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Sediments from stormwater drainage system as sorbents of organic pollutants

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ABSTRACT

Natural sorbents which are sediments formed in the aquatic environment play a key role in the deposition and circulation of organic compounds derived from natural and anthropogenic sources. In this paper, the qualitative composition of sediments from the urban stormwater drainage system was determined and their sorption capacity with respect to selected organic substances was evaluated. The material was subjected to physicochemical analyzes including pH value, dry residue, mineral and organic matter content, particle size distribution, mineral composition, specific surface area, the ionic composition including cations (Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Li^+, and K^+) and anions (Cl^-, Br^-, F^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, and NO_2^-) and the sum of sixteen polycyclic aromatic hydrocarbons (SPAHs) including naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenzo[ah]anthracene, benzo[ghi]perylene and indeno[1,2,3-cd]pyrene. The sediments accumulated in the stormwater sewer system cause problems that are related not only to the system operation but also to the hazard they may pose when delivered to the receiver. Because of their properties, the sediments are characterized by a high affinity for accumulating and storing toxic pollutants in their structure, such as heavy metals and also organic compounds (PAHs). When the sediment structure is disturbed, or the physicochemical conditions are altered, pollutants may be released and they may migrate to the environment. A hazard of this kind may be encountered when the stormwater sewer system is cleaned, or when settlers and separators in the treatment facility overflow. After conducting a number of tests it turned out these sediments may pose a potential threat to the environment due to their properties. In the case of sediments that have already have in their structure chemical contamination, it was still possible sorption, also the sorption capacity of the material is not fully used. This means that not only the organic matter of the sediment matrix but also the mineral parts are responsible for the sorption of organic pollutants. Therefore, to determine the bond strength of chemical micropollutants with the matter forming sediment, and to properly assess the degree of contamination should be taken into consideration to examine their sorption capacity.

Keywords: Sediments; Persistent organic pollutants; Sorption of contaminants; Mineral composition

1. Introduction

The urban environment is a complex structure with interlinked social, ecological and technical structures and the issues of the quality of the water environment remain invariably at the center of attention of research centers and institutions managing environmental protection, due to their importance for the functioning of ecosystems. Intensive modifications of land cover in urban areas and the associated large increase in catchment imperviousness

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lead to hydrological, physicochemical perturbations of the receiving aquatic ecosystems [1,2]. Urban stormwater represents a major non-point source of chemicals introduced into the environment. In fact, stormwater from urban catchments contains also large wastes (i.e., drink cans), suspended solids, organic matter (i.e., plant debris), nutrients, minerals (i.e., heavy metals) and organic (hydrocarbons and pesticides) micropollutants and microorganisms such as bacteria [3]. The ranking and identification of chemical hazards procedure have been used to prioritize organic contaminants considered to pose a risk in sediments when stormwater is discharged to surface water. Lists of priority pollutants based on chemicals frequently detected in stormwater have been produced and include heavy metals, organotin compounds, polycyclic aromatic hydrocarbons (PAHs), pesticides and polychlorinated dibenzofurans/dioxins [4].

In many parts of the world, direct discharge of stormwater runoff generated from urban roads and highways into natural water bodies is prohibited in order to protect their quality. In this case, the municipalities are obligated to use the different methods depending on the region to collect the road runoff and treat it before discharging it into the environment [5]. Sediments accumulating in the aquatic environment (lakes, rivers, seas, stormwater drainage systems) are a valuable source of information on the quality status of this environment. This is due to the fact that they are widely recognized as a place of deposition of chemical pollutants introduced into the aquatic environment, and thus as an important component of their circulation in nature. The type and sources of their origin, transport processes as well as chemical, geochemical and biochemical transformations occurring in water, sediment and also at the border of these two phases significantly determine its physicochemical properties [6–8].

The role of some of the most dangerous organic micropollutants plays a large group of compounds – PAHs. These hydrocarbons are ubiquitous environmental pollutants. They are human carcinogens and mutagens, they are toxic to all living organisms [9]. Atmospheric PAHs may cause respiratory problems, impair pulmonary function and cause bronchitis [10]. The European Community [11] and the United States Environmental Protection Agency (US EPA) have listed them as priority pollutants [12]. Hydrophobicity, high melting and boiling points, and low vapor pressures are responsible for their persistence in the environment [13]. PAHs can originate from natural processes such as biomass burning, volcanic eruptions and diagenesis. However, especially in heavily urbanized or industrialized regions, the majority of these compounds are anthropogenic, especially coal and wood burning, petrol and diesel oil combustion and industrial processes [14].

The aim of this study was to (1) determine the content of sixteen PAH as a sum of them (SPAHs) including naphthalene (NAPT), acenaphthylene (ACNY), acenaphthene (ACEN), fluorene (FLUR), phenanthrene (PHEN), anthracene (ANTH), fluoranthene (FLTH), pyrene (PYR), benzo[a]anthracene (B(a)A), chrysene (CHRY), benzo[b]fluoranthene (B(b)F), benzo[k]fluoranthene (B(k)F), benzo[a]pyrene (B(a)P), dibenzo[ah]anthracene (D(ah)A), benzo[ghi]perylene (B(ghi)P) and indeno[1,2,3-cd]pyrene (INPY), (2) examination of sorption properties of stormwater sediments, and finally (3) determination of mineral composition to find the connection between these properties. These activities allowed us to find some important information about the mechanisms relationships occurring not only in rainwater but also in sediments.

2. Materials and methods

2.1. Study site

The study covered four urban catchments located in the north-western part of Kielce (Fig. 1). These catchments differ in terms of surface area, relief and land development, as well as the length of the sewage system.

The largest area (A = 805 ha) is occupied by the catchment of the stormwater treatment plant (SWTP) Jarząbek. The catchment is dominated by green areas, which cover 38.70% of its total area, and industrial areas (22.30%) (Table 1). Rainwater from the catchment area is drained through a sewer network with a total length of L_{pip} = 38.0 km. The sewerage system consists of two main collectors with diameters of ϕ = 300–1,800 mm, equipped with more than 300 street rain inlets and two open ditches with a length of 5.20 km. The highest point in the catchment area rises to 339 m above sea level, while the lowest point lies at 245.00 m above sea level. The catchment area has fallen by 3.38%. The second-largest catchment is the SWTP Jesionowa catchment (A = 355 ha). It is located in the north-western part of Kielce and includes areas with a high degree of urbanization. The rainwater drainage network with a total length of L_{pip} = 16.0 km (ϕ = 200–1,500 mm) is equipped with approximately 300 street inlets. The catchment development is dominated by industrial areas including large-format commercial facilities (71.30%) and low-rise residential buildings (14.10%). The highest point in the catchment area lies at an altitude of 315.00 m above sea level, the lowest at 265.0 m above sea level. The slope of the catchment is equal to 2.65%. The SWTP Bp. Kaczmarka catchment is located in the center of Kielce (Fig. 1). The land development is dominated by high residential buildings (36.60%), industrial and service areas (26.20%) and also residential buildings (24.20%). The sewerage system consists of the main collector (ϕ = 300–600 mm) 2.1 km long, as well as side channels (ϕ = 200–1,000 mm) with a total length of 13.4 km. About 400 rainwater inlets and connections to residential and commercial buildings are connected to the sewer system. The highest point in the catchment area is Góra Karczówka at 339 m above sea level. The lowest point is located at 258.00 m above sea level. The fall of the catchment is 5.2%. The smallest of the surveyed objects is the Witosa SWTP catchment. Its total area is 82.0 ha. The sewerage system consists of the main collector (ϕ = 1,200–1,400 mm) and side channels (ϕ = 300–800 mm) of total length 7.65 km. It collects rainwater from the area of the estate, where nearly 400 single and multi-family houses are located. The sewage system is equipped with 192 rain gullies and sewage connections to drain rainwater from the roofs of the buildings. Housing development covers an area of 36.5 ha (44.5%) of the drained area. The remaining part of the catchment area (45.5 ha) is green. The highest point in the catchment area is

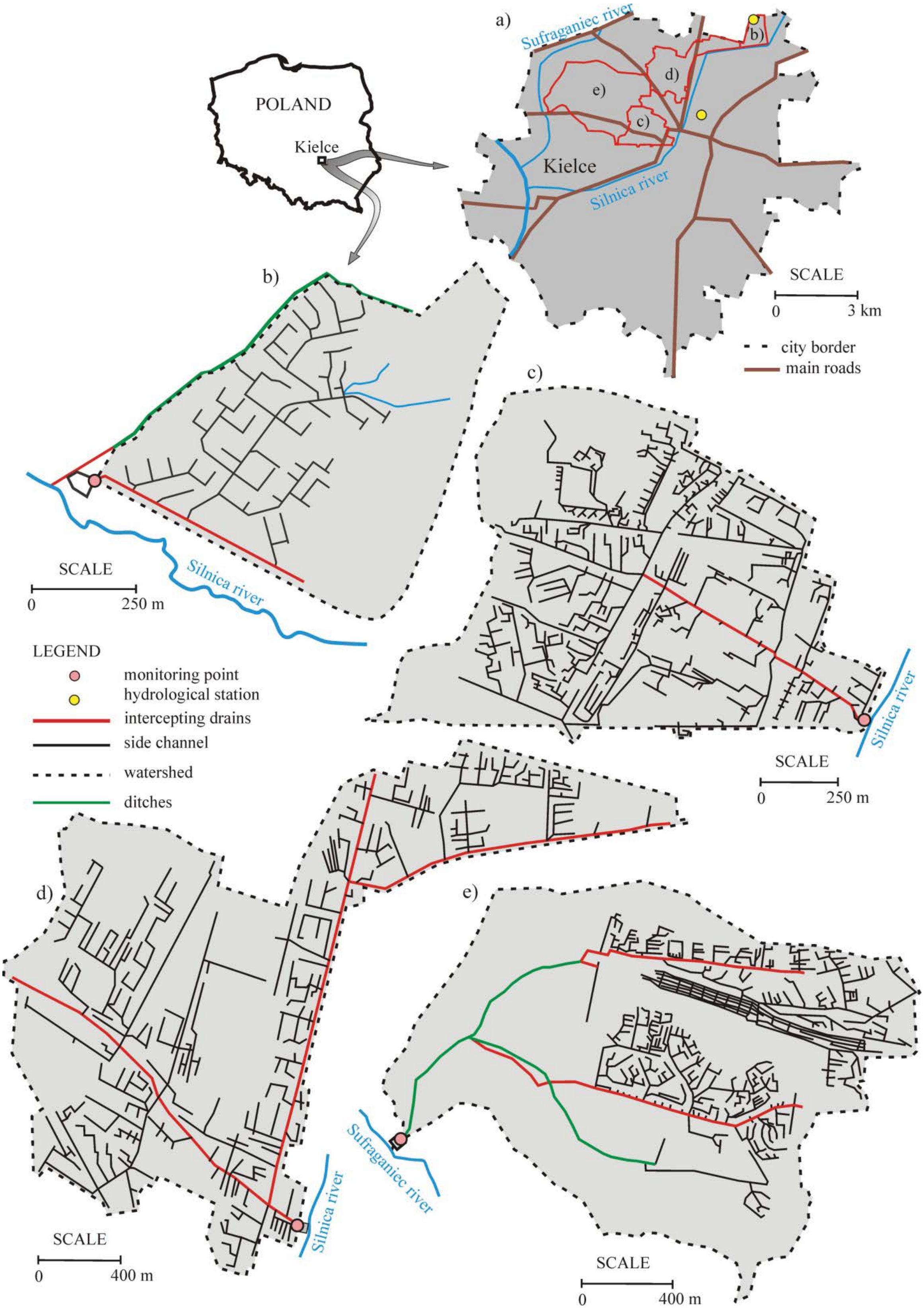

Fig. 1. Study area (a) location in the City of Kielce, (b) Witosa SWTP catchment, (c) Bp. Kaczmarka SWTP catchment, (d) Jesionowa SWTP catchment, and (e) Jarząbek SWTP catchment.

Table 1
Characteristics of the catchment

Catchment	A	Catchment area coverage					ΣL_{pip}	ΔH
		Low-rise buildings	High-rise buildings	Industrial areas	Green areas	Others		
	ha	%					km	m
Witosa	82	44.50	–	–	55.50	–	7.65	47.3
Jesionowa	355	14.10	3.50	71.30	4.10	7.00	16.00	50.0
Bp. Kaczmarka	224	24.20	36.60	26.20	8.10	4.90	15.50	81.0
Jarząbek	805	19.40	12.20	22.30	38.70	7.40	38.00	94.0

365.50 m above sea level, while the lowest point is 291.25 m above sea level. The fall of the catchment is 8.2%.

2.2. Samples collection

Samples of stormwater sediments from studied urban catchments were collected seasonally in 2016 according to PN-EN ISO 5667–15:2009 [15] standard method and the sampling sites are shown in Fig. 1. Immediately after collection, sediment samples were placed into sterile polyethylene containers, in compliance with international standards. Containers with samples were tightly sealed and transported to the laboratory for physicochemical analyses. Then the samples were divided into two parts. The first part (without drying) was analyzed for particle size and PAHs and the other part was homogenized and naturally dried to obtain air-dry condition. Sediment samples prepared in this way were stored in pre-washed glass containers at room temperature and conducted to the remaining analysis.

2.3. Sediment quality analysis

2.3.1. Determination of pH, dry residue, loss of ignition (LOI) and particle size distribution

The pH value, dry residue were measured promptly after sample homogenization in accordance with the PN-EN 12176:2004 method using SevenMulti™ meter (Mettler Toledo, Greifensee, Switzerland) [16,17]. Organic content, measured as a loss of ignition (LOI), was determined in accordance with the standard method [18], which involved drying the sediment at 105°C to a constant weight, and then heating it at 550°C for 2 h. Sediment particle size distribution was examined using a combination of sieving (wet sieving with different mesh size sieves, Conbest equipment, Cracow, Poland) and laser diffraction analysis (Mastersizer 3000, Malvern, United Kingdom).

2.3.2. Determination of chemical (C,H,N) composition

Elemental analysis of EA C,H,N was made by the catalytic combustion method elemental analyzer with a TCD (thermal conductivity detector) detector. On the basis of the thermal conductivity measurement of the combustion products, they were determined the percentage content of carbon, hydrogen and nitrogen. Samples were analyzed using elemental analyzer Vario MACRO (Sartorius AG, Göttingen, Germany).

2.3.3. Determination of mineralogical composition – X-ray diffraction

The dried powdered sub-samples were analyzed by X-ray diffraction (XRD) using an Xpert-Pro diffraction system (Malvern). Samples were scanned from 5° to 120°2θ (Theta) in continuous scan using a Cu-Kα radiation anode and a voltage 40 kV and 30 mA with the constant temperature at 25°C. The relative proportions of the various minerals were determined by measuring the heights of the main reflections.

2.3.4. Determination of specific surface area and porosity

The dried samples were analyzed by Micromeritics® (Norcross, United States) apparatus using gas adsorption manometry which is the method generally used for the determination of adsorption isotherms of nitrogen at the temperature of liquid nitrogen (~77 K) to determine the specific surface area (SSA) (denoted as S_{BET}). This type of approach is known as a 'volumetric determination' (or alternatively as the 'Brunauer–Emmett–Teller (BET) volumetric method') since it originally involved the measurement of gas volumes, before and after adsorption.

2.3.5. Determination of PAHs

Sediment samples with a mass of 1g were extracted in dichloromethane to determine the total sum of PAHs. These compounds are grouped into two categories based on their molecular weights and these are low and high. Low molecular weight PAHs containing two- and three-rings with molecular weight from 152 to 202 g mol^{-1} include NAPT, ACNY, ACEN, FLUR, PHEN, and ANTH. The high molecular weight PAHs have four-rings to seven-rings with molecular mass ranging from 228 to 278 g mol^{-1} include FLTH, PYR, B(a)A, CHRY, B(b)F, B(k)F, B(a)P, D(ah)A, B(ghi)P, and INPY. Concentrations of PAHs were identified in samples in accordance with the PN-EN 15527:2008 method [19]. To determine the reliability of the PAH data, including the efficiency of extraction methods and interferences that may be introduced during sample preparation, deuterated internal standards were used (d-8 NAPHT and d-12 B(a)A). These standards ensure that the accuracy of the results obtained is independent of the recovery degree. The next step included wetting the sediment sample with acetone, adding acetone with deuterated standards, an intensive stirring of the sample and undisturbed evaporation of the acetone. This procedure makes it possible to achieve a similar binding form between standards added and the sediment matter. All PAH concentrations were reported on a dry weight basis.

2.3.6. Determination of ion composition

The samples of sediments from the stormwater system were analyzed for the content of selected cations (Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Li^+, K^+) and anions (Cl^-, Br^-, F^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, NO_2^-) after their previous extraction into the liquid phase. The sediment samples were dried to constant weight at 105°C in an electric oven, then 1.5 g of the sample was weighed and extracted using a weak organic acid (in this case 100 mL of 0.01 molar acetic acid). The factor supporting the extraction was shaking and placing samples in an ultrasonic device (Merck Eurolab, Darmstadt, Germany) with a frequency of 35 kHz and temperature stabilization (20°C). The final extracts were purified on hard quality Ø = 12.5 cm (Munktell, Sweden) filters. Solutions prepared in this method were analyzed by ion chromatography on 883 Basic IC Plus (Metrohm, Herisasu, Switzerland) with conductivity and suppression detector according to standards PN-EN ISO 14911:2002P [20] and PN-EN ISO 10304–1:2009/AC:2012 [21], respectively. The obtained results were converted into relevant solid sample weights.

3. Results and discussion

The pH value, dry residue combined with hydration, the content of organic matter (OM), the content of total nitrogen (TN) and total carbon (TC) were measured in the sediment samples. All these parameters are shown in Table 2. The mean pH values were noticed in a similar range for all collection points from 7.16 for Bp. Kaczmarka to 7.93 for Jesionowa catchment and were comparable with other research of runoff and stormwater sediments where the values were included in the scope of 4.0 ÷ 10.0 [22]. Sediments were characterized by a high moisture content (around 70%) for sediments collected from open tanks – Jarząbek and Witosa. The remaining samples were characterized by significantly lower hydration at the level of 30%. Organic matter content, measured as an LOI, was determined in all samples and in three of them – Jarząbek, Witosa and Bp. Kaczmarka content at level 10% was observed, while in Jesionowa reservoir this value was lower by 4 percentage points. In the case of nitrogen and carbon content, the highest concentrations of these nutrients were noticed in Jesionowa samples – a dozen or so percent. The remaining samples showed only a few percent (Table 2).

The analysis of the particle size distribution shows that the sediments were characterized by a similar grain composition depending on the type of the tank. In open tanks – Jarząbek and Witosa, respectively. The dust-clay fraction with a grain diameter below 63 μm, represented on average about 75%, including the clay fraction itself, with grain diameters below 2 μm, ranged between 2.86% for Witosa and 3% for Jarząbek tank. The remaining 25% were assigned to the fine sand fraction. In the case of closed tanks (Kaczmarka and Jesionowa), the participation of dust-clay fraction was significantly lower than in the case of open tanks and ranged from 21% to 33%. The remaining fraction was a group of sands and gravel parts. In the mineralogical composition, XRD indicates the advantage of quartz and calcite in tested sediment. The most amount of calcite occurs in sediment form open tanks, Jarząbek and Witosa, 69% and 58%, respectively. Wherein, in SWTP Bp. Kaczmarka and Jesionowa, is practically is only quartz ~85% with small quantities of dolomite and sylvite – up to 10%. In addition

Table 2
Physicochemical parameters of sediments from chosen sedimentation tanks

Catchment	pH	Dry residue	Hydration	LOI	TN	TC
	–	(%)	(%)	(%)	(%)	(%)
Jarząbek	7.39 ± 0.21	30.012 ± 4.35	69.98 ± 4.34	12.28 ± 1.52	2.11 ± 0.01	2.83 ± 0.28
Witosa	7.70 ± 0.53	32.30 ± 5.86	67.695 ± 5.86	10.07 ± 2.44	4.75 ± 0.01	2.43 ± 0.19
Bp. Kaczmarka	7.16 ± 0.10	68.02 ± 11.51	31.97 ± 11.51	9.11 ± 5.81	3.08 ± 0.01	5.67 ± 0.26
Jesionowa	7.93 ± 0.22	65.21 ± 9.14	34.77 ± 9.14	5.64 ± 3.26	14.40 ± 0.01	15.53 ± 0.38

Table 3
Mineral composition and specific surface area of tested sediments

Catchment	Calcite	Quartz	Dolomite	Sylvite	SSA	Total volume in pores
	$CaCO_3$	SiO_2	$CaMg(CO_3)_2$	KCl	S_{BET}	
	(%)	(%)	(%)	(%)	($m^2\ g^{-1}$)	($cm^3\ g^{-1}$)
Jarząbek	69.21	30.79	–	–	7.75 ± 0.03	0.02136
Witosa	58.26	35.01	6.73	–	6.11 ± 0.02	0.01714
Bp. Kaczmarka	11.55	84.12	–	4.33	1.58 ± 0.01	0.00434
Jesionowa	3.96	83.35	12.69	–	1.85 ± 0.01	0.00237

to the mineral composition, it was additionally carried out the determination of SSA (named S_{BET}) and total pores volume to precise sorption properties of stormwater sediments (Table 3). The best results were obtained in samples from SWTP Witosa and Jarząbek, where the values ranged from 6.11 to 7.75 m^2 g^{-1}, respectively.

To complete the information about the composition of the sediments the samples from the stormwater system were analyzed for the content of selected ions: cations (Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Li^+, K^+) and anions (Cl^-, Br^-, F^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, NO_2^-). The results are shown in Figs. 2 and 3. In the case of cations, the highest concentration values reported for calcium and magnesium ions for SWTP Jarząbek (5,190.8 and 178.94 mg kg^{-1}) and SWTP Witosa (5,002.75 and 89.67 mg kg^{-1}). Whereas, in the case of anions the largest amounts of Cl^- and SO_4^{2-} in each collection point were

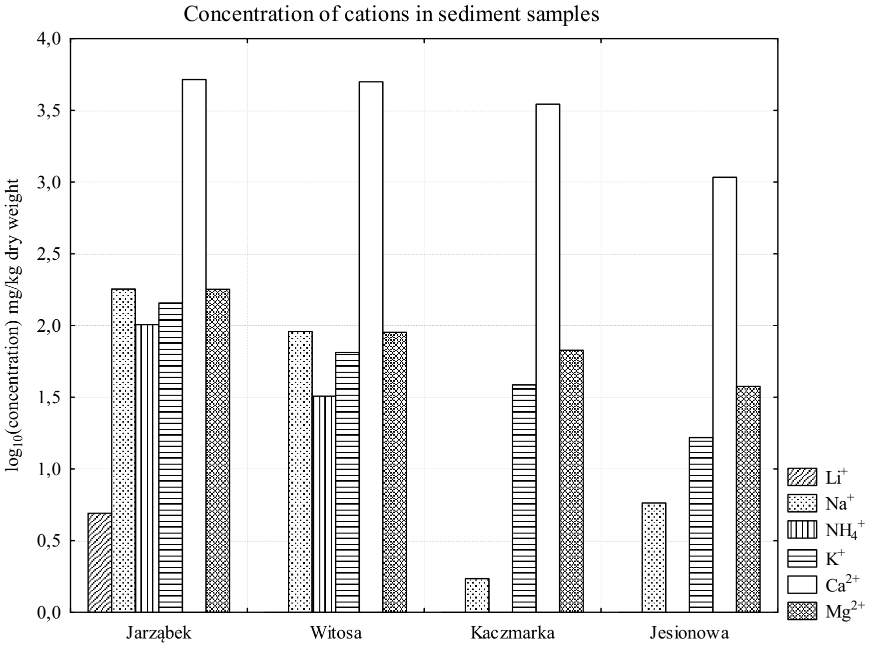

Fig. 2. The concentration of cations Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Li^+, K^+ in stormwater sediments.

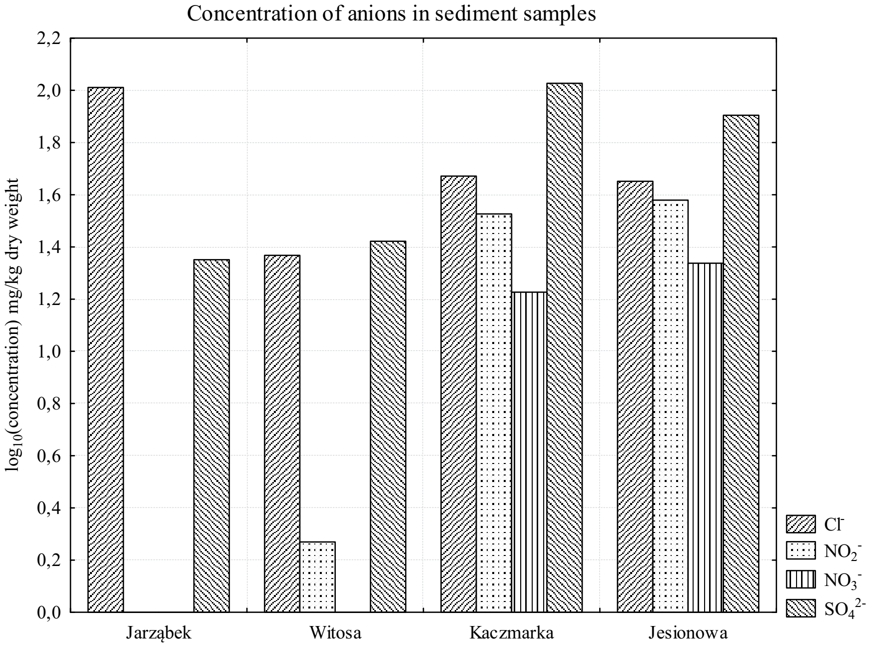

Fig. 3. The concentration of anions Cl^-, Br^-, F^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, NO_2^- in stormwater sediments.

noticed. In our previous work [23] we found a strong effect of drying sediments on the sorption of polar and non-polar compounds. The samples of sediments from the stormwater sewage system were evaluated for their sorptive abilities relative to polar substances on the example of water vapor sorption and for non-polar aromatic organic compounds including benzene and its two homologs toluene and para-xylene using dynamic vapor sorption method. Continuing research on sorptive properties of sediments in this paper's attention was focused on investigating the composition of sediment also for persistent organic pollutants such as PAHs are. Sixteen compounds from the PAHs group were designated in the study material. Their total content in the analyzed sediments is presented in Fig. 3. These data show that the sediments were characterized by significant spatial differentiation of the obtained results. In the material tested for the study, fifteen PAH compounds were measured.

The total content of PAHs in the examined sediments is presented in Fig. 4. The highest concentrations of compounds from the PAH group were recorded for sediments collected from the Piekoszowska and Jesionowa reservoirs, respectively 35.71–856.78 mg kg^{-1} and 28.56–417.58 mg kg^{-1}. In other reservoirs, concentration values were much lower. In the sediments from the Kaczmarka reservoir, there were 25.97 ± 14.01 mg kg^{-1}, and in the case of the Witosa reservoir, it reached 93.70 ± 112.95 mg kg^{-1}. To make a proper assessment of sediment quality for organic micropollutants it is necessary to use special criteria. Numerous methods have been developed to determine quality standards for bottom sediments. Sediment quality guidelines (SQGs) are based on both chemical and biological aspects. Poland still lacks legal regulations on the assessment of the harmful effect of chemical compounds in water sediments for the organisms that inhabit this environment. Many approaches have been made to establish SQGs. They rely on the different theoretical or empirical basis used to assess the hazard posed by the presence of organic compounds and heavy metals in bottom sediments. The most widely used are threshold effects level (TEL) and probable effects level (PEL) parameters, which are components of the empirical method applied to benthic organisms. The TEL specifies the upper limit of pollutant concentration range, below which the harmful effect on aquatic organisms is found relatively seldom. The PEL is defined as the lower limit of pollutant concentration, which may significantly adversely affect the living organisms [24].

The sediment classification proposed by Bojakowska [25] incorporates ecotoxicological parameters TEL and PEL used in the USA and Canada. Sediments are categorized on a four-level scale, where, class I. unpolluted sediments (none of the harmful component content exceeds the TEL parameter), class II. low-polluted sediments (the content of at least one harmful component is higher than the TEL parameter, the content of all components is lower than the PEL parameter) class III. polluted sediments (the content of at least one harmful component exceeds the limit of class II). Class IV. strongly-polluted sediments (the content of at least one harmful component exceeds the limit of class III). Sediments categorized as class I and class II can be freely applied to both aquatic and land environments. They are most often used as soil fertilizers, or to restore damaged banks of water reservoirs and rivers. Class III sediments can be relocated to designated sites and managed to a limited extent. Due to the elevated concentrations of hazardous compounds, those can be applied to industrial crops or may be excluded from agricultural use. Strongly-polluted class IV sediments should be treated before they are placed in the environment, or they should be stored at protected

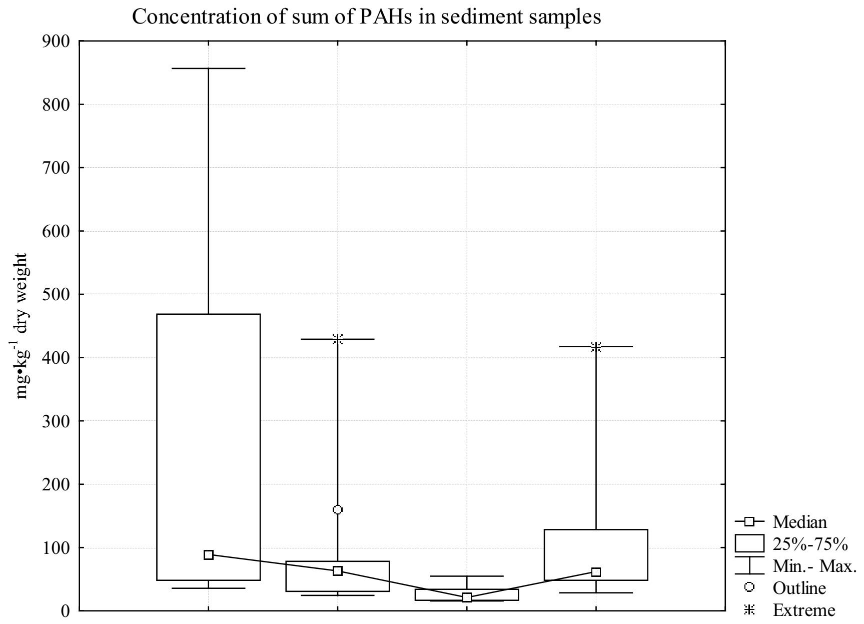

Fig. 4. Polycyclic aromatic hydrocarbons sediment concentrations in the sedimentation tanks (mg kg^{-1} dry weight).

refuse sites under controlled conditions. The $SPAHs_{16}$ concentrations in sediments were compared with local background values, for I, II, III and IV class – 1, 7.5, 15, and >15 mg kg^{-1}, respectively. The material of concern was categorized as class IV – for all samples. As regards class IV, that is, strongly polluted sediments, it is recommended that they should be treated before they are disposed of into the environment. Otherwise, they should be stored at protected refuse sites under controlled conditions. Many factors may be affected by high PAHs contents in these sediment samples. First of all, the particle size distribution has probably the biggest influence of sorptive properties of sediments as noted in previous studies [26]. Particles size below 2 and 63 µm are contributed to higher ΣPAH loads on sediment, especially this is evident in the case of tanks: Jarząbek and Witosa. These findings correspond with other studies where the following dependencies were found. First, some major sources of PAHs, such as vehicle exhaust and tire wear, produce particulates with smaller particle sizes. Second, finer particles from high SSA can enhance the adsorption of pollutants [27,28]. Therefore, SSA of sediments might be a fundamental property that determines the nature of sediment surface reactions and influences ecosystem-level, biological processes. Sediments with the smallest dimensions will, therefore, have higher values of SSA, as this takes place in samples of open tanks where the values ranged from 6.11 to 7.75 m^2 g^{-1}, respectively. While in other cases they did not exceed the value of 1.85 m^2 g^{-1}. Both the particle size distribution and specific area are strongly related to land-use catchments [29]. Therefore, the next step that should be accomplished is to evaluate the impact of land-use on the distribution of PAHs in each grain fraction of sediment and identify the primary origins of PAHs regarding the different land-use types to assess the potential ecological risk posed by PAHs derived from the identified sources.

4. Conclusions

The paper presents the results of analyzes of sediment collected from four stormwater treatment plants. The material was subjected to physicochemical analyzes including pH value, dry residue, mineral and organic matter content, particle size distribution, mineral composition, SSA, the ionic composition including cations (Na^+, NH_4^+, Ca^{2+}, Mg^{2+}, Li^+, K^+) and anions (Cl^-, Br^-, F^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, NO_2^-) and sum of sixteen SPAHs. Due to the fact that these sediments are natural sorbents, the aim of the work was to assess their sorption properties with respect to selected chemical substances, with particular emphasis on organic pollutants. The conducted sorption capacity test confirmed that these sediments may pose a potential threat to the environment due to their properties. In the case of sediments that have already have in their structure chemical contamination, it was still possible sorption, also the sorption capacity of the material is not fully used. This means that not only the organic matter of the sediment matrix but also the mineral parts are responsible for the sorption of organic pollutants. Therefore, to determine the bond strength of chemical micropollutants with the matter forming sediment, and also to properly assess the degree of contamination should also be taken into consideration to examine their sorption capacity.

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