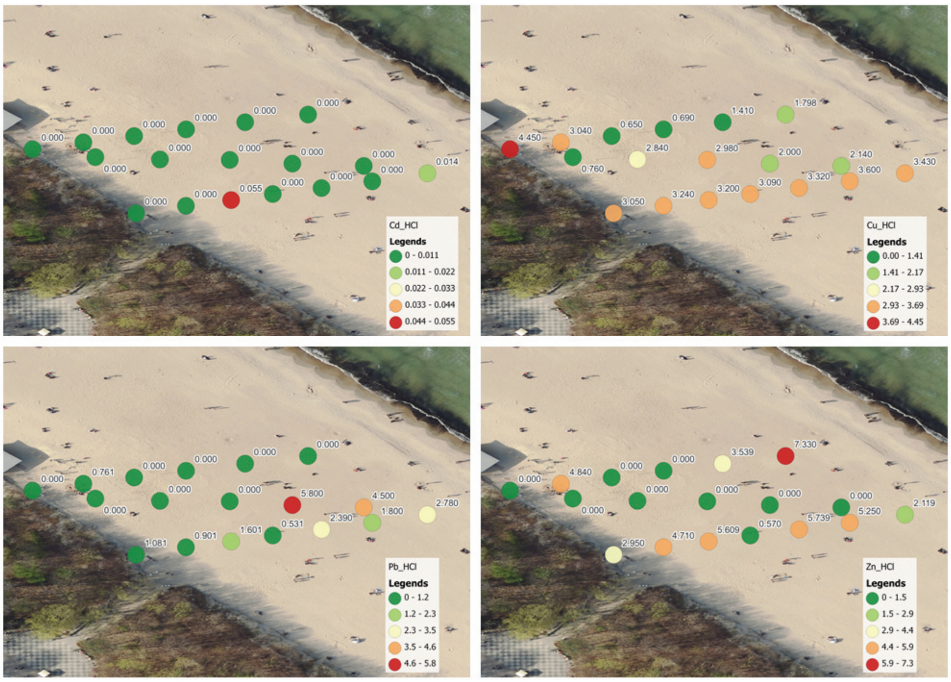

Fig. 2. Heavy metal content in soil after extraction with 1 M HCL

Table 2
Heavy metal content in soil after extraction in aqua regia

		HNO_3+3 HCl		
Nr	**Cd**	**Cu**	**Pb**	**Zn**
1	0.000	2.030	3.421	8.883
2	0.000	3.658	7.691	9.113
3	0.000	2.758	5.401	11.163
4	0.000	2.968	0.271	8.553
5	0.000	3.168	0.501	10.643
6	0.004	5.018	13.441	9.523
7	0.054	2.998	3.061	8.803
8	0.000	3.538	6.321	9.073
9	0.000	2.628	6.661	7.793
10	0.000	2.488	5.471	8.093
11	0.114	4.938	3.381	8.783
12	0.000	4.658	2.421	9.393
13	0.190	5.548	2.950	9.173
14	0.070	4.238	5.150	10.013
15	0.094	9.528	3.910	7.993
16	0.030	6.338	6.010	10.493
17	0.140	3.658	2.870	9.473
18	0.340	3.338	4.990	10.253
19	0.200	4.848	4.950	6.413
20	0.220	2.768	1.880	13.183
Mean	0.073	4.056	4.538	**9.341**
SD	**0.098**	**1.720**	**2.883**	**1.421**
Median	**0.030**	**3.658**	**4.538**	**9.173**

ed in group b of soils. The threshold values of 0.5 mg·kg^{-1} for cadmium, 45 mg·kg^{-1} for copper, 70 mg·kg^{-1} for zinc, and 50 mg·kg^{-1} for lead, respectively, were not exceeded in any of the analysed samples. Due to this, based on the aforementioned guidelines, the Arenosols can be considered as unpolluted with natural contents of trace metals.

Another method of determination of heavy metals in samples Arenosols collected from the beach was mineralisation with aqua regia, i.e. a mixture of HCl and HNO_3. No uniform trend of heavy metal content in the samples was determined (Table 2 and Fig. 3.).

Cadmium content in 9 out of 18 samples was detectable. It varied from 0.004 to 0.34 mg·kg^{-1}. Cadmium content in the remaining 9 samples was at the threshold of detectability. In control samples taken 500 m from the bathing area, the average cadmium content is 0.21 mg·kg^{-1}. Copper content was relatively variable, in a range from 2 mg·kg^{-1} to 9.53 mg·kg^{-1}. No trend of changes in the sandy soil formations copper content was determined. Mean copper content in the area was 4.05 mg·kg^{-1}. Outside the bathing area, control samples showed copper content of 3.8 mg·kg^{-1}.

Lead content was highly variable, from 0.27 to 13.44 mg·kg^{-1}. No uniform trend Arenosols of content of the element was found in the study area. Mean lead content in the analysed bathing area was 4.54 mg·kg^{-1}. In control samples collected 500 m from the bathing area, lead content was lower than at the beach, reaching 3.5 mg·kg^{-1}.

In all sandy soil samples, zinc content was detectable. In the remaining samples Arenosols, the content of the element varied from 7.7 to 11.16 mg·kg^{-1}. Mean zinc content in the analysed samples from the bathing area was 9.3 mg·kg^{-1}. In control samples, the content of the element increased, reaching 9.7 mg·kg^{-1}.

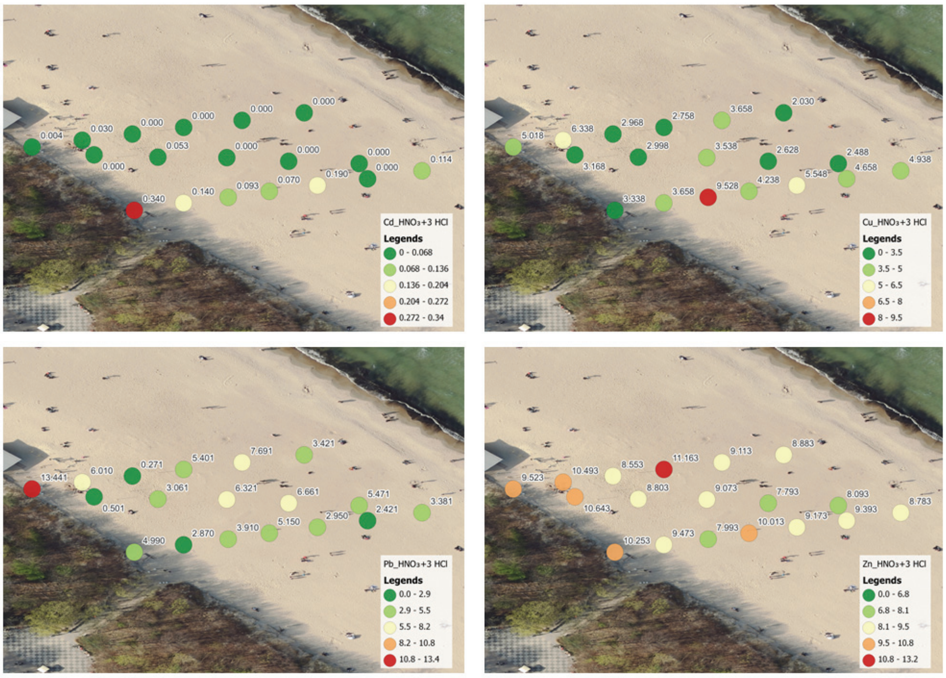

Fig. 3. Content of heavy metals in soil after mineralization in a aqua regia

The above results were compared with the permissible values set by the Ordinance of the Minister of the Environment of September 1, 2016 on how to conduct an assessment of pollution of the earth's surface (Journal of Laws 2016, item 1395). The studied land was classified as Group I land due to areas intended for sports and recreation. The content of no element exceeded the values permitted by the Minister (cadmium 2 mg·kg^{-1}, copper 200 mg·kg^{-1}, lead 200 mg·kg^{-1} and zinc 500 mg·kg^{-1}).

3.2. Soil reaction

The highest ratio of the available form to total form was obtained for copper, reaching 61%, followed by lead at 26%. The share of the available form was slightly lower for zinc – 25%. Cadmium showed the smallest share of only 5% (Fig. 4).

Soil analysis by means of the potentiometric method in suspension with KCl showed neutral reaction in 22% of the studied samples (Table 3 and Fig. 5). Alkaline soils accounted for as much as 78% of samples. Control samples showed a reaction of 7.95 and 8.2, and were therefore included in alkaline soils. Somewhat different results were obtained during the analysis of soil reaction in distilled water. In that case, alkaline soil constituted 28%, and neutral 11% of all soil samples. The highest share of samples had weakly acidic (44%) and acidic reaction (17%).

Statistical analysis using Student's t-test was performed to compare the mean concentration values of the four metals (Cd, Cu, Pb, Zn) in two different solutions: HCl and aqua regia (Table 4). All differences were statistically significant, meaning that

Table 3
Soil pH examined in KCl and H_2O

	pH	
Nr	**KCl**	**H2O**
1	7.19	7.3
2	7.64	7.16
3	7.7	7.57
4	7.31	6.64
5	7.52	7.53
6	6.97	5.82
7	6.94	6.22
8	7.19	6.18
9	7.26	5.91
10	7.35	5.86
11	7.49	6.31
12	7.3	6.34
13	7.21	6.11
14	7.23	7.47
15	7.56	7.71
16	8.81	6.5
17	8.14	6.6
18	7.48	7.13
19	7.95	6.33
20	8.2	7.64
Mean	**7.522**	**6.7165**
SD	**0.457253**	**0.65368**
Median	**7.480**	**6.600**

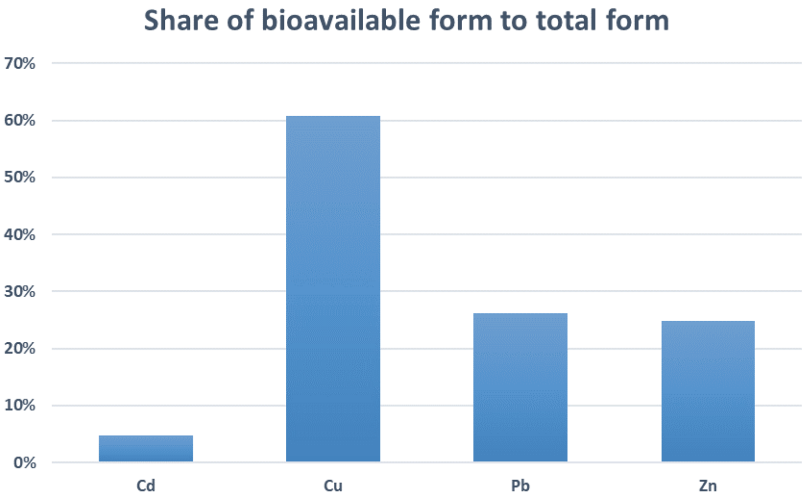

Fig. 4. Proportion of bioavailable from to total form

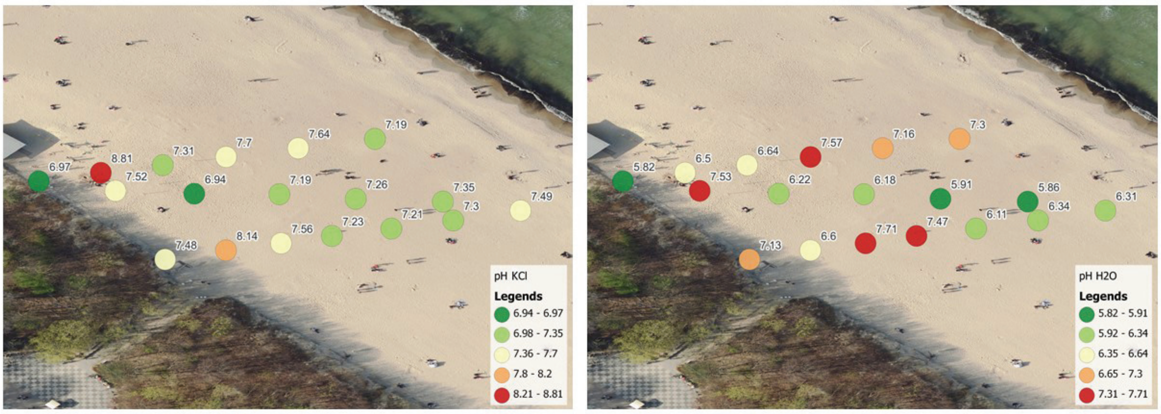

Fig. 5. The pH of the studied samples

the mean values of the metal concentrations in the two solutions are significantly different.

Table 4
Statistical analysis of both extraction methods using student's t-test

metals	mean		p-value
	HCl	aqua regia	
Cd	0.00	0.07	0.003
Cu	2.47	4.06	0.001
Pb	1.19	4.54	0.000
Zn	2.31	9.34	0.000

4. Discussion

Research on the content of heavy metals in beaches is conducted all over the globe. The obtained results are not uniform, and depend on many factors, primarily the latitude and location Arenosols towards areas under industrial use (Buzzi et al., 2022). Research conducted in beaches of the Bay of Bengal in India showed that the contents of lead, copper, zinc, and nickel exceeded levels acceptable for bathing areas, posing a threat for the public health (Satpatia et al., 2020). Research conducted in the beaches of Qingdao in China revealed high contents of heavy metals in the Arenosols, exceeding levels acceptable for bathing areas (Wang et al., 2013). Similar conclusions were drawn based on research conducted in the sandy soil formations of the Gulf of Mexico. It showed high contents of heavy metals, including lead, copper, zinc, and cadmium, exceeding levels acceptable for bathing areas. The cause of exceedance in the area could have been the vicinity of heavy industry (Hidalgo et al., 2016). The analysis of the content of heavy metals in beaches along the Kenyan coast revealed low concentrations of lead, cadmium, zinc, and copper, but higher than average mercury content. Researchers suggest that the source of pollution could be industrial and transport emissions (Muohi et al., 2003). Research Arenosols conducted in along the coast of the Persian Gulf showed variable cadmium, lead, copper, and zinc contents depending on the type of beach and distance from pollution sources. The highest contents of heavy metals were determined in urban beaches in the vicinity of ports and refineries (Naser, 2013). Another study conducted in beaches along the coast of the Black Sea showed high variability of the contents of cadmium, lead, copper, and zinc depending on the location and sources of pollution. The highest concentration of heavy metals was found in urban beaches in the vicinity of industrial and urban centres (Strezov, 2012). Research on the contents of heavy metals in Arenosols along the Mexican coast showed that the contents of cadmium, lead, copper, and zinc were variable depending on the pollution sources. Their highest values were found in urban beaches and in the vicinity of ports (Hidalgo et al., 2016). Research on concentrations of heavy metals in beaches along the north-eastern coast of Pakistan revealed variability of contents of cadmium, lead, copper, and zinc depending on the location and pollution sources. The highest contents of heavy metals were found in urban beaches in the vicinity of ports and industrial centres (Wang et al., 2013). The cited studies clearly point to the relation between the pollution of Arenosols and their location in the vicinity of ports and other industrial areas.

Research on the content of cadmium in beaches is important from the point of view of environmental protection and public health due to the recreational use of the area. A study conducted several years ago in north Poland showed content of cadmium in collected sandy soil formations samples varying from 0.03 to 0.30 mg·kg^{-1}. The values are approximate to those obtained in an experiment conducted several years ago on the bedrock (Czarnowska, 1996). In our study, cadmium was detected in only 2 samples. The amount of cadmium in the analysed area was approximately 0.003 mg·kg^{-1}. Similar dependencies were also obtained for the beaches at the Baltic Sea, where it was evidenced that cadmium contents in sandy soil are relatively low, but can increase in the vicinity of an industrial or port zone (Karloniene et al., 2021). Research conducted in beaches of south Spain showed the content of cadmium in sand higher in the vicinity of a petroleum refinery, potentially leading to the pollution of marine waters, and posing a threat for the public health (Nelson et al., 1993). Another study conducted in Egypt showed generally lower contents in the analysed beach. According to the authors, it may be related to the lack of heavy industry in the analysed region (Abbas et al., 2013).

Copper content in Arenosols can depend on many factors, including geographic location, industrial emissions, and tourist traffic (Buzzi et al., 2022). In a similar study, content of copper varied from 1.58 to 8.95 mg·kg^{-1} (Chrzan, 2013). Research conducted in the beaches of the Gulf of Mexico showed variable concentration of copper in beach sand, in a range from 2.2 to 46.5 mg·kg^{-1}. The results suggest that the primary sources of pollution are industrial emissions, marine transport, and tourist traffic (Buzzi et al., 2022). Another study conducted in beaches around the Iberian Peninsula showed that the concentration of copper in sandy soil formations sediments was low, and varied from 0.22 to 8.02 mg·kg^{-1}. The results suggest that the primary sources of pollution include road transport and pollution from agriculture (Nelson et al., 1993). Our study showed low content of copper, averaging 2.5 mg·kg^{-1}, with the lowest value at 0.65 mg·kg^{-1}. It may be determined by the lack of industrial or agricultural activity in the area Arenosols, the only threat being tourist transport.

Lead content in beaches can depend on various factors, including geographic location, industrial emissions, and tourist traffic (Han et al., 2021). In her study from 2013, A. Chrzan determined that the content of lead was relatively low, within a range from 12.5 to 8.8 mg·kg^{-1}, and it did not exceed the threshold values. Research conducted in the Arenosols of the Mediterranean Sea in Egypt showed a concentration of lead in beach sediments varying from 2.65 to 13.82 mg·kg^{-1}. The results suggest that the primary sources of pollution are tourist traffic and pollution related to marine transport (Han et al., 2021). Another study conducted in beaches around the city of Rio de Janeiro in Brazil showed low content of lead in sandy soil formations sediments. The results suggest that the main pollution sources are road transport and petroleum refineries (Cabrini et al., 2017). Our study showed low but variable content of lead, averaging 1.19 mg·kg^{-1}.

Content of zinc in beaches can depend on many factors, including the effect of anthropogenic activity and natural conditions of a given area (Hidalgo et al., 2016). Research on beaches showed Zn content of 148 ±77 mg·kg^{-1}. It did not exceed the threshold value of content of the element pursuant to the regulation of the Minister of the Environment (Chrzan, 2013). Another study conducted at the coast of the Baltic Sea in Poland showed content of zinc in beaches averaging 65.4 mg·kg^{-1}. The results suggest that the source of pollution can be predominantly tourist traffic, including the use of cosmetics and sunscreen protection by beachgoers (Manzetti, 2020). Other research conducted in beaches of the Black Sea in Turkey revealed that the content of zinc in beach sediments depends on the effect of the ocean and local pollution sources. The results suggest that zinc contents are higher in beaches with intensive tourist traffic, and those in the vicinity of river mouths (Bat et al., 2015). In our study, the content of zinc was much lower, but strongly variable, in a range of 0.00–7.33 mg·kg^{-1}. The only threat of an increase in the element in the soil in the area comes from tourist traffic.

Research on soil reaction is crucial, because soil conditions affect vegetation and soil quality, and therefore the beach ecosystem. Many studies have been conducted for the purpose of understanding the dependency of soil pH in beach areas. According to one of such studies from 2022 conducted at a beach in Egypt, soil pH varied between 7.2 and 8.5. Soil pH was determined to be more alkaline than that of soil in the vicinity of marine coasts. According to the same study, higher soil reactions at the beach can be accredited to high content of salt and stones that can affect the stability of the pH value (Nour et al., 2022). Other studies conducted at Arenosols around the globe also revealed that soil pH at the beach is variable and depends on many factors such as soil type, salinity, and humidity (Yajin et al., 2022). The conducted research strongly suggests that soil pH at the beach can affect vegetation and the ecosystem, and should therefore be monitored and maintained in a n appropriate range. In our study, pH was in a range of 7.95–8.2, approximate to the values obtained in the studies cited above.

5. Conclusions

Poland is currently facing a high deficit of studies dealing with the problem of Arenosols pollution with heavy metals. The issue is frequently omitted due to the lack of use of sandy soil formations for purposes other than tourism. It should be remembered, however, that thousands, or even millions of tourists globally spend their free time in such areas every year. It has become commonplace to refer to pollution with waste left behind by tourists. It is the primary problem of such areas. The beach is under constant mutual influence with the Baltic Sea the pollution of which is currently more commonly investigated by individual countries.

The conducted research on soil reaction and content of heavy metals at the sandy soil formations shows no pollution posing a threat for the visiting tourists or other living organisms.

The content of heavy metals in the study area was arranged in the order Zn>Pb>Cu>Cd. The share of the mobile form in the total ranged from 5% to 61%. This was the case of Cu- 61%, Pb- 26%, Zn- 25% and Cd- 5%.

The content of heavy metals in the beach in Gdańsk does not exceed norms acceptable either in the Regulation of the Minister of the Environment or the guidelines of IUNG in Puławy.

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Ocena zanieczyszczenia arenosoli na plaży miejskiej w Gdańsku

Słowa kluczowe

Plaża
Zanieczyszczenie
Gdańsk
Metale ciężkie
Odczyn gleby

Streszczenie

Celem badań była ocena zanieczyszczenia arenosoli na plaży, w tym celu zbadano odczyn gleby oraz zawartości metali ciężkich (Cd, Cu, Zn, Pb). Do wykonania badań wybrano plażę miejską w Gdańsku przy ul. Jantarowej, która jest intensywnie odwiedzana przez turystów przez cały rok. Pobrano 20 próbek gleby piaszczystej z plaży, 18 próbek z terenu wyznaczonego kąpieliska oraz 2 próbki kontrolne 500 metrów dalej. Pobierano je, co 10 metrów z powierzchniowych warstw gleby piaszczystej (0–25 cm) za pomocą laski Egnera. Badania zostały wykonane wiosną 2022 roku. Przyjrzano się konstrukcji plaży i przeanalizowano możliwości jej gospodarczego wykorzystania. Skupiono się na problemie zanieczyszczenia plaż na świecie oraz zwrócono uwagę na małą ilość badań na ten temat, co może być związane z niewykorzystywaniem terenu plaż do działalności innej niż turystyczna. Przeanalizowano potencjalne źródła zanieczyszczeń i określono te najbardziej szkodliwe ze wskazaniem powiązania z obecnością dużych zakładów przemysłowych w pobliżu. Określono czy dopuszczalne normy zawartości metali ciężkich oraz odczynu gleby nie są przekroczone na podstawie Rozporządzenia Ministra Środowiska z dnia 1 września 2016 r. w sprawie sposobu prowadzenia oceny zanieczyszczenia powierzchni ziemi oraz wytycznych Instytutu Uprawy Nawożenia i Gleboznawstwa w Puławach. Nie stwierdzono zagrożenia na podstawie granicznych wartości metali śladowych, w związku z tym uznano glebę piaszczystą, jako niezanieczyszczoną o naturalnych zawartościach metali śladowych. Średnia zawartość kadmu na tym obszarze wynosi 0,073 mg·kg^{-1}, cynku – 9,34 mg·kg^{-1}, miedzi – 4,06 mg·kg^{-1}, ołowiu – 4,54 mg·kg^{-1}.